FLORIDA TOMATO INSTITUTE PROCEEDINGS

SEPTEMBER 8, 2010

UNIVERSITY OF FLORIDA
IFAS EXTENSION

THE GROWER

CITRUS+ VEGETABLE

COMPILED BY:
Monica Ozores-Hampton, UF/IFAS, Southwest Florida Research and Education Center, Immokalee
Crystal Snodgrass, UF/IFAS, Manatee County Extension Service, Palmetto

Vance

2010 FLORIDA TOMATO INSTITUTE

The Ritz-Carlton, Naples, Florida | September 8, 2010 | PRO 53

Wastewater characterization in Florida tomato packinghouses

Gurpal S. Toor[1], Maninder K. Chahal[1], and Bielinski M. Santos[2]
[1] University of Florida/IFAS, Soil & Water Quality Laboratory, GCREC, Wimauma, FL, gstoor@ufl.edu
[2] University of Florida/IFAS, GCREC, Wimauma, FL

INTRODUCTION

Water Use and Wastewater Production in Tomato Packinghouses. There are about 70 tomato packinghouses in Florida that pack field-grown tomatoes. A packinghouse in Florida typically packs about 1.1 million kg of tomatoes in a day (http://www.sixls.com/packing.php). In packinghouses, fresh water is used for rinsing, washing, and sanitizing the tomatoes before packing. Thus, a large amount of municipal water is used in the dump tanks (or waste stream) depending upon the type of tomatoes. For instance, the amount of water used for cleaning round tomatoes typically range from 36,000 to 68,000 L day-1 while for roma and grape tomatoes, it varies from 3,700 to 28,400 L day-1 (Florida Tomato Committee, 2007). Most packinghouses in Florida use fresh water before the beginning of packing operation in a day and replace the wastewater in the dump tanks at end of the day. As a result, there is continuous recirculation of water in the dump tanks where field tomatoes are dumped and washed during a typical 6 to 8 hours of packing in a day. At end of packing operation, approximately 3,800 to 18,200 L per day of wastewater is produced in the dump tanks (Florida Tomato Committee, 2007). This equates to about 231 million L of wastewater each year in tomato packinghouses in Florida, which needs to be disposed in an environmentally sustainable way.

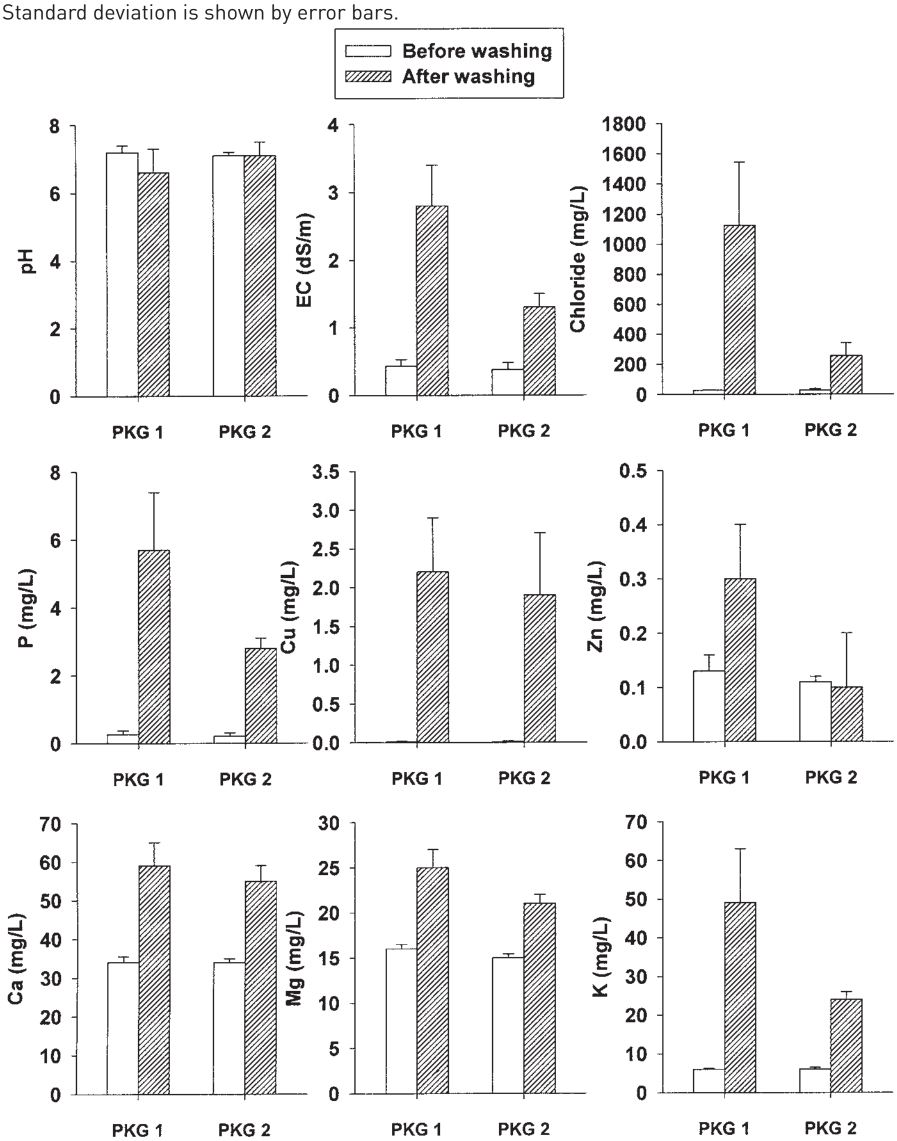
Wastewater Reuse. According to a survey of Florida packinghouses, wastewater produced is mainly disposed in three ways: 1) land application in agricultural fields (54%), 2) discharge into sewage systems (31%), and 3) no disposal or third party disposal (15%) (Florida Tomato Committee, 2007). Urbanization and the close proximity of packinghouse to Florida's sensitive water bodies is especially problematic as the packers need to comply with increased regulations on using wastewater either on-site or disposing of in city sewerage systems. Information about the concentrations of nutrients and trace metals in wastewater might provide ways to safely use wastewater in the environment and reduce the operational costs of managing wastewater in packinghouses. No information is available about the different contaminants present in wastewater. Therefore, the objective of this study was to characterize the chemical composition of wastewater generated in two tomato packinghouses in central Florida.

MATERIALS AND METHODS

Packing Operations in Tomato Packinghouses. In west-central Florida, there are two major tomato growing seasons: July–Dec (Fall) and Jan–April (Spring). During each season, tomatoes are harvested usually 10–12 weeks after planting and the packing of tomatoes is continued for about 1–2 months. Field-harvested tomatoes are transported to the packinghouses for washing and sanitizing prior to packing. The tomatoes are first dumped into a water flume system (also called "dump tank"). To avoid the cross-contamination of pathogens during washing in the dump tanks, sanitizers such as chlorine gas are constantly added in the water to maintain 150–200 mg L-1 of free chlorine in the waste stream at water pH of 6.5 to 7.5 (Bartz et al., 2009).

Wastewater Sample Collection. Wastewater samples from two major tomato packinghouses (hereafter referred to PKG 1 and PKG 2) were collected during May–June 2009, which refers to the packing season of tomatoes grown

Figure 1. Mean values of pH, EC, chloride, and selected metals (P, Cu, Zn, Ca, Mg, K) in wastewater samples collected before washing (time = 0 hour) and after washing (time = 6-8 hours) in dump tanks of two central Florida tomato packinghouses (labeled as PKG 1 and PKG 2). Wastewater samples represent mean values of four sampling events in each packinghouse. Standard deviation is shown by error bars.



in Jan–April 2009. In both packinghouses, typical operational time of tomato packing varied from 6 hours in PKG 2 to 8 hours in PKG 1. For each of the two packinghouses, four sampling events were conducted on a weekly basis. During each sampling event, samples were collected from the dump tanks at 30–minute intervals for about 6–8 hours. In addition, municipal water samples were collected before the beginning of the packing operation during each sampling event. The collected samples were chilled on ice, brought to the laboratory, and analyzed.

Laboratory Analysis. Collected wastewater samples were analyzed for pH, electrical conductivity (EC), and chloride. Total P and 18 metals (Al, As, B, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, Se, and Zn) in the wastewater samples were also determined using inductively coupled plasma–optical emission spectroscopy (ICP–OES). Eleven metals (Al, As, B, Cd, Co, Cr, Mo, Mn, Ni, Pb, and Se) were below the detection limits of ICP–OES and therefore are not discussed.

RESULTS AND DISCUSSION

Chemical Characteristics of Municipal Water Used in Packinghouses. As municipal water was used in the dump tanks of both packinghouses to wash and sanitize the field-harvested tomatoes, the pH (7.1–7.2) and EC (0.38–0.43 dS m^{-1}) of water was similar. Concentrations of all chemical constituents such as chloride, P, Ca, Mg, K, Cu, and Zn in the municipal water were also similar (Figure 1) as both packinghouses were located in a close proximity to each other and had the same source of municipal water.

Chemical Characteristics of Wastewater Produced at End of the Packing Operations. The chemical composition of wastewater at end of the packing operations showed elevated concentrations of all elements but the magnitude of increase was much greater for some elements (Figure 1). The pH was maintained in the neutral range as recommended for Florida packinghouse waste stream. However, the EC showed marked increase in both wastewaters and was much greater in PKG 1 (2.8 dS m^{-1}) than PKG 2 (1.3 dS m^{-1}) due to the much greater chloride (1125 mg L^{-1}) in PKG 1 than PKG 2 (255 mg L^{-1}). The high chloride in the wastewater was because of the reaction of added sanitizer such as chlorine in the dump tanks.

All chemical constituents showed a greater magnitude of increase in PKG 1 wastewater as compared to PKG 2 due to greater contact time of tomatoes with water which was 55–72 seconds in PKG 1 compared to 32–40 seconds in PKG 2 per 454 kg of dumped tomatoes. Among all metals, the greatest increase was observed for Cu whose concentrations increased from 0.01 mg L^{-1} in municipal water to 1.9–2.2 mg L-1 in wastewater. This was followed by increase in total P concentrations in wastewater from <0.27 mg L^{-1} to 2.8 (PKG 2)–5.7 (PKG 1) mg L^{-1}. Other elements i.e. Ca, Mg, K, and Zn showed marginal increases in wastewater than municipal water. The variability in wastewater in two packinghouses highlight the importance of extrinsic (residues of pesticides, fungicides containing metals that were carried with tomatoes from field to packinghouses) and intrinsic (wastewater chemistry in packinghouses particularly high chloride content in PKG 1) factors in determining concentrations of different constituents in wastewater.

ACKNOWLEDGEMENTS

Authors thank U.S. Environmental Protection Agency for providing funding for this project. This study would not have been possible to conduct without the cooperation and support of Florida Tomato Committee and two packinghouse personnel.

REFERENCES

Bartz, J.A., S.A. Sargent, and M. Mahovic. 2009. Guide to identifying and controlling post harvest tomato diseases in Florida. IFAS/extension HS 866, University of Florida. Available at http://edis.ifas.ufl.edu/pdffiles/HS/HS13100.pdf

Florida Tomato Committee. 2007. Taskforce on options for utilization of tomato packinghouse waste and wastewater. University of Florida/IFAS.

Some highlights from the University of Florida tomato breeding program

J.W. Scott, S.F. Hutton, J. Strobel
University of Florida/IFAS, Gulf Coast Research & Education Center, University of Florida

Possible Jointless Tomato Hybrid Release We are considering the release of Fla. 8787, a jointless hybrid with high lycopene that is being aimed primarily for Dade County where 'Sanibel' is the predominant variety. This hybrid combines a parent from the IFAS program and a parent developed by Jim Strobel who is now retired, but was a tomato breeder at TREC in the 1960's. In yield trials conducted on a grower farm in 2009 and 2010, marketable yield, fruit firmness, and fruit size of Fla. 8787 was comparable to 'Sanibel'. The interior color of Fla. 8787 was a deeper red than 'Sanibel'. We feel 8787 has better flavor than 'Sanibel' but have not been able to demonstrate that in taste panels so far. We have been crossing to obtain more seed for testing on grower farms and any Florida growers with interest in testing 8787 in small scale strip trials are encouraged to contact Jay Scott at jwsc@ufl.edu or 813-633-4135. If further testing warrants release, the tomato will be named after Herb Bryan the outstanding horticulturalist who worked tirelessly at TREC until his untimely death in 2004. There has not been a large-fruited jointless tomato released by anyone since before this millennium started. Although having jointless pedicels is a desired characteristic that is controlled by a single recessive gene, it has been difficult for tomato breeders to obtain jointless varieties that are comparable in marketable yield to presently grown jointed varieties.

Progress in Developing Compact Growth Habit (CGH) Tomatoes with Jointless Pedicels Availability and affordability of farm labor is an important issue for Florida tomato growers. Mexican tomatoes can be produced more cheaply than can be done in Florida and present immigration issues are of great concern to American agriculture. The CGH tomato breeding project is aimed at developing varieties that can be grown efficiently on the ground-beds without staking. Furthermore, if varieties are jointless they could be harvested once-over by machine. Machine harvesting of tomatoes is not a new topic as the MH-1 tomato was released in 1971 (Crill et al., 1971) and numerous IFAS scientists, including Herb Bryan, were involved in the development of the variety and in the development of a machine that could do the harvesting. CGH tomatoes have increased side branching with shortened internodes due to the brachytic (br) gene and are prostrate in growth due to as yet undefined gene(s) (Ozminkowski et al., 1990). These plants tend to cover the plastic mulch but not grow into the row middles. The plants being developed have a concentrated fruit set and they are generally early in maturity. Emphasis has been placed on developing CGH tomatoes with jointless pedicels and in spring 2010 lines emerged that appeared to have potential as parents for commercial hybrids. Fla. 8834 in particular had a nice CGH vine with a concentrated fruit set of firm, smooth, large fruit. Seed was saved so that rows of it can be grown this winter on farms in Dade County to assess the performance.

Plum Breeding Line Release Possibilities Breeding plum tomatoes has not been a major focus of the breeding program, but it is a part of each project and breeding lines with TYLCV resistance have been released to the seed industry. In our recent genetic work on bacterial spot resistance, one of the main sources of resistance was plum line Fla. 8517. We now

Table 1. Yield and bacterial spot disease severity for VF36, VF36 transformed with the Bs2 gene and Florida tomato varieties in Fall 2007 and Spring 2008 Balm, Florida.

Genotype	Marketable Yield (kg/plant)	Total Yield (kg/plant)	Fruit Weight (g)	Disease Severity[2]
VF36	0.25 b[1]	0.80 b	133 c	7.4 a
VF36 Bs2 homozygous	0.96 a	1.78 a	132 c	3.0 d
VF36 Bs2 hemizygous	1.01 a	1.97 a	138 c	3.0 d
FL 47	1.19 a	1.94 a	176 a	5.6 c
FL 91	1.26 a	1.71 a	180 a	5.6 c
Sebring	1.18 a	1.67 a	170 ab	6.1 b

[1] Means in column with the same letter are not significantly different at $P \leq 0.05$ Duncans multiple range test.
[2] Disease severity based on the Horsfall-Baratt scale, lower number means less disease.

Table 2. Summary of survey results from three cities comparing flavor of Tasti-Lee, tomatoes on the Vine (TOV) and field tomatoes. There were over 90 respondents to the survey.

Variety	Excellent	Good	OK	Bad	Terrible
	----------	----------	%----------	----------	----------
Tasti- Lee	22.2	48.9	21.1	6.7	1.1
TOV	28.1	33.7	22.5	7.9	7.9
Field	14.1	37.0	38.0	10.9	0.0

have a number of bacterial spot tolerant lines with plum-shaped fruit and some of these may be released in the future. At present, data are being collected from some other plum tomato lines that have tolerance to bacterial spot. The two possible releases are Fla. 8611 and Fla. 8835. In spring 2010 marketable yield of both were slightly less than 'Picus' but the percentage of marketable fruit of the two breeding lines were more than the latter. The breeding lines had smaller fruit that were not as long. These both have good flavor and should provide seed company breeders with good sources of bacterial spot resistance for their plum breeding programs.

Transgenic Bacterial Spot Resistance Status Conventional bacterial spot resistance breeding has yet to yield commercial varieties for Florida due to a combination of the evolution of virulent pathogen races that have overcome resistance and rather complex genetic control of resistance. Much effort is still being expended on conventional breeding and progress has recently been made in marker discovery that should expedite the process (Hutton et al., 2010). Another approach has been to transfer the Bs-2 gene from pepper into tomato by genetic transformation. This transfer was accomplished in the lab of Brian Staskawicz at the University of California, Berkeley. The gene was inserted into 'VF-36', an old inbred variety from the University of California, Davis. We have done several seasons of testing of Bs-2 in tomato both in homozygous and hemizygous (heterozygous) condition. The gene is effective against both races T3 and T4 in tomato. 'VF-36' was very susceptible to bacterial spot, but lines with Bs-2 homozygous or hemizygous were highly resistant. The transformed plants have essentially no bacterial spot. Data for two trials is shown in Table 1. Yield also increased for the transformed lines compared to 'VF-36'. Fruit size of 'VF36' or transformed VF36 was less than that of 'Florida 47', 'Florida 91', and 'Sebring' (Table 1). At present inbred Fla. 8000 is being transformed with Bs-2 and the transformed line should be available in 2011. Fla. 8000 carries conventional resistance to race T3 of bacterial spot, is heat-tolerant, and is a parent in hybrid Fla. 8314. This hybrid has been tested in many IFAS yield trials and has had high yields of marketable fruit more consistently than any tomato variety ever tested by the senior author. Often it has had the highest numerical marketable yield, something that is very uncommon. The drawback of Fla. 8314 is that the percentage of 5 x 6 fruit is not as high as that of presently grown varieties. Meanwhile TYLCV resistance is being backcrossed into the other parent of Fla. 8314. Thus, in a few years we may have a Fla. 8314 with resistance to TYLCV and bacterial spot, the two most important diseases facing our industry. However, it will be a GMO and thus there may be concerns about this. Yet it is only a pepper gene in a tomato, people are already eating peppers with this gene so it seems rather innocuous. For the moment this is food for thought. A GMO soybean with high oleic acid has now been released and it is likely that the health benefits from its use in fried foods will have reduced GMO fears by the time our GMO is ready.

Tasti-Lee™ Consumer Survey Greenhouse tomatoes, both tomatoes on the vine (TOV) and hydroponic ones with the calyx attached, have taken considerable market share away from field grown tomatoes over the last 5-10 years. One way Florida growers may be able to recapture and perhaps increase supermarket sales to new levels would be to grow the Fla. 8153 variety (Tasti-LeeTM)(Scott et al., 2008) and harvest them vine ripe to the stores. Last fall the Florida Department of Agriculture and Consumer Services conducted surveys in Atlanta Georgia, Richmond Virginia, and Indianapolis Indiana where they compared Tasti-Lee, TOV, and field tomatoes and flavor results are in Table 2. The respondents that thought the tomatoes were excellent to good were 71.1% for Tasti-Lee, 61.8% for TOV, and 51.1% for the field grown tomato. Thus, it would appear that a good way to get tomatoes from the field to the grocery store would be to grow Tasti-Lee and sell it as a branded product. Analysis of the survey suggested Florida should grow 1000 acres of Tasti-Lee to accommodate the demand. We feel Tasti-Lee vine-ripes could be grown at less expense than growing grape tomatoes. The monetary return to the farm may prove more stable than has been the case with mature green crops. Given the severe plunge in the market last spring when tomato volume increased, it is a good time to consider some alternatives.

Summary As we look to the future considering information presented above, perhaps the mature green industry could grow jointless, CGH varieties that are harvested by machine to save on labor and thus help maintain a competitive edge. These would go primarily to food service or to provide a cheaper product for supermarkets. We do not want to put farm workers out of work, so labor could be used to harvest vine ripe Tasti-Lee type tomatoes for the premium supermarket trade. The varieties will not be static. Adding new traits to these variety types will be done. Resistances include TYLCV and bacterial spot that have been mentioned and others such as fusarium crown rot, tomato spotted wilt virus, and sweet potato whitefly that are being developed but have not been presented here. Quality traits include higher sugars, fruity-floral aromatic notes, and glossy, deep red exterior fruit color. Again these projects are being worked on, but time does not permit discussion here. Furthermore, all the projects mentioned even briefly are just some of what is going on in the large UF breeding program. Grower input is always welcome. The Florida tomato industry faces many challenges and survival in these times may require some diverse approaches.

LITERATURE CITED

Crill, Pat, J.W. Strobel, D.S. Burgis, H.H. Bryan, C.A. John, P.H. Everett, J.A. Bartz, N.C. Hayslip, and W.W. Deen. 1971 Florida MH-1, Florida's first machine harvest fresh market tomato. Fla. Agric. Expt. Sta. Circ. S-212 12p.

Hutton, Samuel F., Jay W. Scott, Yang, Wencai, Sim, Sung-Chur, Francis, David M., and Jones, Jeffrey B. 2010. Identification of QTL Associated with Resistance to Bacterial Spot Race T4 in Tomato. Theor. Appl. Genet. 120: (in press).

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

Scott, John W., Elizabeth A. Baldwin, Harry J. Klee, Jeffery K. Brecht, Stephen M. Olson, Jerry A. Bartz, and Charles A. Sims. 2008. Fla. 8153 hybrid tomato; Fla. 8059 and Fla. 7907 breeding lines. HortScience 43(7):2228-2230.

Evaluation of tomato yellow leaf curl virus (TYLCV) resistant and Fusarium crown rot (FCR) resistant tomato variety under commercial conditions in southwest Florida

Monica Ozores-Hampton[1], Eugene McAvoy[2], Steve Sargent[3] and Pamela Roberts[1]
[1]University of Florida/IFAS, SWFREC, Immokalee, FL. [2]Hendry County Extension Service, LaBelle, FL.
[3]University of Florida, Horticultural Sciences Department, Gainesville, FL.

INTRODUCTION

Tomato yellow leaf curl virus (TYLCV) and Fusarium crown rot (FCR), caused by Fusarium oxysporum f. sp. radicis-lycopersici (FORL) are considered by some to be the worst tomato virus and soil fungal disease affecting the tomato industry in South Florida. Both diseases cause a significant yield reduction in tomato production.

Plants infected with the TYLCV virus have stunted growth and flower abortion with early infections resulting in almost no fruit set (Schuster and Stansly, 1996). Management of whitefly and TYLCV relies primarily on insecticides and tomato-free planting periods initiated by timely crop destruction after harvest (Schuster and Polston, 1999). However, whitefly resistance to insecticide(s) is creating an urgent need for alternative management tools such as TYLCV resistant varieties. TYLCV-resistant cultivars adapted to our needs and environment have already been developed by companies such as Hazera, Harris Moran, Seminis, Syngenta, and Sakata. Some resistant varieties have been evaluated in UF trials within the previous 8 years (Gilreath et al, 2000, Cushman and Stansly 2006 and Ozores-Hampton et al., 2008). Evaluations from Ozores-Hampton et al. (2008) included nine round and two plum tomato cultivars that resulted in very distinctive performances in the field and fruit quality after the postharvest evaluation under a high virus pressure during spring 2007.

Fusarium crown rot has been a serious disease of tomatoes on fumigated soils for the last 20 years, but its biology and control has been studied only for the past 12 years (Jarvis, 1998). Chemical control, such as methyl bromide, has limited efficacy and in some instances is not highly effective. The disease, however, can be managed with resistant cultivars, but the lack of consistent fruit quality is a major factor for not adopting Fusarium crown rot and TYLCV resistant varieties by the Florida tomato industry. Therefore, growers plant these resistant varieties in limited acreages and continue to take a risk by planting susceptible varieties such as FL47. Variety evaluations need to be continued as new genetic material becomes available and information is needed on TYLCV and Fusarium tolerance. Additionally, horticultural qualities including postharvest should be investigated since for many new cultivars this information is lacking or insufficient. Ongoing variety evaluation provides independent scientific information regarding updated variety recommendations other than commercial breeding programs. The objective of the study was to document the TYLCV and Fusarium crown rot resistance and horticultural characteristics of currently available TYLCV and Fusarium crown rot resistant tomato cultivars under commercial field conditions.

MATERIALS AND METHODS

Two independent TYLCV and one Fusarium crown rot resistant (FCR) variety were evaluated and compared to susceptible grower standards in a completely randomized experimental design with four replications during spring 2009 and 2010 (Table 1). The trials were located on a tomato farm under commercial growing conditions typical of the Immokalee and Estero area. A field with a history of FCR was used for this evaluation. Twelve (2009) and nine (2010) TYLCV and five (2010) entries of FCR resistant round tomato cultivars were evaluated and compared with the susceptible grower standards FL 47 and Sebring for the TYLCV and FL47 for the FCR trial (Table 1).

Cultural Practices. Seeds were planted in flats and grown by Redi Plants, Corp. The field was rototilled, and the pre-plant fertilizer (bottom mix and top "hot" mix) was applied following the modified broadcast method to supply 300-60-462 lb.acre-1 of N-P2O5-K2O (1 acre = 7,260 linear bed feet). In each trial, tomatoes were grown following industry standards for production practices (Table 2) and pesticide applications were made as needed in response to regular scouting reports according to UF/IFAS recommendations (Olson et al., 2007). Plant population was approximately 4,035 plants/acre for TYLCV and FRC in both years. Each tomato variety was pruned following the seed company's specifications (Table 1). The field was seepage irrigated and tomato plants were staked and tied.

The whitefly (Bemisia argentifolii) population was monitored using a leaf-turn method, and TYLCV symptomatic plants were counted at the third harvest on 20 May and second harvest 18 May for 2009 and 2010, respectively. The number of plants showing symptoms of Fusarium crown rot (caused by Xanthomonas perforans and bacterial speck caused by Pseudomonas syringae pv. Tomato) was rated as percentage foliar cover (disease severity) at third harvest 20 May (TYLCV 2009), second harvest 18 May (TYLCV 2010) and 11 May for FRC 2010. All trial tomatoes were graded in the field using a portable grading table according to USDA specifications for extra-large (5x6), large (6x6), and medium (6x7) fruit categories (USDA, 1997). For the TYLCV total unmarketable tomato fruit numbers were recorded and categorized into cracking (CR), scaring (SC), and odd shape/zipper (OS/Zipper) described by Ozores-Hampton et al. (2008).

Tomatoes were harvested at the green mature stage on 21 April 2009 (TYLCV harvest 1) and 28 April 2010 (FCR harvest 1). Tomatoes were placed in 25-lb boxes and transported to the Garguilo, Inc. packinghouse (Immokalee, FL.). After 7 days of ethylene ripening treatment (full color), a subsample of 10 tomatoes from each variety and replication was transported to the UF Postharvest Horticulture Laboratory in Gainesville, FL (Spring 2009) and Southwest Florida Research and Education Center Vegetable Laboratory in Immokalee, FL (Spring 2010) for quality evaluation. For TYLCV 2010 tomatoes were harvested at breaker stage on 18 May (harvest 2). Fruits were stored at 68°F until they reached table-ripe stage defined as "the point at which red-ripe tomatoes become noticeably softer when pressure is applied with thumb and fingertips to the equatorial region of each fruit." All postharvest quality parameters were evaluated once the tomatoes reached table-ripe stage. Firmness was measured as fruit deformation by using an 11-mm probe and 1 kg-force applied to the fruit surface of the fruit equator area after 5 s of applied force with a portable digital firmness tester (IRREC tester; Ritenour et al., 2002). Higher values of fruit deformation indicate softer fruit. Color was measured using a 1-to-10 scale.

A field day was conducted at first harvest on 21 April, (TYLCV 2009), 3 May (TYLCV 2010) and 28 April (FCR 2010). Participants using a 1-to-5 scale (1 = very poor; 5 = very good) in a blind test evaluated the varieties in earliness, plant vigor, fruit size, firmness, fruit quality, potential yield and an overall plant rating. Data yield components, firmness, and field evaluation to TYLCV and FCR variety responses were analyzed using ANOVA and Duncan's Multiple Range Test at 5%. The number of fruit defects by TYLCV, Fusarium crown rot, and bacterial spot percentage by variety were transformed by Arcsin distribution before the ANOVA, Duncan's Multiple Range Test, and Least Significant Difference, respectively (SAS, 2008).

Extension Activities: A total of three well-attended field days (two TYLCV 2009 and 2010 and one FRC 2010) were held at the grower's cooperator in Immokalee and Estero, FL.

RESULTS AND DISCUSSION

Overall weather conditions during the trials in Southwest Florida recorded by the Florida Automated Weather Network (FAWN) were cool and dry with five freeze events (21-23, Jan., 5 Feb. and 3 Mar.), and an accumulation of rainfall of 3.0 inches during the spring of 2009 (TYLCV); and wet and lower than usual temperatures with five freeze events (7 Jan. and 10-13 Jan.), and an accumulation of 22.7 inches during the spring of 2010 (TYLCV). Similarly, there were a total of seven freeze events (5-7 Jan., and 10-13 Jan.) for the location of the FCR trial, and an accumulation of rainfall of 20.6 inches during the spring of 2010.

Whitefly population, TYLCV incidence, bacterial spot, and Fusarium crown rot rating: Whitefly pressure was low in spring 2009 with an average whitefly count of 0.5 to 1 ± 1.0 and 2 to 5 ± 1.0 adult per leaf at the beginning and end of the season, respectively. In spring 2010, there were no whiteflies during the season. There were no TYLCV symptomatic plants among varieties in both years (Table 1). Disease pressure for bacterial disease was severe in spring 2010. Therefore, there were significant differences in bacterial spot and speck among TYLCV and FCR 2010, but not in TYLCV 2009 among varieties at second and third harvest, respectively (Table 1). The incidence of bacterial spot and speck range from 25 to 37% (TYLCV 2009), 23 and 70% (TYLCV 2010) and 38 and 70% (FCR 2010). The results from TYLCV and FRC 2010 indicate that there may be different levels of damage incurred by bacterial spot and speck among the varieties tested, with some having at least a 50% or more reduction

Table 1. Pruning, TYLCV virus incidence, bacterial spot, and Fusarium crown rot of Tomato Yellow Leaf Curl Virus (TYLCV 2009-10) and Fusarium Crown Rot (FCR 2010) resistant tomato varieties and advanced breeding lines evaluation grown in Estero, FL.

Variety	Source	Pruning N° Suckers	Virus incidence (%)	Bacterial Spot Rating (%)	Fusarium crown rot (%)
TYLCV Spring 2009					
BHN 765	BHN Seed	No	0	31.7	0
FLA 8577	UFz	3	0	25.0	0
FLA 8578	UF	3	0	30.0	10.0
HA 3075 (Ofri)	Hazera	3	0	33.3	0
HA 3095	Hazera	3	0	30.0	10.0
HA 3096	Hazera	3	0	31.7	20.0
HM 8845	Harris Moran	2	0	31.7	0
Sak 5230	Sakata	3	0	33.3	13.3
Sak 5443	Sakata	No	0	36.7	10.0
SVR 200	Seminis	3	0	30.0	6.7
Tycoon	Hazera	3	0	35.0	46.7
Tygress	Seminis	3	0	28.3	0
FL 47 (control)	Seminis	3	0	28.3	6.7
Sebring (control)	Syngenta	3	0	25.0	0
P value	-	-	-	0.81	0.10
Sig.	-	-	-	ns	ns
TYLCV Spring 2010					
Charger	Sakata	No	0	36.3 bcdey	0
Katana	Takii	4	0	45.0 bc	0
Security 28	Harris Moran	2	0	31.3 cde	0
SVR 200	Seminis	3	0	41.3 bcd	0
Tygress	Seminis	3	0	26.3 de	0
Tycoon	Hazera	3	0	70.0 a	0
XTM 5467	Sakata	No	0	50.0 b	0
UF 8784	UFL	4	0	23.3 e	0
UF 8785	UFL	4	0	26.7 de	0
FL 47 (control)	Seminis	3	0	35.0 bcde	0
Sebring (control)	Syngenta	3	0	52.5 ab	0
P value				0.0002	
Sig.				**	
FCR Spring 2010					
BHN 585	BHN	3	0	47.5 b	0
Crown Jewel	Seminis	3	0	50 b	0
HMX 8849	Harris Moran	3	0	47.5 b	0
Sebring	Syngenta	3	0	50 b	0
Soraya	Syngenta	3	0	67.5 a	0
FL 47	Seminis	3	0	37.5 b	0
P value				0.006	
Sig.					

z University of Florida
y Means separation by Duncan's Multiple Range Test at P ≤ 0.05 Level, and LSD (for FCR data) at the P level in table, means followed by the same letter are not statistically different
** Significance at P ≤ 0.01; * Significance at P ≤ 0.05; ns Not significance.

Table 2. Summary of cultural practices used in Tomato Yellow Leaf Curl Virus (TYLCV 2009-10) and Fusarium Crown Rot (FCR 2010) resistant varieties.

Cultural practice	TYLCV 2009	TYLCV 2010	FCR 2010
Plant spacing (inch)	22	22	22
Bed spacing (feet)	5.25	6	5.25
Methyl Bromide: Chloropicrin	50:50 @ 100lb/acre	50:50 @ 100lb/acre	50:50 @ 100lb/acre
Mulch	Metalized/Silver	Metalized/Silver	Metalized/Silver
Planted length (feet)	37 (20 plants)	37 (20 plants)	37 (20 plants)
Harvest length (feet)	18 (10 plants)	18 (10 plants)	18 (10 plants)
Replications	3	4	4
Bed width (inch)	32	32	32
Transplant date	8 Jan. 2009	7 Jan. 2010	29 Dec. 2009
Harvest dates	21 Apr., 6 May and 20 May, 2009	3 May and 18 May 2010	28 Apr. and 11 May 2010

compared to others. There were no FCR symptomatic plants among varieties in spring 2010 for TYLCV and FCR trials (Table 1). However, there were FCR symptomatic plants, but there were no significant differences among TYCLV varieties at third harvest in spring 2009. Fusarium crown rot was 0 to 47% ($P \leq 0.05$).

Fruit yields: First harvest extra-large fruit ranged from 336 to 1,733 (TYLCV 2009), 69 to 581 (TYLCV 2010) and 443 to 945 (FCR 2009), total extra-large (all harvests combined) 2,165 to 462 (TYLCV 2009), 164 to 642 (TYLCV 2010) and 836 to 1,463 (FCR 2009), and total harvest (all sizes and harvests combined) 1,549 to 3,210 (TYLCV 2009), 431 to 899 (TYLCV 2010) and 1,403 to 1,954 (FCR 2009) boxes/acre (Table 3).

TYLCV 2009: By all measures, yields were greater for 'Tygress' and 'SVR 200' than the rest of the varieties ($P \leq 0.05$) (Table 3). How-

Table 3. First, total marketable and unmarketable (cull) fruit yield categories for Tomato Yellow Leaf Curl Virus (TYLCV 2009-10) and Fusarium Crown Rot (FCR 2010) resistant tomato varieties grown in Estero, FL.

	Yield (boxes[z]/acre)								
	First Harvest				Total Harvest				
	XL[y]	L[y]	M[y]	FHT	XL	L	M	Cull	Total
	TYLCV Spring 2009								
BHN 765	1,031cx	437	164ab	1,632abcd	1,457bcd	747bcde	464cdef	2,524a	2,675abc
FLA 8577	575def	445	188ab	1,209efgh	863efg	727bcdef	558cde	2,012abc	2,148cde
FLA 8578	336f	351	194ab	881h	462g	543defg	543cdef	2,007abc	1,549e
HA 3075 (Ofri)	390f	335	192ab	917h	757efg	791b	792ab	1,725abcd	2,339bcd
HA 3095	457ef	288	214a	959h	801efg	530defg	614bcd	1,578bcd	1,945de
HA 3096	684cdef	316	147ab	1,147fgh	1,070def	523efg	429cdef	2,222ab	2,022de
HM 8845	965c	348	138abc	1,452cdefg	1,417bcd	764bc	629bcd	1,301cd	2,810ab
Sak 5230	520ef	368	165ab	1,054gh	663fg	563cdefg	413def	2,130ab	1,639e
Sak 5443	812cde	394	182ab	1,387defg	1,106def	748bcd	655bc	1,695bcd	2,509bcd
SVR 200	1,369b	335	121abc	1,824abc	1,876ab	515fg	372ef	928d	2,763abc
Tycoon	922cd	327	129abc	1,378defg	1,233cde	543defg	368ef	1,634bcd	2,144cde
Tygress	1,733a	225	35c	1,992a	2,165a	429g	309f	1,023d	2,903ab
FL 47 (control)	1,422ab	436	94bc	1,952ab	1,568bcd	781b	598bcde	1,140d	2,947ab
Sebring (control)	963c	401	134abc	1,498cdef	1,247cde	1,057a	906a	1,098d	3,210a
P value	0.0001	0.29	0.08	0.0001	0.0001	0.0001	0.0001	0.0004	0.0001
Sig.	**	Ns	*	**	**	**	**	**	**
	TYLCV Spring 2010								
Charger	208cde	95a	54	357b	310bc	215a	236a	1,150bc	762ab
Katana	187de	94a	47	328b	261cd	187ab	182abc	520ef	631bc
Security 28	581a	77ab	87	745a	642a	116cd	141bcd	998c	899a
SVR 200	315c	94a	29	438b	412b	145bcd	98d	799d	655bc
Tygress	245cd	59abc	35	338b	291bcd	104d	142bcd	543ef	537cd
Tycoon	198cde	83ab	33	314bc	241cd	139cd	91d	1,255b	471cd
XTM 5467	309cd	76ab	64	450b	353bc	122cd	109cd	1,465a	584bcd
UF 8784	69f	45bc	34	148d	164d	114d	153bcd	606def	431d
UF 8785	90ef	32c	50	172cd	214cd	97d	206ab	411f	517cd
FL 47 (control)	228cd	96a	57	381b	327bc	164bc	139bcd	714de	630bc
Sebring (control)	468b	96a	81	646a	542a	143bcd	168abcd	671de	852a
P value	0.0001	0.01	0.29	0.0001	0.0001	0.0001	0.003	0.0001	0.0001
Sig.	**	*	Ns	**	**	**	**	**	**
	FCR Spring 2010								
BHN 585	457b	128	56	641	836b	362	280ab	631 a	1,479b
Crown Jewel	443b	191	60	694	860b	440	290ab	478 ab	1,591b
HMX 8849	945a	111	24	1,080	1,463a	322	169c	407 b	1,954a
Sebring	477b	114	61	653	900b	381	332a	404 b	1,613b
Soraya	527b	148	39	713	1,025b	370	228bc	362 b	1,623b
FL 47	492b	137	41	669	883b	319	202c	408 b	1,403b
P value	0.02	0.63	0.14	0.12	0.002	0.27	0.002	0.04	0.04
Sig.	*	ns	Ns	ns	**	ns	**	*	*

[z] 25-lb tomatoes/box
[y] XL= Extra-large (5x6 industry grade); L=Large (6x6); M=Medium (6x7)
[x] Means separation by Duncan's Multiple Range Test, $P \leq 0.05$ Level, means followed by the same letter are not statistically different.
** Significance at $P \leq 0.01$; * Significance at $P \leq 0.05$; ns Not significance.

ever, 'Tygress' and 'SVR 200' total first harvest (all sizes combined), first and second harvests combined (all sizes combined), total harvest (all sizes and harvests combined) were not significantly different than 'BHN 765', HM 8845, FL 47 (control) and Sebring (Control). Total unmarketable tomato categories for first harvest, first and second harvests combined (all sizes combined) and total harvest (all sizes and harvests combined) were lowest with 'Tygress', 'SVR 200', 'FL 47' and 'Sebring' and the highest 'BHN 765' 'FLA 8577 and 78', 'HA 3075 and 3096', and 'Sak 5230' (Table 3). The most common defect types as a percentage of the total unmarketable yields were odd shape (OS) ranging from 18 to 43%, scaring (SC) 21 to 66%, and blossom end scar (BES) 7 to 37 % (Table 4).

TYLCV 2010: Yields were greater for 'Security 28' than the rest of the varieties (P≤0.05) (Table 3). However, 'Security 28' total first harvest (all sizes combined), Sebring (control) and total harvest (all sizes and two harvests combined) were not significantly different than 'Charger' and 'Sebring' (control). Total unmarketable tomato categories for total harvest (all sizes and two harvests combined) were lowest with 'Tygress', 'UF 8784-85', and 'Katana and the highest with 'XTM 5467' (Table 3). The most common defect types as a percentage of the total unmarketable yields were scaring (SC) ranging from 25 to 60%, odd shape (OS) 16 to 47%, and cracking/zippers (CR-Z) 13 to 40 % (data not shown).

The large unmarketable (odd shape, scar, blossom end scar, and zippers) fruit found with TYLCV-resistant varieties was consistent with results from spring 2007 and 2008 (Ozores et al., 2008), but in contrast to other studies (Gilreath et al, 2000; Scott, 2004 and Cushman and Stansly, 2006).

FCR 2010: Yields were greater for 'HMX 8849' than the rest of the varieties in total extra-large first harvest, total extra-large (two harvests combined) and total marketable harvest (all sizes and two harvests combined) (P≤0.05) (Table 3). Total unmarketable tomato categories for total harvest (all sizes and two harvests combined) were lowest with 'FL47', 'HMX 8849', 'Sebring' and 'Soraya' and the highest 'BHN and Crown Jewell' (Table 3). However, 'Crown Jewell' was not different than the rest of the varieties.

Post-harvest and blind test evaluation: There were no significant differences in firmness and color among TYLCV (2009) varieties (Table 4). However, fruit of 'Charger' had significantly (P≤0.01) higher firmness (less fruit deformation) than 'Tygress', 'Tycoon', 'XTM5467' and 'UF 8784' during spring 2010. Out of all varieties, 'Tycoon' had significantly the softest fruit. In 2010, 'Soraya' had significantly (P≤0.01) higher fruit firmness values among FCR varieties. The softer fruits were produced by 'Crown Jewel'. The highest color rating was that of 'Tygress' and the lowest 'Katana', 'Secutity 28', 'XTM 5467', 'UF 8784', 'FL 47', and 'Sebring' (Table 4). Among FCR, the highest color rating was that of 'FL 47' and the lowest 'Soraya' during spring 2010.

A blind evaluation indicated that 'Tygress' had significantly (P≤0.01) the highest overall rating compared to all other TYLCV 2009 varieties, followed closely by 'HM 8845' and SVR 200' (Table 4). The lowest overall ratings were obtained by 'FA 8578', 'HA 3075', 'HA3095', and 'HA 8845'. In 2010, the variety 'Tygress' was not as well rated as in 2009. The significantly (P≤0.01) highest overall rate was given to 'Security 28' compared to all other TYLCV varieties, while the lowest rate was given to 'UF8785'. A blind test comparison among FCR

Table 4. Post-harvest firmness (as fruit deformation), color of fruits at table ripe stage from first harvest and blind evaluation for tomato plant and fruit (from the contribution of 23, 16 and 14 participants for Tomato Yellow Leaf Curl Virus (TYLCV 2009-10) and Fusarium Crown Rot (FCR 2010) resistant tomato varieties grown in Estero, FL, respectively). (Blind evaluation based on rating scale 1-5; 1= very poor and 5 = very good).

Varieties	Post-harvest		Blind Evaluation
	Deformation (mm)	Color (1-10)	Overall Rating (1-5)
	TYLCV Spring 2009		
BHN 765	3.56	6.0	3.6b
FLA 8577	4.15	6.0	2.8cd
FLA 8578	3.13	7.0	2.3ef
HA 3075 (Ofri)	2.79	6.0	2.3ef
HA 3095	3.39	7.0	2.5def
HA 3096	3.56	7.0	2.2f
HM 8845	3.73	7.0	3.7ab
Sak 5230	3.05	6.0	3.0c
Sak 5443	3.47	6.5	3.1c
SVR 200	2.88	6.0	3.7ab
Tycoon	3.30	7.0	2.6de
Tygress	2.71	6.5	4.0a
FL 47 (control)	2.46	6.0	3.1c
Sebring (control)	2.96	5.0	2.9cd
P value	0.09	0.08	0.0001
Sig.	Ns	Ns	**
	TYLCV Spring 2009		
Charger	2.23az	6.0b	2.6cde
Katana	2.41ab	5.0c	2.5de
Security 28	2.59abc	5.0c	4.1a
SVR 200	2.63abc	6.0b	3.5b
Tygress	3.09bcd	7.0a	2.7cde
Tycoon	4.91e	6.0b	2.5de
XTM 5467	3.36cd	5.0c	3.1bcd
UF 8784	3.81d	5.0c	2.5de
UF 8785	2.89abc	6.0b	2.3e
FL 47 (control)	2.71abc	5.0c	2.8cde
Sebring (control)	2.42ab	5.0c	3.1bc
P value	0.0001	0.01	0.0001
Sig.	**	**	**
	TYLCV Spring 2009		
BHN 585	1.99bc	6.0b	2.6d
Crown Jewel	2.05c	6.0b	3.0cd
HMX 8849	1.75bc	6.0b	4.0a
Sebring	1.63b	5.0c	3.3bc
Soraya	1.20a	4.0d	3.7ab
FL 47	1.82bc	7.0a	3.8a
P value	0.0006	0.01	0.0001
Sig.	**	**	**

[z] Means separation by Duncan's Multiple Range Test, P ≤ 0.05 Level, means followed by the same letter are not statistically different
** Significance at P ≤ 0.01; * Significance at P ≤ 0.05; ns Not significance.

2010 cultivars indicated that 'HMX 8849' and 'FL 47' had significantly (P≤0.01) the highest overall rate, while 'BHN 585' had the lowest.

The extension activities: A field day held at the grower's cooperator in Immokalee was well-attended: 65 (TYLCV 2009), 42 (TYLCV 2010), and 35 (FCR 2010) attendees. According to 23 (TYLCV 2009), 16 (TYLCV 2010) and 14 (FRC 2010) responses from participants in the blind test, best overall TYLCV varieties for the TYLCV spring 2009 were 'Tygress', 'SVR 200' and 'HM 8845', TYLCV spring 2010 was 'Security 28' and FCR 2010 was 'HMX 8849' based on earliness, plant vigor, fruit size, firmness, fruit quality, potential yield and an overall plant rating (Table 4).

ACKNOWLEDGEMENTS

The authors wish to thank the Florida Tomato Committee, BHN, Harris Moran, Hazera, Sakata, Seminis, Takii, Redi-Plants, and Six'L Farms for providing monetary or in-kind support to these projects.

REFERENCES

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.

Jarvis, WR. 1998. Fusarium crown and root rot of tomatoes. Phytoprotection. Vol.69, no. 2, pp. 49-64.

Ritenour, M.A., E.M. Lamb, P.J. Stoffella, and S.A. Sargent. 2002. A portable, digital device for measuring tomato firmness. Proc. Fla. State Hort. Soc. 115:49-52.

Olson, S.M., W.M. Stall, M.T. Momol, S.E. Webb, T.G. Taylor, S.A. Smith, E.H. Simonne, and E. McAvoy. 2007. Tomato production in Florida, pp. 409-430 In: S.M. Olson and E. Simonne (Eds.) 2007-2008 Vegetable Production Handbook for Florida, Vance Pub., Lenexa, KS.

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.

SAS. 2008. SAS/STAT user's guide, Ver. 9.2, SAS Institute, Cary, NC.

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

Schuster, D. J., P. A. Stansly and Jane E. Polston. 1996. Expressions of plant damage of Bemisia. In: Bemisia 1995: Taxonomy, Biology, Damage Control and Management. Andover, Hants, UKD.D. Gerling and R. T. Mayer {Eds.} PP: 153-165.

USDA. 1997. United States standards for grades of fresh tomatoes. Agr. Markt. Serv. http://www.ams.usda.gov/standards/tomatfrh.pdf.

Environmental and geographical variables associated with tylcv epidemics in southwest Florida

William W. Turechek

U.S. Dept. of Agriculture – Agricultural Research Service, U.S. Horticultural Research Laboratory, Fort Pierce, FL

INTRODUCTION

Tomato yellow leaf curl virus (TYLCV) was first detected in south Florida in 1997 (Polston, et al., 1999) and it has since appeared in varying degrees in all subsequent seasons resulting in millions of dollars of lost production. The virus, which is vectored by the silverleaf whitefly (Bemisia tabaci biotype B), has spread widely in Florida and has been reported elsewhere in the Southeast including South Carolina and Alabama (Ling et al., 2006, Akad et al., 2007). Managing the disease and its whitefly vector has been challenging. A more complete understanding of the temporal and spatial (geographical) features associated with TYLCV epidemics may help with efforts in designing and testing new management options. For example, by identifying local "hot spots" surveys can be designed to focus in on the vegetation of the surrounding area in an effort to identify reservoir hosts and/or crops for the virus. It should be noted, that no reservoir hosts have been found in Florida to date (Polston et al. 2009). A hot spot analysis may also be helpful in identifying pockets of insecticide-resistant whiteflies, which have recently become a problem (Schuster et al. 2006).

MATERIALS AND METHODS

In collaboration with growers and industry representatives we set out to characterize spatial and temporal patterns of TYLCV epidemics and whitefly densities in production fields to gain an understanding of how epidemics develop. A comprehensive map of vegetable fields in southwest Florida was developed in consultation with local scouts and University of Florida extension personnel in the spring and summer of 2007. Currently, we have mapped approximately 82,000 acres of vegetable production, and we received scouting reports for approximately 17,000-20,000 acres of tomato and vegetable production each year from the 2006 thru 2010 growing seasons. Regional weather data were obtained from three stations maintained by the National Climate Data Center and from a single station located in Immokalee and maintained by Florida Automated Weather Network (FAWN) so we could measure the correlations between various climatic variables, TYLCV incidence, and whitefly densities. The data were mapped and analyzed using a variety of statistical and mapping software packages.

RESULTS AND DISCUSSION

The data in Figure 1 shows the relationship between the average number of whiteflies and the severity of TYLCV incidence over all fields that were in production over the time period represented. As expected, the severity of TYLCV closely follows the increase in mean whitefly density, as well as the average age of the fields in production. Figure 2 shows the linear relationship between the average numbers of whiteflies in neighboring fields, i.e., fields that share a common boundary. This relationship exists not only for neighboring fields but for fields that are located two and three fields over, although the strength of the relationship decreases with distance. The disease and insect pressure that one field places on its neighbors is further emphasized by a significant correlation between the location of a field, via its north-south and east-west coordinates, and TYLCV incidence and whitefly density (results not shown). Lastly, spatial analysis of the surveyed region does show the existence of hot spots for both whiteflies and virus, but they are not necessarily associated with each other or with a single grower or farm. A prominent hot spot is associated with the central growing area, which is typical given the concentration of production. Smaller hot spots tended to be located around the edges or perimeters of farms and would be good areas to concentrate future surveys of the plant population.

Certain climatic variables appear to impact disease and its vector as well. The most consistent relationship is the positive correlation between wind speed and whitefly density. Temperature has a negative impact on both whitefly density and TYLCV, meaning that hotter temperatures are less conducive to epidemic development. However, because of the strong correlation between whitefly density and TYLCV severity, it is difficult to determine whether the impact of temperature is directly affecting whiteflies, disease development, or both. Wintertime minimum temperature, particularly the number and duration of sub-freezing events, has an impact on both whitefly populations and virus incidence. This was clearly evident in the past two growing seasons, and its effect hinders a number of whitefly transmitted viruses including several of the cucurbit viruses. In some years, precipitation has a small negative correlation on whitefly density and others years it has had no noticeable effect.

Figure 1. Mean proportion of TLYCV infection (top panel) and the mean number of whiteflies (bottom panel) in all fields that were in production at the specified time during four growing seasons in southwest Florida.

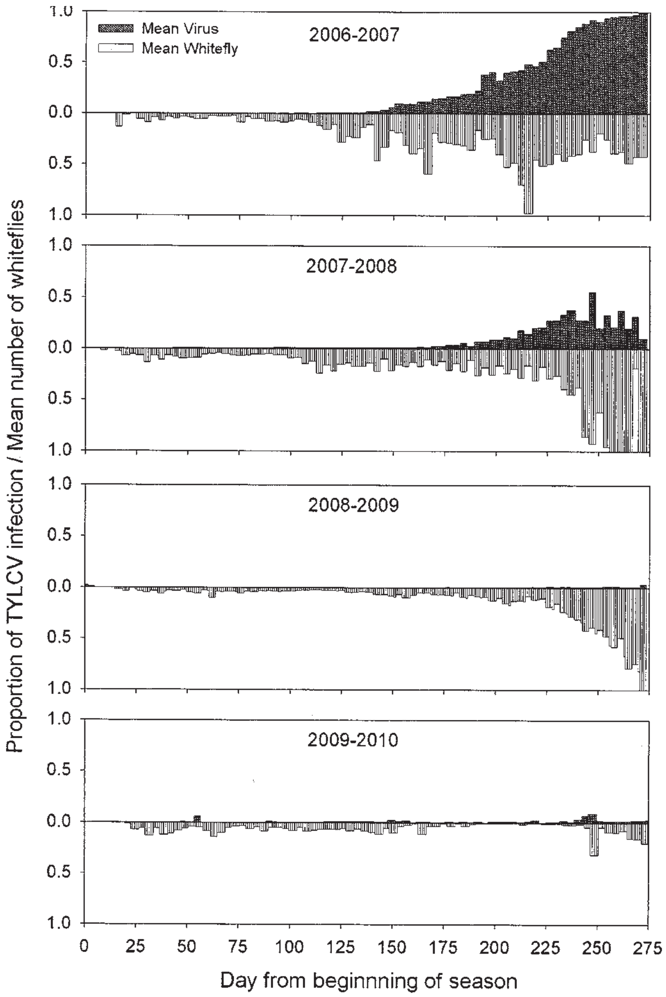
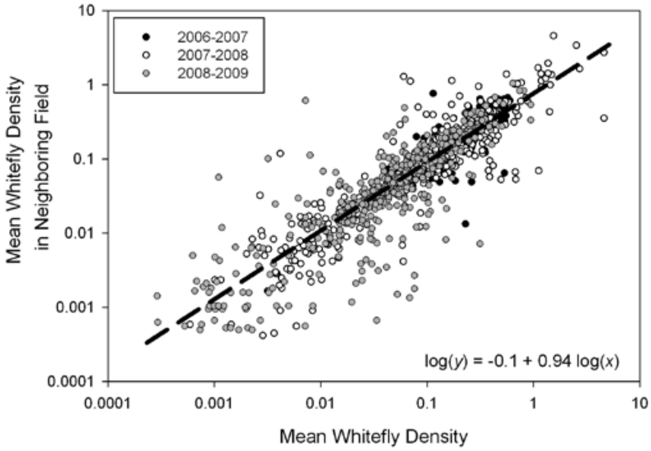


Figure 2. Relationship between the mean number of whiteflies in a given field and the mean number of whiteflies in the field's nearest neighbors. The broken line is the best linear fit to the data.



The results of the analyses described above argue for a greater regional effort in managing whiteflies and TYLCV, and there are several examples where regional growers have banded together to combat a particularly difficult pest through the implementation of an area-wide pest management program. Using the information obtained from the research described above in combination with the comprehensive GIS-based map of vegetable fields in southwest Florida, we are developing a decision support system for management and tracking whiteflies and virus across commodities. The idea is that growers would report pest density through an interactive, GPS-driven system which can then be accessed by participating growers in real-time. The system could provide warnings, for example, to alert growers that whitefly pressure is expected to increase in the region due to the presence of the insect in neighboring fields in combination with harvesting activity. The incidence of TYLCV and other diseases could also be closely monitored in an effort to better focus pesticide applications. Lastly, because the system is digital, reports are stored and can be easily accessed for further analysis of the historical data which could ultimately lead to more efficient pest and disease management.

ACKNOWLEDGEMENTS

We would like to acknowledge the numerous growers who have generously contributed their data to this study. There were several individuals who helped us to compile the data and we would like to acknowledge these individuals (in alphabetical order): Kevin Bryan, Galen Frantz, Leon Lucas, Gene McAvoy, Charlie Mellinger, Wes Roan, Kevin Seitzinger, and Mark Verbeck.

REFERENCES

Akad, F., Jacobi, J.C., and Polston, J.E. 2007. Identification of Tomato yellow leaf curl virus and Tomato mottle virus in Two Counties in Alabama. Plant Disease 91:906.

Ling, K.S., Simmons, A.M., Hassell, R.L., Keinath, A.P., and Polston, J.E. 2006. First report of Tomato yellow leaf curl virus in South Carolina. Plant Disease 90:379.

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

Polston, J.E., Schuster, D.J., and Taylor, J.E. 2009. Identification of weed reservoirs of Tomato yellow leaf curl virus in Florida, pp. 32-33. In E. Simone, C. Snodgrass, and M. Ozores-Hampton [eds.], 2009 Fla. Tomato Institute Proc., Univ. Fla., PRO 526.

Schuster, D.J., Mann, R., and Gilreath, P.R. 2006. Whitefly resistance update and proposed mandated burn down rule, pp. 24-28. In P. Gilreath and K. Cushman [eds.], 2006 Fla. Tomato Institute Proc., Univ. Fla., PRO 523.

Investigating the Q invasion of bemisia tabaci in Florida: Current status and update

Cindy McKenzie[1], Greg Hodges[2], Lance S. Osborne[3], Frank J. Byrne[4], and Robert G. Shatters, Jr.[1]
[1]USDA-ARS, U.S. Horticultural Research Laboratory, Fort Pierce, FL
[2]Florida Department of Agriculture and Consumer Sciences, Division Plant Industry, Gainesville, FL
[3]University of Florida, Mid-Florida Research & Education Center, Apopka, FL
[4]Department of Entomology, University of California, Riverside, CA

History of whiteflies in the USA Worldwide agricultural production losses due to infestations of Bemisia tabaci (Gennadius) have escalated over the past 25 years as new and more virulent biotypes have spread to all continents except Antarctica (De Barro et al. 2005). The current count of whitefly biotypes described exceeds twenty with the two most invasive and well known being the B and Q biotypes (Perring 2001). Following the introduction of biotype B into the USA around 1985, unprecedented losses began occurring in the late 1980s in Florida (Hamon and Salguero 1987; Hoelmer et al. 1991; Schuster et al. 1989) and rapidly spread across the southern states to Texas, Arizona and California where extreme outbreaks occurred during the early 1990s (Perring et al. 1991; 1993; Gonzalez et al. 1992). In addition to having an expanded host range and being a more aggressive colonizer of crops, other traits identified at the morphological (Bellows et al. 1994; Costa et al. 1995; Rosell et al. 1997), biochemical (Costa and Brown 1991, Perring et al. 1992; Brown et al. 2000) and molecular levels (Gawal and Bartlett 1993; De Barro et al. 2005; Boykin et al. 2007) were considered sufficiently different from the indigenous populations to warrant new species designation. (i.e. Bemisia argentifolii Bellows & Perring, the silverleaf whitefly) (Perring et al. 1993; Bellows et al. 1994).

Indistinguishable in appearance from silverleaf whitefly (B. tabaci biotype B), biotype Q is extremely problematic to agricultural production because it has a high propensity to develop resistance to insect growth regulators (Horowitz et al. 2003) and neonicotinoid insecticides (Horowitz et al. 2004). Both classes of insecticides play crucial roles in controlling whiteflies in many different cropping systems including cotton (Ellsworth and Martinez-Carrillo 2001), vegetables (Palumbo et al. 2001), and ornamentals (http://mrec.ifas.ufl.edu/lso/documents/Export%20Mgmt%20Plan-7-07.pdf). Biotype Q was first detected in the USA in December 2004 on poinsettias from a southwest retail outlet in Arizona during routine resistance monitoring surveys (Dennehy et al. 2005). Determined to be essentially unaffected by pyriproxyfen in egg bioassays (~1,000-fold resistance), these whiteflies also had noticeably reduced susceptibility to acetamiprid, buprofezin, mixtures of fenpropathirn and acephate, imidacloprid, and thiamethoxam in laboratory bioassays (Dennehy et al. 2005). Other examples of resistance in biotype Q have helped foster a reputation that biotype Q is especially capable of developing resistance under intensive insecticide use conditions (Nauen et al. 2002, Horowitz et al. 2005, Nauen and Denholm, 2005). While there is no definitive evidence that biotype Q is biologically more capable of resisting insecticides than other B. tabaci biotypes, its track record in both protected and open agriculture suggests that caution is advisable.

Associated with the appearance of biotype Q in the U.S. were reports, primarily from ornamental growers, of increasing problems in controlling whitefly infestations. After the discovery of the B. tabaci Q biotype in the U.S., there was an urgent need to determine its spread. During the past 5 years, biotype Q has been detected in 26 states across the country, including Florida (http://mrec.ifas.ufl.edu/LSO/BEMISIA/positive_states.htm). As part of an APHIS coordinated multi-state, multi-agency and multi-institutional USA Q biotype task force initiative and coordinated whole country survey, an extensive survey of B. tabaci biotypes was conducted in Florida. The primary objective of the survey was to monitor the introduction and distribution of both the B and Q biotypes. Following are the results of an extensive survey of B. tabaci biotypes in Florida that serve to investigate and document the "Q" invasion into the state and provides a model for the rest of the country (McKenzie et al. 2009).

MATERIALS AND METHODS

Sampling The majority of the samples were provided through cooperation with the Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Glades Crop Care, University of Florida and Agricultural Research Service entomologists, vegetable and ornamental growers from across the state. Actual sample technique depended on the individual sampler, but once adults were collected they were immediately placed in 95% ethanol for molecular analysis. B. tabaci are haplodiploid with 2N females and 1N males (Byrne and Devonshire 1996); therefore female whiteflies were identified and selected for further analysis to allow microsatellite genotyping of homozygous and heterozygous individuals within populations. At least 12 adult female whiteflies were processed from each sample. If no adults were present, leaves from host plants were collected to obtain whitefly nymphs for mtCOI sequence analysis but not for microsatellite studies.

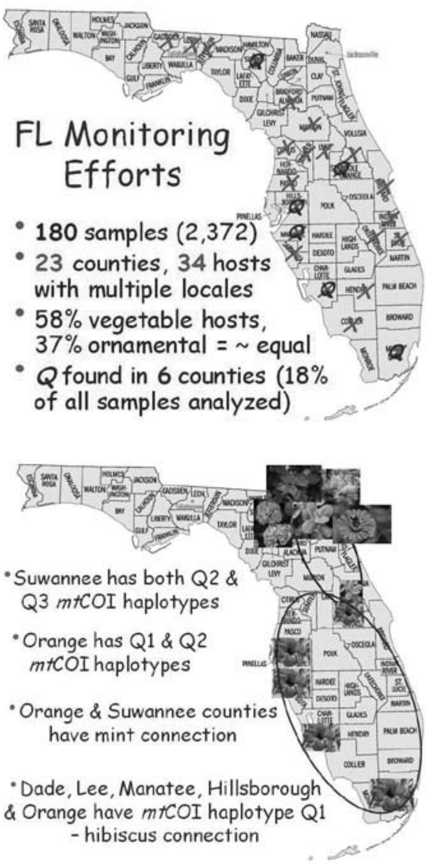
Methods Used to Determine Biotype- Because B. tabaci biotypes are identical morphologically, molecular techniques were used to distinguish whitefly biotypes and included esterase zymogram assays (Frank Byrne, UC Riverside), analysis of mitochondrial Cytochrome Oxidase I small subunit (mtCOI) DNA sequence (Frolich et al. 1999; Shatters et al. 2009) and microsatellite fragment analysis (DeBarro et. al. 2003). Q biotype Bemisia can be distinguished from B biotype insects based on the esterase electrophoretic banding patterns (Byrne and Devonshire 1991) and this method was used to routinely confirm biotype status results utilizing mtCOI sequence and microsatellite data analysis. Preliminary analysis in our laboratory showed that two microsatellite markers BEM6 ((CA)8imp) and BEM23 ((GAA)31imp), were found to be diagnostic for B and Q biotypes and were used to determine biotype status in conjunction with analysis of mtCOI DNA sequence.

RESULTS

Extensive whitefly surveys were conducted from 2005 – 2008 from multiple locations across Florida representing 23 different counties and 34 different host plants (Figure 1). Sample hosts were split between ornamental and herb (37%) and vegetable (58%) commodities but also included alfalfa, peanut and some weeds. The same crops were surveyed across multiple locations, when possible, and many counties were sampled multiple times. Tomato was the most extensively sampled host, with collections from 10 counties representing 35% of all the samples collected. Hibiscus was also sampled from 10 counties but not as extensively as tomato (31 samples or 17% of all samples collected).

The biotype status of submitted B. tabaci samples was determined using a mtCOI small subunit sequence, unique microsatellite markers and esterase zymogram analysis. A total of 2,372 individual whiteflies from 180 different collections were analyzed by mtCOI and microsatellite markers. Of those individuals, 1,944 (82%) individuals from 168 collections were biotype B and 428 (18%) individuals from 32 collections were biotype Q. When biotype Q was detected, 34% of the samples were from collections containing a mix of both biotypes. Biotype B was detected in 23 counties and on

Figure 1. Florida Whitefly monitoring efforts 2005-2008



all hosts sampled except hydrangea; however hydrangea was only sampled on one occasion. Biotype Q was detected in six counties, all of which were on ornamentals and herbs in greenhouses (Table 2). Some counties had more than one positive Q sample, but in no case, did the Q biotype continue to spread and all populations were managed with no new finds in terms of county or host plant since the summer of 2006. Samples were routinely split and sent to California for esterase zymogram analysis. In all cases, esterase comparisons concurred with mtCOI and microsatellite results.

Sequence comparison of the mtCOI gene identified three separate haplotypes for biotype Q within Florida that were defined as Q1, Q2 and Q3 (Table 1). There were 38 single nucleic polymorphisms (SNP) between biotype B and the biotype Q haplotype Q1 (the biotype Q haplotype most similar to biotype B). Among the biotype Q haplotypes, Q2 and Q3 were the most similar with only a single G/C polymorphism at position 109. The Q1 haplotype was the most divergent with six and seven polymorphisms between Q2 and Q3, respectively. In contrast, all biotype B whitefly individuals analyzed from Florida had identical mtCOI sequence in the region amplified and sequenced. Within the Q biotype, haplotypes could be used to associate populations known to be related by plant host and plant source (Table 2). For example, collections from five counties were made on hibiscus linked to the same grower

Table 1. Polymorphisms between three Q haplotypes collected in Florida.

Haplotype designation	Base number on the amplified mtCOI fragment[1] 109	232	502	523	562	682	731
Q1	C	T	T	T	C	T	C
Q2	C	C	C	C	T	C	T
Q3	G	C	C	C	T	C	T

[1]GenBank Accession Number EU427719

Table 2. Biotype Q detection in Florida counties by host and haplotypes.

County	Host	Haplotype
Dade	Hibiscus	Q1
Hillsborough	Hibiscus	Q1
Lee	Hibiscus	Q1
Manatee	Hibiscus	Q1
Orange	Hibiscus	Q1
Suwannee	Asparagus Fern	Q2
		Q3
	Hydrangea	Q2
	Mint	Q2
		Q3
	Poinsettia	Q2
		Q3
	Zinnia	Q2
		Q3

and all samples contained only the Q1 haplotype (Figure 1). Biotype Q was detected on five different host plants in Suwannee County and these populations contained a mix of the Q2 and Q3 haplotypes. Four of the five plant hosts were all located at the same nursery and the other plant host (mint) was being grown within a two mile radius of this nursery. These data support the conclusion that the Q biotype must have entered Florida through at least two separate introductions.

Our data also show that two microsatellite markers are a cost effective diagnostic alternative for biotype B and Q identification providing 100% concurrence with mtCOI sequence data (Table 3). The two markers must be used simultaneously and provide confirmatory results. When comparing microsatellite markers (indicated in Table 3 as size in bases of the fragment that was amplified), all populations containing the Q1 mitochondrial COI haplotype had only two BEM6 markers, 210 and 217, and three BEM23 markers, 407, 410, and 224, with greater than 98% of the alleles being 210 and 407 for the BEM6 and BEM23 microsatellites, respectively. The Q2 population had only the 210 BEM6 marker and a 410 BEM 23 marker, while the Q3 had a unique single 204 marker for BEM6, and 410, 407, and 230 markers for BEM 23. The BEM23 marker distinguished the Q1 from the Q2 and Q3 populations and within Q2 and Q3, BEM6 was diagnostic. It was surprising to find distinctions among the nuclear microsatellite markers between Q2 and Q3 because they were often collected in the same populations. This suggests that they may not have existed together for a long period

Table 3. Bemisia tabaci biotype mtCOI haplotypes correlated to diagnostic microsatellite primers BEM6 and BEM23 in Florida.

mtCOI	Size in bases of the amplified fragment (%)	
haplotype	BEM6 (CA)$_8$ imp	BEM23 (GAA)$_{31}$ imp
Q1	210 (99%); 217 (1%)	224 (1%); 407 (98%); 410 (1%)
Q2	210	410
Q3	204	230 (5%); 407 (2%); 410 (93%)
Biotype B	217 (98%); 224 (2%)	224

of time and only had limited opportunity to interbreed. Comparison of the B and Q microsatellite markers showed no sharing of markers between the two biotypes, even when B and Q whiteflies were collected from the same host plant. Because the microsatellite markers were imperfect, we were able to sequence the products and determine exactly where the addition or deletion occurred relative to the imperfection. Although alleles appeared to be shared (same size amplicon) 1% of the time between biotype B and haplotype Q1, in all cases, these additions/deletions were the result of independent events (they occurred in different places relative to the imperfection). Consequently, we could find no evidence of hybridization (mating) between the two whitefly biotypes in Florida.

DISCUSSION

Earlier surveys of B. tabaci populations in Florida (McKenzie et al. 2004) using RAPD PCR techniques indicated the presence of only the B biotype of B. tabaci. However in that study, herbs and ornamental hosts were not surveyed. In this survey, 17 herb and ornamental hosts were surveyed from 18 counties with biotype Q being detected on five different ornamental hosts and one herb (Table 2). There was great concern among growers and researchers alike that biotype Q would make the jump from protected ornamental greenhouse production to open agriculture (Dalton 2006). In Florida, tomato transplants for field production can be grown in the same greenhouses that grow a variety of ornamental plants so there were opportunities for biotype Q to infest tomato transplants destined for the field. We surveyed 13 preferred whitefly field-grown vegetable hosts in 14 counties and did not detect biotype Q in any of the samples. In fact, no new biotype Q detections have been made in Florida since August 2006 on hibiscus and sample submission has drastically declined. The reduced number of submissions for whitefly biotype determination during the past two years may be an indication that growers took note of the extent of the problem and were diligent in their efforts to implement best management practices for the control of this pest. A "Management Program for Whiteflies on Propagated Ornamentals with an Emphasis on the Q-Biotype" was developed in 2006 (Bethke et al. 2006) and continues to be distributed to more than 10,000 ornamental growers and propagators (http://www.mrec.ifas.ufl.edu/LSO/bemisia/bemisia.htm).

In-depth analysis of insecticide resistance profiles of different biotype Q populations indicates that different populations have different insecticide resistance profiles (Denholm et al. 1998, Ebert and Nauen 2000, Nauen et al. 2002, Dennehy et al. 2005, Horowitz et al. 2005, Nauen and Denholm, 2005); therefore, the ability to identify the Q haplotype is of practical importance to growers. However, currently published taxonomic comparisons of the B. tabaci populations worldwide are not sensitive enough to allow statistically supported distinctions of unique Q biotype classes (Boykin et al. 2007). Using a genotyping method referred to as microsatellite analysis or simple sequence repeats (SSRs) to characterize individuals from Q biotype infestations throughout Florida, in combination with mtCOI markers, we have been able to identify 3 distinct haplotypes of the Q biotype. The Q biotype has much greater mtCOI and microsatellite diversity than observed for the B biotype in the U.S. The genetic diversity of the Q biotype is similar to that reported for the indigenous Asia–Pacific genotypes (De Barro, 2005). The mtCOI and microsatellite results show that these are powerful genotyping methods that could be employed to provide information that will improve management decision making with respect to pesticide applications. Future work coordinating the mtCOI and microsatellite genotyping with insecticide resistance profiles will be conducted to determine if these genotyping methods can be used as a predictor of insecticide resistance profiles. Furthermore, the use of these molecular tools will allow investigators to track the likely origin(s) of whitefly biotypes allowing for the implementation of management efforts against the insects before they arrive on U.S. shores.

ACKNOWLEDGMENTS

The authors thank, Dave Schuster, Jim Price, Gary Leibee, Phil Stansly, Glades Crop Care, KAC Agricultural Research, Inc., Epcot Science, Valent USA Corporation, Farm-OP, Inc., and DPI staff for whitefly submissions for identification. We also thank John Prokop, Laurie Keidong, and Ankush Zutshi (USDA, ARS, U.S. Horticultural Research Laboratory, Fort Pierce, FL) for their dedicated technical laboratory assistance. This research was partially funded by the Ornamental Research Initiative.

REFERENCES

Bellows, Jr., T. S., T. M. Perring, R. J. Gill, and D. H. Headrich. 1994. Description of a species of Bemisia (Homoptera: Aleyrodidae). Ann. Entomol. Soc. Am. 76:310-313.

Bethke, J., L. Canas, J. Chamberlin, R. Cloyd, J. Dobbs, R. Fletcher, D. Fujino, D. Gilrein, R. Lindquist, S. Ludwig, C. McKenzie, R. Oetting, L. Osborne, C. Palmer, and J. Sanderson. 2006. Management Program for Whiteflies on Propagated Ornamentals with an Emphasis on the Q-Biotype. http://www.mrec.ifas.ufl.edu/LSO/bemisia/bemisia.htm

Boykin, L. M., R. G. Shatters, Jr., R. C. Rosell, C. L. McKenzie, R. A. Bagnall, P. DeBarro, and D. R. Frohlich. 2007. Global relationships of Bemisia tabaci (Hemiptera: Aleyrodidae) revealed using Bayesian analysis of mitochondrial COI DNA sequences. Molecular Phylogenetics and Evolution 44: 1306-1319.

Brown, J. K., T. M. Perring, A. D. Cooper, I. D. Bedford, and P. G. Markham. 2000. Genetic analysis of Bemisia tabaci (Hemiptera: Aleyrodidae) populations by isoelectric focusing electrophoresis. Biochemical Genetics 38:13-25.

Byrne, Frank J., and Alan L. Devonshire. 1991. In vivo inhibition of esterase and acetylcholinesterase activities by profenofos treatments in the tobacco whitefly Bemisia tabaci (Genn.): implications for the routine biochemical monitoring of these enzymes. Pesticide Biochemistry and Physiology 40: 198-204.

Byrne, F. J., and A. L. Devonshire. 1996. Biochemical evidence of haplodiploidy in the whitefly Bemisia tabaci. Biochemical-Genetics. 34(3-4): 93-107.

Costa, H. S., and J. K. Brown. 1991. Variation in biological characteristics and esterase patterns among populations of Bemisia tabaci, and the association of one population with silverleaf symptom induction. Entomol. Exp. Appl. 61: 211-219.

Costa, H. S., D. M. Westcot, D. E. Ullman, R. Rosell, J. K. Brown, and M. W. Johnson. 1995. Morphological variation in Bemisia endosymbionts. Protoplasma 189:194-202.

Dalton, Rex. 2006. The Christmas Invasion. Nature 443: 898-900.

De Barro, P. J., K. D. Scott, G. C. Graham, C. L. Lange, and M. K. Schutze. 2003. Isolation and characterization of microsatellite loci in Bemisia tabaci. Molecular Ecology Notes 3:40-43.

De Barro, P. J. 2005. Genetic structure of the whitefly Bemisia tabaci in the Asia-Pacific region revealed using microsatellite markers. Molecular Ecology 14:3695-3718.

De Barro, P. J., J. W .H. Rueman, and D.R. Frohlich. 2005. Bemisia argentifolii is a race of B. tabaci (Hemiptera: Aleyrodidae): the molecular genetic differentiation of B. tabaci populations around the world. Bull. Entomol. Res. 95: 193-203.

Denholm, I., M. Cahill, T. J. Dennehy, and A. R. Horowitz. 1998. Challenges with managing insecticide resistance in agricultural pests, exemplified by the whitefly Bemisia tabaci. Phil. Trans. R. Soc. Lond. B. 353: 1757-1767.

Dennehy, T.J., B. A. Degain, V. S. Harpold, J. K. Brown, S. Morin, J. A. Fabrick, F. J. Byrne, and R. L. Nichols. 2005. New challenges to management of whitefly resistance to insecticides in Arizona. The University of Arizona - Cooperative Extension Report. 32 pp.

Elbert, A., and R. Nauen. 2000. Resistance of Bemisia tabaci (Homoptera: Aleyrodidae) to insecticides in southern Spain with special reference to neonicotinoids. Pest Manag. Sci. 56: 60-64.

Ellsworth, P. C. and J. L. Martinez-Carrillo. 2001. IPM for Bemisia tabaci: A case study from North America. Crop-Protection. 20(9): 853-869.

Frohlich, D., I. Torres-Jerez, I. D. Bedford, P. G. Markham, and J. K. Brown. 1999. A phylogeographic analysis of the Bemisia tabaci species complex based on mitochondrial DNA markers. Mol. Ecol. 8:1593-1602.

Gawel, N. J., and A. C. Bartlett. 1993. Characterization of differences between whiteflies using RAPD-PCR. Insect Mol. Biol. 2: 33-38.

Gonzalez, R. A., J. I. Grieshop, G. E. Goldman, S. R. Sutter, E. T. Natwick, T. Funakoshi, H. R. Rosenberg, and S. Davila-Garcia. 1992. Whitefly invasion in Imperial Valley costs growers, workers millions in losses. Calif Agric 46(5):7-8.

Hamon, A. B., and V. Salguero. 1987. Bemisia tabaci, sweetpotato whitefly, in Florida (Homoptera: Aleyrodidae: Aleyrodinae). Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Entomology Circular 292.

Hoelmer, K. A., L. S. Osborne, and R. K. Yokomi. 1991. Foliage disorders in Florida associated with feeding by sweetpotato whitefly, Bemisia tabaci. Florida Entomol 74(10): 162-166.

Horowitz, A. R., K. Gorman, G. Ross, and I. Denholm. 2003. Inheritance of pyriproxyfen resistance in the whitefly, Bemisia tabaci (Q biotype). Archives of Insect Biochemistry and Physiology. 54(4): 177-186.

Horowitz, A. R., S. Kontsedalov, and I. Ishaaya. 2004. Dynamics of resistance to the neonicotinoids acetamiprid and thiamethoxam in Bemisia tabaci (Homoptera: Aleyrodidae). J. Econ. Entomol. 97: 2051-2056.

Horowitz, A. R., S. Kontsedalov, V. Khasdan, and I. Ishaaya. 2005. Biotypes B and Q of Bemisia tabaci and their relevance to neonicotinoid and pyriproxyfen resistance. Arch. Ins. Biochem. Physiol. 58: 216-225.

McKenzie, C. L., P. K. Anderson, and N. Villreal. 2004. Survey of Bemisia tabaci Homoptera: Aleyrodidae) in agricultural ecosystems in Florida. Florida Entomol. 87(3): 403-407.

McKenzie, C. L., Greg Hodges, Lance S. Osborne, Frank J. Byrne and Robert G. Shatters, Jr. 2009. Distribution of Bemisia tabaci (Hemiptera: Aleyrodidae) biotypes in Florida – Investigating the "Q" invasion. J Econ Entomol 102(2):670-676.

Nauen, R., N. Stumpf, and A. Elbert. 2002. Toxicological and mechanistic studies on neonicotinoid cross resistance in Q-type Bemisia tabaci (Hemiptera: Aleyrodidae). Pest Manag. Sci. 58: 868-875.

Nauen, R., and I. Denholm. 2005. Resistance of insect pests to neonicotinoid insecticides: current status and future prospects. Arch. Ins. Biochem. Physiol. 58: 200-215.

Palumbo, J., A. R. Horowitz, and N. Prabhaker. 2001. Insecticidal control and resistance management for Bemisia tabaci. CROP PROTECTION 20(9):739-765.

Perring, T. M. 2001. The Bemisia tabaci species complex. Crop Prot. 20: 725-737.

Perring, T. M., A. Cooper, D. J. Kazmer, C. Shields, and J. Shields. 1991. New strain of sweetpotato whitefly invades California vegetables. Calif Agric 45(6): 10-12.

Perring, T. M., A. Cooper, A., and D. J. Kazmer. 1992. Identification of the poinsettia strain of Bemisia tabaci (Homoptera: Aleyrodidae) on broccoli by electrophoresis. J. Econ. Entomol. 85: 1278-1285.

Perring, T. M., A. D. Cooper, R. J. Russell, C. A. Farrar, and T. S. Bellows, Jr. 1993. Identification of a whitefly species by genomic and behavioral studies. Science 259: 74-77.

Rosell, R. C., I. D. Bedford, D. R. Frohlich, R. J. Gill, P. G. Markham, and J. K. Brown. 1997. Analyses of morphological variation in distinct populations of Bemisia tabaci. Ann. Entomol. Soc. Am. 90: 575-589.

Schuster, D. J., J. F. Price, J. B. Kring, and P. H. Everett. 1989. Integrated management of the sweetpotato whitefly on commercial tomato. Univ. Fla. IFAS, Bradenton GCREC Res. Rep. BRA1989-12.

Shatters, Robert G. Jr., Charles A. Powell, Laura M. Boykin, He Lian Sheng, and C. L. McKenzie. 2009. Improved DNA barcoding method for Bemisia tabaci (Gennadius) and related Aleyrodidae: Development of universal and Bemisa tabaci biotype-specific mtCOI PCR primers. J Econ Entomol J Econ Entomol 102(2):750-758.

Current and future needs and opportunities for the Florida tomato industry

Bielinski M. Santos[1], Eugene J. McAvoy[2], Monica Ozores-Hampton[3], Crystal A. Snodgrass[4], and Alicia J. Whidden[5]
[1]Gulf Coast Research and Education Center, IFAS, University of Florida
[2]Hendry County Extension, IFAS, University of Florida
[3]Southwest Florida Research and Education Center, IFAS, University of Florida
[4]Manatee County Extension, IFAS, University of Florida
[5]Hillsboorugh County Extension, IFAS, University of Florida

DESCRIPTION

Background and Objective. The prolonged freezing temperatures of late 2009 and early 2010 in Florida, along with recent concerns about labor costs and availability, modified production practices, and the increased regulatory environment has prompted some growers to question the long-term sustainability of the tomato industry in Florida. Because of that situation, a detailed questionnaire was designed in March 2010 by a team of researchers, extensionists and industry representatives. The objective of this questionnaire was to identify preliminary information on problems and limitations, as well as opportunities for improving tomato production and sustainability through appropriate research and extension efforts.

Methodology. The questionnaire was distributed in April 2010 to round tomato growers mainly in west-central, southwest, south, and southeast Florida, regardless of harvested acreage, and it was either administered in person or received by fax, regular mail and electronic mail. The covered subjects were soil fumigation, breeding, water and fertilizer management, alternative production systems, pest management, water/nutrient/fumigation regulations, food safety regulations, and labor laws.

The survey had three types of questions: a) general information, b) qualitative assessment, and c) open-ended questions. The general information questions asked about production area, number of seasons per year, and county where the farm is located. The identity of the owners and managers was not disclosed outside some members of the research team. Qualitative questions used a 1 to 5 scale (i.e. 1 = not needed and 5 = extremely needed) to grade the current perception on specific subjects (Table 1). Open-ended questions offered an opportunity to the growers to provide additional comments on each subject.

In June 2010, preliminary information was organized and tomato growers were stratified in two groups according to their acreage: growers with ≥500 acres and growers with <500 acres. The frequencies of answers in each category were converted to percentages and tabulated. A paired t-test at the 5% significance level was performed to compare the cumulative percentages of the responses of both groups.

RESULTS

General Information Questions. The questionnaire covered a planted area of 21,803 acres (Table 1), which is approximately 50% of the annual planted area in Florida. It was answered by 16 tomato operations located in Manatee, Hendry, Collier, Broward, Hillsborough, Leon, St. Lucie, Palm Beach, and Hardee Counties. The average number of tomato seasons per year was 1.9.

Qualitative Assessment Questions. On the question about the future of the tomato industry, there was a significantly higher skepticism among growers with ≥500 acres than those growing <500 acres. About 71% of the growers with ≥500 acres (representing 17,800 acres) responded "terrible" or "bad", in contrast with only 29% of growers with <500 acres of tomato.

On the specific issues for present and long-term sustainability, both groups answered similarly to the last two categories of each question (i.e. highly needed and extremely needed), which indicated the level of agreement on those issues, with the exception of "the need for alternative production systems". For this question, growers with <500 acres seemed more open than their larger counterparts (72% vs. 43%) to explore non-traditional production systems, such as protected agriculture, soilless culture, and organic production.

Growers with ≥500 acres considered the following issues as either highly or extremely needed for the tomato industry: a) new labor rules and laws to facilitate production and packing (72%), b) new cultivars/varieties (72%), c) new pest management practices (58%), d) new research on alternative production systems (43%), and e) new water and fertilizer management practices (29%). Approximately 57% of the growers believed that current water/nutrient/fumigation regulations will affect their operations, whereas 43% thought that food safety regulations will be important. Among the most limiting factors cited for growing tomatoes in 2010, cold weather was the most frequently answered reason (33% of all the answers), followed by labor availability (19%), foreign competition (19%), and fruit prices (14%).

The majority of those interviewed, regardless of farm size, considered that the main issues with soil fumigation were application regulations, high prices and costs of application, and efficacy against weeds and diseases.

Open-ended Questions. Some of the most often-repeated suggestions were:

a) Characteristics of new varieties/cultivars. Resistance to bacterial spot and speck and tomato yellow leaf curl virus (64% of the surveys), and nematodes (21%). Better taste (29%), higher yields and fruit size (29%), and firmer fruit (21%).
b) Fertilizer/water management research. Efficient drip irrigation and fertilizer placement, reduced application costs, correct nutrient ratios, compliance with EPA numeric standards, proper organic fertilization, and knowledge of controlled-release fertilizers.
c) Pest management. Resistance through breeding new varieties and new practices and products to control diseases.
d) Regulations. Foreign competition adhering to food safety standards enforced in the U.S. Suggestions for implementing best management practices might not be practical.

Table 1. Preliminary results of a tomato industry questionnaire administered between May and June 2010 in four tomato production areas of Florida.

Questions	Growers ≥500 Acres	Growers <500 Acres	Significance (P≤0.05)
	----------- % -----------		
How do you rank the future of the tomato industry?			
Excellent or good	0	28.6	
Regular	28.6	42.9	
Bad or terrible	71.4	28.6	*
How do you rank for the next five years the need for new cultivars/varieties?			
Not needed or slightly needed	14.3	0	
Somewhat needed	14.3	14.3	
Highly needed or extremely needed	71.4	85.8	NS
New water and fertilizer management practices?			
Not needed or slightly needed	28.6	14.3	
Somewhat needed	42.9	57.1	
Highly needed or extremely needed	28.6	28.6	NS
Research on alternative production systems?			
Not needed or slightly needed	14.3	28.6	
Somewhat needed	42.9	0	
Highly needed or extremely needed	42.9	71.5	*
New pest management practices?			
Not needed or slightly needed	14.3	14.3	
Somewhat needed	28.6	28.6	
Highly needed or extremely needed	57.2	57.2	NS
New labor rules and laws to facilitate production and packing?			
Not needed or slightly needed	28.6	14.3	
Somewhat needed	0	14.3	
Highly needed or extremely needed	71.4	71.5	NS
How do you think that current water/nutrient/fumigation regulations will affect your operation?			
Not affected or slightly affected	14.3	0	
Somewhat affected	28.6	42.9	
Highly affected or extremely affected	57.1	57.2	NS
Food safety regulations will affect your operation?			
Not affected or slightly affected	14.3	28.6	
Somewhat affected	42.9	14.3	
Highly affected or extremely affected	42.9	57.2	NS
Most limiting factors for growing the crop in 2010:			
Cold weather	33.3	33.3	
Labor availability	19.0	14.3	
Foreign competition	19.0	4.8	
Fruit prices	14.3	9.5	
Diseases	9.5	14.3	
State/federal regulations	4.8	14.3	
Fruit yields	0	9.5	
Insects, weeds, irrigation, varieties, fumigation, packing	0	0	
What are the most concerning issues on soil fumigation?			
Application regulations	28.6	36.4	
High prices/cost of application	23.8	45.5	
Efficacy against weeds	23.8	18.2	
Efficacy against diseases	14.3	0	
Efficacy against nematodes	4.8	0	
Inconsistency under different conditions	4.8	0	
Equipment modifications	0	0	
Sample size (n)	16		
Cumulative acreage	21,803		
Average tomato seasons per year	1.9		

* Indicates a significant difference using paired T-test.
NS and * = non-significant and significant differences, respectively, according to a paired t-test ($P \leq 0.05$).

Differentiation and management of tomato bacterial speck and spot

Gary Vallad[1], Pam Roberts[2], and Jeff Jones[3]
[1]University of Florida/IFAS, GCREC, Wimauma, FL, gvallad@ufl.edu GCREC
[2]University of Florida/IFAS, SWFREC,
[3]University of Florida/IFAS,Plant Pathology Dept.,

The winter of 2010 will surely go down as a season that many in the tomato industry would rather forget. Not only did growers have to contend with the unprecedented weather, but also with the largest outbreak of bacterial speck in more than two decades. The objectives of this discussion are to review findings from the bacterial speck outbreak and review current recommendations for management of bacterial speck and spot.

Baby it's cold outside The sequence of events began in January, when weather conditions resulted in several consecutive days of below freezing temperatures throughout tomato production areas (Table 1). While the freezing temperatures were worse in Hillsborough, Manatee, and Hardee Counties, most tomato growers in these areas had not set their transplants yet. However, growers further south in Collier, Hendry, and Dade Counties had plants in the field and some mature plants already flowering in Dade Co. during this period of time. The more severe weather in Collier and Hendry Counties occurred on January 11, when temperatures in Immokalee dipped to a low 26.7 °F, with more than 10 hours below freezing (Fig. 1). Historically, these cold periods are short lived. However, the El Nino weather pattern experienced in early 2010 kept temperatures unseasonably cool (4 to 6 degrees below normal) and also increased the precipitation levels to near historical levels (Table 2). This cool, wet weather pattern not only reduced transplant establishment, plant vigor, and reduced and delayed fruit harvest, but was also conducive for bacterial speck.

In Collier and Hendry Counties, tomato production was severely affected with fields planted in December and January exhibiting severe foliar blighting and large necrotic stem lesions resembling symptoms commonly associated with late blight. Within a week, discrete lesions were evident on leaves, and after 10 days lesions were also present on the fruit. Fields planted in February and later fared better; that is they did not exhibit the large stem lesions. Throughout Hillsborough, Manatee, and Hardee Counties, bacterial speck severity varied with moderate foliar symptoms in early plantings (January through early February) and minor symptoms in later plantings. None of the severe stem lesions were observed in Hillsborough, Manatee, or Hardee Counties.

The cause of the outbreak Of the foliar and stem samples collected and sent to Dr. Jeff Jones in Gainesville, Dr. Pam Roberts in Immokalee, and Dr. Gary Vallad in Balm, several Pseudomonas and Xanthomonas strains were collected using standard bacterial isolation procedures on a semi-selective medium. Several of the Pseudomonas strains were characterized as P.s. tomato based on cultural, biochemical, and fatty acid profiles. Subsequent pathogenicity tests demonstrated that these P.s. tomato strains produced typical bacterial speck symptoms on tomato.

Attempts to isolate fungal pathogens from stem lesions were unsuccessful. Bacterial streaming was often associated with the stem lesions. Whether P.s. tomato alone accounted for the unusual stem lesions or was either exacerbated by the unusual weather or an association with another pathogen remains unclear. Also, whether the outbreak of 2010 was initiated from a natural endemic population of P.s. tomato or through the introduction of new strains (through planting material) is also uncertain.

Genotypic characterization of the collected isolates is still in progress. However, some key differences were found among some strains for the production of fluorescent pigment and coronatine suggesting that a mixed bacterial population was associated with the bacterial speck outbreak. Initial isolations recovered three P.s. tomato strains from infected tomato plants. Two of the three strains produced a fluorescent pigment on a semi-selective medium. This fluorescent pigment is characteristic of most Pseudomonas spp. and is due to the production of siderophores, high-affinity iron chelating compounds used to scavenge iron from the environment (Höfte, 1993). Another characteristic trait of Pseudomonas syringae strains is the production of coronatine (COR), a key phytotoxin that functions to disrupt plant defenses (Mittal and Davis, 1995; Uppalapati et al., 2007). Based on a PCR test, one of the two fluorescent P.s. tomato strains either lacked or carried a different COR allele. The second fluorescent strain was positive for the COR gene, typical of P.s. tomato, and caused moderate to severe foliar lesions with extensive chlorosis and considerable blighting on inoculated tomato plants. Strains lacking COR are impaired in pathogenicity; as such, the isolated COR negative strain only caused mild symptoms consisting of limited chlorosisand no foliar blighting on inoculated tomato plants. Interestingly, while the COR negative strain was clearly less aggressive compared to the two COR positive strains, there was no difference in disease associated with the lack of fluorescent pigment production. An additional 20 strains were isolated from symptomatic tomato plants from March through May and await further characterization.

Bacterial Speck vs. Bacterial Spot Pseudomonas syringae pv. tomato could be considered the cool weather cousin to Xanthomonas perforans (formerly called Xanthomonas axonopodis pv. vesicatoria or Xanthomonas campestris pv. vesicatoria) the causal agent of bacterial spot. Bacterial speck is favored by high relative humidity and temperatures of 64 to 75 °F, however the bacterium can still persist at temperatures as high as 85 °F (as it did in many tomato fields from April through June in Florida). Bacterial spot is favored by temperatures above 75 °F in addition to high relative humidity. Symptoms of both bacterial speck and spot affect the foliage, stems, petioles, inflorescent

Table 1. Number of freeze events in 2010 (Jan. - March).

	No. days with temperatures:	
Location	**≤ 32(°F)**	**≤ 28(°F)**
Balm	11	4
Ona	11	4
Immokalee	4	1
Homestead	1	0

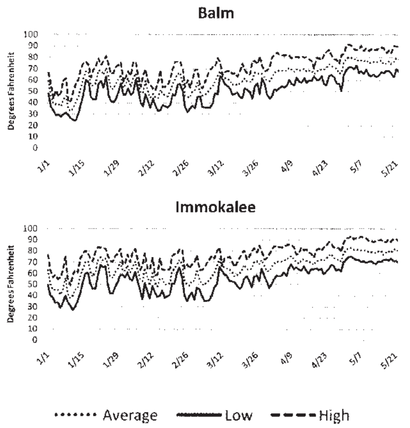
* Based on records from FAWN database (http://fawn.ifas.ufl.edu/)

Table 2. Rain totals and number of rain events ≥0.10 inches in 2010 (Jan. - May).

	January February March April May									
Location	**Total**	**No.**	**Total**	**No.**	**Total**	**No.**	**Total**	**No.**	**Total**	**No.**
Balm	3.18	6	2.23	5	6.14	7	2.80	5	0.89	4
Ona	1.95	4	2.39	2	5.92	6	2.84	3	6.48	7
Immokalee	2.08	5	2.68	5	8.62	8	7.21	6	5.01	4
Homestead	0.92	4	4.12	4	2.35	4	4.43	5	4.53	4

* Based on records from FAWN database (http://fawn.ifas.ufl.edu/)

Figure 1. Daily average, high and low temperatures recorded in Balm and Immokalee, FL from Jan. 1 to May 31, 2010. Records from FAWN database (http://fawn.ifas.ufl.edu/).



tissues and fruit of tomato, and can be tricky to differentiate in the field. Foliar symptoms of both consist of small circular lesions that can coalesce under ideal conditions leading to general blighting of foliage. Bacterial spot lesions are generally brown with a greasy appearance when the relative humidity is high. Bacterial speck lesions are often dark brown to black, don't have a greasy appearance, and often are surrounded by a discrete chlorotic (yellow) halo. However, this chlorotic halo is not always diagnostic, as development varies depending on environmental conditions and cultivar susceptibility. Also, leaves severely affected by bacterial spot often develop a general chlorosis that usually leads to blighting and can lead to some confusion. The name 'bacterial speck' can be misleading, since lesions can be as large as or larger than bacterial spot lesions; however, they usually are not as symmetrical as spot lesions. These large lesions have been commonly associated with recent bacterial speck outbreaks in Florida. Bacterial speck and spot are more clearly differentiated by fruit symptoms. Fruit lesions of bacterial speck are slightly raised or sunken, generally much smaller (1/16 in.) than those of bacterial spot, are quite superficial, and do not crack or become scaly as those associated with bacterial spot.

Management Disease management for bacterial speck and spot is very similar. Both require an integrated approach for best results.

1. Rotate tomato fields to avoid carryover on crop residue. Neither bacterium survives long in the absence of host material (Jones et al. 1986; Peterson, 1963). However, P.s. tomato is able to survive in crop residue for an extended period of time (up to 30 weeks in some studies; Chambers and Merriman, 1975), especially in cooler soils that may allow for carry over into winter-spring plantings (McCarter et al., 1983)
2. Eliminate any volunteers and weed species (especially solanaceous weeds) that can act as a reservoir. Pseudomonas syringae pv. tomato can survive on the leaves and roots of both (McCarter et al., 1983; Schneider and Grogan, 1977).
3. Start with clean, healthy transplants preferably produced in facilities removed from tomato and pepper production. Both X. perforans and P.s. tomato are seed-borne, which allows for the movement of strains on a global scale (McCarter et al. 1983; Jones et al. 1986). Both pathogens can persist on tomato leaves without causing symptoms when conditions are unfavorable for disease development.
4. Refrain from field activities when foliage is wet to minimize spreading either bacterium throughout the plant canopy and the field.
5. Apply bactericidal pesticides as necessary. When applying copper-based bactericides mix with mancozeb for the control of copper resistant strains (Conover and Gerhold, 1981), which are prevalent among both pathogens.

Exclusion is the best tactic to manage bacterial speck and spot on tomato. The goal of field rotations, destroying infected debris, volunteers, and weeds, and using disease-free tomato transplants is to minimize the amount of inoculum in the field at the beginning of the season. Refraining from field activities when the plant canopy is wet and making timely application of bactericides reduces the movement of bacteria throughout the plant canopy and field. Bactericides, like most fungicides in general, are preventative in nature. Unfortunately, even the best bactericidal treatment offers only limited protection when environmental conditions are favorable for rapid disease development, especially during periods of heavy, wind-driven rains; further stressing the need to implement preventive tactics that exclude both pathogens and to avoid production during periods associated with high rain events (summer months).

Numerous studies have demonstrated the use of various compounds and biological control agents for the suppression of bacterial spot and speck; including plant defense elicitors, bacteriophage, salts of phosphorous acid, and various antagonistic strains of bacteria (Balogh et al., 2003; Ji et al., 2006; Louws et al., 2001; Obradovic et al., 2004 & 2005; Roberts et al., 2008; Wen et al., 2009; Wilson et al., 2002) . Unfortunately, none of these strategies have resulted in consistent improvement in the management of bacterial speck or spot over the standard application of copper + mancozeb/maneb. This emphasizes the need to develop tomato varieties with improved resistance to bacterial speck and spot.

REFERENCES

Balogh, B., J.B. Jones, M.T. Momol, S.M. Olson, A. Obradovic, L.E. Jackson. 2003. Improved Efficacy of Newly Formulated Bacteriophages for Management of Bacterial Spot on Tomato. Plant Dis. 87:949-954.

Chambers, S.C. and P.R. Merriman. 1975. Perennation and control of Pseudomonas tomato in Victoria. Australian Journal of Agricultural Research 26:657-663.

Conover, R.A. and N.R. Gerhold. 1981. Mixtures of copper and maneb or mancozeb for control of bacterial spot of tomato and their compatibility for control of fungus diseases Phytophthora infestans, Stemphylium solani, Xanthomonas campestris pv. vesicatoria, Florida . Proc. Fla. State Hort. Soc. 94:154-156

Höfte, M. 1993. Classes of microbial siderophores, p. 3-26. In L.L. Barton and B.C. Hemming (ed.), Iron chelation in plants and soil microorganisms. Academic Press, San Diego, CA.

Ji, P., H.L. Campbell, J.W. Kloepper, J.B. Jones, T.V. Suslow, and M. Wilson. 2006. Integrated biological control of bacterial speck and spot of tomato under field conditions using foliar biological control agents and plant growth-promoting rhizobacteria. Biological Control 36:358-367.

Jones, J.B., K.L. Pohronezny, R.E. Stall, and J.P. Jones. 1986. Survival of Xanthomonas campestris pv. vesicatoria in Florida on tomato crop residue, weeds, seeds, and volunteer tomato plants. Phtopathology 76:430-434.

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

McCarter, S.M., J.B. Jones, R.D. Gitaitis, and D.R. Smitley. 1983. Survival of Pseudomonas syringae pv. tomato in association with tomato seed, soil, host tissue, and epiphytic weed hosts in Georgia. Phytopatholology 73:1393-1398.

Mittal, S. and K.R. Davis. 1995. Role of the phytotoxin coronatine in the infection of Arabidopsis thaliana by Pseudomonas syringae pv. tomato. Molecular Plant-Microbe Interactions 8:165-171.

Obradovic, A., J.B. Jones, M.T. Momol, B. Balogh, and S.M. Olson. 2004. Management of Tomato bacterial spot in the field by foliar applications of bacteriophages and SAR inducers. Plant Disease, 88: 736-740.

Obradovic, A., J. B. Jones, M. T. Momol, S. M. Olson, L. E. Jackson, B. Balogh, K. Guven, and F. B. Iriarte. 2005. Integration of Biological Control Agents and Systemic Acquired Resistance Inducers Against Bacterial Spot on Tomato. Plant Dis. 89:712-716.

Peterson, G.H. 1963. Survival of Xanthomonas vesicatoria in soil and diseased tomato plants. Phytopathology 53:765-767.

Roberts, P.D., M.T. Momol, L. Ritchie, S.M. Olson, J.B. Jones, and B. Balogh. 2008. Evaluation of spray programs containing famoxadone plus cymoxanil, acibenzolar-S-methyl, and Bacillus subtilis compared to copper sprays for management of bacterial spot on tomato. Crop Protection 27:1519-1526.

Schneider, R.W. and R.G. Grogan. 1977. Bacterial speck of tomato: Sources of inoculum and establishment of a resident population. Phytopathology 67:388-394.

Uppalapati, S.R., Y. Ishiga, T. Wangdi, B. Kunkel, A. Anand, K. Mysore, and C. Bender. 2007. The phytotoxin coronatine contributes to pathogen fitness and is required for suppression of salicylic acid accumulation in tomato inoculated with Pseudomonas syringae pv. tomato DC3000. Molecular Plant-Microbe Interactions 8:955-965.

Wilson, M., Campbell, H. L., Jones, J. B., and Cuppels, D. L. 2002. Biological Control of Bacterial Speck of Tomato Under Field Conditions at Several Locations in North America. Phytopathology. 92:1284 -1292.

Effects of shoot pruning on bacterial spot severety and yields of tomato cultivars

Bielinski M. Santos[1], Gary E. Vallad[1], Teresa P. Salame-Donoso[1], and Crystal A. Snodgrass[2]
[1]Gulf Coast Research and Education Center, IFAS, University of Florida, 14625 CR 672, Wimauma, FL 33598
[2]Manatee County Extension, IFAS, University of Florida, 1303 17th St W, Palmetto, FL 34221

INTRODUCTION

Among the many diseases that affect tomato, bacterial spot is one of the most troublesome (Bouzar et al. 1999; Jones et al., 2004; O'Garro and Charlemagne, 1994; O'Garro and Tudor, 1994; Pernezny et al., 1996; Pohronezny and Volin, 1983). This disease is caused by X. perforans, X. vesicatoria, X. euvesicatoria, and X. gardneri (formerly referred to as X. campestris pv. vesicatoria) and favored by warm, humid weather conditions, but often initiated by episodes of wind-driven rain. On the leaves, infection begins when the bacterium enters the plant through natural openings and wounds. Within a few days, the first symptoms, water-soaked lesions, can be observed on lower leaf surfaces. If ideal environmental conditions persist, lesions can enlarge and coalesce causing extensive leaf chlorosis and defoliation. Once established, the disease can still cause significant losses even in the absence of rain. Under conditions of high relative humidity such as a heavy dew or fog, the disease can spread around the leaf margin and cause a general blighting that can lead to premature leaf drop. All aboveground tissues are susceptible to the disease. Fruit lesions begin as small raised blisters on the fruit surface that are a lighter green than the rest of the immature fruit. As the lesions enlarge, they turn brown to black and develop a layer of scab-like tissue (Jones, 1991).

Control of bacterial spot relies on cultural exclusion of the pathogen from production areas, use of resistant cultivars, and diligent application of copper-based bactericides. Regardless, bacterial spot epidemics occur every season in most tomato production regions. The presence of infected tomato volunteers and weedy hosts are common sources of local inoculum. The use of copper-based bactericides can offer some level of control, except under the most extreme weather conditions. However, the reliance on copper in agriculture has led to widespread copper tolerance among bacterial pathogens on many crops. A dithiocarbamate (either maneb or mancozeb) is routinely combined with copper-based bactericides to enhance bacterial spot control (Conover and Gerhold, 1981; Jones et al., 1991), but reduces the fungicidal activity of the dithiocarbamate (Jones and Jones, 1985). There is a need for additional practices to manage bacterial spot.

Most growers of round tomatoes in Florida perform shoot pruning on their crops during the early part of the growing season to reduce the number of unwanted lateral branches. This practice usually occurs between 2 and 4 weeks after transplanting (WAT) and it could be accomplished once or twice during that period by removing shoots from ground level up to the primary fork below the first flower cluster. Previous research showed that for some cultivars, shoot pruning is unnecessary (Kemble et al., 1994; Santos, 2008). However, other studies established otherwise. Carlton et al. (1994) and Sikes and Coffey (1976) determined that shoot pruning increased early yield, but reduced total

Table 1. Effects of early shoot pruning levels, tomato cultivars, and bacterial spot inoculation on tomato plant height at 3 and 6 WAT and average area under the disease progress curve (AUDPC). Spring and Fall 2009, Balm, Florida.

	Plant height[z]		AUDPC[y]
	3 WAT	6 WAT	
	(cm)		
	Pruning		
Non-pruned	31.3	57.1	1157
Light	33.0	57.1	1091
Heavy	31.7	58.8	1150
Significance ($P \leq 0.05$)	NS	NS	NS
	Cultivar		
'Security-28'	32.2	57.8	1028b
'Tygress'	31.8	57.5	1238a
Significance ($P \leq 0.05$)	NS	NS	*
	Bacterial spot		
Non-inoculated	32.5	59.3	821b
Inoculated	31.5	56.1	1445a
Significance ($P \leq 0.05$)	NS	NS	*

[z]Column means separated by Fisher's protected least significant difference test ($P \leq 0.05$). Values followed by the same letter in the same column do not differ at the 5% significance level.
[y]Disease severity was rated using the Horsfall-Barratt scale, a non-dimensional 12 point scale, to assess the percentage of canopy affected by bacterial leaf spot. Values were converted to mid-percentages and used to generate AUDPC
NS and * = non-significant and significant, respectively.
1 cm = 2.5400 inches.

Table 2. Effects of early shoot pruning levels, tomato cultivars, and bacterial spot inoculation on early extra-large and total marketable fruit weight. Spring and Fall 2009, Balm, Florida.

Extra-large fruit weight[z] (ton/acre)		Marketable fruit weight (ton/acre)	
Pruning		Pruning x cultivar	
Non-pruned	3.5	Non-pruned, 'Security-28'	7.4 a
Light	3.6	Light, 'Security-28'	7.1 a
Heavy	3.4	Heavy, 'Security-28'	6.3 a
Significance ($P \leq 0.05$)	NS	Heavy, 'Tygress'	4.4 b
Cultivar		Light, 'Tygress'	3.7 b
'Security-28'	5.1 a	Non-pruned, 'Tygress'	3.4 b
'Tygress'	1.9 b	Significance ($P \leq 0.05$)	*
Significance ($P \leq 0.05$)	*		
Bacterial spot		Bacterial spot	
Non-inoculated	4.2 a	Non-inoculated	6.4 a
Inoculated	2.9 b	Inoculated	4.8 b
Significance ($P \leq 0.05$)	*	Significance ($P \leq 0.05$)	*

[z]Column means separated by Fisher's protected least significant difference test ($P \leq 0.05$). Values followed by the same letter in the same column do not differ at the 5% significance level.
NS and * = non-significant and significant, respectively.

Table 3. Effects of early shoot pruning levels, tomato cultivars, and bacterial spot inoculation on seasonal extra-large and total marketable fruit weight. Spring and Fall 2009, Balm, Florida.

Extra-large fruit weight[z] (ton/acre)		Marketable fruit weight (ton/acre)	
Cultivar x bacterial spot		Pruning	
Non-inoculated, 'Security-28'	11.1a	Non-pruned	18.2a
Inoculated, 'Security-28'	8.1b	Light	17.4ab
Non-inoculated, 'Tygress'	7.0c	Heavy	16.3b
Inoculated, 'Tygress'	7.5c	Significance ($P \leq 0.05$)	*
Significance ($P \leq 0.05$)	*	Cultivar	
Pruning		'Security-28'	18.3a
		'Tygress'	15.0b
		Significance ($P \leq 0.05$)	*
Non-pruned	8.4	Bacterial spot	
Light	8.3	Non-inoculated	18.1a
Heavy	8.4	Inoculated	15.2b
Significance ($P \leq 0.05$)	NS	Significance ($P \leq 0.05$)	*

[z]Column means separated by Fisher's protected least significant difference test ($P \leq 0.05$). Values followed by the same letter in the same column do not differ at the 5% significance level.
NS and * = non-significant and significant, respectively.

yield. Navarrete and Jeannequin (2000) found that when shoot pruning was performed every 21 d, tomato stem diameter, vigor, fruit number and weight decreased. It is hypothesized that shoot pruning could be a potential practice to reduce bacterial spot infection because: a) it reduces the amount of foliage near the soil that could serve as an initial point of entry for the bacterium, and b) it changes architecture of plant canopies thus changing air and moisture flow through the leaves (Carlton et al., 1994). Additionally, shoot pruning costs about $50/acre, which is a significant expense for tomato production. The objective of this study was to determine the effect of early shoot pruning on the severity of bacterial spot, and on the growth and yield of different tomato cultivars.

Small-plot studies Two field trials were conducted in the Spring and Fall 2009 at the Gulf Coast Research and Education Center of the University of Florida in Balm, FL, where the soil is classified as a Myakka fine sand siliceous hyperthermic Oxyaquic Alorthod with 1.5% organic matter and pH 7.3. Planting beds were pre-formed with a standard bedder and were 32 inches wide at the base, 28 inches wide at the top, 8 inches high, and spaced 5 ft apart on centers. Beds were fumigated 3 weeks before transplanting with methyl bromide plus chloropicrin (67:33 v/v) at a rate of 175 lb/acre applied through three chisels spaced 12 inches apart, which delivered fumigant 6 inches deep. A single line of drip irrigation tubing was placed 1 inch deep down the center of the beds, which were covered with silver on black mulch. Tomato seedlings in the four-true-leaf stage (8 inches tall) were transplanted in single rows and 2 inches offset of bed centers. Planting in-row distance was 18 inches.

Twelve treatments resulted from the combination of two tomato cultivars, two bacterial spot inoculation regimes, and three shoot pruning programs. The tomato cultivars were 'Tygress' and 'Security-28', which are resistant to the tomato yellow leaf curl virus. Shoot pruning levels were heavy and light, and a non-pruned treatment was added. Light pruning was defined as carefully removing by hand only two to three lateral buds ("suckers") from the main stems from ground level to 6 inches high, whereas heavy pruning was defined as the removal of all the lateral buds and stems up to 6 inches high. Early shoot pruning occurred between 3 and 4 WAT. Bacterial spot treatments consisted of non-inoculated plots and plots inoculated with a suspension of X. perforans strain XT4 (1 x 106 cfu/mL), which was applied to the foliage with a conventional backpack sprayer at 5 WAT at a volume of approximately 15 mL per plant. These treatments were arranged in a split-split plot design with five replications, where the tomato cultivars were in the main plots, bacterial spot inoculation in the subplots, and shoot pruning regimes in the sub-subplots. Experimental units were 20 ft long (10 tomato plants/plot) with a 5-ft-long length of bed as a non-treated buffer zone between experimental units. Each trial was 12 weeks, from the time of transplanting to the last harvest.

Plant heights were determined at 3 and 6 WAT and tomato fruit were harvested twice (10 and 12 WAT) in the mature green stage and graded following current market standards as extra-large and marketable fruit of all categories. Fruit yield from the first harvest (10 WAT) were considered early fruit weight, while the summation of the two harvests (10 and 12 WAT) was the seasonal fruit weight. For bacterial spot, plots were monitored for disease and rated for severity at 7 and 9 WAT in the spring trial, and at 9 and 11 WAT in the fall trial using the Horsfall-Barratt scale, a non-dimensional 12 point scale, to assess the percentage of canopy affected by bacterial leaf spot (Horsfall and Barratt, 1945). Disease severity values were converted to mid-percentages and used to generate area under disease progress curve (AUDPC) using the trapezoidal method prior to statistical analyses (Jeger, 2004). Data were subjected to analysis of variance to determine significance ($P<0.05$) of main effects and their interactions on the variables. Significant treatment means were separated using Fisher's-protected least significant difference (LSD) test at the 5% level.

Grower field validations Five large validations were established in two commercial tomato fields (West Coast Tomato at Duette and Pacific Tomato Growers at Parish) located in Manatee Co., FL. At the first location, 'XP-200' tomato was transplanted on Jan. 20 and 25, and Feb. 4, 2010, whereas at the latter location 'XP-200' and 'Tygress' tomatoes were planted on Feb. 9, 2010. The planting densities ranged between 3350 and 3600 plants/acre. At Duette, seepage irrigation was used to grow the crop, while at Parish seepage irrigation was applied for the first three weeks and a combination of seepage and drip was utilized the rest of the growing season.

Pruning treatments were "light" pruning performed as described before and non-pruned plots (control). At Duette, plots planted on Jan. 20 and 25, and Feb. 4 were pruned on Feb. 25, Mar. 15 and 17, respectively. At Parish, tomato plants were pruned on Mar. 15. At the first location, plots consisted of two beds between 400 and 600 ft long, depending on the configuration of the fields, whereas at the second location plots were single beds (400 ft long). The treatments were established in a randomized complete block design and replicated three times in each planting date and location, resulting in five separate trials. Plant height, leaf greenness (as an estimate of chlorophyll content), and petiole $N\text{-}NO_3$ were collected on Mar. 25 and Apr. 8 at Duette and Parish, respectively. Early and total marketable fruit weights were collected at Duette in early and late planting dates. Only early fruit weight was determined in the middle planting date at this location. Data was analyzed as previously described.

RESULTS AND DISCUSSION

Small-plot studies Data from two seasons were combined for analysis. Tomato plant height at 3 and 6 WAT was not influenced by any of the three factors under study or their interactions (Table 1). Thus, tomato plants were the same heights averaging 32.0 cm when shoot pruning was performed (3 WAT) and shoot pruning did not affect the length of tomato main stems at 6 WAT, which ranged between 57.1 and 58.8 cm at 6 WAT, regardless of cultivars and bacterial spot inoculation.

The effect of bacterial spot inoculation was significant with disease severity based on AUDPC of 1445 (an average disease severity of 41%) in inoculated versus an AUDPC of 821 (an average disease severity of 29%) in non-inoculated plots averaged across both seasons (Table 1).

Table 4. Effects of early pruning programs on tomato plant height, leaf greenness, petiole sap NO_3-N, early and total fruit weight. Spring 2010, Duette and Parish, Florida.

Pruning programs	Plant height^z	Leaf greenness	Petiole NO_3-N	Marketable fruit weight	
	-----------------------Mar. 25---------------			Early	Total
	(inches)	(SPAD value)	(ppm)	(ton/acre)	
	Duette, FL				
Jan. 20 planting ('XP-200')					
Non-pruned	21.4	56	1133	14.8	24.1
Light pruning	21.7	53	947	15.2	24.5
Significance ($P \leq 0.05$)	NS	NS	NS	NS	NS
Jan. 25 planting ('XP-200')					
Non-pruned	17.7	46	1133	13.5	NA
Light pruning	17.3	43	1100	12.8	NA
Significance ($P \leq 0.05$)	NS	NS	NS	NS	
Feb. 4 planting ('XP-200')					
Non-pruned	15.6	41	997	13.6	21.3
Light pruning	15.8	41	1100	13.1	21.1
Significance ($P \leq 0.05$)	NS	NS	NS	NS	NS
	Parish, FL				
Feb. 9 planting ('XP-200')					
	--------------------------Apr. 8--------------------------				
Non-pruned	20.0	54	1133	NA	NA
Light pruning	20.5	54	1167	NA	NA
Significance ($P \leq 0.05$)	NS	NS	NS		
Feb. 9 planting ('Tygress')					
Non-pruned	19.6	50	1433	NA	NA
Light pruning	20.1	52	1367	NA	NA
Significance ($P \leq 0.05$)	NS	NS	NS	-	-

^{z}Column means separated by Fisher's protected least significant difference test ($P \leq 0.05$).
NS = non-significant. NA = yield non-available.

Disease severity was greater at the end of the spring trial in comparison to the end of the Fall 2009 trial (65% and 35%, respectively). Inversely, initial disease severity was much greater in the fall study (24% disease severity in non-inoculated plots) than the spring trial (1.5% disease severity in non-inoculated plots). 'Tygress' was more susceptible to bacterial spot than 'Security-28', exhibiting 20.4% more disease on average based on AUDPC.

Early extra-large fruit weight was affected by tomato cultivars and the inoculation of bacterial spot, but not by pruning programs or the interaction among factors. 'Security-28' had the highest early extra-large fruit weight with 5.1 ton/acre, which was more than 2.5 times higher than that obtained with 'Tygress' (Table 2). Tomato plants inoculated with bacterial spot reduced their extra-large fruit weight by 31% in comparison with those non-inoculated with the bacterium. Pruning programs resulted in extra-large yields ranging between 3.4 and 3.6 ton/acre. Early marketable fruit weight was influenced by the interaction between cultivars and pruning programs, and separately by the inoculation of bacterial spot (Table 2). There were no differences on early marketable fruit weight among the combinations of 'Security-28' and the three pruning programs, which averaged 6.9 ton/acre of fruit. At the same time, all pruning programs in plots planted with 'Tygress' did not differ among each other, while having significantly lower marketable fruit weight at 10 WAT than the 'Security-28' and pruning combinations. Tomato plants in plots inoculated with bacterial spot decreased their marketable fruit weight at 10 WAT by 25% in comparison with the non-inoculated plants.

The cultivar by bacterial spot inoculation interaction affected the seasonal extra-large fruit weight. The highest seasonal extra-large fruit weight was obtained in plots non-inoculated with bacterial spot and planted with 'Security-28' (11.1 ton/acre), followed by the combination of 'Security-28' and bacterial spot inoculation (Table 3). There was no effect of the bacterial spot inoculation on the seasonal extra-large fruit weight obtained in plots planted with 'Tygress'. All three factors individually influenced the seasonal marketable fruit weight of tomato. Non-inoculated plots produced 21% higher seasonal yields (18.1 ton/acre) in comparison with plants inoculated with bacterial spot (15.0 ton/acre). When comparing pruning programs, there was no difference between light pruned plants and the non-pruned control for seasonal marketable fruit weight, regardless of tomato cultivars (Table 3). However, heavy pruning did reduce seasonal yields by 10% in comparison with the non-pruned control.

Grower Field Validations. In both grower fields, there were no significant differences between both pruning treatments for plant height, leaf greenness, petiole sap NO_3-N, regardless of planting date and cultivars. The same responses were observed for early and total marketable fruit weight at the Duette location, with average early and total yields of 13.8 and 22.8 ton/acre, respectively.

These studies suggested that "light" shoot pruning, which is the standard grower practice in Florida, did not improve tomato yield of total and extra-large marketable fruit. At the same time, this practice did not reduce bacterial spot severity on 'Security-28' and 'Tygress' tomato leaves. In contrast, heavy pruning reduced seasonal marketable yields in comparison with non-pruned plants. It is possible that other cultivars may benefit from shoot pruning, as the tested cultivars are newer hybrids introduced to the market for their resistance to tomato yellow leaf curl virus. These results agreed with those previously reported by Kemble et al. (1994) and Santos (2008). Data emphasized the impact of bacterial spot on fruit production, especially the production of early extra-large fruit, and the importance of selecting varieties with improved tolerance to bacterial spot when disease pressure is high. By eliminating light shoot pruning from routine cultural practices, tomato growers can save up to $50/acre, which might translate into near $2 million per year in savings for all the planted areas in Florida.

ACKNOWLEDGEMENTS

The authors thank the support of West Coast Tomato and Pacific Tomato Growers.

LITERATURE CITED

Bouzar, H., J.B. Jones, R.E. Stall, F.J. Louws, M. Schneider, J.L.W. Rademaker, F.J. de Bruijn, and L.E. Jackson. 1999. Multiphasic analysis of xanthomonads causing bacterial spot disease on tomato and pepper in the Caribbean and Central America: evidence for common lineages within and between countries. Phytopathology 89:328-335.

Carlton, W.M., M.L. Gleason, and E.J. Braun. 1994. Effects of pruning on tomato plants supporting epiphytic populations of Clavibacter michiganensis subsp. michiganensis. Plant Dis. 78:742-745.

Conover R.A. and N.R. Gerhold. 1981. Mixtures of copper and maneb or mancozeb for control of bacterial spot of tomato and their compatibility for control of fungus diseases. Proc. Fla. State Hort. Soc. 94:154-156.

Horsfall, J.G. and R.W. Barratt. 1945. An improved grading system for measuring plant disease. Phytopathology 35:655.

Jeger, M.J. 2004. Analysis of disease progress as a basis for evaluating disease management practices. Annu. Rev. Phytopathol. 42:61-82.

Jones, J.B. 1991. Bacterial spot, p. 27. In: J.B. Jones, J.P. Jones, R.E. Stall, and T.A. Zitter (eds.). Compendium of tomato diseases. APS Press, St. Paul, MN.

Jones, J.B., and J.P. Jones. 1985. The effect of bacteri¬cides, tank mixing time, and spray schedule on bacterial leaf spot of tomato. Proc. Fla. State Hort. Soc. 98:244 247.

Jones, J.B., G.H. Lacy, H. Bouzar, R.E. Stall, and N.W. Schaad. 2004. Reclassification of the xanthomonads associated with bacterial spot disease of tomato and pepper. Systematic Appl. Microbiol. 27:755-762

Jones, J.B., S.S. Woltz, J.P. Jones, and K.L. Portier. 1991. Population dynamics of Xanthomonas campestris pv. vesicatoria on tomato leaflets treated with copper bactericides. Phytopathology 81:714-719.

Kemble, J.M., J.M. Davis, R.G. Gardner, and D.C. Sanders. 1994. Spacing, root cell volume, and age affect production and economics of compact-growth-habit tomato. HortScience 29:1460-1464.

Navarrete, M. and B. Jeannequin. 2000. Effect of frequency of axillary bud pruning on vegetative growth and fruit yield in greenhouse tomato crops. Scientia Hort. 86:197-210.

O'Garro, L.W. and E. Charlemagne. 1994. Comparison of bacterial growth and activity of glucanase and chitinase in pepper leaf and flower tissue infected with Xanthomonas campestris pv. vesicatoria. Physiol. and Mol. Plant Pathol. 45:181-188.

O'Garro, L.W. and S. Tudor. 1994. Contribution of 4 races of Xanthomonas campestris pv. vesicatoria to bacterial spot in Barbados. Plant Dis. 78:88-90.

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

Pohronezny, K. and R.B. Volin. 1983. The effect of bacterial spot on yield and quality of fresh-market tomatoes. HortScience 18:69-70.

Santos, B.M. 2008. Early pruning on 'Florida-47' and 'Sungard' tomato. HortTechnology 18:467-470.

Sikes, J. and D.L. Coffey. 1976. Catfacing of tomato fruits as influenced by pruning. HortScience 11:26-27.

Food safety and economic impacts on Florida tomato producers

Gabrielle Ferro and John VanSickle

University of Florida/IFAS, Food & Resource Economics Dept., Gainesville, FL, sickle@ufl.edu

President Clinton presented a proposal in 1997 for a food safety initiative titled 'Food Safety from Farm to Table'. This proposal outlined the six agencies in charge of food borne illnesses and was intended to reduce the risk of these pathogens in produce. Out of this proposal came the push for the Hazard Analysis and Critical Control Point (HACCP) system, which outlined the process for identifying points of potential contamination. Federal regulations allowed state laws to go above and beyond regulations imposed at the federal level. While there were standards for meat and poultry no clear standards existed for produce. These were deferred to the states (Guidance for industry, 2010).

The State of Florida implemented food safety standards in 2007 requiring mandatory food safety audits in an attempt to mitigate the risk associated with food borne illness in growing tomatoes. These standards came about in response to a multistate outbreak originating from tomatoes in July, 2007. Many packinghouses and handlers required that growers submit to additional private audits to ensure the safety of their produce. Food safety audits are an additional cost to the grower but provide some assurance that the product is safe. Whether these audits provide a benefit to the grower remains to be seen. Lloyd (2001) and Arnade (2009) determined that there is no discrimination when a food borne incident occurs, finding that regardless of the source of the outbreak, a food borne illness incident affects all growers of the same product.

According to the Center for Disease Control (CDC), since 1990 there have been 12 multistate outbreaks and numerous small outbreaks of Salmonella that can be attributed to the production of tomatoes. While Florida has been enforcing Good Agricultural Practices (GAP) and Best Management Practices (BMP) since 2007 other states that produce tomatoes do not have the same standards. Regardless of the point of impact (i.e., origin of food borne illness incident) the affect remains the same. Florida tomatoes take the brunt of food borne illness incidents because of their high volume of production relative to other producing areas. The question remains; do the standards implemented in 2007 effect the risk that farmers undergo to produce fresh market tomatoes?

METHODOLOGY

A price dependent model was specified to analyze the impacts of food borne illness on the returns to Florida growers. Data used to quantify the incidence of food borne illnesses associated with fresh market tomatoes was gathered from the CDC. These data included: the location of outbreak, the month of outbreak, the number of ill and the confirmed etiology when it was caused by tomatoes or tomato products. The price of tomatoes was specified as a function of the number of cartons produced (quantity) in Florida and Mexico, the price of a substitute product, consumer income and finally whether or not the month had a food safety scare associated with tomatoes. The quantity of Florida and Mexican tomatoes is measured in cartons (25 pounds) of tomatoes. The price of Florida cucumbers was included in the model to account for substitution effects. Consumer income is measured by the national consumer income reported by the Bureau of Economic Analysis. In addition, an interaction term between consumer income and the price of Florida cucumbers was added to the model. Finally, there are two dummy variables, each measuring a different food etiology that has occurred; salmonella and hepatitis A.

SAS computer analysis program software was used to estimate the model discussed above. Formally, this model can be written as

$$P = \beta_0 + \beta_1 CI + \beta_2 QQS + B_3 SALMONELLA + \beta_4 HA + \beta_5 CUC + \beta_6 CIC \qquad \text{Equation (1)}$$

The variables in the equation are defined as follows: P is the monthly price of Florida tomatoes, as reported by the Florida Agriculture Statistical Directory; QQS is the quantity shipped (1,000 cartons) of Florida and Mexican tomatoes as reported by the annual Florida Tomato Committee Reports; CI is consumer income as reported by the Bureau of Economic Analysis, measured as compensation received by employees (not deflated, seasonally adjusted at an annual rate); CUC is the price of Florida cucumbers as reported by the Florida Agriculture Statistical Directory; $SALMONELLA$ is a dummy variable equal to 1 when there was an outbreak of salmonella during the month in question as reported by the CDC, 0 otherwise; HA is a dummy variable equal to 1 when there was an outbreak of hepatitis A during the month in question as reported by the CDC, 0 otherwise, and; CIC is an interaction term between consumer income and cucumber price.

The results of equation (1) were used to estimate the impacts of food borne illnesses associated with fresh tomatoes on the returns to Florida growers. The model was simulated for the 2007 season using actual data collected for the regression analysis and then simulated with values for the Salmonella and HA dummy variables set to 0. The results of these calculations were multiplied by the volume of tomatoes marketed during each period over that season to estimate the total revenues received during the season and what would have been received had there not been an associated food borne illness reported. The difference in the two revenue streams represents the overall impact of the incidences of Salmonella and Hepatitis A. These simulated revenues were used to estimate the percentage decrease in revenues associated with the food safety incidences.

RESULTS

The data used in the model for equation (1)

[1]The data analysis for this paper was generated using SAS software, Version 9.2 of the SAS System for University of Florida. Copyright © 2002-2008 SAS Institute Inc. SAS and all other SAS Institute Inc product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA

Table 1. Estimated parameters for equation (1) corrected for first order autocorrelation

Number of Observations N = 44, R2 = 0.453 Variable	Parameter	Standard Error	Pr > |t|
INTERCEPT	-91.8992	70.1857	0.1987
CI	0.0363	0.023	0.1233
QQS	-0.000576	0.000224	0.0142
SALMONELLA	-2.6138	1.58	0.1068
HA	-4.1024	3.4081	0.2365
CUC	9.0225	4.9798	0.0784
CIC	-0.002946	0.001637	0.0802

spanned 4 years from 2004 to 2007. The coefficients on the dummy variables for Salmonella and Hepatitis A are both negative indicating that incidents of these food borne illnesses associated with tomatoes anywhere in the U.S. cause the price of Florida tomatoes to decrease. The results suggest that lower prices result from a decline in demand for the product as a result of food safety concerns. Hepatitis A had the larger impact, causing tomato price to fall $4.10 per carton when it occurred compared to prices falling $2.61 per carton when Salmonella was present (Table 1).

Price is simulated for 2007 using equation (1) with actual data collected for the regression analysis, yielding price estimates with the food safety occurrences that happened in 2007. CDC identified Salmonella associated with tomatoes in 3 months of 2007 – June, July and October. There were no occurrences of Hepatitis A associated with tomatoes in 2007. The simulated returns with the Salmonella food safety incidents that actually occurred in 2007 averaged $10.71 per carton. The equation was simulated a second time assuming that no food safety incident occurred (i.e., setting the Salmonella values to 0 for all time periods). Using the regression data and calculating an average price assuming there was no food safety incident results in an estimate for average price of $11.15, or $0.45 per carton higher than they were with the food safety incidents associated with tomatoes in 2007. While this impact appears to be small, the impact occurred in the months of June, July and August when volumes from Florida were low. The impact of the Salmonella incidents for June, July and October is estimated to be $2.61 per carton, implying that average values in those months would have been 17.7% higher in June and July, 2007 and 22.6% higher in October, 2007.

The simulation of the tomato markets using the regression model in equation (1) indicates that had there been no incidence of salmonella in the tomato market grower returns would have totaled $452,571,587 in the state of Florida in 2007. When the model is simulated with the Salmonella incidents that occurred in 2007, the revenue was estimated to be $434,559,368. The difference between these two revenues is the estimated impact of the food safety incidents on the Florida fresh tomato industry in 2007, $18,012,218. This represents only 3.98% of the total value of the 2007 crop, but 28.32% of the crop value for the months June, July and October when the food safety incidents occurred. The $18,012,218 does represent the value that could have been spent on food safety initiatives in 2007 to insure that no food borne illness risks were associated with Florida growers. This is the upper limit on costs that growers as an industry could have expected to pay in 2007 for audits and changes in production and handling practices to still be worthwhile in terms of revenue streams.

CONCLUSIONS

Evidence does exist that infers food safety standards are working and affecting the price of Florida tomatoes. As reported by the National Agricultural Statistical Service (NASS) there was a large decline in the price of Florida tomatoes in 2007 when the food incidents were at their highest, in terms of consumer awareness. Prices fell to $31.90 per 100 lb in 2007. This was with quantity produced more or less the same as in 2006 when price was at $40.90 per 100 lb. With the implementation of food safety standards and a decrease in quantity produced due to the lower returns for growers, the average price rose in 2008 to $59.50 per 100 lb with a reduction in food safety incidents. While some of the price increase can be attributed to the quantity decrease, the data provide anecdotal evidence to support the results in the quantitative analysis that food safety standards in Florida did result in higher prices (U.S. Tomato Statistics 2010).

An average cost of $262.50 per farm ($75.00 per hour for 3 ½ hours) was estimated for the cost of a public audit. An average cost of $1,500.00 was assumed for the cost of a private audit. The implications are such that the substantial income that is lost as a result of a food safety incident appears to justify the added cost of $262.50 for a public audit if it lowers the probability of a food safety incident. The value associated with the additional expense of the private audit is dependent on the added safety the private audit provides (i.e., the incremental decrease in probability associated with a food safety incident).

Further research on this subject can be done to determine the overall impact that public and private audits have on risk mitigation for farmers. From the data presented in this study it can be inferred that public audits appear to have provided some value to growers by mitigating some of the food safety risk associated with tomato production. While the overall impact may be small (3.8%), the impact on growers during the periods when food safety incidents have occurred is large (28.32%).

CITATIONS

Arnade, Carlos, Linda Calvin, and Fred Kuchler. "Consumer Response to a Food Safety Shock: The 2006 Food-Borne Illness Outbreak of E. coli O157: H7 Linked to Spinach." Review of Agricultural Economics 31.4 (2009): 734-750. Print.

"Guidance for Industry: Guide to Minimize Microbial Food Safety Hazards of Tomatoes; Draft Guidance." FDA. Food and Drug Administration, 31 July 2009. Web. 30 Mar. 2010.http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/ProduceandPlanProducts/ucm173902.htm.

Lloyd, T, et al. The Impact of Food Scares on Beef and Inter-Related Meat Markets. N.p.: n.p., 2001.
N. pag. Print.

Outbreak Surveillance Data. Centers for Disease Control and Prevention, 20 Jan. 2010. Web. 12
Mar. 2010. <http://www.cdc.gov/outbreaknet/surveillance_data.html>.

"U.S. Tomato Statistics." Economic, Statistics, and Market Information System. Economic Research Service, n.d. Web. 13 Apr. 2010. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1210.

New fumigant regulations coming in December

Joseph W. Noling[1] and Andrew MacRae[2]

[1]University of Florida, IFAS, Citrus Research and Education Center, Lake Alfred, FL

[2]University of Florida, IFAS, Gulf Coast Research and Education Center, Balm, FL

With reregistration of the soil fumigants near complete, EPA has mandated the addition of many new changes to fumigant labels which include a variety of new risk mitigation measures in a 2-year stepwise approach. The fact that the reregistration process is nearly over should come as no surprise to anyone since we have been presenting 'the doom and gloom' message to growers for a number of years now. So again, as another advanced warning, be advised that some of the new label requirements will begin this December 2010, while others will be required to be included on revised labels which will appear on product containers in mid to late 2011. Beginning December 2010, new label language will appear which will formally require certified applicators to complete a written, site specific Fumigant Management Plan (FMP) prior to any day's fumigant application in the field. For this 1st phase of new labels in December, the FMP's must only capture current and first phase label requirements. In 2011, the FMP's must also capture second phase label requirements which will require the certified applicator to document compliance with new buffer zone requirements and emergency preparedness measures and procedures.

Fumigant management plans When the new fumigant labels appear in 2010, each fumigant applicator will need to ensure that a site-specific FMP has been prepared before beginning a fumigant application in the field on any given day. The certified applicator will also be required to complete a daily checklist and prepare a post application summary report to document any deviations from the FMP that may have been necessary, as well as any results of air monitoring done during and/or after the application in the field or within the buffer zone perimeter. EPA believes that the FMP's will reduce potential risks to bystanders, people living in close proximity, as well as handlers in the field by requiring that applicators have carefully planned each day's fumigation, and by forcing applicators to document (in writing) how they intend to comply with all of the new label changes and requirements.

A partial list of some of the major elements within the FMP that certified applicators will need to address include general site and applicator information, application method and tarp repair procedures, weather and soil conditions, and a description of how the fumigator plans to comply with label requirements for GAP's, buffer zones, air monitoring, worker training and protective equipment, posting of signage, and providing notification to neighbors should it be needed. The FMP's will also require the applicator to identify the names and addresses of handlers participating in the fumigation prior to the event, plans for communication between the applicator and others involved in the fumigation, and to document how emergency situations will be handled. Additionally, EPA will require (via the new labels) that applicators complete a post-fumigation summary that will describe any deviations from the FMP, measurements taken to comply with GAPs, and information about any problems, such as complaints or incidents, that occurred as a result of the fumigation. The new fumigant labels also will specify requirements for archiving the FMP for 2 years and that FMPs must be provided, upon request, to enforcement officials, handlers involved in the fumigation, and emergency response personnel. Other noteworthy fumigant label changes mandated by EPA include requirements for medical certification, safety training, and fit testing of workers to satisfy EPA respirator requirements when and if needed in the field. The certified applicator will also be required to monitor for pungent odors of fumigant gases in areas between the buffer zone perimeter and residences or other occupied areas four times during the day (dawn, dusk, and once during the night and day) to ensure perceived odors do not exceed the action levels requiring enforcement of emergency procedures and notification of neighboring landowners surrounding the field.

Fmp availability Once the application begins, the certified applicator must be prepared to make a copy of the FMP available for viewing by handlers involved in that day's fumigation. The certified applicator or the owner/operator of the application block must also be prepared to provide a copy of the FMP to any federal, state, tribal, or local enforcement personnel who may request copy of the FMP. In the case of an emergency, the FMP must also be made readily available when requested by federal/state/local emergency response and enforcement personnel.

Farm wide fmp's For situations where an initial FMP is developed and certain elements do not change for multiple fumigation sites such as the certified applicator information, authorized on-site personnel, tarp repair, record keeping, and emergency procedures, all of the information that remains unchanged can be captured once and reprinted to a new FMP and only elements that have changed, such as block location, application rates, weather and soil conditions, need to be updated in each new days site-specific FMP. This will not preclude the requirement for:

• The certified applicator supervising the application to verify all of the different elements of the FMP, including those elements that are current and applicable to the application block before it is fumigated and documented within the site-specific FMP.
• It also requires that the same recordkeeping requirements are followed for the entire FMP, including elements that do not change.

Soil and weather conditions Prior to a day's fumigation, the weather forecast for the day of the application and the 48-hour period following the fumigation must be checked to determine if unfavorable weather conditions exist or are predicted to occur. These weather reports are to be used to determine whether fumigation for that day should proceed. Detailed local forecasts for weather conditions, wind speed, and air stagnation advisories must be obtained and documented within the site-specific FMP. The site-specific management plan also requires soil moisture to be measured and recorded at a depth of 9 inches at either end of the field, no more than 48 hours prior to application. Soil moisture must be measured or estimated to be 50 to 80% of field holding capacity (depending on the specific product label) before proceeding with a fumigant application. For sand soils in Florida, there will be an exemption on the label since to form a bed we must have soil moistures in the range of 160 to 240%. Soil moisture must be determined by one of the following methods: The USDA Feel and Appearance Method for testing or with an instrument, such as a tensiometer. If soil moisture is inadequate (too low, or too high), the soil moisture must be adjusted by irrigation or tillage operation. The method in which soil moisture is determined must be reported in the FMP and the results from either method documented within the Post application summary. We believe it behooves the applicator to spend the time to take the measurements to avoid compliance infractions and to minimize potential liabilities and future litigation, should claims of incidents of exposure arise at some future time.

Good agricultural practices (GAP'S) EPA has specified a number of good agricultural practices (GAP's) that will be required to be fulfilled before soil applications of a fumigant can proceed. The GAP's are being required to reduce fumigant emissions and potential for worker and bystander exposures. EPA has determined that applicators must (1) check the weather forecast and make a decision whether to proceed with a planned fumigation, based on conditions that are predicted, (2) only begin a fumigant application:

• If wind speed is a minimum of 2 mph at the start of the application or forecasted to reach at least 5 mph during the application.
• The maximum soil temperature at the depth of injection shall not exceed 90 degrees F at the beginning of the application.
• Soil is properly prepared and at the surface generally be free of clods that are golf ball size or larger. The area to be fumigated shall be tilled to a depth of 5 to 8 inches.
• Field trash must be properly managed. Residue from a previous crop must be worked into the soil to allow for decomposition prior to fumigation. Little or no crop residue shall be present on the soil surface.
• Any trash (plastic, twine, crop residue) pulled by the shanks to the ends of the field must be covered with tarp, or soil, depending on the application method before making the turn for the next pass.

Definition of handlers The new fumigant labels will clarify fumigation tasks that meet EPA's definition of handler activities to include most, if not all, people in the field. More specifically, Handlers are defined as those who:

• Participate in the fumigant application as supervisors, loaders, drivers, tractor co-pilots, shovelers, cross ditchers, or as other direct application participants (note: the application starts when the fumigant is first introduced into the soil and ends after the fumigant has stopped being delivered/dispensed to the soil);
• Those using devices to take air samples to monitor fumigant air concentrations;
• Persons cleaning up fumigant spills (this does not include emergency personnel not associated with the fumigation application);
• Handling or disposing of fumigant containers;

• Cleaning, handling, adjusting, or repairing the parts of fumigation equipment that may contain fumigant residues;
• Installing, repairing, or operating irrigation equipment in the fumigant application block or surrounding buffer zone during the buffer zone period;
• Entering the application site or surrounding buffer zone during the buffer zone period to perform scouting, crop advising, or monitoring tasks;
• Installing, perforating (cutting, punching, slicing, poking), removing, repairing, or monitoring tarps.

Documenting and certifying handlers
Another change in fumigant labeling needing further discussion involves the new requirement within the Fumigant Management Plan (FMP) to identify all handlers working in the field, including names, phone numbers, addresses, tasks they are trained and authorized to perform, and dates of training certifications completed prior to the start of each days soil fumigation activity. For many farms who employ office staff capable of efficiently documenting new workers and providing scan able ID cards and WPS training videos and certifications for handlers while their paperwork is being processed, this new requirement for generating a printed list of handlers in the field prior to beginning a days fumigation may not be a difficult or insurmountable problem. There is however another universe of growers who lack office staff and computer capability who will be seriously challenged by this new requirement to publish a printed listing of all handler names, addresses, phone numbers and dates of required certifications before start of fumigations in the field each morning. For those fumigants which will require use of respirators, or if certified applicators decide to continue fumigating after receiving any handler complaints of sensory irritation to fumigant gases, additional training, fit testing, and medical certifications will be required before allowing handlers to work in the field. This will also require the certified applicator to list these additional certifications to the handler list each morning before beginning each day's fumigation activity. Those farm operations which currently rely on labor contractors to provide field workers on an as needed basis, must demand that the contractor provide an accurate printed list of all handlers and the dates of their certifications to the certified applicator each morning, such that the applicator can append this information to the FMP. From a compliance standpoint, the certified applicator will bear the full burden of responsibility for the accuracy and completeness of the FMP if an inspection should occur, and a copy of the completed FMP cannot be provided as requested for viewing by handlers or to include in the inspectors records. Adding these new recording keeping and retrieval processes to on-farm operations will not come without additional costs, which will likely hurt everybody, particularly the "small people" or less electronically sophisticated farms or businesses.

Concluding remarks Clearly, the new fumigant labels will represent a significant change in the way growers have used soil fumigants in the past. Grower obligations required to develop and implement the new fumigant label requirements will be complex and time consuming, and will add a new burden of grower responsibility and liability. For the grower and certified applicator, the future of fumigant use in Florida will demand a broader respect, recognition, and need for stricter adherence to fumigant label language and it will require a more vigilant understanding and observance of Good Agricultural Practices. Additionally, these changes will require closer observance of and participation in newly required product stewardship and worker safety certification programs, as well as greater consideration of people and land areas surrounding a fumigated field. At the farm level, the new fumigant use requirements will clearly demand an increased focus on clerical and communication skills by farm personnel, including an expedited system of documenting, training, and certifying new workers who participate in a soil fumigation activity on a daily basis.

The new labeled changes being mandated by EPA this fall will introduce new requirements for certified applicators in the form of more detailed instructions, reporting and application restrictions that will be imposed on use of soil fumigants. As indicated previously, new fumigant specific training programs, developed and provided by registrants, will require applicators to recertify every three years before applying the product in the field. To further ensure applicators understand and are complying with the newly revised fumigant labeling, the University of Florida, IFAS is completing development of an on-line training and certification program for applicators in charge of soil fumigations, worker safety certifications for handlers, and for Florida Department of Agriculture and Consumer Services inspectors and compliance officers on the proper labeled uses of and best management practices for soil fumigants.

LITERATURE CITED
Joseph W. Noling, University of Florida, IFAS, Citrus Research and Education Center, 700 Experiment Station Road, Lake Alfred, FL 33850, jnoling@ufl.edu

Methyl bromide alternatives research update

Andrew W. MacRae[1] and Joseph W. Noling[2]
[1]University of Florida, IFAS, Gulf Coast Research and Education Center, Balm, FL
[2]University of Florida, IFAS, Citrus Research and Education Center, Lake Alfred, FL

INTRODUCTION
As Florida tomato growers transition into the post-methyl-bromide era of soil fumigation, a number of crop production and soil fumigation costs and practices could change. These changes will include:
1) With certain fumigant products, the cost of fumigation will increase due to a higher cost of the alternative product compared to methyl bromide, and/or with the added expense of having to use a high barrier, gas impermeable plastic mulch.
2) The expense of fumigation application will also increase due to implementation costs of the new pre-registration eligibility regulations soon to be mandated by EPA. Some new costs will accrue in the form of added labor costs to complete and implement the newly required fumigant management plan (FMP). New requirements for worker personal protection equipment and training will also add significant costs to fumigant application, particularly if respirators and new filters are required for each day's use, and if workers must be medically certified and respirator fit tested prior to use.
3) None of the currently proposed fumigant alternatives are quite as effective as methyl bromide in sustaining high yields and controlling soilborne pests and diseases. While alternative fumigants may achieve close to that level of effectiveness, most will not be quite as effective as 350–400 lb of methyl bromide 98:2, as it was typically applied a decade ago.

With the potential for these increased costs and a small drop in efficacy for current methyl bromide alternatives, growers must receive all of the benefits of these products to maximize yield potential and pest control. A single-season approach to fumigant application can no longer be biologically and economically justified. Instead, growers will need to develop a sustainable program for each field in which they farm. Sustainability will become the key concept motivating programmatic change. It will no longer be possible to correct pest problems in one season when flawed and imperfect programs were used in previous seasons. Pest control will have to become an integrated,

Table 1. Annual Grass Counts for Years 1 and 2 [a]

Fumigant Treatment	Rate	Annual Grass			
		Year 1		Year 2	
		Herbicide	No Herbicide	Herbicide	No Herbicide
		(plants per acre)			
Non-treated Control		725 b	1742 b	1514 b	5341 b
Methyl Bromide 67:33	175 lbs/A	52 a	73 a	10 a	83 a
Telone II Chloropicrin KPam	12 gal/A 150 lbs/A 60 gal/A	10 a	21 a	41 a	52 a
Telone II Chloropicrin	12 gal/A 150 lbs/A	31 a	197 a	425 ab	2116 a
Midas 50:50	160 lbs/A	0 a	62 a	0 a	72 a
Paladin Pic 79:21	60 gal/A	871 b	1732 b	4138 c	7208 b

[a] Means within a column followed by the same letter are not different as according to Fisher's protected LSD ($p \leq 0.05$).

Table 2. Yellow and Purple Nutsedge Counts for Years 1 and 2.[a]

Fumigant Treatment	Rate	Nutsedge			
		Year 1		Year 2	
		Herbicide	No Herbicide	Herbicide	No Herbicide
		(plants per acre)			
Non-treated Control		93 ab	1805 b	3423 b	31228 b
Methyl Bromide 67:33	175 lbs/A	52 ab	17 a	31 a	135 a
Telone II Chloropicrin KPam	12 gal/A 150 lbs/A 60 gal/A	0 a	31 a	0 a	104 a
Telone II Chloropicrin	12 gal/A 150 lbs/A	31 a	778 ab	62 a	1379 a
Midas 50:50	160 lbs/A	21 a	21 a	21 a	135 a
Paladin Pic 79:21	60 gal/A	135 b	809 ab	21 a	1732 a

[a] Means within a column followed by the same letter are not different as according to Fisher's protected LSD ($p \leq 0.05$).

Table 3. Marketable Yield (medium, large and extra-large sizes) of Tomatoes for Years 1 and 2.[a]

Fumigant Treatment	Rate	Marketable Yield			
		Year 1[b]		Year 2	
		Herbicide	No Herbicide	Herbicide	No Herbicide
		(boxes[c] per acre)			
Non-treated Control		927 b	935 c	1122 c	1044 d
Methyl Bromide 67:33	175 lbs/A	1177 a	955 bc	1411 ab	1500 ab
Telone II Chloropicrin KPam	12 gal/A 150 lbs/A 60 gal/A	1229 a	1143 a	1439 a	1603 a
Telone II Chloropicrin	12 gal/A 150 lbs/A	1126 a	977 bc	1400 ab	1417 bc
Midas 50:50	160 lbs/A	1118 a	1048 ab	1275 b	1383 bc
Paladin Pic 79:21	60 gal/A	1174 a	1140 a	1394 ab	17321 c

[a] Means within a column followed by the same letter are not different as according to Fisher's protected LSD ($p \leq 0.05$).
[b] Marketable yield consists of the combined grades: medium, large and extra large.
[c] 25 lb. box of tomatoes

programmatic effort to maintain pest populations at their lowest levels and to extend the productive life of methyl bromide alternative programs.

In the coming post-methyl bromide era, successful fumigation programs will also rely less on fumigant selection and more on field preparation, new technologies for fumigant application, and other good agricultural crop production practices (GAPs). With methyl bromide, variations in soil tilth, temperature, or moisture seldom played a prominent role in defining or lowering overall performance. However, in order to achieve maximum efficacy with a methyl bromide alternative program, it will be necessary to pay attention to every detail involved in field preparation, application, and environmental condition. Simply stated, methyl bromide was forgiving, the alternatives are not. The alternatives currently being trialed by the growers may actually fail in their control of soilborne pests if used in the same manner as methyl bromide.

Trials have been initiated to determine the effect of cultural programs on the sustainability of methyl bromide alternatives as they relate to weed control. We are expanding our outlook from the analysis of specific fumigants to the whole systems approach as it relates to soil borne pest control. The results below represent that of one trial with the objective of determining the long term sustainability of methyl bromide alternatives in tomato.

Evaluation of the long term sustainability of four fumigant systems as methyl bromide alternatives In the fall of 2008 a trial was initiated to look at the sustainability of four methyl bromide alternatives in a Florida double crop system. The initial treatments included Methyl Bromide 67:33 at 175 lbs/A, Midas 50:50 at 160 lbs/A, Paladin Pic at 60 gal/A (Paladin Pic is a formulated combination of 79% DMDS and 21% chloropicrin), Telone II at 12 gal/A plus Chloropicrin at 150 lbs/A (2-Way), Telone II at 12 gal/A plus Chloropicrin at 150 lbs/A plus KPam at 60 gal/A (3-Way), and a non-treated control. All treatments were placed at 8 inches below the top of the bed except Telone II which was placed 12 inches below the bed top and KPam which was injected into the beds using two drip tapes. Each treatment had a split plot of herbicide or no herbicide which was applied beneath the plastic on finished bed top just prior to laying of the plastic mulch. The herbicides were applied beneath the plastic mulch and consisted of V10142 (0.3 lbs ai/A) and Devrinol 50WP (4 lbs/A) in year one and Reflex (1 pt/A) and Devrinol 50WP (4 lbs/A) in year two. This trial consisted of tomato and pepper planted in the initial crop followed by summer squash in the double crop. We have funding through USDA-NIFA for the 3rd year of the study but will be seeking further funds to extend this trial through year 5. Only weed control and tomato yield for the first two years of the study will be discussed in this article.

Annual Grass Counts. Our annual grass complex consisted of 85% goosegrass, with the remainder being large crabgrass and crowfootgrass. The application of the herbicide under the plastic mulch increased annual grass control. Paladin Pic and the non-treated control had similar annual grass counts in both year 1 and year 2 (Table 1). All other fumigation treatments had lower annual grass counts and were similar to each other. Paladin Pic had higher annual grass counts than any of the other fumigation treatments. We expect that when Paladin is registered it will come with a recommendation for the addition of a herbicide program. For the 2-Way program we are observing increasing levels of annual grasses from year one to year 2. This may suggest that this fumigant program will be weak on annual grasses and will require a post emergent application of a herbicide for grass control. In our trial we did not use a post emergent herbicide, but starting in year 3 we will control any grass escapes so we can concentrate on the nutsedge and broadleaf weed control.

Yellow and Purple Nutsedge Counts. The application of a herbicide under the plastic mulch improved nutsedge control. The nutsedge pressure was low in this field at the beginning of the trial and all fumigation treatments provided similar control (Table 2). We observed a large population increase from year one to year two in the non-treated control. Without the use of herbicides there was a slight increase in nutsedge populations for both the 2-Way and Paladin Pic fumigant programs. This increase still only resulted in a population of one nutsedge plant per 5 to 6 feet of bed.

Tomato Marketable Yield (mediums + large + extra large). The majority of fumigation treatments produced greater yield than the non-treated control (Table 3). There was no consistent benefit to yield with the use of a herbicide program. The 3-Way treatment consistently produced the greatest yield with all fumigants being similar in year 1 with the use of herbicides. In year 1 without the use of herbicides, only Midas 50:50 and Paladin Pic were similar to the 3-Way. In year two with herbicides, The Methyl Bromide 67:33, 2-Way, and Paladin Pic programs were similar to the 3-Way. In year 2 without herbicides, only Methyl Bromide 67:33 was similar to the 3-Way.

CONCLUSIONS

In conclusion, all fumigation treatments provided acceptable crop yields. However, the 3-Way treatment provided the most consistent high yields and weed control. Paladin Pic produced high yields but also had higher weed counts. These weed counts were greatly reduced with the addition of a herbicide and it would be expected that this product will be required to have a herbicide program as part of its control strategy. All fumigant systems showed an improvement in weed control with the addition of a herbicide. After year 2 of this trial, all fumigant systems showed promise as a methyl bromide alternative, but it appears as though a herbicide program may be required for all fumigant systems to improve sustainability, especially that of the 2-Way and Paladin Pic programs.

Tomato varieties for Florida

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

[1]North Florida Research & Education Center, Univeristy of Florida, Quincy, FL

[2]Hendry County Extension, Univeristy of Florida, LaBelle, FL

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

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

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

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

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

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

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

CURRENT VARIETY SITUATION

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

TOMATO VARIETIES FOR COMMERCIAL PRODUCTION

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

LARGE FRUITED VARIETIES

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

Bella Rosa. Midseason maturity. Heat tolerant determinate type. 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. (Sakata)

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)

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)

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

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

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

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

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. (Seminis)

Fletcher. Midseason maturity. Large, globe to deep oblate fruit with compact plants. Does best with moderate pruning and high fertility. Good flavor, color and shelf-life. For vine ripe use only due to nipple characteristic on green fruit. Replacement for Mountain Spring where Tomato spotted wilt is a problem. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1,2,3), Tomato spotted wilt and root-knot nematode.

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

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. (Seminis)

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

Linda. Main season. Large round, smooth, uniform shouldered fruit with excellent firmness and a small blossom end scar. Strong determinate bush with good cover. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1,2), Alternaria stem canker and Gray leaf spot. (Sakata)

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. (Seminis)

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. (Seminis)

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. (Harris Moran)

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), Grey leaf spot. (Syngenta)

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. (Seedway)

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. (Seminis)

Sebring. A late midseason determinate, jointed hybrid with a smooth, deep oblate, firm, thick walled fruit. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1,2,3), Fusarium crown rot and Gray leaf spot. (Syngenta)

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). (Harris Moran)

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. (Harris Moran)

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. (Seminis).

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. (Syngenta)

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. (Syngenta)

Tasti-Lee. It was 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), Tomato spotted wilt. (Vilmorin)

Tribute. Vigorous plant with good cover. Medium large to large, smooth, globed-shaped fruit with excellent firmness and color. Resistance: Tomato spotted wilt and Tomato yellow leaf curl. (Sakata)

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

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 Seed)

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. (Sakata)

Monica. Midseason. Vigorous bush with good cover. High percentage of firm extra-large, elongated fruit. Jointed pedicel and uniform green fruit color. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1,2), Bacterial speck, and Grey leaf spot. (Sakata).

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. (Seminis)

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. (Harris Moran).

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), Tomato yellow leaf curl. (Western Seed)

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. (Seminis)

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), Fusarium wilt (race 1). (BHN Seed)

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. (Siegers Seed)

Cherry Blossom. 70 days. Large cherry, holds and yields well. Determinate bush. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1,2), Bacterial speck (race 0), root-knot nematodes, Alternaria stem canker and Gray leaf spot. (Seedway)

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), Verticillium wilt (race 1). (Syngenta Rogers Seed).

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

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). (Siegers Seed, Seedway)

GRAPE TOMATOES

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). (BHN)

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. ((Harris Moran)

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. (Seminis)

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. (Siegers Seed)

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. (Thompson and Morgan)

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

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), Fusarium wilt (race 1) (Seedway)

Sweethearts. Indeterminate bush with intermediate internodes. Brilliant red, firm, elongated grape-shaped fruit. Matures between 70 and 75 days. Good flavor, crack-resistant and high brix. Resistance: Tobacco mosaic virus.

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

Water management for tomato

Eric H. Simonne[1] and Monica Ozores-Hampton[2]
[1]UF/IFAS Horticultural Sciences Department, Gainesville, Fl esimonne@ufl.edu
[2]University of Florida/IFAS, SWFREC, Immokalee, FL. Ozores@ufl.edu

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

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

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

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

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

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

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

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

Typical CF values for fully-grown tomato should not exceed 0.75 (Locascio and Smajstrla, 1996). A third method for estimated tomato crop water requirement is to use modified Bellani plates also known as atmometers. A common model of 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 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.

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.

Table 2. Summary of irrigation management guidelines for tomato.

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

[z] Efficient irrigation scheduling also requires a properly designed and maintained irrigation 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

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 their use. 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

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

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

at both depths is useful to understand the dynamics of soil moisture. When both SWT readings 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%.

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. and B. Morgan. 2005. Denitrification in seepage irrigated vegetable fields in South Florida, EDIS, HS 1004, http://edis.ifas.ufl.edu/HS248.Simonne, E.H., D.W. Studstill, R.C. Hochmuth, J.T. Jones and C.W. Starling. 2005. On-farm demonstration of soil water movement in vegetables grown with plasticulture, EDIS, HS 1008, http://edis.ifas.ufl.edu/HS251.

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

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

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

Fertilizer and nutrient management for tomato

Eric H. Simonne[1] and Monica Ozores-Hampton[2]

[1]UF/IFAS Horticultural Sciences Department, Gainesville, Fl esimonne@ufl.edu

[2]University of Florida/IFAS, SWFREC, Immokalee, FL. Ozores@ufl.edu

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

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

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

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

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

[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 preplant fertilizer.
[r] A leaching rain is defined as a rainfall amount of 3 inches in 3 days or 4 inches in 7 days.
[q] Supplemental amount for each leaching rain
[p] Plant nutritional status must be diagnosed after each harvest before repeating supplemental fertilizer application.

Table 2. Deficient, adequate, and excessive nutrient 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 range	3.0	0.3	3.0	1.0	0.3	0.3	40	30	25	20	5	0.2
				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 range	2.8	0.2	2.5	1.0	0.3	0.3	40	30	25	20	5	0.2
				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 range	2.5	0.2	2.5	1.0	0.25	0.3	40	30	20	20	5	0.2
				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 range	2.0	0.2	2.0	1.0	0.25	0.3	40	30	20	20	5	0.2
				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 range	2.0	0.2	1.5	1.0	0.25	0.3	40	30	20	20	5	0.5
				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.

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 calcium 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 magnesium 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 magnesium is low, apply magnesium sulfate or potassium-magnesium sulfate.

Changes in soil pH may take several weeks to occur when carbonate-based liming materials are used (calcitic or dolomitic limestone). Oxide-based liming materials (quick lime -CaO^- or dolomitic quick lime -CaO, MgO^-) are fast reacting and rapidly increase soil pH. Yet, despite these advantages, oxide-based liming materials are more expensive than the traditional liming materials, and therefore are not routinely used.

The increase in pH induced by liming materials is not due to the presence of calcium or magnesium. Instead, it is the carbonate (CO_3) and oxide (O) part of $CaCO_3$ and CaO, respectively, that raises the pH. Through several chemical reactions that occur in the soil, carbonates and oxides release OH^- ions that combine with H^+ to produce water. As large amounts of H^+ react, the pH rises. A large fraction of the Ca and/or Mg in the liming materials gets into solution and binds to the sites that are freed by H^+ that have reacted with OH^-.

Fertilizer-related physiological disorders

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

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

Factors that impair the ability of tomato plants to obtain water will increase the risk of BER. These factors include damaged roots from

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

flooding, mechanical damage or nematodes, clogged drip emitters, inadequate water applications, alternating dry-wet periods, and even prolonged overcast periods. Other causes for BER include high fertilizer rates, especially potassium and nitrogen.

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

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

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

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

Fertilizer application

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

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

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

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-P2O5-K2O. About 30% to 50% of the total applied N should be in the nitrate form for soil treated with multi-purpose fumigants and for plantings in cool soil. Controlled-release nitrogen sources may be used to supply a portion of the nitrogen requirement. One-third of the total required nitrogen can be supplied from sulfur-coated urea (SCU), isobutylidene diurea (IBDU), or polymer-coated urea (PCU) fertilizers incorporated in the bed. Nitrogen from natural organics and most controlled-release materials is initially in the ammoniacal form, but is rapidly converted into nitrate by soil microorganisms.

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

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

Sap testing and tissue analysis

While routine soil testing is essential in designing a fertilizer program, sap tests and/or tissue analyses reveal the actual nutritional status of the plant. Therefore these tools complement each other, rather than replace one another.
When drip irrigation is used, analysis of tomato leaves for mineral nutrient content (Table 2) or quick sap test (Table 3) can help guide a fertilizer management program during the growing season or assist in diagnosis of a suspected nutrient deficiency.

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

Supplemental fertilizer applications

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

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

SUGGESTED LITERATURE

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

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

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

Weed Control in Tomato

William M. Stall[1]

[1]University of Florida/IFAS, Horticultural Sciences Dept., Gainesville, FL, wmstall@ufl.edu

Although weed control has always been an important component of tomato production, its importance has increased with the introduction of the sweet potato whitefly and development of the associated irregular ripening problem. Increased incidence of several viral disorders of tomatoes also reinforces the need for good weed control. Common weeds, such as the difficult-to-control nightshade, and volunteer tomatoes (considered a weed in this context) are hosts to many tomato pests, including sweet potato whitefly, bacterial spot, and viruses. Control of these pests is often tied, at least in part, to control of weed hosts. Most growers concentrate on weed control in row middles; however, peripheral areas of the farm may be neglected. Weed hosts and pests may flourish in these areas and serve as reservoirs for re-infestation of tomatoes by various pests. Thus, it is important for growers to think in terms of weed management on all of the farm, not just the actual crop area.

Total farm weed management is more complex than row middle weed control because several different sites, and possible herbicide label restrictions are involved. Often weed species in row middles differ from those on the rest of the farm, and this might dictate different approaches. Sites other than row middles include roadways, fallow fields, equipment parking areas, well and pump areas, fence rows and associated perimeter areas, and ditches.

Disking is probably the least expensive weed control procedure for fallow fields. Where weed growth is mostly grasses, clean cultivation is not as important as in fields infested with nightshade and other disease and insect hosts. In the latter situation, weed growth should be kept to a minimum throughout the year. If cover crops are planted, they should be plants which do not serve as hosts for tomato diseases and insects. Some perimeter areas are easily disked, but berms and field ditches are not and some form of chemical weed control may have to be used on these areas. We are not advocating bare ground on the farm as this can lead to other serious problems, such as soil erosion and sand blasting of plants; however, where undesirable plants exist, some control should be practiced, if practical, and replacement of undesirable species with less troublesome ones, such as bahiagrass, might be worthwhile.

Certainly fence rows and areas around buildings and pumps should be kept weed-free, if for no other reason than safety. Herbicides can be applied in these situations, provided care is exercised to keep them from drifting onto the tomato crop.

Field ditches and canals present special considerations because many herbicides are not labeled for use on aquatic sites. Where herbicidal spray may contact water and be in close proximity to tomato plants, for all practical purposes, growers probably would be wise to use Diquat only. On canals where drift onto the crop is not a problem and weeds are more woody, Rodeo, a systemic herbicide, could be used. Other herbicide possibilities exist, as listed in Table 1. Growers are cautioned against using Arsenal on tomato farms because tomatoes are very sensitive to this herbicide. Particular caution should be exercised if Arsenal is used on seepage irrigated farms because it has been observed to move in some situations.

Use of rye as a windbreak has become a common practice in the spring; however, in some cases, adverse effects have resulted. If undesirable insects such as thrips build up on the rye, contact herbicide can be applied to kill it and eliminate it as a host, yet the remaining stubble could continue serving as a windbreak.

The greatest row middle weed problem confronting the tomato industry today is nightshade. Nightshade has developed varying levels of resistance to some post-emergent herbicides in different areas of the state. Best control with post-emergence (directed) contact herbicides is obtained when the nightshade is 4 to 6 inches tall, rapidly growing and not stressed. Two applications in about 50 gallons per acre using a good surfactant are usually necessary.

With post-directed contact herbicides, several studies have shown that gallonage above 60 gallons per acre will actually dilute the herbicides and therefore reduce efficacy. Good leaf coverage can be obtained with volumes of 50 gallons or less per acre. A good surfactant can do more to improve the wetting capability of a spray than can increasing the water volume. Many adjuvants are available commercially. Some adjuvants contain more active ingredient than others and herbicide labels may specify a minimum active ingredient rate for the adjuvant in the spray mix. Before selecting an adjuvant, refer to the herbicide label to determine the adjuvant specifications.

Postharvest Vine Desiccation Additionally important is good field sanitation with regard to crop residue. Rapid and thorough destruction of tomato vines at the end of the season always has been promoted; however, this practice takes on new importance with the sweet potato whitefly. Good canopy penetration of pesticidal sprays is difficult with conventional hydraulic sprayers once the tomato plant develops a vigorous bush due to foliar interception of spray droplets. The sweet potato whitefly population on commercial farms was observed to begin a dramatic, rapid increase about the time of first harvest in the spring of 1989. This increase appears to continue until tomato vines are killed. It is believed this increase is due, in part, to coverage and penetration. Thus, it would be wise for growers to continue spraying for whiteflies until the crop is destroyed and to destroy the crop as soon as possible with the fastest means available. Gramoxone Inteon and Firestorm are labeled for postharvest desiccation of tomato vines. Follow the label directions.

The importance of rapid vine destruction cannot be overstressed. Merely turning off the irrigation and allowing the crop to die will not do; application of a desiccant followed by burning is the prudent course.

Table 1. Chemical weed controls: tomatoes

Herbicide	Labeled Crops	Time of Application to Crop	Rate (lbs. AI./Acre) Mineral	Muck
Carfentrazone (Aim)	Tomato	Preplant Directed-hooded row middles	0.031	0.031
Remarks: Aim may be applied as a preplant burndown treatment and/or as a post-directed hooded application to row middles for the burndown of emerged broadleaf weeds. May be tank mixed with other registered herbicides. May be applied at up to 2 oz (0.031 lb ai). Use a quality spray adjuvant such as crop oil concentrate (coc) or non-ionic surfactant at recommended rates.				
Clethodim (Select 2 EC) (Arrow) (SelectMax)	Tomatoes	Postemergence	0.9-.25	----
Remarks: Postemergence control of actively growing annual grasses. Apply at 6-16 fl oz/acre. Use high rate under heavy grass pressure and/or when grasses are at maximum height. Always use a crop oil concentrate at 1% v/v in the finished spray volume, or a non-ionic Surfactant with SelectMAX. Do not apply within 20 days of tomato harvest.				
DCPA (Dacthal W-75)	Established tomatoes	Posttransplanting after crop establishment (non-mulched)	6.0-8.0	----
Remarks: Controls germinating annuals. 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 crops within 8 months.				
EPTC (Eptam 7E)	Tomatoes	Pretransplant	2.62-3.5	----
Remarks: Labeled for transplanted tomatoes grown on plastic mulch. Apply 3-4 pints/A to the bed top and shoulders immediately prior to the installation of the mulch. Do not transplant the tomato plants for a minimum of 14 days following the application. A 24c special local needs label for Florida.				
Flumioxazin (Chateau)	Fruiting Vegetables Tomatoes	Directed Row-middles	0.125	----
Remarks: Chateau may be applied up to 4 ox product/application to row middles of raised plastic mulched beds that are at least 4 inches higher than the treated row middle and the mulched bed must be a minimum of a 24-inch bed width. Do not apply after crops are transplanted. All applications must be made with shielded or hooded equipment. For control of emerged weeds, a burn down herbicide may be tank-mixed. Label is a Third-Party registration (TPR, Inc.). Use without a signed authorization and waiver of liability is a misuse of the product.				
Glyphosate (Roundup, Durango, Touchdown, Glyphomax)	Tomatoes	Chemical fallow Preplant, Preemergence, Pretransplant	0.3-1.0	----
Remarks: Roundup, Glyphomax and Touchdown have several formulations. Check the label of each for specific labeling directions.				
Halosulfuron (Sandea)	Tomatoes	Pretransplant Postemergence Row middles	0.024-0.036	----
Remarks: A total of 2 applications of Sandea may be applied as either one pre-transplant soil surface treatment at 0.5-0.75 oz. product; one over-the-top application 14 days after transplanting at 0.5-0.75 oz. product; and/or postemergence applications(s) of up to 1 oz. product (0.047 lb ai) to row middles. A 30-day PHI will be observed. For postemergence and row middle applications, a surfactant should be added to the spray mix.				
Lactofen (Cobra)	Fruiting vegetables	Row middles	0.25-0.5	----
Remarks: Third Party label for use pre-transplant or post transplant shielded or hooded to row middles. Apply 16 to 32 fluid oz per acre. A minimum of 24 fl oz is required for residual control. Add a COC or non-ionic surfactant for control of emerged weeds. 1 pre and 1 post application may be made per growing season. Cobra contacting green foliage or fruit can cause excessive injury. Drift of Cobra treated soil particles onto plants can cause contact injury. Do not apply within 30 days of harvest. The supplemental label must be in the possession of the user at the time of application.				
S-Metolachlor (Dual Magnum)	Tomatoes	Pretransplant Row middles	1.0-1.3	----
Remarks: Apply Dual Magnum preplant non-incorporated to the top of a pressed bed as the last step prior to laying plastic. May also be used to treat 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. Good results have been seen at 0.6 pts to 1.0 pints especially in tank mix situations under mulch. Use on a trial basis.				
Metribuzin (Sencor DF) (Sencor 4)	Tomatoes	Postemergence Posttransplanting after establishment	0.25 - 0.5	----
Remarks: Controls small emerged weeds after transplants are established or when direct-seeded plants reach 5 to 6 true leaf stage. Apply in single or multiple applications with a minimum of 14 days between treatments and a maximum of 1.0 lb ai/acre within a crop season. Avoid applications for 3 days following cool, wet or cloudy weather to reduce possible crop injury.				
Metribuzin (Sencor DF) (Sencor 4)	Tomatoes	Directed spray in row middles	0.25 - 1.0	----
Remarks: Apply in single or multiple applications with a minimum of 14 days between treatments and maximum of 1.0 lb ai/acre within crop season. Avoid applications for 3 days following cool, wet or cloudy weather to reduce possible crop injury. Label states control of many annual grasses and broadleaf weeds including, lambsquarter, fall panicum, Amaranthus sp., Florida pusley, common ragweed, sicklepod, and spotted spurge.				
Napropamide (Devrinol 50DF)	Tomatoes	Preplant incorporated	1.0-2.0	----
Remarks: 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. For direct-seeded or transplanted tomatoes.				
Napropamide (Devrinol 50DF)	Tomatoes	Surface treatment	2.0	----
Remarks: Controls germinating annuals. 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. A special Local Needs 24(c) Label for Florida. Label states control of weeds including Texas panicum, pigweed, purslane, Florida pusley, and signalgrass.				
Oxyfluorfen (Goal 2XL) (Goaltender)	Tomatoes	Fallow bed	0.25-0.5	----
Remarks: 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 1/2 to 1 pt/A for Goaltender. Mulch may be applied any time during the 30-day interval.				
Paraquat (Gramoxone Inteon) (Firestorm)	Tomatoes	Premergence; Pretransplant	0.62-0.94	----
Remarks: Controls emerged weeds. Use a non- ionic spreader and thoroughly wet weed foliage.				
Paraquat (Gramoxone Inteon) (Firestorm)	Tomatoes	Post directed spray in row middles	0.47	----
Remarks: Controls emerged weeds. Direct spray over emerged weeds 1 to 6 inches tall in row middles between mulched beds. Use a non-ionic spreader. Use low pressure and shields to control drift. Do not apply more than 3 times per season.				
Paraquat (Gramoxone Inteon) (Firestorm)	Tomatoes	Postharvest desiccation	0.62-0.93	0.46-0.62
Remarks: Broadcast spray over the top of plants after last harvest. Gramoxone label states use of 2-3 pts. Use a non-ionic surfactant at 1 pt/100 gals to 1 qt/100 gals spray solution. Thorough coverage is required to ensure maximum herbicide burndown. Do not use treated crop for human or animal consumption.				
Pelargonic Acid (Scythe)	Fruiting vegetables (tomato)	Preplant Preemergence Directed-shielded	3-10% v/v	----
Remarks: Product is a contact, nonselective, foliar applied herbicide. There is no residual control. May be tank mixed with several soil residual compounds. Consult the label for rates. Has a greenhouse and growth structure label.				
Pendimethalin Prowl H 2 **O**	Tomatoes	Post-directed Row Middles	0.0475-0.72	----
Remarks: May be applied pre-transplant but not under mulch. May be applied at 1.0 to 1.5 pts/A to row middles. Do not apply within 70 days of harvest.				
Rimsulfuron (Matrix)	Tomatoes	Posttransplant and directed-row middles	0.25-0.5 oz	----
Remarks: Matrix may be applied preemergence (seeded), postemergence, posttransplant and applied directed to row middles. May be applied at 1-2 oz. product (0.25-0.5 oz ai) in single or sequential applications. A maximum of 4 oz. product per acre per year may be applied. For post (weed) applications, use a non-ionic surfactant at a rate of 0.25% v/v. for preemergence (weed) control, Matrix must be activated in the soil with sprinkler irrigation or rainfall. Check crop rotational guidelines on label.				
Sethoxydim (Poast)	Tomatoes	Postemergence	0.188 - 0.28	----
Remarks: Controls actively growing grass weeds. A total of 4 1/2 pts. product per acre may be applied in one season. Do not apply within 20 days of harvest. Apply in 5 to 20 gallons of water adding 2 pts. of crop oil concentrate per acre. Unsatisfactory results may occur if applied to grasses under stress. Use 0.188 lb ai (1 pt.) to seedling grasses and up to 0.28 lb ai (1 1/2 pts.) to perennial grasses emerging from rhizomes etc. Consult label for grass species and growth stage for best control.				
Trifloxysulfuron (Envoke)	Tomatoes (transplanted)	Post directed	0.007-0.014	----
Remarks: Envoke can be applied at 0.1 to 0.2 oz product/A post-directed to transplanted tomatoes for control of nutsedge, morningglory, pigweeds and other weeds listed on the label. Applications should be made prior to fruit set and at least 45 days prior to harvest. A non-ionic surfactant should be added to the spray mix.				
Trifluralin (Treflan HFP) (Treflan TR-10) (Trifluralin 4EC)	Tomatoes (except Dade County)	Pretransplant incorporated	0.5	----
Remarks: Controls germinating annuals. 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.				

Tomato fungicides and other disease management products.

Ordered by FRAC group according to mode of action. (Updated June 2010)

Gary E. Vallad, University of Florida/IFAS, GCREC, Wimauma, FL gvallad@ufl.edu

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

Chemical (active ingredient)	Fungicide Group[1]	Maximum Rate / Acre / Applic.	Maximum Rate / Acre / Season	Min. Days to Harvest	Pertinent Diseases or Pathogens	Remarks[2]
(copper compounds) Many brands available: Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	M1	SEE INDIVIDUAL LABELS		1	Anthracnose, Bacterial speck, Bacterial spot, Early blight, Grey leaf mold, Grey leaf spot, Late blight, Septoria leaf spot	Mancozeb or maneb enhances bactericidal effect of fix copper compounds. See label for details.
(sulfur) Many brands available: Cosavet DF, Kumulus DF, Micro Sulf, Microfine Sulfur, Microthiol Disperss, Sulfur 6L, Sulfur 90W, Super Six, That Flowable Sulfur, Tiolux Jet, Thiosperse 80%, Wettable Sulfur, Wettable Sulfur 92, Yellow Jacket Dusting Sulfur, Yellow Jacket Wettable Sulfur	M2	SEE INDIVIDUAL LABELS		1	Powdery mildew	Follow label closely, may cause leaf burn if applied during high temperatures.
(maneb) Many brands available: Maneb 75DF, Maneb 80WP, Manex	M3	SEE INDIVIDUAL LABELS		5	Early blight. Late blight, Gray leaf spot, Baceterial spot*, Anthracnose, Leaf mold, Septoria leaf spot	*Bacterial spot control only when tank mixed with a copper fungicide. See label for details.
(mancozeb) Many brands available: Dithane DF, Dithane F45, Dithane M45, Manzate, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP)	M3	SEE INDIVIDUAL LABELS		5		
Ziram 76DF (ziram)	M3	4 lbs	23.7 lbs	7	Anthracnose, Early blight, Septoria leaf spot	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	Anthracnose, Bacterial spot, Bacterial speck, Late blight, Early blight, Gray leaf spot, Septoria leaf spot	See label
ManKocide (mancozeb + copper hydroxide)	M3 / M1	5 lbs.	112 lbs.	5		
(chlorothalonil) Many brands available: Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720)	M5	SEE INDIVIDUAL LABELS		0	Early blight, Late blight, Gray leaf spot Leaf mold, Target spot Botrytis, Rhizoctonia fruit rot	Use higher rates at fruit set and lower rates before fruit set, see label
Allpro Exotherm Termil (20 % chlorothalonil)	M5	1 can / 1000 sq. ft.	-	7	Botrytis, Leaf mold, Late blight, Early blight Gray leaf spot, Target spot	Greenhouse use only. Allow can to remain overnight and then ventilate. Do not use when greenhouse temperature is above 75 F. See label for details.
Rally 40WSP Nova 40 W Sonoma 40WSP (myclobutanil)	3	4 oz.	1.25 lbs.	0	Powdery mildew	Note that a 30 day plant back restriction exists, see label.
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
Ridomil MZ 68 WP (mefenoxam + mancozeb)	4 / M3	2.5 lbs.	7.5 lbs.	5	Late blight	Limit is 3 appl./crop, see label
Ridomil Gold Copper 64.8 W (mefenoxam + copper hydroxide)	4 / M1	2 lbs.		14	Late blight	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	Early blight, Late blight Gray leaf spot, Target Spot	Limit is 4 appl./crop, see label
Endura (boscalid)	7	12.5 oz	25	0	Target spot, Early Blight	Alternate with non-FRAC code 7 fungicides, see label
Scala SC (pyrimethanil)	9	7 fl oz	35 fl oz	1	Early blight, Botrytis	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	Early blight, Black mold, Gray leafspot, Powdery mildew, Septoria leafspot, Target spot, Anthracnose, Leaf mold	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	Early blight, Botrytis, Powdery mildew	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	Anthracnose, Early blight, Late blight, Sclerotinia Powdery mildew, Target spot, Buckeye rot, Septoria leaf spot	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 lb.s	0		
Quadris FL (azoxystrobin)	11	6.2 fl. oz.	37 fl. oz.	0		
Cabrio 2.09 F (pyraclostro-bin)	11	16 fl oz	96 fl oz	0	Early blight, Late blight, Sclerotinia Powdery mildew, Target spot, Buckeye rot	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	Early blight, Late blight, Gray leaf spot	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	Early blight, Late blight, Southern blight, Target spot	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	Early blight , Late blight Septoria leaf spot, 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	Anthracnose, Black mold, Buckeye rot, Early blight, Powdery mildew, Septoria leaf blight, Target spot, Late blight	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	Early blight, Black mold, Gray leafspot, Powdery mildew, Septoria leafspot, Target spot, Anthracnose, Leaf mold	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	Late blight, Target spot, Bacterial spot (suppression)	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 fl oz	3	Pythium and Phytophthora root rots	<u>Greenhouse use only</u>. See label for details
Blocker 4F Terraclor 75 WP (PCNB)	14	See Label	See Label	Soil treatment at planting	Southern blight (*Sclerotium rolfsii*)	See label for application type and restrictioins
Par-Flo 4F (PCNB)	14	12 fl oz per 100 gal.	2 apps	Soil drench	*Rhizoctonia solani*	Limited to only container-grown plants in nurseries or greenhouse; see label
Botran 75 W (dichloran)	14	1 lb. per 43,680 sq. ft.	4 lbs	10	Botrytis	<u>Greenhouse use only</u>. Limit is 4 appl. Seedlings or newly set transplants may be injured, see label

Ph-D WDG (Polyoxin D zinc salt)	19	6.2 oz	31.0 oz	0	Powdery mildew, Botrytis rot, Early blight, Anthracnose (suppression)	Limit is 5 apps. on 10-14 day interval. Alternate with a non-FRAC code 19 fungicide. See label.
Ranman (cyazofamid)	21	2.1-2.75 oz	16 oz	0	Late Blight	Limit is 6 appl./crop, see label
Gavel 75DF (zoaximide + mancozeb)	22 / M3	2.0 lbs	16 lbs	5	Buckeye rot, Early blight, Gray leaf spot, Late blight, Leaf mold	See label
Agri-mycin 17 Ag Streptomycin Bac-Master Fire Wall (streptomycin sulfate)	25	200 ppm	-	-	Bacterial spot, Bacterial speck	See label for details. For transplant production only. Many isolates are resistant to streptomycin.
Curzate 60DF (cymoxanil)	27	5 oz	30 oz/ year	3	Late Blight	Do not use alone, see label for details
Previcur Flex or Promess (propamocarb hydrochloride)	28	1.5 pts	7.5 pts	5	Late blight, Early blight	Must tank mix with Chlorothalonil, maneb or mancozeb; see label.
		1.5 pts/ treated acre	7.5 pts/ treated acre	5	root rots and seedling diseases (*Pythium* spp.)	Applied to lower portion of plant and soil; or as a soil drench or drip irrigation; see label
		See label	See label		*Phytophthora Pythium*	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	Late blight, Early blight, *Pythium* spp.	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	*Phythophthora* spp. *Pythium* spp., *Fusarium* spp. Rhizoctonia, Late Blight, Powdery Mildew	Do not apply with copper-based fungicides. See label for restrictions and details
Aliette 80 WDG (fosetyl-al)	33	5 lbs.	20 lbs.	14	Phytophthora root rot	See label for warnings concering the use of copper compounds.
Acrobat 50 WP (dimethomorph)	40	6.4 oz	32 oz	4	Late blight	See label for details
Forum (dimethomorph)	40	6 oz	30 oz	4	Late blight	Only 2 sequential appl. See label for details
Revus (mandipropamid)	40	8 fl oz	32 fl oz	1	Late blight	Supplemental label; No more than 2 sequential appl.; See label
Revus Top (mandipropamid + difenoconazole)	40/3	7 fl oz	28 fl oz	1	Anthracnose, Black mold, Gray leafspot, Late blight, Leaf mold, Powdery mildew, Septoria leafspot, Target spot	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	Late blight *Phythophthora* 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
Serenade ASO, Serenade Max, Serenade Soil, Rhapsody (*Bacillus subtilis* strain QST 713)	44	See label	See label	0	Bacterial spot, Early Blight, Late Blight, Powdery mildew, Target spot, Botrytis, Rhizoctonia spp., Pythium spp., Fusarium spp., Verticillium spp., Phytophthora spp.	For foliar applications mix with copper compounds. Some formulations compatible with soil drench and in-furrow applications. See label for details. OMRI listed.
Actigard (acibenzolar-S-methyl)	P	0.75 oz.	4.75 oz	14	Bacterial spot Bacterial speck	See label for details
Regalia SC (Extract of *Reynoutria sachalinensis*)	P	1 % (v/v)	See label	0	Bacterial spot, Bacterial speck, Powdery mildew, Target spot, Gray mold, Late blight, Early blight, Bacterial canker	Limit is 6 apps per season. Do not apply more than 100 gallons of a 1% spray solution per acre. Do not apply more than 2 Qts per acre 7 days prior to harvest. See label for details.
Actinovate (*Streptomyces lydicus* WYEC 108)	NC	See label	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 Kaligreen Milstop (Potassium bicarbonate)	NC	See label	-	0	Powdery mildew	See label for details.
JMS Stylet-Oil (paraffinic oil)	NC	3 qts.	-	-	Potato Virus Y, Tobacco Etch Virus, Cucumber Mosaic Virus	See label for restrictions and use (e.g. use of 400 psi spray pressure)
PlantShield HC , RootShield G (*Trichoderma harzianum* Rifai strain KRL-AG2)	NC	See label	See label	0	See label	See label for details. OMRI listed
Oxidate (hydrogen peroxide)	NC	1:100 dilution	-	0	Anthracnose, Bacterial speck, Bacterial spot, Botrytis, Early blight, Late blight, Powdery mildew, Rhizoctonia fruit rot	See label for details.
Sonata, Taegro, (*Bacillus* sp.)	NC	See label	See label	0	Bacterial spot, Early Blight, Late Blight, Powdery mildew, Target spot, Botrytis	Mix with copper compounds, see label for details. OMRI listed
Soilgard 12G (*Gliocladium virens* GI-21)	NC	See label	See label	0	See label	See label for details. OMRI listed
Sporatec (oils of clove, rosemary and thyme)	NC	3 pts / 100 gal	See label	0	See label	Exercise care when applying. Do not apply when temps are above 90°F. See label for details. OMRI listed
Trilogy (neem oil)	NC	See label	See label	0	See label	See label for details. May cause leaf burn if applied during high temperatures. OMRI listed.

[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 2009; http://www.frac.info/ (FRAC = Fungicide Resistance Action Committee).

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

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.
Actara (thiamethoxam)	2.0-5.5 oz	12	0	aphids, 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) (for rates for other brands, see labels)	7-10.5 fl oz	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 0.15EC (abamectin)	8-16 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 48 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-listed2.
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), European corn borer, flea beetles, hornworms, potato aphid, southern armyworm(1), stink bugs, tomato fruitworm, tomato pinworm, variegated cutworm , western flower thrips, whitefly adults(2)	3	(1) 1st and 2nd instars only (2) Suppression Do not apply more than 0.132 lb ai per acre per season.
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-listed2.
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 1.0 lb ai per acre per season.
Coragen (rynaxypyr)	3.5-7.5 fl oz	4	1	beet armyworm, Colorado potato beetle, fall armyworm, hornworms, leafminer larvae, loopers, southern armyworm, tomato fruitworm, tomato pinworm	28	Can be applied by drip chemigation or as a soil application at planting. See label. For hornworms, can use as little as 2.0 fl oz/acre when applied as a foliar spray.
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-listed2.
*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 organophosphate-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. OMRI-listed2.
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	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-listed2.
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, mites	1B	Can be used in greenhouse (8F).
*Monitor 4EC (methamidophos) [24(c) labels] FL-800046 FL-900003	1.5-2 pts	96	7	aphids, fruitworms, leafminers, tomato pinworm(1), whitefly(2)	1B	(1) Suppression only (2) Use as tank mix with a pyrethroid for whitefly control. Do not apply more than 8 pts per acre per crop season, nor within 7 days of harvest.
Movento (spirotetramat)	4.0-5.0 fl oz	24	1	aphids, psyllids, whitefly	23	Maximum of 10 fl oz/acre per season.
M Pede 49% EC (Soap, insecticidal)	1-2% V/V	12	0	aphids, leafhoppers, mites, plant bugs, thrips, whitefly	--	OMRI-listed2.
*Mustang (zeta cypermethrin)	2.4-4.3 oz	12	1	beet armyworm, cabbage looper, Colorado potato beetle, cutworms, fall armyworm, flea beetles, grasshoppers, green and brown stink bugs, hornworms, leafminers, leafhoppers, Lygus bugs, plant bugs, southern armyworm, tobacco budworm, tomato fruitworm, tomato pinworm, true armyworm, yellowstriped armyworm. Aids in control of aphids, thrips and whitefly.	3	Not recommended for vegetable leafminer in Florida. Do not make applications less than 7 days apart. Do not apply more than 0.3 lb ai per acre per season.
Neemix 4.5 (azadirachtin)	4-16 fl oz	12	0	aphids, armyworms, hornworms, psyllids, Colorado potato beetle, cutworms, leafminers, loopers, tomato fruitworm (corn earworm), tomato pinworm, whitefly	un	IGR, feeding repellant. OMRI-listed[2].
NoMate MEC TPW (pheromone)		0	0	tomato pinworm	--	For mating disruption - See label.
Oberon 2SC (spiromesifen)	7.0-8.5 fl oz	12	1	broad mite, twospotted spider mite, whiteflies (eggs and nymphs)	23	Maximum amount per crop: 25.5 fl oz/acre. No more than 3 applications.
Platinum Platinum 75 SG (thiamethoxam)	5-11 fl oz 1.66-3.67 oz	12	30	aphids, Colorado potato beetles, flea beetles, leafhoppers, thrips, tomato pinworm, whitefly	4A	Soil application. See label for rotational restrictions. Do not use with other neonicotinoid insecticides
Portal (fenpyroximate)	2.0 pt	12	1	mites, including broad mites	21A	Do not make more than two applications per growing season.

*Pounce 25 W(permethrin)	3.2-12.8 oz	12	0	beet armyworm, cabbage looper, Colorado potato beetle, dipterous leafminers, granulate cutworm, hornworms, southern armyworm, tomato fruitworm, tomato pinworm	3	Do not apply to cherry or grape tomatoes (fruit less than 1 inch in diameter). Do not apply more than 0.6 lb ai per acre per season.
*Proaxis Insecticide (gamma-cyhalothrin)	1.92-3.84 fl oz	24	5	aphids(1), beet armyworm(2), blister beetles, cabbage looper, Colorado potato beetle, cucumber beetles (adults), cutworms, hornworms, fall armyworm(2), flea beetles, grasshoppers, leafhoppers, plant bugs, southern armyworm(2), spider mites(1), stink bugs, thrips(1), tobacco budworm, tomato fruitworm, tomato pinworm, vegetable weevil (adult), whitefly(1), yellowstriped armyworm(2)	3	(1) Suppression only. (2) First and second instars only. Do not apply more than 2.88 pints per acre per season.
*Proclaim (emamectin benzoate)	2.4-4.8 oz	12	7	beet armyworm, cabbage looper, fall armyworm, hornworms, southern armyworm, tobacco budworm, tomato fruitworm, tomato pinworm, yellowstriped armyworm	6	No more than 28.8 oz/acre per season.
Provado 1.6F (imidacloprid)	3.8-6.2 fl oz	12	0	aphids, Colorado potato beetle, leafhoppers, whitefly	4A	Do not apply to crop that has been already treated with imidacloprid or thiamethoxam at planting. Maximum per crop per season 19 fl oz per acre.
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, 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, 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.
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.
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-listed2.
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 soil: 5-6 oz	12	foliar: 1 soil: 21	Colorado potato beetle, flea beetles, leafhoppers, leafminers, thrips, whitefly	4A	Use only one application method (soil or foliar). Limited to three applications per season. Toxic to honeybees.
Vetica (flubendiamide and buprofezin)	12.0-17.0 fl oz	12	1	armyworms, cabbage looper, cutworms, garden webworm, suppression of leafhoppers and mealybugs, saltmarsh caterpillar, tobacco budworm, tomato hornworm, tomato fruitworm, tomato pinworm, suppression of whiteflies	28, 16	Do not apply more than 3 times per season or apply more than 38 fl oz per acre per season. Same 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

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

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
PIC Chlor 60[1]	19.5 – 31.5 gal	12"	3	20-25 gal 250-300 lb	57- 90 fl oz
Telone II[2]	9 -18 gal	12"	3	4.5-9.0 gal	26-53 fl oz
Telone EC[2]	9 -18 gal	Drip applied	See label for use guidelines and additional considerations		
Telone C-17[2]	10.8-17.1 gal	12"	3	5.4-8.5 gal	31.8-50.2 fl oz
Telone C-35[2]	13-20.5 gal	12"	3	6.5-13 gal	22-45.4 fl oz
Telone Inline[2]	13-20.5 gal	Drip applied	See label for use guidelines and additional considerations		
Metham Sodium	50-75 gal	5"	6	25-37.5 gal	56-111 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 2010. 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, 2010 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.

New Fumigant Regulations Coming in December

Joseph W. Noling[1] and Andrew MacRae[2]
[1]University of Florida, IFAS, CREC, Lake Alfred, FL
[2]University of Florida, IFAS, GCREC, Balm, FL

With reregistration of the soil fumigants near complete, EPA has mandated the addition of many new changes to fumigant labels which include a variety of new risk mitigation measures in a 2 year stepwise approach. The fact that the reregistration process is nearly over should come as no surprise to anyone since we have been presenting 'the doom and gloom' message to growers for a number of years now. So again, as another advanced warning, be advised that some of the new label requirements will begin this December 2010, while others will be required to be included on revised labels which will appear on product containers in mid to late 2011. Beginning December 2010, new label language will appear which will formally require certified applicators to complete a written, site specific Fumigant Management Plan (FMP) prior to any day's fumigant application in the field. For this 1st phase of new labels in December, the FMP's must only capture current and first phase label requirements. In 2011, the FMP's must also capture second phase label requirements which will require the certified applicator to document compliance with new buffer zone requirements and emergency preparedness measures and procedures.

Fumigant Management Plans

When the new fumigant labels appear in 2010, each fumigant applicator will need to ensure that a site-specific FMP has been prepared before beginning a fumigant application in the field on any given day. The certified applicator will also be required to complete a daily checklist and prepare a post application summary report to document any deviations from the FMP that may have been necessary, as well as any results of air monitoring done during and/or after the application in the field or within the buffer zone perimeter. EPA believes that the FMP's will reduce potential risks to bystanders, people living in close proximity, as well as handlers in the field by requiring that applicators have carefully planned each day's fumigation, and by forcing applicators to document (in writing) how they intend to comply with all of the new label changes and requirements.

A partial list of some of the major elements within the FMP that certified applicators will need to address include general site and applicator information, application method and tarp repair procedures, weather and soil conditions, and a description of how the fumigator plans to comply with label requirements for GAP's, buffer zones, air monitoring, worker training and protective equipment, posting of signage, and providing notification to neighbors should it be needed. The FMP's will also require the applicator to identify the names and addresses of handlers participating in the fumigation prior to the event, plans for communication between the applicator and others involved in the fumigation, and to document how emergency situations will be handled. Additionally, EPA will require (via the new labels) that applicators complete a post-fumigation summary that will describe any deviations from the FMP, measurements taken to comply with GAPs, and information about any problems, such as complaints or incidents, that occurred as a result of the fumigation. The new fumigant labels also will specify requirements for archiving the FMP for 2 years and that FMPs must be provided, upon request, to enforcement officials, handlers involved in the fumigation, and emergency response personnel. Other noteworthy fumigant label changes mandated by EPA include requirements for medical certification, safety training, and fit testing of workers to satisfy EPA respirator requirements when and if needed in the field. The certified applicator will also be required to monitor for pungent odors of fumigant gases in areas between the buffer zone perimeter and residences or other occupied areas four times during the day (dawn, dusk, and once during the night and day) to ensure perceived odors do not exceed the action levels requiring enforcement of emergency procedures and notification of neighboring landowners surrounding the field.

FMP Availability

Once the application begins, the certified applicator must be prepared to make a copy of the FMP available for viewing by handlers involved in that day's fumigation. The certified applicator or the owner/operator of the application block must also be prepared to provide a copy of the FMP to any federal, state, tribal, or local enforcement personnel who may request copy of the FMP. In the case of an emergency, the FMP must also be made readily available when requested by federal/state/local emergency response and enforcement personnel.

Farm Wide FMP's

For situations where an initial FMP is developed and certain elements do not change for multiple fumigation sites such as the certified applicator information, authorized on-site personnel, tarp repair, record keeping, and emergency procedures, all of the information that remains unchanged can be captured once and reprinted to a new FMP and only elements that have changed, such as block location, application rates, weather and soil conditions, need to be updated in each new days site-specific FMP. This will not preclude the requirement for

• The certified applicator supervising the application to verify all of the different elements of the FMP, including those elements that are current and applicable to the application block before it is fumigated and documented within the site-specific FMP.

• It also requires that the same recordkeeping requirements are followed for the entire FMP, including elements that do not change.

Soil and Weather Conditions

Prior to a days fumigation, the weather forecast for the day of the application and the 48-hour period following the fumigation must be checked to determine if unfavorable weather conditions exist or are predicted to occur. These weather reports are to be used to determine whether fumigation for that day should proceed. Detailed local forecasts for weather conditions, wind speed, and air stagnation advisories must be obtained and documented within the site specific FMP. The site specific management plan also requires soil moisture to be measured and recorded at a depth of 9 inches at either end of the field, no more than 48 hours prior to application. Soil moisture must be measured or estimated to be 50 to 80% of field holding capacity (depending on the specific product label) before proceeding with a fumigant application. For sand soils in Florida there will be an exemption on the label since to form a bed we must have soil moistures in the range of 160 to 240%. Soil moisture must be determined by one of the following methods: The USDA Feel and Appearance Method for testing or with an instrument, such as a tensiometer. If soil moisture in inadequate (to low, or to high), the soil moisture must be adjusted by irrigation or tillage operation. The method in which soil moisture is determined must be reported in the FMP and the results from either method documented within the Post application summary. We believe it behooves the applicator to spend the time to take the measurements to avoid compliance infractions and to minimize potential liabilities and future litigation, should claims of incidents of exposure arise at some future time.

Good Agricultural Practices (GAP's)

EPA has specified a number of good agricultural practices (GAP's) that will be required to be fulfilled before soil applications of a fumigant can proceed. The GAP's are being required to reduce fumigant emissions and potential for worker and bystander exposures. EPA has determined that applicators must (1) check the weather forecast and make a decision whether to proceed with a planned fumigation, based on conditions that are predicted, (2) only begin a fumigant application

• If wind speed is a minimum of 2 mph at the start of the application or forecasted to reach at least 5 mph during the application.

• The maximum soil temperature at the depth of injection shall not exceed 90 degrees F at the beginning of the application.

• Soil is properly prepared and at the surface generally be free of clods that are golf ball size or larger. The area to be fumigated shall be tilled to a depth of 5 to 8 inches.

• Field trash must be properly managed. Residue from a previous crop must be worked into the soil to allow for decomposition prior to fumigation. Little or no crop residue shall be present on the soil surface.

• Any trash (plastic, twine, crop residue) pulled by the shanks to the ends of the field must be covered with tarp, or soil, depending on the application method before making the turn for the next pass.

Definition of Handlers:

The new fumigant labels will clarify fumigation tasks that meet EPA's definition of handler activities to include most, if not all, people in the field. More specifically Handlers are defined as those who:

• Participating in the fumigant application as supervisors, loaders, drivers, tractor co-pilots, shovelers, cross ditchers, or as other direct application participants (note: the application starts when the fumigant is first introduced into the soil and ends after the fumigant has stopped being delivered/dispensed to the soil);

• those using devices to take air samples to monitor fumigant air concentrations;

• Persons cleaning up fumigant spills (this does not include emergency personnel not associated with the fumigation application);

• Handling or disposing of fumigant containers;

• Cleaning, handling, adjusting, or repairing the parts of fumigation equipment that may contain fumigant residues;

• Installing, repairing, or operating irrigation equipment in the fumigant application block or surrounding buffer zone during the buffer zone period;

• Entering the application site or surrounding buffer zone during the buffer zone period to perform scouting, crop advising, or monitor-

ing tasks;
• Installing, perforating (cutting, punching, slicing, poking), removing, repairing, or monitoring tarps:

Documenting and Certifying Handlers

Another change in fumigant labeling needing further discussion involves the new requirement within the Fumigant Management Plan (FMP) to identify all handlers working in the field, including names, phone numbers, addresses, tasks they are trained and authorized to perform, and dates of training certifications completed prior to the start of each days soil fumigation activity. For many farms who employ office staff capable of efficiently documenting new workers and providing scan able ID cards and WPS training videos and certifications for handlers while their paperwork is being processed, this new requirement for generating a printed list of handlers in the field prior to beginning a days fumigation may not be a difficult or insurmountable problem. There is however another universe of growers who lack office staff and computer capability who will be seriously challenged by this new requirement to published a printed listing of all handler names, addresses, phone numbers and dates of required certifications before start of fumigations in the field each morning. For those fumigants which will require use of respirators, or if certified applicators decide to continue fumigating after receiving any handler complaints of sensory irritation to fumigant gases, additional training, fit testing, and medical certifications will be required before allowing handlers to work in the field. This will also require the certified applicator to list these additional certifications to the handler list each morning before beginning each day's fumigation activity. Those farm operations which currently rely on labor contractors to provide field workers on an as needed basis, must demand that the contractor provide an accurate printed list of all handlers and the dates of their certifications to the certified applicator each morning, such that the applicator can append this information to the FMP. From a compliance standpoint, the certified applicator will bear the full burden of responsibility for the accuracy and completeness of the FMP if an inspection should occur, and a copy of the completed FMP cannot be provided as requested for viewing by handlers or to include in the inspectors records. Adding these new recording keeping and retrieval processes to on-farm operations will not come without additional costs, which will likely hurt everybody, particularly the "small people" or less electronically sophisticated farms or businesses.

Concluding Remarks:

Clearly, the new fumigant labels will represent a significant change in the way growers have used soil fumigants in the past. Grower obligations required to develop and implement the new fumigant label requirements will be complex and time consuming, and will add a new burden of grower responsibility and liability. For the grower and certified applicator, the future of fumigant use in Florida will demand a broader respect, recognition, and need for stricter adherence to fumigant label language and it will require a more vigilant understanding and observance of Good Agricultural Practices. Additionally, these changes will require closer observance of and participation in newly required product stewardship and worker safety certification programs, as well as greater consideration of people and land areas surrounding a fumigated field. At the farm level, the new fumigant use requirements will clearly demand an increased focus on clerical and communication skills by farm personnel, including an expedited system of documenting, training, and certifying new workers who participate in a soil fumigation activity on a daily basis.

The new labeled changes being mandated by EPA this fall will introduce new requirements for certified applicators in the form of more detailed instructions, reporting and application restrictions that will be imposed on use of soil fumigants. As indicated previously, new fumigant specific training programs, developed and provided by registrants, will require applicators to recertify every three years before applying the product in the field. To further ensure applicators understand and are complying with the newly revised fumigant labeling, the University of Florida, IFAS is completing development of an on-line training and certification program for applicators in charge of soil fumigations, worker safety certifications for handlers, and for Florida Department of Agriculture and Consumer Services inspectors and compliance officers on the proper labeled uses of and best management practices for soil fumigants.

Table 1. Partial list of major elements of a site-specific Fumigant Management Plan (FMP) that certified fumigant applicators must provide documentation within a formal written plan prior to each day's field fumigation activity.

1. Certified Applicator Information, including licenses, training certifications	10. Posting Signs
2. General Fumigation Site Information and Detailed Map	11. Site Specific Response & Management plan
3. General Application Information, methods, rates, acres treated per day	12. Notice to State Tribal Agencies (if required)
4. Tarps / Tarp Repair methods and procedures	13. Communication with Handlers
5. Description of Soil Conditions (temperature, moisture content)	14. Handler Information, names, job duties and dates of training certification
6. Weather Conditions and Forecast	15. Air Monitoring Plan for Buffer Zones
7. Buffer Zone distances and calculations	16. Handlers w/o Respiratory Protection
8. PPE label requirements for Handlers	17. Handlers with Respirator Protection
9. Emergency Response Plan	