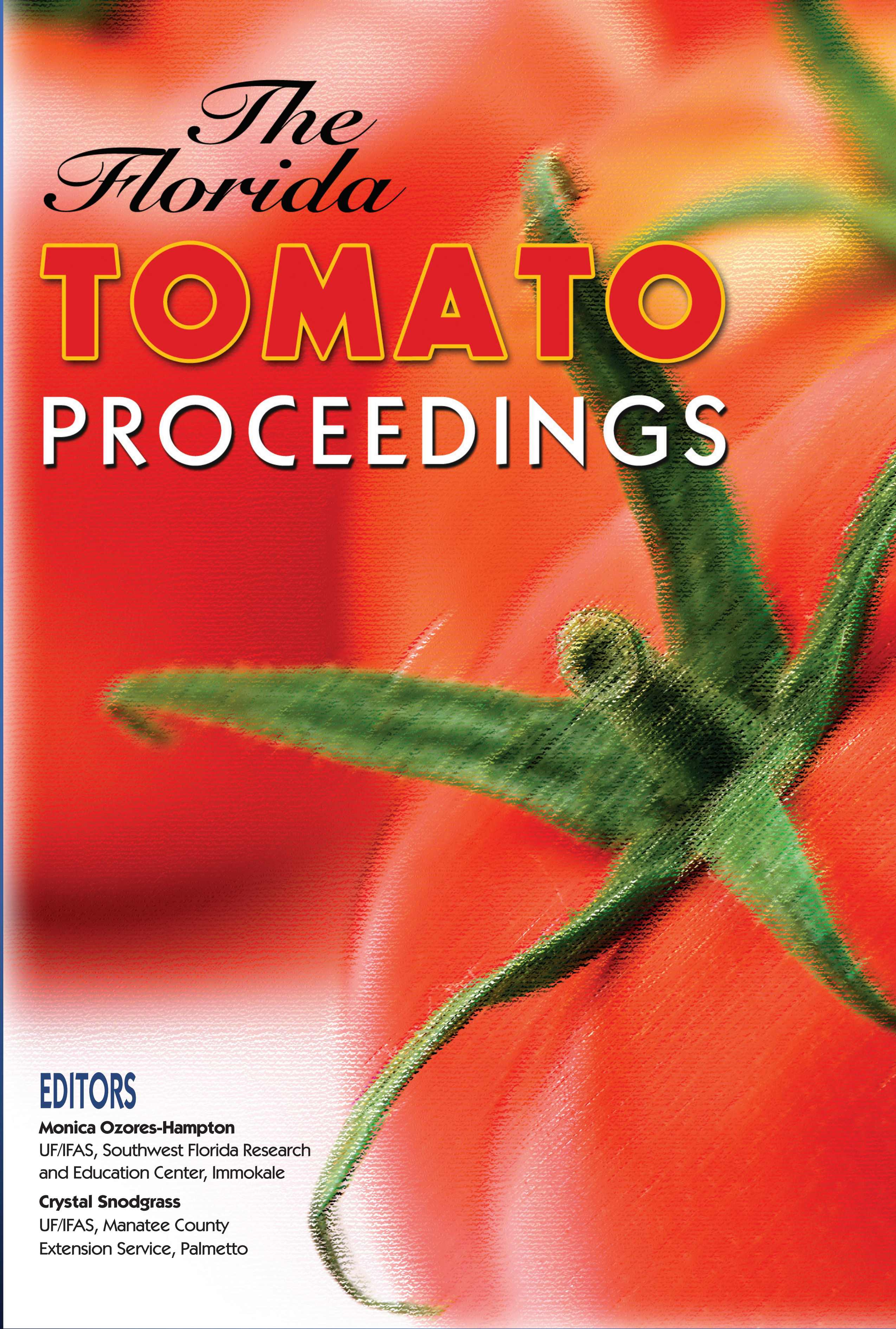
2014

The Florida TOMATO PROCEEDINGS



EDITORS

Monica Ozores-Hampton
UF/IFAS, Southwest Florida Research and Education Center, Immokale

Crystal Snodgrass
UF/IFAS, Manatee County Extension Service, Palmetto

VANCE
INNOVATIVE SOLUTIONS THAT GROW BUSINESSES

THE GROWER'S CITRUS+VEGETABLE

UNIVERSITY OF FLORIDA
IFAS EXTENSION

2014 FLORIDA TOMATO INSTITUTE PROGRAM

The Ritz-Carlton Golf Resort, Naples, Florida | September 3, 2014/PRO 530

University of Florida Tomato Breeding 33 Years and Counting; Retrospective, Introspective, Prospective

Jay Scott and Samuel Hutton[1]

University of Florida/IFAS, Gulf Coast Research & Education Center, Wimauma, FL, jwsc@ufl.edu

[1] Jay Scott is the old guy, Sam Hutton has been involved in the breeding program for about 5 ½ years as a post-doc and then Assistant Professor and although heavily involved in all the present research was not dealing directly with the breeding program before 2008.

INTRODUCTION

Bacterial spot resistance. The University of Florida (UF) tomato (*Solanum lycopersicum* L.) breeding program has had a long and proud history (Scott, 1999) and the senior author has been fortunate to be a part of it. Actually, a rather long part of it, at least longer than any of my predecessors (Scott, 1999). I started in July 1981 and when I arrived a heat-tolerance crop was in the ground. The young plants looked good for about two weeks when an epidemic of bacterial spot (*Xanthomonas euvesicatoria*) [we now know it was race T1, there were no known races at the time] came in and covered the plants with greasy black spots. It was my first real introduction to bacterial spot on tomato. I was pretty depressed at the devastation but it was also a time when plant pathologist, Jeff Jones, started and when I showed him the crop he was grinning like a Cheshire cat. My first goal was to find resistance to this disease to help the tomato industry primarily but also to wipe that smile off of Jeff's face. It is well known that horticulturalists have always found plant pathologists to be weird. So I gathered all the tomato germplasm I could find that had some reported bacterial resistance and screened those 300 or so lines in 1982. Many (200) of these came from data kindly sent to me from Bill Summers at Iowa State University who had screened about 5,000 accessions under growth chamber conditions (Lawson and Summers, 1984). We found some tolerance but nothing real exciting. In the intervening year UF Fort Pierce plant pathologist, Ron Sonoda, sent me seed of Hawaii 7998 because he heard of my bacterial spot screening. He said it was a bacterial wilt (now known as *Ralstonia solanacearum*) resistant line that wasn't being used because the fruit size was less than our bacterial wilt resistant source Hawaii 7997. In 1983 we found a very high level of resistance to bacterial spot race T1 in Hawaii 7998 and the breeding effort started. I remember naively thinking that the chemical companies selling copper formulations to tomato growers would be worried once resistant varieties came out a few years hence. It is 30 years later and a bacterial spot resistant variety still has not been released. This has been due to the emergence of virulent races of the pathogen in Florida from race T1 to T3 in the early 1990s and from race T3 to race T4 in the early 2000s (Horvath et al., 2012). This has happened despite complex genetic control of resistance which according to the host pathogen text books should not happen (Scott et al., 2011).

Another important source of resistance in the program has been PI 114490 an accession sent to the USDA from Kew Gardens in the UK in 1936. This was among the 200 best lines from the Iowa State testing. Thus, it was tested in 1982 but did not look good and in retrospect this was likely due to its high susceptibility to early blight (*Alernaria solani*) that may have masked the bacterial spot resistance. In the early 1990s UF Ph.D. student, Jaw-Fen Wang, used a leaf dip method developed by plant pathologist, Bob Stall, to identify resistance to race T2, a race that has not been found in Florida. In testing her best 25 genotypes in Ohio with plant pathologist, Sally Miller, and later tomato breeder, David Francis, we found PI114490 had excellent resistance to race T2 (Scott et al., 2003). Later testing in Ohio indicated that this PI also had resistance to races T1 while Florida testing indicated moderate resistance to race T3 and high resistance to race T4. However, in subsequent breeding line development in Florida and Ohio no lines were developed that had resistance comparable to PI 114490. In the past few years the USDA sponsored SolCAP project developed thousands of molecular (snp) markers that allowed us to identify over 2,000 markers polymorphic between PI 114490 and susceptible lines. Sam Hutton and I then developed 92 lines with various levels of resistance and these were genotyped with the markers and tested in the field for race T4 in Florida and the other three races plus *X. gardneri* in Ohio with David Francis. From this ongoing work we have identified at least 7 QTLs that associate with resistance across the races and further work with the QTLs could allow for commercially acceptable varieties with high levels of resistance to be developed. Since the QTLs work across races it would lower the likelihood that new virulent races would develop. So for the future there are tools available that we didn't have in the past but there is still a lot of work to do. An easier solution would be to use tomato lines transformed with the pepper *Bs2* gene where we have done extensive trialing of hybrids with excellent resistance and yield (Horvath et al., 2012; Scott et al., 2012). We now have good hybrids with resistance to bacterial spot, TYLCV, and fusarium crown rot (*Fusarium oxysporum* f.sp. *radicus-lycopersici*) or fusarium wilt race 3. However, since these are GMOs there is aversion to commercialization of such products even though the same gene in bell peppers has been consumed without concern or ill effects for about 30 years. To provide adequate food for future generations, plant breeders will need all the tools that work at their disposal including GMO technology. Hopefully the non-scientific hysteria about GMOs will change as the public is made aware of the benefits of some transformation systems.

Fusarium wilt race 3 resistance. The first report of fusarium wilt race 3 (*Fusarium oxysporum* f.sp. *lycopersici* race 3) was from Australia in 1979 but it was discovered on a farm in Manatee County in 1982 (Jones et al., 1982) invoking great fear in the tomato industry because of the devastation caused by race 2 in the 1960s. Finding resistance quickly became a major goal of the tomato breeding program. With the help of plant pathologist, J.P. Jones, over 1000 accessions were screened and seed was saved from many with over 50% resistance. Resistance was found in several difficult to work with *Lycopersicon peruvianum* accessions but also in LA716, a *L. pennellii* accession (Scott and Jones, 1986). The latter was the source of single gene dominant resistance (*I*-3) (Scott and Jones, 1989) that has been the gene used in race 3 resistant varieties around the world (Scott and Jones, 1995). Today numerous commercial varieties are available to tomato growers in Florida and the disease is gradually spreading. It did not become widespread quickly as did fusarium wilt race 2. There are some weaknesses associated with fusarium wilt race 3 resistances with a major one being susceptibility to bacterial spot (Hutton et al., 2014). We have overcome this sensitivity by combining *I-3* with bacterial spot QTLs and a non-blighting (NB) trait where leaves hold their green color despite bacterial spot infection. Sam Hutton has two Ph.D. students working on fusarium wilt race 3 and NB and there could be some interesting advancements to improve fusarium wilt race 3 varieties in the future.

Geminivirus (Begomovirus) resistance. In the 1980s I was thinking I had my hands full with bacterial spot, fusarium wilt race 3, and other resistance breeding efforts but at least I didn't have to contend with sweetpotato whitefly (*Bemisia tabaci*) vectored viruses such as *tomato yellow leaf curl virus* (TYLCV). In 1988 the whitefly arrived and the first problem growers encountered was irregular ripening (Schuster et al., 1990). In 1989 *tomato mottle virus* (ToMoV) was discovered (Abouzid et al., 1992) and I set out to find resistance to that disease that was causing over 100 million dollars in damage to the Florida industry. In 1990 entomologist, Dave Schuster, and I screened 97 accessions with reported virus resistance including 36 accessions of the wild species *L. chilense.* Dani Zamir of the Hebrew University in Israel had shared pre-publication information about resistance from *L. chilense* accession LA1969 and Asgrow plant breeder, Bob Heisey, had said this species was showing resistance to some viruses in Mexico. Resistance was found in several accessions with introgression and breeding being done primarily with three chilense accessions. TYLCV came into Florida in 1997 and in a few years replaced ToMoV. Fortunately, the ToMoV bred lines were resistant to TYLCV so the program continued with emphasis on TYLCV. Space does not permit adequate discussion of this major breeding effort so only a few highlights will be mentioned. Yuanfu Ji, a post-doctoral scientist in our lab, located the *Ty-3,* and *Ty-4* genes. Recently, as part of a SolCAP grant, Sam Hutton located the yet to be officially named *Ty-6* gene. At present we are in the process of releasing Fla. 8923, a large-fruited breeding line with the *Ty-3* gene in a very small introgressed *L.chilense* segment that resulted from a four year research effort (supported by a USDA-AFRI grant) to remove almost all of the introgression. This work would have been virtually impossible if it were not for markers developed as a result of tomato genome sequencing. We are also releasing breeding line Fla 8624 that has the *Ty-6* gene and Fla. 8638B that has the *Ty-6* and the *Ty-5* gene derived from a cross with Tyking (Hutton et al., 2012). To date tomato growers have not liked TYLCV resistant varieties, almost all based on resistance from the *Ty-1* gene, because of linkage drag that has resulted in uneven yields, fruit quality, and foliar disease issues. The *Ty-1* gene has not held up in some areas of the world and this could be a concern in Florida in the future. The availability of other resistance genes that are free of linkage drag offer tomato breeders more flexibility to produce varieties in the future that have improved horticultural traits and durability of resistance to the pathogen. Marker assisted selection (MAS) is being utilized for this and other resistances and will allow for acceleration of breeding improved varieties in the future. This will include the stacking of more and more disease resistance genes in single varieties. Breeders will have to monitor any detrimental effects from these combined resistances. More breeding tools are available but there will no doubt be challenges to discover and overcome.

Mechanical harvest tomato varieties. Labor availability and expense is a major issue facing Florida tomato growers. Thus, a major effort to develop tomato varieties that do not have to be staked has been ongoing for over 20 years. The breeding effort is based on the development of compact growth habit (CGH) tomatoes that have a short main stem and enhanced side branching resulting from the brachytic (*br*) gene (Kemble et al., 1994). The original breeding material was generously provided by Randy Gardner of the North Carolina State tomato breeding program. Our main focus has been to incorporate the jointless pedicel (*j2*) gene into CGH tomatoes since it is a necessary component for once-over mechanical harvest. These tomatoes also must have a concentrated fruit set to maximize yield at a single harvest. By nature they are early in maturity which will save growers money as the cropping time will be reduced by a month or more. For success CGH varieties will require a high level of fruit firmness. Also, they must be tolerant of any serious defects such as catfacing and graywall that could cause unforgiving levels of cull tomatoes in a single harvest. Growers never like these weather induced problems but with staked tomatoes with three harvests such problems usually dissipate for two of the three harvests. In spring 2014 for the first time we made hybrids that looked good and we did a single harvest of red fruit as when assessing the hybrids we wanted to monitor fruit firmness and cracking. Yields were over 1900 25 lb. boxes/acre for the best CGH jointless hybrids which were significantly greater and about twice that of conventional hybrids. It is a challenge to develop high quality large-fruited varieties with the jointless gene but it appears that acceptable hybrids could be available to the Florida industry in the not too distant future.

Heat-tolerance. It has long been my philosophy that if a heat-tolerant variety with good main season characteristics was developed, it would take considerable market share throughout the tomato growing seasons in Florida because heat-tolerant varieties tend to set fruit more reliably under other stress conditions such as cold temperatures. However, to date the heat-tolerant varieties available do not have the characteristics needed for optimal main season production. This isn't due to a lack of trying, one of the problems breeders run into is the highly reproductive nature of heat-tolerant varieties. They have a high harvest index with less vine per fruit and generally such types get more bacterial spot.

Solar Set was my first heat-tolerant release (Scott et al., 1989). North Florida growers were in need of a heat-tolerant variety for their fall crops. Horticulturalist, Steve Olson, called me about the problem in the late 1980s so I put together a number of hybrids and then chose 6 of these that seemed possible and harvested fruit from single plots of each. From that data two looked possible; one had better fruit set but was smaller fruited and the other had less heat-tolerance but larger fruit. The latter was based on data from a single six plant plot at the old center in Bradenton. Steve showed the data to the growers and they wanted the larger fruited one so we had some seed produced by a seed company. The next year we had about 40 acres of what became Solar Set grown on three North Florida farms. One grower had 18 acres and got over 2000 boxes per acre from that crop while "Sunny" did not do nearly as well. The grower made a lot of money and then it seemed like every tomato grower in Florida wanted to grow Solar Set. We had more seed made for the next year but not enough so Steve and I had to dole out seed on a limited basis which was not a lot of fun since I think we disappointed the growers with what they could get. There was a fair acreage in North Florida and it was budget time in Tallahassee. I had heard that IFAS administration was worried that if Solar Set didn't perform well that season the growers would complain to the legislature and it could adversely affect the IFAS budget. Talk about pressure with expectations based on one season of a variety on 18 acres. Fortunately Solar Set did well and the budget was ok too.

In the last few years we have increased the emphasis on developing heat-tolerant inbreds. One parent line we are interested in now is Fla. 8925 which has been looking pretty good for the last two years. If it sets well next fall it will likely be released as a breeding line. Perhaps after that a hybrid will be released but more testing is needed for that to happen.

Tasti- Lee^{tm}. Tasti-Lee was released as Fla. 8153 (Scott et al., 2008) as a premium type tomato. Tasti-Lee has good flavor and a deep red interior color due to the *og*^{c} gene. The fruit hold up well under rainy weather and yields have been good under a wide range of growing conditions. It is being sold as a branded item and not as a commodity. By contract it has to be harvested vine-ripe by growers licensed to do so with contracts set various retail stores. Pricing is set and does not fluctuate much as does the normal tomato market. Market share has been gained in the grocery stores for these field grown tomatoes. I don't know how that was going to happen with field grown commodity tomatoes. There would likely be demand for Tasti-Lee from restaurants but they are not available in the food service market. This would be a product that Florida would have that greenhouse growers and others would not. However, many of the mature green growers in Florida have not shown interest in growing Tasti-Lee for the food service market. This is a complicated topic and I can't really cover it here. However, I am sorry that Tasti-Lee has upset many in the tomato industry that I feel I have been trying to help my whole career. In the future perhaps there will be a better understanding of what is needed to keep the Florida tomato industry sustainable and healthy. This may well mean more diversification in products provided.

Synopsis. It has only been possible to scratch the surface in trying to describe three decades of tomato breeding. I hope a few things are apparent from what has been presented. Any success attained has been largely the result of assistance of many outstanding cooperators and only a few have been mentioned. John Donne said "No man is an Island" and certainly no tomato breeder is either. Not only have I had cooperation in my career, but I was able to start where I did based on an incredible amount of tomato breeding and genetic progress made by my predecessors. "If I have seen a little further it is by standing on the shoulders of Giants."-Isaac Newton. I have also had a huge number of dedicated employees who have been an integral part of advancements we have been able to make. The financial support of the Florida Tomato Committee has been essential to the functioning of the breeding program. There are only a few public tomato breeding programs in the United States and the world for that matter. Florida is a good place to breed tomatoes and I hope the industry will thrive and continue to support the breeding program. The generosity of the DiMare family in supporting the second tomato breeding position at UF has allowed for Sam Hutton to be hired and no matter what happens to my position, Florida will have a strong and capable breeder to take the program to greater heights. I'm not out the door yet, that will happen in summer 2015 but the door is now in sight. Where does the time go? Best wishes and success to all involved in the Florida tomato industry.

LITERATURE CITED

Abouzid, A. M., J.E. Polston, and E. Heibert. 1992. The nucleotide sequence of tomato mottle virus, a new geminivirus isolated from tomatoes in Florida. J. Gen. Virol. 73:3225-3229.

Horvath DM, Stall RE, Jones JB, Pauly MH, Vallad GE, Dahlbeck, D, Staskawicz, BJ, Scott, JW. 2012. Transgenic Resistance Confers Effective Field Level Control of Bacterial Spot Disease in Tomato. PLoS ONE 7(8): e42036. doi:10.1371/journal.pone.0042036

Hutton, S.F., J.W. Scott, and G.E. Vallad. 2014. Association of the fusarium wilt race 3 resistance gene, *I-3*, on chromosome 7 with increased susceptibility to bacterial spot race T4 in tomato. J. Amer. Soc. Hort. Sci. 139:282-289.

Hutton, Samuel F., Jay W. Scott, and David J. Schuster. 2012. Recessive resistance to *Tomato yellow leaf curl virus* from the tomato cultivar Tyking is located in the same region as *Ty*-5 on chromosome 4. HortScience 47(3):324-327.

Jones, J.P., J.B. Jones, and J.W. Miller. 1982. Fusarium wilt of tomato. Fla. Dept. Agr. & Consumer Serv., Div. Plant Industry, Plant Path. Cir. No. 237. 2p.

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 tomatoes. HortScience 29:1460-1464.

Lawson, Vince F. and W. L. Summers. 1984. Disease reaction of diverse sources of *Lycopersicon* to *Xanthomonas campestris* pv. *Vesicatoria* pepper strain race 2. Plant Disease 68:117-1119.

Schuster, D.J., T.F. Mueller, J.B. Kring, and J.F. Price. 1990. Relationship of the sweetpotato whitefly to a new tomato fruit disorder in Florida. HortScience 25:1618-1620.

Scott, J.W. 1999. University of Florida tomato breeding accomplishments and future directions. Soil Crop Sci. Soc. Fla. Proc. 58:8-11.

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.

Scott, J.W., Francis, D.M., Miller, S.A., Somodi, G.C., and J.B. Jones. 2003. Tomato bacterial spot resistance derived from PI 114490; inheritance to race T2 and relationship across three pathogen races. J. Amer. Soc. Hort. Sci. 128(5):698-703.

Scott, JW. S.F. Hutton, G.E. Vallad, J.B. Jones, R.E. Stall, and D.M. Horvath. 2012. Is it time for a transgenic tomato variety?! 2012 Florida Tomato Institute Proceedings. 8-9.

Scott, J.W., J.B. Jones and S.F. Hutton. 2011. Oblique resistance: the host-pathogen interaction of tomato and the bacterial spot pathogen. Acta Horticulturae 914:441-447.

Scott, J.W. and J.P. Jones. 1995. Fla. 7547 and Fla. 7481 tomato breeding lines resistant to *Fusarium oxysporum* f. sp. *lycopersici* races 1, 2, and 3. HortScience 30(3):645-646.

Scott, J.W. and J.P. Jones. 1986. Sources of resistance to Fusarium wilt race 3. Rept. Tomato Genetics Coop. 36:28-30.

Scott, J.W. and J.P. Jones. 1989. Monogenic resistance in tomato to Fusarium oxysporum f. sp. lycopersici race 3. Eupthtica 40:49-53.

Scott, J.W., S.M. Olson, H.H. Bryan, T.K. Howe, P.J. Stoffella, and J.A. Bartz. 1989. Solar Set: A heat tolerant, fresh market tomato hybrid. Fla. Agr. Exp. Sta. Circ. S-359 10p.

Scott, J.W. and D.J. Schuster.1991. Screening of accessions for resistance to the Florida tomato geminivirus. Rept. Tomato Genetics Coop. 41:48-50.

Verlaan, Maarten G., Samuel F. Hutton, Ragy M. Ibrahem, Richard Kormelink, Richard G. F. Visser, John W. Scott, Jeremy D. Edwards, and Yuling Bai. 2013.The Tomato Yellow Leaf Curl Virus Resistance Genes Ty-1 and Ty-3 Are Allelic and Code for DFDGD-Class RNA–Dependent RNA Polymerases. PloS Genetics http://www.plosgenetics.org/article/info:doi/10.1371/journal.pgen.1003399

The New Late Blight Genotypes and Their Management in Field Trials

Pamela Roberts[1], Ryan Donahoo[1], Charles Mellinger[2], and Galen Franz

[1] University of Florida/IFAS, Department of Plant Pathology, Southwest Florida Research and Education Center, Immokalee, FL.
[2] Glades Crop Care, Inc. 949 Turner Quay, Jupiter, FL, pdr@ufl.edu

INTRODUCTION

Late blight on tomato and potato is caused by the fungal-like pathogen *Phytophthora infestans*. Although previously classified as fungi, the genus *Phytophthora*, including *Phytophthora infestans,* is now separately classified as an oomycete. In order to understand the pathogen and the variability in the population regarding features such as fungicide sensitivity and epidemic potential, a standard set of tools utilizing molecular (DNA based) and phenotypic (physical traits) are used to characterize and differentiate isolates of the pathogen. A genotype is given in the "US", to indicate origin as US, followed by a number 1 through 24. The higher the number, the more recently identified the genotype, such as US-23 and US-24 (Table 1). In spring 2012 near Immokalee, a new genotype, US-24, was first detected causing symptoms on potato but within two weeks had spread to nearby tomatoes. In an analysis of late blight populations from tomato and potato throughout the US, it was found that US-24 was present in the northeast states at least one to two years before appearing in Florida potatoes. Similarly, the current predominant genotype, US-23, in 2014 was found in other production regions outside of Florida (north) prior to being found in Florida. This gives evidence that the initial source of inoculum for late blight epidemics is probably still from non-endemic sources, meaning that inoculum is being introduced seasonally from outside sources. Whether this introduction is via infected plant material or a natural pathway such as long-distance wind dispersal is unknown.

LATE BLIGHT GENOTYPE: DOES IT MATTER?

Genotyping can give rapid identification of certain characteristics of the pathogen such as mefenoxam sensitivity, mating type, and a reference to previous epidemiological field behavior. A summary of recent genotypes and key characteristics is presented in Table 2. As an example, the particularly virulent and difficult to control US-20 that caused widespread losses in 2005 was intermediate in sensitivity to mefenoxam. The current predominant genotype, US-23, in contrast, while it can be difficult to control when environmental conditions are conducive, but generally good control can be achieved with fungicides and is sensitive to mefenoxam. Also of importance is the lack of detection of sexual reproduction of the population within Florida and the US despite the presence of both mating types. Sexual reproduction through the formation of oospores can occur when both A1 and A2 mating types of *P. infestans* are present. Oospores are a type of structure that can survive long periods in the soil and increase genetic diversity which can make control of the disease more difficult, as experienced with the situation in Europe. In Florida, asexual reproduction through the production of sporangia and subsequent release of motile zoospores is the important source of spread and infection.

MANAGEMENT OF LATE BLIGHT CAUSED BY RECENT GENOTYPES: NO DIFFERENCE?

Basically, despite the change documented in the pathogen population, management of late blight remains the same with the exception of being able to determine more quickly whether the pathogen is sensitive to

Table 1. Historical occurrence of ***Phytophthora infestans*** genotypes in Florida (Donahoo and Roberts, 2012 at http://edis.ifas.ufl.edu/pp301).

Year	Region	Crop affected	Clonal Lineage	Mating Type	Mefenoxam Sensitivity
1991 and before	All	Potato	US-1	A1	
1993 [a]	Immokalee, Tampa, Hastings	Tomato/Potato	US-1, US-6, US-7	A1 A2	* Resistant
1994, 1995 [b]	Immokalee, Tampa, Hastings	Tomato/Potato	US-7, US-8	A2	Resistant
1996 [b]	Immokalee	Tomato	US-17		
2004, 2005	Immokalee	Tomato	US-20	A2	Intermediate
2006, 2007	Immokalee	Tomato	US-21	A2	Intermediate
2008, 2009, 2010 [de]	All	Tomato/Potato	US-22	A2	Sensitive
2011	Homestead, Immokalee	Tomato/Potato	US-23, US-24	A1	Sensitive
2012	Homestead, Immokalee, Tampa	Tomato/Potato	US-8, US-11, US-23, US-24	A1 A2	S I R
2013 [f]	All	Tomato/ Potato	US-23	A1	Sensitive

[a] Goodwin, S. B., Sujkowski, L. J., Dyer, A. T., Fry, B. A., and Fry, W. E. 1995. Direct detection of gene flow and probable sexual reproduction of *Phytophthora infestans* in northern North America. Phytopathology 85:473-479.
US-1 six states in 1992 then in FL in 1993. US-1 dominant genotype until 1989. US-1 in SWFL initiated by ND and ME seed.

[b] Goodwin, S. B., Smart, C. D., Sandrock, R. W., Deahl, K. L., Punja, Z. K., and Fry, W. E. 1998. Genetic change within populations of *Phytophthora infestans* in the United States and Canada during 1994 to 1996: Role of migration and recombination. Phytopathology 88:939-949.

[c] Schultz, D., Donahoo, R. S., Perez, F. G., Tejeda, S., Roberts, P. D., and Deahl, K. L. 2010. A survey of Tomato and Potato fields in Florida reveals unique genotypes of *Phytophthora infestans* between 2005 and 2007. Hort. Sci. 45:1064-1068.

[d] Hu, C. H., Perez, F. G., Donahoo, R. S., McLeod, A., Myers, K., Ivors, K., Secor, G., Roberts, P. D., Deahl, K. L., Fry, W. E., and Ristaino, J. B. 2012. Recent Genotypes of *Phytophthora infestans* in the Eastern United States Reveal Clonal Populations and Reappearance of Mefenoxam Sensitivity. Plant Dis. 96:1323-1330.

[e] Fry, W. E., McGrath, m. T., Seaman, A., Zitter, T. A., McLeod, A., Danies, G., Small, I., Myers, K., Everts, K., Gevens, A. J., Gugino, B. K., Johnson, S., Judelson, H. S., Ristaino, J., Roberts, P., Secor, G., Seebold, K., Snover-Clift, K., Wyenandt, A., Grunwald, N. J., and Smart, C. D. 2012. The 2009 Late Blight Pandemic in Eastern USA. APSnet Features August 2012:http://www.apsnet.org/publications/apsnetfeatures/Pages/default.aspx.

[f] http://www.usablight.org/

mefenoxam. Current populations are documented as sensitive (Table 2) which would allow for fungicides containing this active ingredient to remain effective. However, at the beginning of the epidemic, the genotype is unknown and must be determined. As of the previous season (beginning fall 2013), we are able to send samples for prompt genotyping (several days) and use this information to make decisions regarding usage of mefenoxam.

Table 2. Summary of some key characteristics of recent US genotypes of *Phytophthora infestans* on tomato and potato*.

Genotype	Host	Mating type	Sensitivity to mefenoxam
US-8	Potato	A2	Intermediate to Resistant
US-11	Potato/ Tomato	A1	Resistant
US-20	Tomato	A2	Intermediate to Resistant
US-21	Tomato	A2	Sensitive to Intermediate
US-22	Potato/ Tomato	A2	Sensitive to Intermediate
US-23	Potato/ Tomato	A1	Sensitive to Intermediate
US-24	Potato	A1	Intermediate

* Reference Table 1 for sources and usablight.org

Examples of effective fungicide programs are presented in Table 3. A broad spectrum, contact fungicide is suitable for preventative sprays. When late blight is present and additional control is needed, fungicides specifically targeting oomycetes may be added to the program. Additionally, when weather conditions are conducive and control efforts appear less than satisfactory, the interval between fungicide applications may need to be shortened.

Fungicide trials evaluating timing, rotation and different products are conducted each spring at SWFREC, Immokalee. Results from the spring 2013 trial are shown in Table 3. Previous reports with additional fungicide efficacy are available at http://swfrec.ifas.ufl.edu/programs/plant-path/publications.php. There are several, highly effective fungicides to choose from for management of late blight that can be used in rotation or combination to manage late blight in tomato.

LINKS OF INTEREST:

USA Blight- US Occurrence Map, Additional Photos and Information
http://www.usablight.org/

Disease Control for Florida Tomatoes
http://edis.ifas.ufl.edu/vh056

Chemical Control Guide for Diseases of Vegetables
http://edis.ifas.ufl.edu/pg100

REFERENCES

Goodwin, S. B., Cohen, B. A., and Fry, W. E. 1994. Panglobal distribution of a single clonal lineage of the Irish potato famine fungus. Proc. Natl. Acad. Sci. 91:11591-11595.

Goodwin, S. B., Sujkowski, L. J., Dyer, A. T., Fry, B. A., and Fry, W. E. 1995. Direct detection of gene flow and probable sexual reproduction of *Phytophthora infestans* in northern North America. Phytopathology 85:473-479.

Hu, C. H., Perez, F. G., Donahoo, R. S., McLeod, A., Myers, K., Ivors, K., Secor, G., Roberts, P. D., Deahl, K. L., Fry, W. E., and Ristaino, J. B. 2012. Recent Genotypes of *Phytophthora infestans* in the Eastern United States Reveal Clonal Populations and Reappearance of Mefenoxam Sensitivity. Plant Dis. 96:1323-1330.

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

Table 3. Selected fungicide treatments for the management of late blight caused by *Phytophthora infestans* US-23 genotype, Spring 2014.

	Treatments, Rate, and Application Code[a]			Disease Severity (Percentage Leaf Area Affected)					AUDPC[b]
				Apr-4-2014	Apr-8-2014	Apr-11-2014	Apr-14-2014	Apr-21-2014	
1	Untreated Control			4.3 ab	17.0 ab	17.8 ab	41.9 ab	85.0 a	628.1 ab
2	Bravo WeatherStik	1.5 pt/a	ABC	0.3 b	0.5 c	0.9 d	1.5 de	6.9 de	36.4 d
	Tanos	8 oz/a	DFHJ						
	Presidio	4 oz/a	EGIK						
3	Prophytex EC	32 oz/a	D-K	0.5 b	4.5 c	6.0 cd	15.9 cd	60.0 b	324.1 c
	Bravo WeatherStik	1.5 pt/a	ABC						
4	Prophytex EC	40.5 oz/a	DFHJ	0.8 b	2.5 c	3.8 d	31.3 b	86.3 a	479.6 bc
	Bravo WeatherStik	1.5 pt/a	ABC						
5	Zampro	14 oz/a	EGIK	0.0 b	0.3 c	0.6 d	0.9 de	0.8 de	9.8 d
	Ranman	2.75 oz/a	DFHJ						
	Bravo WeatherStik	1.5 pt/a	ABC						
6	K-phite	1 qt/a	D-K	0.0 b	0.8 c	1.4 d	2.9 de	5.5 de	40.4 d
	DKP extract	1 gal/a	D-K						
	Bravo WeatherStik	1.5 pt/a	ABC						
7	Revus Top	7 fl oz/a	DFHJ	0.0 b	0.3 c	0.5 d	1.6 de	1.4 de	15.3 d
	Induce	0.125 % v/v	DFHJ						
	Bravo WeatherStik	1.5 pt/a	ABCEGIK						
8	Bravo WeatherStik	1.5 pt/a	ABCDEHIJK	0.5 b	3.3v	3.1 d	8.1 de	11.8 d	103.5 d
	Ridomil	1 pt/a	FG						
LSD (P=.05)				6.15	11.00	11.34	15.30	11.10	164.88
Standard Deviation				4.35	7.77	8.02	10.82	7.85	116.59
Treatment Prob(F)				0.0465	0.0014	0.0002	0.0001	0.0001	0.0001

[a] Codes for application dates were: A= 25 Feb; B= 4 Mar; C= 11 Mar; D= 14 Mar; E= 18 Mar; F= 25 Mar; G= 31 Mar; H=1 Apr; I=8 Apr; J=15 Apr; K=21 Apr.

[b] Area under the disease progress curve

[c] Means followed by same letter do not significantly differ (P=.05, LSD)

Late Blight-Resistant Tomato Varieties Evaluation

Monica Ozores-Hampton and Pamela Roberts.

University of Florida/IFAS, SWFREC, Immokalee, FL, ozores@ufl.edu

INTRODUCTION

Tomato is one of the most economically important vegetable crops in Florida with a production value of US$ 455 million in the 2013 season [U.S. Department of Agriculture (USDA), 2014]. In 2013, Florida ranked first nationally in fresh-market tomato production with 34,000 acres harvested and an average fruit yield of 26,500 lb/acre (USDA, 2014).

In Florida, late blight (LB) caused by *Phytophthora infestans* (*P. infestans*) can be of great importance, since it is an aggressive pathogen responsible for entire crop losses in the *Solanaceae* family, including the tomato, potato, eggplant and nightshades. Literally meaning, "plant destroyer", *P. infestans* is a serious threat to crops in today's agriculture (Kroon et al., 2012). *Phytophthora infestans* causes large-scale and widespread damages primarily to Florida's winter tomato production because of the ideal climatic conditions for the pathogen development. Low temperatures and high relative humidity are conducive for reproduction and spread of *P. infestans* (Schumann and D'Arcy, 2000). Once plants are infected, a complete crop loss will be projected. In tomato and potato similar plant symptoms can be described. *Phytophthora infestans* affects the petioles by causing the leaves, stems, and the developing fruit to wilt and rot, leading to the inability to photosynthesize, production of secondary inoculum, and then death of the plant (Berg, 1926). Loss of the entire crop can occur in less than five days (Birch and Whisson, 2001).

Commercially available pesticides and biological controls have proven effectiveness in delaying the onset of LB. Curative fungicides exist to treat plants infected with *P. infestans*, however, the rapid spread of the pathogen and the inability to apply a curative agent prior to total economic loss can be difficult (Apel et al., 2003). Biological controls, or antagonistic microorganisms, compete with disease-causing pathogens for resources, space, and by predation on the pathogen (Koné et al., 2010). Bacterial antagonists, as opposed to fugal, are the most successful in the control of *P. infestans* (Tran et al., 2007). Different ratio combinations of the rhizobacterial antagonists, *Bacillus cercus*, *Cellulomonas flavigena, Candida sp.,* and *Cryptococcus sp.,* display significant decreased disease severity on tomatoes (Júnior et al., 2006). Integrated pest management (IPM) recommends the use of pesticides, cultural controls, and LB forecasting to aid in the prevention of the infestation. Cultural controls include scouting fields regularly for infected plants, using disease free transplants, and removing volunteer plants (Roberts, 2006). Although conventional and biological controls reduce losses due to LB, the development of disease-resistant tomato varieties offers the most effective solution.

Currently, tomato cultivars resistant to *P. infestans* are available in the market; however, evaluation of resistance levels of these varieties has not been performed under Florida environmental conditions. Understanding the resistance level and horticultural characteristics of LB-resistant tomato varieties will help growers to choose a variety that can minimize losses of marketable yield and fruit quality. Therefore, the objective of this study was to evaluate *P. infestans* resistant tomato varieties on disease resistance, yield, and fruit quality in southwest Florida.

Table 1. Tomato varieties, late blight-resistance, seed sources, and plant growth habit.

Variety	Resistance	Company	Growth habit
		Round	
Defiant PhR	Heterozygous; *Ph2* and *Ph3*[z]	Johnny's Selected Seeds	Determinate
Mountain Merit	Heterozygous; *Ph2* and *Ph3*	Bejo Seeds	Determinate
Iron Lady	Homozygous; *Ph2* and *Ph3*	High Mowing Organic Seeds	Determinate
FL 47	Susceptible	Seminis	Determinate
		Roma	
Plum Regal	Homozygous; *Ph3*	Bejo Seeds	Determinate
		Mini-Roma	
Juliet	Susceptible	Johnny's Selected Seeds	Indeterminate
		Campary	
Mountain Magic	Heterozygous; *Ph2* and *Ph3*	Bejo Seeds	Indeterminate
		Cherry	
Jasper	Undetermined resistance; likely *Ph2 and/or Ph3*	Johnny's Selected Seeds	Indeterminate

[z] Late blight resistance genes.

Source: http://extension.psu.edu/plants/vegetable-fruit/news/2013/late-blight-effectively-managed-with-resistant-tomatoes-on-long-island-in-2012

MATERIALS AND METHODS

The study was conducted at the Southwest Florida Research and Education Center (UF/IFAS/SWFREC) in Immokalee, FL during spring 2014. Beds were 8 inches high, 36 inches wide, and covered with black, virtually impermeable polyethylene mulch (1.1 mm). On Dec. 16 2013, beds were formed, fertilized, and fumigated with 160 lb/acre methyl bromide and chloropicrin (50:50). The beds were fertilized with a bottom and a top mix totaling 220 lb/acre nitrogen, 102 lb/acre phosphorus, and 238 lb/acre potassium. Guidelines established by the University of Florida/IFAS were followed for land preparation, fertility, irrigation, weed management, and insect control. Seven LB resistant and two LB susceptible tomato varieties were planted in a single row on beds placed 6-feet center to center with 18 inches in-row spacing for a plant population of 4,840 plants/acre (Table 1). The plots were 24-ft long, composed of 10 plants, and arranged in a randomized complete block design with four replications. Tomato varieties were transplanted on 2 Jan. 2014, as 6-week old transplants, grown in 200-cell foam trays, produced by Redi Plants Corp (Naples, FL). The crop was irrigated by a hybrid system of drip and seepage irrigation. Pesticide applications were performed as needed according to regular scouting reports and UF/IFAS recommendations.

Data collection

Symptoms of LB were first identified on plants in the field on 18 Feb. An estimate of disease severity as a percentage (0-100%) of foliage exhibiting symptoms was taken at four-day intervals until disease severity was higher than 80% on susceptible plants. Tomato fruit were manually harvested at maturity stages two to six (breaker to red) (Table 2). Round tomato fruit were graded into marketable yield size categories according to the USDA specifications for extra-large (5x6), large (6x6), medium (6x7), and small fruit (7x7) (USDA, 1997). Roma-type tomatoes were graded into extra-large, large, medium, and small fruit (USDA, 1997). Campari tomato fruit were graded into large, medium, and small size categories. Cherry and mini-roma tomatoes were graded into marketable and unmarketable. Unmarketable fruit weight was recorded according to the presence of off-shape, scratch, and blossom end scar for all tomato types (Ozores-Hampton et al., 2013). For each plot a sub-sample of four tomato fruit were collected, transported to the UF/SWFREC Vegetable Horticulture Laboratory, and held at room temperature until table ripe stages (five to six -light red and red) for postharvest evaluations. Fruit external color was determined using a one to six scale where 1= green and 6= red (USDA, 1997). Brix and pH were measured using the fruit juice of the four fruit sampled with a portable refractometer (Model Eclipse 45-02; Bellingham and Stanley Inc., Suwanee, GA) and a pH meter (Model 420A; Orion research Inc., Boston, MA), respectively. Late blight data was entered into ARM 9.0 and analyzed by analysis of variance (ANOVA) with LSD means separation. Marketable and unmarketable fruit yield, external fruit color, brix, and pH data were analyzed by (ANOVA) and means were separated by Duncan's multiple range test at 95% confidence level using SAS (SAS 9.3 SAS Institute Inc., Cary, NC, 2011).

RESULTS

Weather conditions

Weather conditions were recorded by the Florida Automated Weather Network (FAWN) for Immokalee, FL. Average, minimum, and maximum air temperatures were 69.0, 49.3 and 89.8°F from 3 Jan. 2014 to 8 May 2014 (Table 3). Total rainfall accumulation was 9.5 inches. Three minimal freeze events occurred on 17 Jan. (31.4°F), 19 Jan. (28.5°F), and on 23 Jan. 2014 (30.2°F); however, freeze damage was not observed in the study. Weather conditions were average for southwest Florida during the spring season based on 10 years of data recorded by FAWN.

Late blight tomato disease severity

Disease severity over time of late blight on the tomato varieties evaluated is presented in Table 4. Highly susceptible varieties with no known resistance genes, 'FL 47' and 'Juliet', had most of the foliage (95 and 87%, respectively) with LB symptoms. Moderately susceptible 'Plum Regal' was significantly higher than varieties containing both resistance genes but still was greatly reduced in disease severity compared to the susceptible varieties. Tomato varieties containing both Ph2 and Ph3, 'Defiant', 'Mountain Merit', 'Iron Lady', 'Mountain Magic', and 'Jasper' had less than 10% of symptomatic foliage. 'Iron Lady' was virtually disease free although some small lesions could be detected and *P. infestans* microscopically identified.

Fruit yields

For round tomatoes, the total marketable yields ranged from 1,102 to1,369 boxes/acre (Table 5). 'Mountain Merit' had higher extra-large fruit yield than the other varieties evaluated. The highest large fruit yields were 'Mountain Merit' and 'Iron Lady', medium fruit yield was 'Iron Lady' and small fruit yields were 'Defiant PhR' and 'Iron Lady'. 'FL 47' had the highest LB severity, thus plants were not able to produce tomatoes (Table 4). Total season marketable and unmarketable yields (all sizes combined) were not different among LB-resistant varieties and higher than 'FL 47'. The roma-type tomato 'Plum Regal' produced 1,492 boxes/acre total season marketable yield of which 40% was in the large fruit category. The cherry tomato 'Jasper' produced a total season marketable yield of 134.4 tons/acre with an average fruit size of 5.8 g (Table 6). However, mini-roma LB-susceptible 'Juliet' produced only 2.7 tons/acre total season marketable yield with an average fruit size of 22.7 g. Campari tomato 'Mountain Magic', total season marketable yields was 12.7 tons/acre of which 54% was medium fruit size (Table 7).

Postharvest evaluation

Among the round tomato varieties, 'Defiant PhR' and 'Mountain Merit' had higher TSS and pH than 'Iron Lady' (Table 8). External fruit color was higher for 'Defiant PhR than for 'Iron Lady'.

CONCLUSION

Tomato varieties containing both *Ph2* and *Ph3* had less than 10% LB symptomatic foliage and produced higher marketable yields than susceptible varieties. Results of this trial indicate that several of these varieties might be suitable for homeowner and potentially organic growers to avoid losses due to LB in Florida. Further studies will be performed to repeat these results.

LITERATURE CITED

Apel, H., S. Paudyal, O. Richter. 2003. Evaluation of treatment strategies of the late blight *Phytophthora infestans* in Nepal by population dynamics modelling. Environ. Modelling & Software. 18:355-364.

Berg, A. 1926. Tomato late blight and its relation to late blight of potato. p 5. West Virginia Univ. Agr. Expt Sta.

Birch, P. and S. Whisson. 2001. *Phytophthora infestans* enters the genomics era. Mol. Plant Pathol. 2:257-263.

Júnior, V., L. Maffia, R. Romeiro, E. Mizubuti. Biocontrol of tomato late blight with the combination of epiphytic antagonists and rhizobacteria. 2006. Biol. Control. 38:331-340.

Koné, S, A. Dionne, R. Tweddell, H. Antoun, and T. Avis. 2010. Suppressive effect of non-aerated compost teas on foliar fungal pathogens of tomato. Biol. Control. 52:167-173.

Kroon, L., H. Brouwer, A. de Cock, and F. Govers. 2012. The genus phytophthora anno 2012. Phytopathol. 102:348-364.

Ozores-Hampton, M., P.A. Stansly, and E. McAvoy. 2013. Evaluation of round and Roma tomato varieties and advanced breeding lines resistant to Tomato Yellow Leaf Curl Virus (TYLCV) in Florida. HortTechnology 23:689-698.

Roberts, P. 2006. Disease management: Late blight, p. 107-108. In: J.L. Gillet, H.N. HansPetersen, N.C. Leppla, D.D. Thomas (eds.). Grower's IPM guide for Florida tomato and pepper production. Univ. Florida, Gainesville, FL.

Schumann, G. and C. D'Arcy. 2000. Late blight of potato and tomato. The Plant Health Instructor. DOI: 10.1094/PHI-I-2000-0724-01.

Tran, H., A. Ficke, T. Asiimwe, M. Höfte, and J.M. Raaijmakers. 2007. Role of the cyclic lipopeptide massetolide A in biological control of *Phytophthora infestans* and in colonization of tomato plants by *Pseudomonas fluorescens*. New Phytologist 175:731- 42.

U.S. Department of Agriculture. 1997. United States standards for grades of fresh tomatoes. U.S. Dept. Agr., Agr. Mktg. Serv., Washington DC. 10 June 2014. http://www.ams.usda.gov/getfile?dDocName=STELPRDC5050331

U.S. Department of Agriculture. 2014. Vegetables 2013 summary. U.S. Dept. Agr., Agr. Mktg. Serv., Washington DC. 24 June 2014. http://usda.mannlib.cornell.edu/usda/current/VegeSumm/VegeSumm-03-27-2014.pdf

Table 2. Harvest dates for late blight-resistant and susceptible tomato varieties grown in Immokalee, FL. during spring 2014.

Harvest dates by variety						
25 Mar.	**2 Apr.**	**10 Apr.**	**16 Apr.**	**24 Apr.**	**30 Apr.**	**8 May**
Jasper	Jasper	Jasper	Jasper	Jasper	Jasper	Jasper
	Juliet	Defiant PhR	Juliet	Juliet	Juliet	Juliet
		Iron Lady	Defiant PhR	Defiant PhR	Defiant PhR	Iron Lady
		Mountain Merit	Iron Lady	Iron Lady	Iron Lady	Mountain Merit
		Mountain Magic	Mountain Merit	Mountain Merit	Mountain Merit	Plum Regal
			Plum Regal	Plum Regal	Plum Regal	Mountain Magic
			Mountain Magic	Mountain Magic	Mountain Magic	

Table 3. Summary of mean, minimum (Min.), and maximum (Max.) temperature and total rainfall in Immokalee, FL. during spring 2014 [z].

	Temperature (°F)			Total rainfall
Period	**Average**	**Min.**	**Max.**	**(inches)**
January	60.7	49.3	73.9	3.2
February	68.5	56.0	84.0	1.1
March	67.8	54.1	82.3	2.3
April	72.7	59.5	88.0	2.9
May	75.5	61.9	89.8	0.1
Average/Total	69.0	56.1	83.6	9.5

[z] Weather data obtained from Florida Automated Weather Network (FAWN) from University of Florida/ Institute of Food and Agricultural Science (IFAS), Southwest Florida Research and Education Center in Immokalee, FL.

Table 4. Disease severity of late blight on tomato in in Immokalee, FL. during spring 2014.

Variety	Disease Severity (%)			
	27 Feb.	3 Mar.	7 Mar.	11 Mar.
Defiant PhR	0.0c	0.0d	1.3e	1.4e
Mountain Merit	0.5c	0.3d	2.5e	4.5de
Iron Lady	0.0c	0.0d	0.3e	0.5e
Plum Regal	7.1c	10.3c	21.3c	13.1c
Mountain Magic	0.0c	0.0d	1.5e	2.4e
Jasper	0.5c	2.3d	12.3d	7.9d
Juliet	36.3b	76.3b	81.3b	86.9b
FL 47	48.1a	82.5a	89.4a	95.0a
LSD (P=0.05)	11.57	3.63	7.14	5.22
P-value	0.0001	0.0001	0.0001	0.0001

[z] Means followed by same letter do not significantly differ (P=.05, LSD). Mean comparisons performed only when AOV variety P (F) is significant at mean comparison OSL.

Table 5. Total season harvest marketable and unmarketable yield categories for round and roma-type for late blight-resistant varieties grown in Immokalee, FL. during spring 2014.

Variety	X-large	Large	Medium	Small	Unmarket-able	Total marketable
	Round[z] (25 lb-box/acre)					
Defiant PhR	145b[y]	155b	240b	563a	370a	1,102a
Iron Lady	168b	280a	381a	541a	484a	1,369a
Mountain Merit	491a	361a	253b	198b	485a	1,303a
FL 47	0b	0c	0c	0c	0b	0b
P-value	0.001	0.0001	0.0001	0.0001	0.002	0.0001
Significance	***	***	***	***	**	***
	Roma[x] (25 lb-box/acre)					
Plum Regal	259	605	313	315	209	1,492

[z] Round Tomato size range: X-large = (5x6 industry grade); Large = (6x6); Medium = (6x7)

[y] Within columns, means followed by different letters are significantly different according to Duncan's multiple range test at 5%.

, * Significant at $P \leq 0.01$ or 0.001, respectively.

[x] Roma-type tomato size range (g): X-large = ≥ 139.1; large = ≥ 113.4; medium = ≥ 81.6, small = ≥ 59.0.

Table 6. Total harvest marketable and unmarketable yield categories for cherry and mini-roma late blight-resistant tomato varieties grown in Immokalee, FL. during spring 2014.

Variety	Marketable (tons/acre)	Unmarketable (tons/acre)	Size (g/fruit)
Jasper	134.4	2.9	5.8
Juliet	2.7	1.1	22.7

Table 7. Total harvest marketable and unmarketable yield categories for the campari late blight-resistant tomato variety grown in Immokalee, FL. during spring 2014.

Variety	Yield (tons/acre)					Size (g/fruit)		
	Large	Me-dium	Small	Unmarket-able	Total market-able	Large	Medium	Small
Mountain Magic	0.7	6.8	5.2	0.5	12.7	61.1	45.5	31.1

Table 8. Postharvest evaluation of total soluble solids (TSS), pH, and fruit external color for late blight-resistant tomato varieties grown in Immokalee, FL during spring 2014.

Variety	TSS (^{0}Brix)	pH (0-14)[z]	Color (Rating 1-6)[y]
	Round		
Defiant PhR	4.10a[x]	4.65a	5.63a
Iron Lady	3.13b	4.36b	5.13b
Mountain Merit	4.23a	4.79a	5.48ab
P-value	0.0001	0.001	0.01
Significance	***	***	**
	Roma		
Plum Regal	3.25	4.74	5.69
	Mini-roma		
Juliet	**6.18**	**4.68**	**5.88**
	Campari		
Mountain Magic	6.23	4.76	5.81
	Cherry		
Jasper	7.28	4.45	5.81

[z] 0 = very acidic and 14 = very alkaline

[y] 1 = green and 6 = red (USDA, 1997)

[x] Within columns, means followed by different letters are significantly different according to Duncan's multiple range test at 5%.

, * Significant at $P \leq 0.01$ or 0.001, respectively.

Marketing Strategies to Promote Florida Tomatoes

Xiang Cao[1], Lisa House[1], Zhifeng Gao[1], and Zhengfei Guan[2]

[1] University of Florida/Food and Resource Economics Department, Gainesville, FL.

[2] University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, guanz@ufl.edu

INTRODUCTION

Fresh tomatoes are a major vegetable crop on the market, with a total crop value of $1.4 billion in the U.S. in 2010. Florida is the largest supplier of fresh tomatoes, accounting for nearly half of the total crop value. However, the industry is facing serious challenges. The number one factor is competition from Mexico. The USDA-NASS (National Agricultural Statistical Service) data shows that U.S. tomato production decreased from 3.9 billion pounds in 2000 to 2.8 billion pounds in 2012, while the Florida production fell from 1.6 to 0.96 billion pounds. During this period, both planted and harvested acreage fell significantly. In stark contrast to the shrinking domestic industry, the amount of tomatoes imported from Mexico (world) jumped from 1.3 (1.6) billion pounds to 3 (3.4) billion pounds, as shown by data from the U.S. Department of Commerce. Mexican imports now account for about 90% of the imported tomatoes and have had a major impact on the U.S. tomato industry, particularly the Florida tomato industry. Mexican tomatoes on the market were about 20% less than Florida's supply volume in 2000, but their market share is now more than 3 times higher than Florida's (Zhu, Guan, and Wu, 2013). With increased competition from Mexico, the farm gate value of Florida tomato industry slumped from $620 million in 2010 to $268 million in 2012 and the national value dropped from $1.4 billion to $0.86 billion.

The evolving market condition and trade relationship between the U.S. and Mexico is posing tremendous challenges to the Florida tomato industry. Against such a background, this paper seeks to provide the struggling industry with marketing information to understand consumer demand for local (Florida/US) tomatoes, as consumer choice is of vital importance to the domestic industry. We will study the effect of three marketing strategies on consumer choice of the Florida/USA tomatoes versus Mexican tomatoes and identify optimal strategies to promote local products.

METHODOLOGY

To determine the impact of different types of information on production origin, a consumer survey was designed and conducted using the mall intercept format. In this way, how participants' respond to country of origin information in a setting that is similar to a grocery store can be observed cost-effectively.

The working hypothesis is that consumers are willing to pay a premium for tomatoes from Florida/US compared to tomatoes from Mexico. It is further hypothesized that consumers will respond differently to the origin information in each labeling scenario, with the least noticing origin in the case of plain labels (current situation) with country of origin, followed by plain labels with Florida identification, followed by the case with point-of-purchase signage.

To test the hypothesis, a mall intercept questionnaire is conducted to survey consumer's fruit and vegetable consumption, their purchasing habits for fresh produce, their awareness of country of origin information, and the impact of different ways of country of origin labeling (COOL) on consumer choice of fresh tomatoes. Participants are first screened to meet the following criteria: adult (older than 18 years), primary grocery shoppers who purchased fresh tomatoes at least once per month in past few months. After answering baseline questions on frequency and location of grocery shopping, participants are presented with two wooden baskets of tomatoes in a setting similar to what would be found in a real produce section. The two baskets are on a table immediately next to each other (as they would be in display in the store). The tomatoes in the two baskets are exactly the same tomatoes except for the different label information that indicates production origins. Random 3-digit numbers are assigned to each label scenario to enable consumers to respond to questions about the tomatoes without calling specific attention to the labels. The origin information is labeled and presented in three different formats: 1) USA and Mexico small stickers on tomatoes (tomato #599 vs. tomato#280); 2) Florida and Mexico small stickers on tomatoes (tomato #462 vs. tomato #280); and 3) "Grown in Florida" sign on top of the basket (similar to point-of-purchase information in a store) plus U.S. small stickers and Mexico small stickers on tomatoes (tomato #828 vs. tomato #280). Tomato #599, tomato #462 and tomato #828 all refer to Florida tomatoes but with different COOL strategies, namely Florida/US tomatoes.

Participants were randomly assigned to one of three treatment groups and asked to indicate which, if any, of the two baskets of tomatoes they are most likely to purchase as well as how much they are willing to pay for both kinds of tomatoes. Using this information, differences in average willingness to pay based on COOL scenarios can be estimated.

After participants indicate which labeled tomatoes they prefer to purchase and how much they are willing to pay, they are asked to identify the reasons why they selected a tomato (if they preferred one). This is first asked in an unaided format. After answering these questions, participants are asked whether they noticed the different origins of the tomatoes, what kind of information on the label of produce they care about and their general consumption preference toward tomatoes from different production origins.

Demographics questions are answered by participants in the end of the survey. After the participants complete the survey, the staff members who observe the participants completing the survey will answer several questions about whether and how the participant touched the tomatoes.

As both Florida/US and Mexican tomatoes are being used for this experiment, it is important to collect data in multiple locations (Florida, Texas and Maryland). It is expected that willingness to pay for Florida/US tomatoes compared to Mexican tomatoes will be highest in Florida. Texas is selected because it is very close to Mexico and participants are likely to see Mexican tomatoes more frequently and be familiar with them. Maryland is selected as a region that does not have a reason to have a focus on either Florida or Mexico, and thus serves as a type of control in this study.

The open-ended contingent valuation method (CVM) is used in this survey to estimate consumers' willingness to pay for fresh tomatoes. One problem of open-ended CVM is that the consumers might encounter difficulty stating their own price. Munro and Sugden (2003) indicated that consumer preferences were dependent on reference; and consumers referred to a reference price point in order to shape their own valuation of a product (Monroe, 1977). Chernev (2003) found that the articulation of reference price before the choice can simplify consumer preference through imposing a structure consistent with the nature of the decision task. Therefore, in this survey, the reference price range of fresh tomato is provided for the consumers, setting from $0.99/lb to $3.99/lb, based on data from Agricultural Marketing Service of the U.S. Department of Agriculture.

RESULTS

Demographics of Participants. After screening the respondents who are qualified as adult (18+ years old), primary grocery shoppers who purchase fresh tomatoes at least once per month in past few months, 632 respondents completed the survey, including 209, 210 and 213 samples in Baltimore, Dallas and Tampa, respectively. Females and males account for 55.5% and 44.5% of the total respondents. Most participants in the sample are less than 40 years old, with an average age of about 36 years old. As for ethnicity, Caucasians account for 51.7%, followed by Black or African American (34.2%), Hispanic (16.0%) and other races (6.1%). People with some college degree or four-year college degree are the largest proportion of the respondents, reaching 53.0%, followed by people with high school degree or equivalent (33.1%). The largest group of participants had a full-time job (46.9%) while the second largest worked part-time (18.7%). There are 50.8% of the participants with 2-3 people in their household, 31.0% of them have 4-6 and 14.9% live alone. About 45.9% of the participants have at least one child in the family; most (24.1%) had two or more children, while few (21.8%) have only one. Those participants who refused to indicate their annual household income accounted for about 14.9% of total participants, while the average estimated household income is in the range of $50,000-$74,999. The results also show that 27.9% of the respondents usually spend $100-$149 per week on food at the grocery store, 21.4% spend $50-$99 and 19.6% spend $150-$199; the average costs on food at the grocery store fall in the range of $150-$199 per week.

Consumers' Purchasing Habits of Fresh Tomatoes. In the survey, consumers were required to answer basic questions about their purchasing habits and attitudes towards fresh tomatoes. The survey results show that 45.4% of the total respondents indicate that they bought fresh tomatoes once per week in the past few months. Approximately 20.9% and 18.0% indicated they purchased fresh tomatoes 2-3 times per month and more than once per week, respectively. As for the location where they usually purchase fresh tomatoes, 64.7% of the respondents buy from supermarkets, 51.5% from local grocery stores and 24.5% from farmer's markets. Another 13.1% indicate they purchase fresh tomatoes from a warehouse or roadside stand. Respondents identified regular tomatoes and tomatoes on the vine as the most frequently purchased types of tomatoes, accounting for 42.3% and 18.7%, respectively. Other tomato choices included heirloom, grape, Roma and cherry.

When asked to identify what factors are most important when purchasing tomatoes, respondents indicated freshness, firmness and color as the top three factors. Price, tomato size and shape were relatively less important and variety, country of origin, on the vine or not and availability of samples were the least important factors.

Consumers' Attitudes and Preference of Different Labeled Fresh Tomatoes. After being given the opportunity to look at and touch the tomatoes in the experiment, respondents were asked about their choice and attitude toward different labeled tomatoes. As shown in table 2, in scenario one, 56.8% of the respondents chose the tomato with the U.S. sticker, 24.2% chose the tomato with the Mexico sticker, and 19.0% indicated no preference; in scenario two, 57.6% of the respondents chose the tomato with the Florida sticker, 30.5% chose the tomato with the Mexico sticker, and 11.9% indicated no preference between the two kinds of tomatoes; in scenario three, 59.7% of the respondents chose tomato with "Grown in Florida" sign on top of the basket, 29.4% chose the tomato with the Mexico sticker, and 10.9% indicated no preference.

In total, 44.3% of the respondents indicated they did notice the stickers or sign which contain COOL information of the tomatoes and 55.7% did not.Specifically, 35.6%, 42.9%, and 54.5% of respondents in scenarios one, two and three, respectively, noticed the stickers or sign.

Participants were asked about what kinds of information they typically look for when they purchase fresh produce. Nearly one-third indicate they generally don't look at labels on fresh produce. For consumers who usually look at the labels, they focus on organic information (48.4%), brand (46.5%), country of origin (43.7%) and nutrition information (33.4%).

Finally, participants were asked directly if they prefer tomatoes grown in the U.S. to those grown in Mexico when they do regular daily shopping. In this case, 48.0% indicated they prefer tomatoes produced in the U.S. Similarly, 49.2% prefer tomatoes produced in Florida compared to tomatoes from Mexico. When asked about preferences between tomatoes grown in Florida or the U.S, more than half (56.8%) had no preference. This did differ by location, with 64.8% of respondents in Tampa preferring tomatoes produced in Florida over tomatoes produced in Mexico. This compares to respondents in Baltimore (48.3%) and Dallas (34.3%). This also occurred with tomatoes produced in Florida compared to the U.S., with 43.7% of respondents in Tampa preferring Florida-grown tomatoes compared to 23.9% in Baltimore and 17.1% in Dallas.

Consumers' WTP for Florida/US Tomatoes and Mexico Tomatoes. Immediately following looking at the tomatoes and indicating which they preferred (if either), participants were asked to indicate what they would be willing to pay for each tomato they saw. As shown in table 2, in scenario 1, participants were willing to pay an average of $1.87/lb for the tomato with the U.S. sticker and $1.55/lb for the tomato with the Mexico sticker; in scenario 2, participants were willing to pay an average of $1.81/lb for the tomato with the Florida sticker and $1.63/lb for the tomato with the Mexico sticker and in scenario 3, participants were willing to pay an average of $1.68/lb for the tomato with "Grown in Florida" sign plus the U.S. sticker and $1.50/lb for the tomato with the Mexico label. It is surprising that the third scenario produced the lowest WTP for Florida tomatoes. Further examination of data showed that this is mainly due to the low WTP values from Tampa consumers. This is likely because Tampa/Florida consumers may believe Florida grown tomatoes should have lower costs (e.g., transportation costs) and therefore lower prices. This in turn may have affected their WTP values for Mexico tomatoes due to the reference effect.

Table 1. Consumers' stated choice of different labeled tomatoes, sorted by scenario and by city.

	By scenario			By city		
	Scenario 1	Scenario 2	Scenario 3	Baltimore	Dallas	Tampa
Florida/US tomatoes	56.9%	57.6%	59.7%	59.8%	58.4%	55.9%
No preference	19.0%	11.9%	10.9%	14.4%	8.6%	18.8%
Mexico tomatoes	24.2%	30.5%	29.4%	25.8%	32.9%	25.4%
Sample Size	211	210	211	209	210	213

Table 2. Consumer willingness to pay for Florida/US and Mexico tomatoes, sorted by scenario and by city (Unit: $/lb).

	Scenario 1		Scenario 2		Scenario 3	
	Tomato with the U.S. sticker	Tomato with the Mexico sticker	Tomato with the Florida sticker	Tomato with the Mexico sticker	Tomato with the Florida sign plus U.S. sticker	Tomato with the Mexico sticker
All city	1.88	1.55	1.81	1.63	1.68	1.50
Baltimore	2.05	1.68	1.81	1.56	1.77	1.47
Dallas	1.66	1.42	1.66	1.47	1.75	1.69
Tampa	1.96	1.56	1.94	1.85	1.50	1.33

CONCLUSIONS

In summary, the consumer survey results reflect that the majority (>55%) of the participants in all selected cities chose Florida/US tomatoes, which is roughly twice as much as those who preferred Mexico tomatoes. Those who indicated indifferences were less than 15%. Additionally, on average, consumers are willing to pay a premium for Florida/US tomatoes over Mexico tomatoes under all country of origin labeling scenarios. Further statistical analysis will be performed to determine the factors that affect consumer choices and their willingness to pay and explore the effects of different labeling strategies on their choice and WTP for fresh tomatoes.

REFERENCES

Chernev, A. (2003). "Reverse Pricing and Online Price Elicitation Strategies in Consumer Choice." Journal of Consumer Psychology 13(1&2): 51-62.

Monroe, K. B. (1977). Objective and subjective contextual influences on price perception. *Consumer and Industrial Buying Behavior*, 287-96.

Munro, A., & Sugden, R. (2003). On the theory of reference-dependent preferences. *Journal of Economic Behavior & Organization*, *50*(4), 407-428.

Zhu, M., Guan, Z., & Wu, F. (2013). An overview of the U.S. tomato industry. The Florida Tomato Proceedings 2013, 28-30. http://swfrec.ifas.ufl.edu/docs/pdf/veghort/tomato-institute/proceedings/ti13_proceedings.pdf

Redesign for Success: Florida Food Connect - an Online Tool that Helps Producers Engage with Local Customers

Laura Conaway, Anna Prizzia, Allen Wysocki, Danielle Treadwell, Tracy Irani, and Joy Rumble

University of Florida/IFAS, Gainesville, FL, aprizzia@ufl.edu

INTRODUCTION

Florida MarketMaker is a free, web-based marketing tool created to assist producers and consumers of specialty crops to establish relationships in local and regional markets, originally funded by the Florida Department of Agriculture and Consumer Services (FDACS), the University of Florida's Institute of Food and Agricultural Sciences (UF/IFAS) and other contributing organizations. MarketMaker is a product of the University of Illinois, now managed and licensed by Riverside Research, which utilizes federal data sets from USDA's Agricultural Marketing Service, Economic Research Service, U.S. Census data and other relevant national data sets to track and predict market opportunities for producers and buyers. The site also allows users to create profiles so they can share information about their businesses and connect with each other. From its inception more than four years ago, Florida MarketMaker had approximately 160 registered users with profiles, considerably less than anticipated.

In an effort to determine the effectiveness of the marketing tool, Florida MarketMaker, the UF/IFAS Center for Public Issues Education in Agriculture and Natural Resources (the PIE Center) received a Florida Specialty Crop Block Grant (SCBG) from FDACS to conduct a qualitative analysis of small farmers within the state and discover their opinions and perceptions of the tool.

Producers in the study revealed some of the barriers they faced when selling local products. Many were unaware that Florida MarketMaker was an online marketing tool aimed at getting local food from the farm to the fork. When shown MarketMaker, producers also identified user interface challenges to using the online tool.

Based on the results of this research, the University of Florida IFAS Extension teamed up the Florida Department of Agriculture and Consumer Services, a design consultant, and MarketMaker developers to re-vision and redesign the tool with more functionality to benefit producers and buyers. The new tool, Florida Food Connect - www.floridafoodconnect.com, offers an easy-to-use format to promote buying and selling of Florida food products.

OBJECTIVES

This research investigated the cause of the disconnect between Florida specialty crop producers and the use of Florida MarketMaker in an effort to gain a better understanding of what message strategies should be used to promote Florida MarketMaker. Additionally, research provided information about what aspects of the design might be inhibiting the usability of the resource. All research was conducted in an attempt to better position Florida-grown specialty crops as the choice for local consumer-based buyers.

Once the research was conducted, the results were used to inform the design process for the improved, user-friendly site – Florida Food Connect. The designers and the UF/IFAS team took each recommendation from the report and used this as the basis for developing a template, or wire-frame, for the new website.

Methods

The PIE Center used a qualitative, focus group design (Conaway, 2013) to analyze producers' beliefs, attitudes and perceptions regarding Florida MarketMaker. The objective of using focus group methodology was to assess the target audience's perceptions of current usability and brand salience of Florida MarketMaker and to test for new branding and usability strategies before redeveloping the marketing plan and website. Qualitative design provided the researchers with information and findings that have yet to be hypothesized and therefore could not have been predicted. Such findings allow the researcher to build off of the data for further detailed research about this area of interest.

The PIE Center conducted six focus groups to identify messages that could resonate with producers and consumers using Florida MarketMaker as a marketing tool to connect these two groups in local markets. Two focus groups, comprised small and medium-scale Florida producers, were conducted in Quincy, two groups in Kissimmee, and one in Sarasota.

Additionally, the research was designed to obtain a more thorough understanding of current marketing and sales strategies used by small producers. A final focus group took place in Orlando involving UF/IFAS extension agents with responsibilities for serving small farm clientele to determine their opinions of the effectiveness of Florida MarketMaker, to seek feedback on how their clients view the tool, and to summarize suggestions for website improvements.

To maintain a level of consistency and accountability, the PIE Center utilized an outside firm to recruit participants from the predetermined population. The Florida Survey Research Center (FSRC), a UF auxiliary, was responsible for participant recruitment and developing screening questions to ensure the target audience was accurately represented. Potential participants were also asked questions to determine whether or not they fit the definition of a Florida small-farm producer for the purpose of this study, as well as their level of awareness of the online marketing tool.

The data from these focus groups and the resulting report was then used to inform the design process for a new website. The flow and basic interface for the site was field-tested by a group of producers and buyers, and the design was developed to reflect user feedback. Additional field-tests followed the completion of the site.

Target Audience

The target audience for the research that informed the re-design was Florida small farmers growing and producing agricultural products for the purpose of sale. Names and contact information of small farmers in Florida were provided to the PIE Center to be included in participant lists. All selected participants had some connection with the agriculture industry. Examples of participants included and were not limited to growers and producers of fruit and vegetables, produce, beef, lamb and dairy, bees, herbs and other specialty crops. Some participants were members of Community Supported Agriculture groups (CSAs), while others produced and marketed on an individual basis. The size of each participant's operation varied, with some businesses operating on a more corporate level with employees and assistants while others had an operation for personal enjoyment and worked independently. The experience level of the participants ranged from farmers who produced as their primary source of income to hobby farmers and part-time farmers.

Instrumentation and Data Collection

Prior to conducting focus groups, the PIE Center developed a moderator's guide, which was reviewed by a panel of experts. The written moderator's guide remained constant throughout the five focus groups with specialty crop producers to allow for comparisons, differing only with the group of extension agents.

Present during each focus group was a moderator, assistant moderator/note taker and a second note taker. The purpose of note takers was to provide back up data. The use of note takers ensured the reliability of the data in the case that the electronic equipment malfunctioned. Additionally, the use of video and audio recorders during each focus group ensured the accuracy of data collected. Video and audio recorders allowed for a more thorough understanding of participants' feelings in order to better apply findings to the entire population. An outside transcription analyst was used to provide thorough, word-for-word transcripts for analysis. All research was conducted under approval of the UF Institutional Review Board to ensure the protection of human subjects.

Data Analysis

Qualitative data analysis was conducted on the transcripts, via the qualitative data analysis software, Weft-QDA. Transcripts were analyzed by the researcher going through each individual question across each focus group so one question was analyzed across the entire group of focus groups before the next question was examined. An audit trail to secure chronological records and provide documentary evidence of the sequence of events of research was implemented and maintained throughout the research process.

This data was used to inform the wire-framing and design phases of Florida Food Connect. Additional user testing provided feedback that was analyzed and used to make minor modifications to the site in order to improve the user experience.

Results

After conducting six focus groups, five of which targeted small farm operators in Florida, it was evident that a lack of overall awareness of Florida MarketMaker existed within the population. Ultimately there was a lack of awareness of Florida MarketMaker in each target group. It appears that a major challenge facing Florida MarketMaker is the lack of a defined purpose and target audience, as well as too broad of a reach. In an attempt to cover all bases, it did not resonate with any particular audience. Instead of "reinventing the wheel," participants suggested that Florida MarketMaker find a niche, define its target audience, and stand out as something unique and different.

Furthermore, a great amount of discussion focused on the aesthetics of the website and its lack of personal touch. As previously stated, the belief that the site was for large corporations and not for the small, local farmer was common and reiterated. A bottom-up approach to marketing instead of top-down approach was suggested to relate more to farmers and ranchers. This was suggested in an effort to avoid appearing academic and corporate.

One participant stated his opinion of the major problem facing the Florida MarketMaker website. He said, "The problem with this is that it is top-down. We are bottoms-up people. And that is how we view the world."

Lastly, as touched on above, a major issue facing Florida MarketMaker is its lack of a clearly defined purpose. As far as the public represented in the focus groups is concerned, a clear purpose was not apparent to the participants and instead, the site seems an attempt to do something that has already seen success elsewhere in websites such as LocalHarvest or EatWild. The results of these focus groups provide a detailed look into the usage and lack of usage of Florida MarketMaker concerning the sale and distribution of local food.

Using this research, UF-IFAS, FDACS and their partners re-designed the site and have developed marketing and targeted purpose for the site to support the Florida Farm to School Program. The new design responds to all the feedback and findings from producers and other users across the state regarding the usability of the site and has tried to respond to the other feedback by providing more focused marketing and purpose for the site.

The new tool, Florida Food Connect - www.floridafoodconnect.com, offers an easy-to-use format to promote buying and selling of Florida food products. Visitors to the site can link to producers to buy or sell a local product in the marketplace, meet prospective buyers or sellers and learn more about their business, and request particular products.

CONCLUSIONS

By using the research findings from the Center PIE focus groups, and working collaboratively with all stakeholders, Florida Food Connect has replaced Florida MarketMaker as a user-friendly, web-based marketing tool created to assist producers and consumers of specialty crops to establish relationships in local and regional markets. Many opportunities exist for producers and growers — both large and small — to diversify sales opportunities and build profitable relationships in Florida's growing local market using this tool.

Florida Food Connect is now ready to connect producers with consumers and other buyers to and boost the sales of local products. Next steps for this project are to develop strategic outreach and training on the tool, including presentations, webinars, and articles in media outlets across the state to increase awareness and participation.

REFERENCES CITED:

Conaway, Laura. UF-IFAS Center for Public Issues Education on Agriculture and Natural Resources. 2013. Research Report: Florida MarketMaker. http://www.piecenter.com/wp-content/uploads/2014/05/Florida-MarketMaker-Final-Report.pdf

Linking Climatic, Hydrologic, and Agronomic Factors to Phosphorous Transport from Plastic Mulch Beds

Sanjay Shukla and Gregory Hendricks

University of Florida/IFAS, Department of Agricultural and Biological Engineering, Southwest Florida Research and Education Center, Immokalee, FL, sshukla@ufl.edu

INTRODUCTION

The successful commercial production of vegetables and melons requires application of phosphorus (P) fertilizers. However, excessive use of P can cause a surplus that results in P leaching into groundwaters that travel into surface waters, which adversely impacts fresh waterbodies. Although considered less mobile than nitrogen, P leaching does occur in Florida due to its sandy soils and affects the quality of water leaving farmlands. The degree of P losses from agricultural crops depend on seasonal rainfall (frequency and intensity), high water table conditions, the sandy nature of Florida soils, and the type of crop produced. In the case of vegetable production, the high risk of P loss can be linked with the intensity and frequency of tillage and the amount of fertilizer P required by each crop.

Most vegetable crops grown in Florida (e.g., watermelon and tomato) are produced on raised crop beds infused with granular fertilizer (including P) and covered with plastic mulch. Plant available P (labile P) not used by the crop during the growing season can be leached from the root zone into shallow groundwater from where most of it travels to drainage ditches in the farm.

Although Best Management Practices (BMPs) have been developed for reducing environmental losses of nutrients, including P, limited information exists on the main factors that control P losses to Florida groundwaters. Soil P studies (Djodjic, et al, 1999; Sims et al., 1998) have considered several factors that influence P leachate and its transport by drainage (e.g., preferential flow pathways, varied P sources, and soil pH), and other studies have focused on the development of soil P indices to access the risk related to dissolved-P losses (Beauchemin and Simard, 1999). However, these studies were found to be of limited use when attempting to predict the P concentration in groundwater. To date, limited work has been done to show a simplified link between varied P inputs and changes in groundwater P concentrations. Here we explore the development of a relationship to predict the response of groundwater P to changes in fertilizer P and irrigation inputs and explore if such a relationship varies by growing season. The objectives of this study were to 1) determine if and how hydrologic and agronomic factors, along with seasonal rainfall, affect groundwater P; and 2) develop regression models to predict groundwater P concentrations using hydrologic, fertilizer and agronomic soil test P data.

METHODS AND MATERIALS

A three year BMP study (six seasons) was conducted at the Southwest Florida Research and Education Center, UF/IFAS, Immokalee, FL. Immokalee fine sands are the main soil type for the study site with a soil profile consisting of A, E, and Bh horizons. The mean saturated hydraulic conductivity for Immokalee sands are relatively high and vary by horizon (A - 11 in/hr, E - 11 in/hr, and Bh - 5 in/hr) (Carlisle et al., 1989). Average Mehlich-1 P (M1P) values measured for the Ap (37 ppm) and E (9 ppm) horizons at the study site were low compared with the Bh horizon (111 ppm). The seasonal high water table typically sits above the Bh horizon (6 - 18 in. deep) for 1 to 6 months (Liudahl, 1998). The average annual rainfall for the study site is 49 in.

Tomato (*Solanum lycopersicum*) and watermelon (*Citrullus lanatus*) were grown during the spring and fall seasons of each year (Hendricks et al., 2011). Plants were grown on plastic mulched raised beds and were seepage irrigated. The study site consisted of a 3.6 ac field that formed a grid of six 0.6 ac plots which were hydrologically separated by an impermeable high density polyethylene barrier (HDPB). The HDPB was installed to minimize mixing of water and nutrients (above the Bh horizon) among the six plots and the outside area. Three water-nutrient systems (two replicates each) were applied among the six plots: 1) Average grower input with seepage irrigation (GI), 2) recommended input with seepage irrigation (RI), and 3) RI with subsurface drip irrigation (RI-SD). Fertilizer P-rates (Table 1) for GI were based on a survey of tomato and watermelon growers in southwest Florida, while P-rates for RI and RI-SD were based on M1P soil test results prior to bed preparation.

Hydrological (soil moisture, water table depth) and weather data were collected at a 15-min frequency. Weekly groundwater quality samples were collected from monitoring wells installed above (25 in) and below (8 ft) the Bh horizon. Water samples were analyzed for total phosphorus (TP). Whole plant biomass samples (with fruits) were collected from the six plots for TP analysis. Composite soil samples were collected (0-8 in) each season from each plot and analyzed for M1P. Fertilizer, soil, and plant data were used to develop a P mass balance equation that was used to estimate surplus fertilizer P in crop beds for each season:

$$P_{init} + P_{input} - P_{plant} - P_{final} = P_{bal} \quad (1)$$

where P_{bal} is the net gain or loss of P stored in raised crop beds for each season, P_{plant} is the P removed by plants, and P_{input} is inorganic P ferilizer added to crop beds at the start of each season. P_{init} and P_{final} are the initial and final soil P measured in crop beds for each season, respectively. Soil organic P was assumed to be in steady state and rainfall and irrigation P were considered negligible. P_{bal} acts as a surrogate for the surplus P_{input} available for future plant uptake or potential leaching to groundwater.

Correlation coefficients (r) between groundwater P and several climatic, hydrologic and agronomic variables were evaluated. The best subset multivariate regression technique was used to develop models for predicting seasonal and annual groundwater P concentrations for shallow wells. Predictor variables included the seasonal means/totals of M1P, P_{input}, water table depth, P_{plant}, rainfall, and soil moisture content. Mallow's Cp (Mallows, 1973) and the coefficient of determination (r^2) were used to help select the best model that explained the variation in groundwater P concentrations for shallow wells.

Table 1. Phosphorus (P_2O_5) rates for treatments with average grower input with seepage irrigation (GI), recommended input with seepage irrigation (RI), and RI with sub-drip irrigation (RI-SD).

Treatment	Season	Watermelon (lb/ac)	Tomato (lb/ac)
GI	All seasons	170	162
RI & RI-SD	Spring 04	100	-
	Fall 04	- [£]	120
	Spring 05	100	-
	Fall 05	-	0
	Spring 06	-	0
	Fall 06	-	0

[£] indicates crop not grown during the season.

RESULTS AND DISCUSSION

Data analyses showed that soil M1P were similar for GI, RI and RI-SD when all three systems received P_{input} for the first three growing seasons (Spring 2004, Fall 2004, and Spring 2005). Values for M1P attained a peak for the RI and RI-SD systems after the last application of P_{input}; but continued to increase steadily with continued P_{input} for GI, reaching a maximum of 145 ppm by the end of the study (Fall 2006, Fig. 1). Values of M1P for GI and RI show the accumulation of P in the A horizon (0-8 in); however, greater accumulation of P in the A horizon for GI (Table 2) created a greater potential for P leaching compared with RI and RI-SD (Fig. 1). The surplus of fertilizer P for GI increased by each season and reached its maximum by the end of the study (Table 2, 270 lb/ac in Fall 2006), and was the result of applying P_{input} above plant needs. The accumulated surplus P (Table 2) for both RI systems increased for each season and then plateaued by Spring 2005 (74-75 lb/ac). After Spring 2005, P_{bal} for RI systems became negative (a result of no P_{inputs}) and shows that plant needs were satisfied by P surplus from the previous season. Hence, a steady decline in accumulated surplus P started in Fall 2005 and reached a minimum (30-36 lb/ac) by the end of the study (Table 2). The continued application of P_{input} for GI resulted in a surplus of P_{input} that reached a threshold governed by the soil's P adsorption capacity. Although both M1P and P_{input} surplus showed similar trends, the increase in the latter was greater.

The accumulated surplus P for GI (270 lb/ac) was approximately 700% greater than the two recommended systems (RI = 30 and RI-SD = 36 lb/ac) indicating that a large part of the accumulated P from the GI leached vertically and/or was transformed to other forms of P.

Correlation analyses showed that P_{input} and P_{plant} had a stronger influence on groundwater P than hydrologic factors (rainfall, irrigation, soil moisture, and groundwater depth). Groundwater P was correlated strongest with M1P ($r = 0.64$, $p < 0.001$, Fig. 2A) followed by P_{plant} ($r = 0.54$, $p < 0.01$, Fig. 2B), P_{input} ($r = 0.49$, $p = < 0.01$, Fig. 2C), and P_{bal} ($r = 0.41$, $p < 0.01$, Fig 2D). Among the hydrologic variables, groundwater depth was the only notable variable with some evidence for significant ($r = -0.27$, $p = 0.11$, Fig. 2E) correlation. Fall and spring seasons differ in rainfall received, with spring being drier. The 40-year average regional rainfall for the fall season (32 in) was 88 % higher than the spring season (17 in) (Weatherbase, 2014). Hydrologic factors became important in explaining the variability in groundwater P when season-specific correlations were examined. Correlations of rainfall ($r = 0.52$, $p = 0.026$) and soil moisture ($r = 0.46$, $p = 0.052$) with groundwater P concentrations were significant for the spring season.

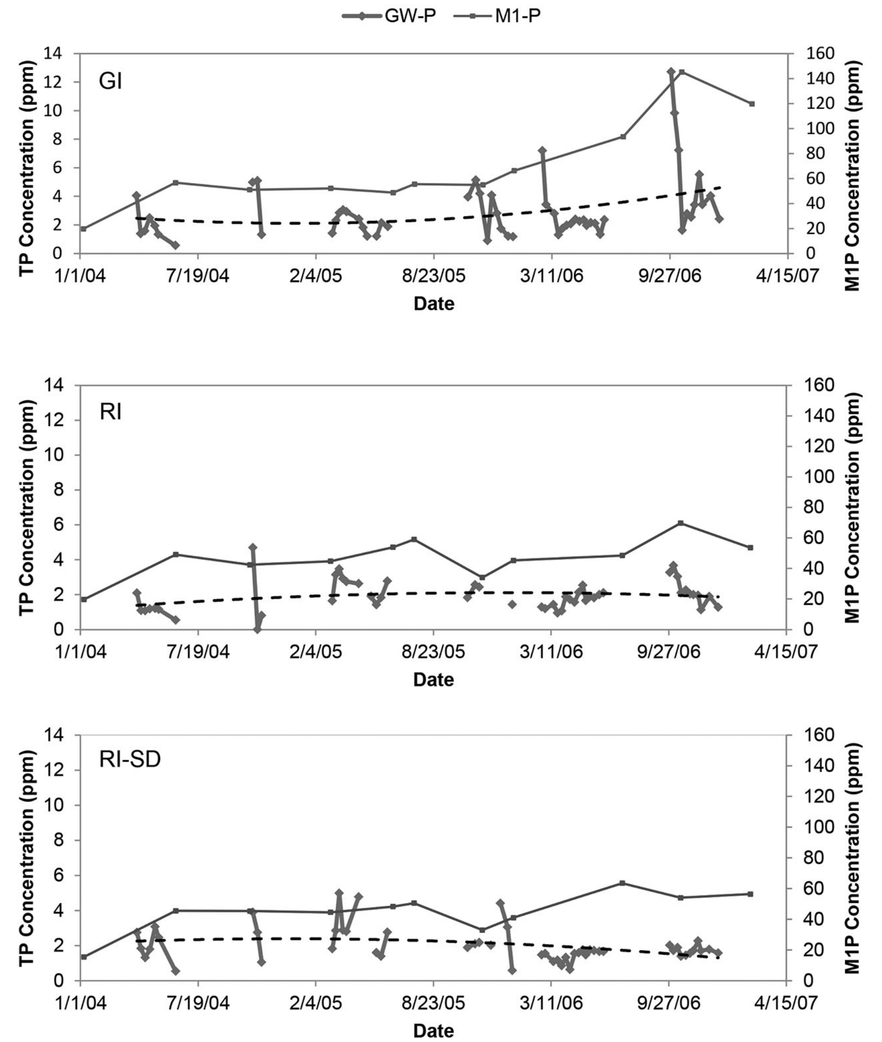


Figure 1. Groundwater total phosphorus (TP) concentrations above the Bh horizon and soil Mehlich-1 P (M1P, 0 – 8 in) for plots with treatments: average grower input with seepage irrigation (GI), recommended input with seepage irrigation (RI), and RI with sub-drip irrigation (RI-SD). The dotted line shows a second order polynomial trend for TP over the period of study for each treatment.

Regression analyses indicated that M1P is a good predictor of groundwater P for the fall growing season as well as on an annual basis. Fertilizer P was also important as it directly affected M1P in the soil. Water table depth and rainfall were important for the dry spring seasons. The following regression models were developed for predicting seasonal and annual groundwater P:

$$GWP_{fall} = 871 + 21.9 \text{ Mehlich-1P} + 15.6 \text{ Fertilizer-P } (r^2 = 0.93) \quad (1)$$

$$GWP_{spring} = -2476 + 12.8 \text{ Fertilizer-P} + 55.5 \text{ WaterTable} + 13.6 \text{ Rainfall } (r^2 = 0.76) \quad (2)$$

$$GWP_{annual} = 595 + 25.2 \text{ Mehlich-1P} + 10.2 \text{ Fertilizer-P } (r^2 = 0.67) \quad (3)$$

1 ppm = 1000 µg/l; 1 ppm = 1 mg/kg;
1 in = 2.5400 cm; 1 lb/ac = 1.1209 kg/ha

where GWP_{fall}, GWP_{spring} and GWP_{annual} are groundwater P concentrations (µg/l) above the Bh horizon for spring, fall, and annual predictions, respectively; Fertilizer-P is the amount of P_{input} applied (kg/ha), Mehlich-1 P is the average soil test P (mg/kg) for each season, Rainfall is the total rainfall (cm) for the season, and Water Table is the average water table depth (cm) for the season. These models (Equations 1, 2, and 3) can be used to estimate the groundwater P concentrations (µg/l) above the Bh (spodic) horizon for spring, fall, and annual periods. These equations are valid for similar production systems and environments, and illustrate that M1P and fertilizer-P are the two most important factors that govern subsurface P losses for vegetable production in shallow water table regions of Florida. The fall and annual equations do not include water related factors and is due to large amounts of rainfall received during the start of each fall season.

SUMMARY AND CONCLUSION

This study was conducted to determine if and how hydrologic and agronomic factors, along with seasonal rainfall, affected groundwater P concentrations; and whether simple models could be developed for predicting groundwater P concentrations using readily available hydrologic, fertilizer, and

Table 2. Mass balance for phosphorus (P) in plots with average grower input with seepage irrigation (GI), recommended external input with seepage irrigation (RI), and RI with sub-drip irrigation (RI-SD) treatments for tomato and watermelon crops.

Season	Treatment	Fertilizer-P (P_{input}, lb/ac)	Plant P (P_{plant}, lb/ac)	Fertilizer-P balance (P_{bal}, lb/ac)[b]	Accumulated surplus P (lb/ac)[c]
Spring 2004[a]	GI	75	-	-	-
	RI	44	-	-	-
	RI-SD	44	-	-	-
Fall 2004	GI	71	18	53	53
	RI	53	13	40	40
	RI-SD	53	15	38	38
Spring 2005[a]	GI	75	12	63	117
	RI	44	9	35	75
	RI-SD	44	8	36	74
Fall 2005	GI	71	6	65	182
	RI	0.00	6	-6	69
	RI-SD	0.00	7	-7	67
Spring 2006	GI	71	31	40	222
	RI	0.00	21	-21	48
	RI-SD	0.00	22	-22	45
Fall 2006	GI	71	23	48	270
	RI	0.00	13	-13	36
	RI-SD	0.00	15	-15	30

[a] Watermelon crop.

[b] Negative values indicate the removal of P from the pool of surplus P generated during the previous crop season.

[c] Assumes P remained fixed in the soil during the period of study.

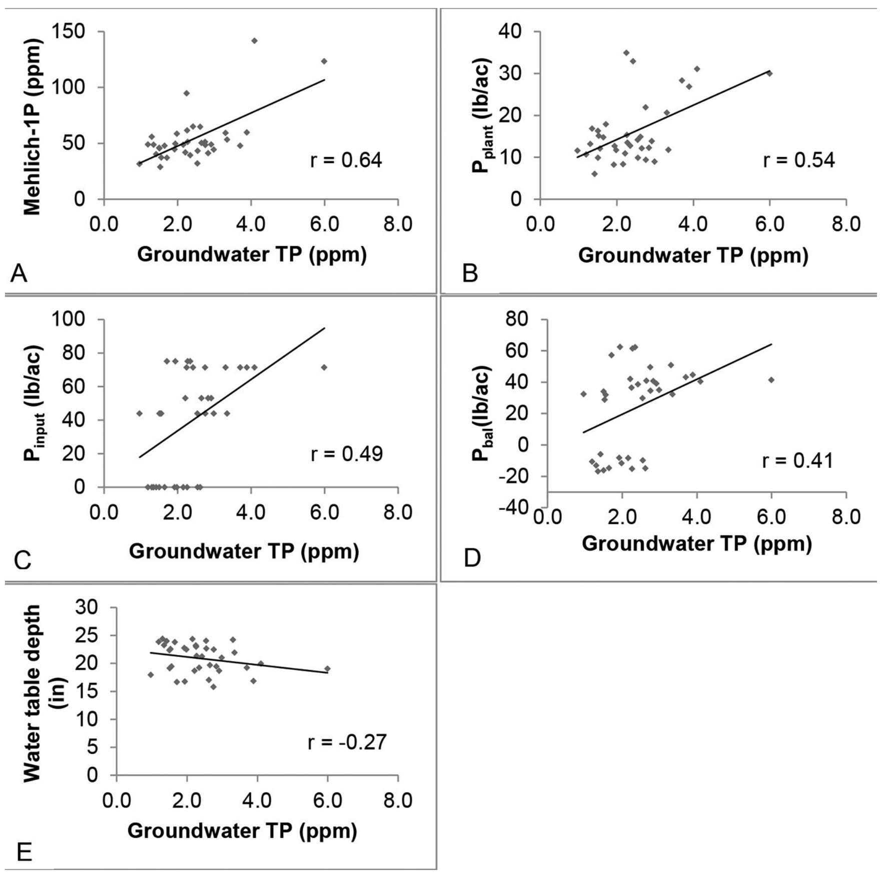


Figure 2. Scatter plot diagrams for correlation of groundwater P with A) plant available P (Mehlich-1 P), B) Plant P uptake (P_{plant}), C) applied fertilizer P (P_{input}), D) intial P – final P (P_{bal}), and E) water table depth. The solid line shows the linear relationship between covariates.

soil test P data. The dataset included a wide range of crop-soil-water-management factors for tomato and watermelon production systems. Two irrigation methods were used (seepage and sub-surface drip) with varying fertilizer-P rates (0 to 75 lb/ac). During the study, soil test P (measured as Mechlich-1 extractable soil P, M1P) varied from 15 to 145 ppm, groundwater concentrations of total P ranged from 0.53 to 1.27 ppm, and daily rainfall reached a maximum of 8 in. with Hurricane Wilma. Data were analyzed by season and year.

Analyses of the data revealed that a greater focus on fertilizer (vs. water) management is required during the wet fall season. However, for dry spring seasons, greater focus is required for irrigation management as water table and rainfall became dominant factors. The models presented here only require readily available data already used by vegetable growers to manage their farms. Growers use rainfall and water table depths to manage irrigation and drainage, and soil test P (M1P) is used to determine the fertilizer P rates required for plants each growing season. These models are unique but simple and can be used as management tools by growers. Although the models represent comprehensive long-term data, they may not necessarily work for all farms. The relationships are representative of dual cropping systems with plastic mulched beds and shallow water table conditions. Once similar data are available for different farms, a generic equation can be derived for its use as a screening tool by growers to manage P losses from their farms.

LITERATURE CITED

Beauchemin, S., R.R. Simard. 1999. Soil phosphorus saturation degree: review of some indices and their suitability for P management in Québec, Canada. Can. J. Soil Sci. 79:615-625.

Carlisle, V.W., F. Sodek III, M.E. Collins, L.C. Hammond, and W.G. Harris. 1989. Characterization data for selected Florida soils. Univ. of Florida-Institute of Food and Agricultural Sciences, USDA-Soil Conservation Service, Gainesville, FL.

Djodjic, F., L. Bergstrom, B. Ulen, and A. Shirmohammadi. 1999. Mode of transport of surface applied phosphorus-33 through a clay and sandy soil. J. Environ. Qual. 28:1273-1282.

Hendricks, G.S., and S. Shukla. 2011. Water and nitrogen management effects on water and nitrogen fluxes in Florida Flatwoods. J. Environ. Qual. 40:1844-1856.

Liudahl, K., D.J. Betz, L. Carey, R.W. Drew, S. Fisher, and P. Pate. 1998. Soil survey of Collier County area, Florida. USDA–NRCS, Washington, DC.

Mallows, C. L. 1973. Some comments on CP". Technometrics 15 (4): 661–675.

Sims, J.T., A.C. Edwards, O.F. Schoumans, and R.R. Simard. 2000. Integrating soil phosphorus testing into environmentally based agricultural management practices. J. Environ. Qual. 29:60–71.

WeatherBase. 2014. Immokalee, Travel Weather Averages. Monthly weather averages summary. <http://www.weatherbase.com/weather/weather.php3?s=69437&cityname=Immokalee-Florida-United-States-of-America> (Jun 20, 2014).

Eliminating Obstacles for the Adoption of Anaerobic Soil Disinfestation in Florida Tomato

Erin Rosskopf [1], Jason Hong [1], Nancy Kokalis-Burelle[1], and David Butler [2]

[1] USDA, ARS, 2001 South Rock Road, Fort Pierce, FL.

[2] Department of Plant Sciences, University of Tennessee, Knoxville, TN, erin.rosskopf@ars.usda.gov

INTRODUCTION

Florida commercial vegetable producers have very few choices for fumigant-based control of soilborne plant pathogens, nematodes, and weeds. Many growers invested in the transition to iodomethane due to its comparability to methyl bromide (MeBr) as a single-compound replacement for broad-spectrum pest control. The loss of iodomethane for use in the United States leaves various formulations and combinations of Telone® (1,3-dichloropropene), chloropicrin (pic), metam sodium/potassium (metam), and dimethyl disulfide (DMDS, Paladin™). Regulatory restrictions on the use of these materials has made their use impossible for some commodities, and created large buffer zone requirements for others (Noling and McRae, 2010). The most recent chemical fumigant alternative is the allyl isothiocynate-based product Dominus® (Isagro USA, Morrisville, NC), which was registered as a biologically-based fumigant (Allan, 2013).

Another biologically-based approach is anaerobic soil disinfestation (ASD), in which the incorporation of organic amendments and soil saturation has been found to suppress many soilborne pests in multiple cropping systems (Shennan et al., 2014). For application in Florida, a labile carbon source (ex. molasses) is incorporated into a preformed bed. The bed is covered with plastic, to limit gas exchange, and irrigation applied to fill soil pore space with water. Anaerobic conditions are created and the soil pH drops significantly throughout the treatment (Butler et al., 2012). These factors return to pretreatment levels after the 3 week process. It has been hypothesized that one of the principle components in the success of ASD and the drop in pH is attributed to the changes in microbial populations; a shift from aerobic to anaerobic bacteria. A previous study showed that after ASD treatment of potted soil, members of the *Firmicutes* phylum, including *Clostridia* and *Bacilli* were detected more often in ASD treated soil than untreated soil (Mowlick et al., 2012).

Two significant limitations to the adoption of ASD are the use of clear solarization film during the ASD process and the application of composted broiler litter (CBL) in combination with the molasses amendment (Butler et al, 2012). Solarization combined with ASD was used in Florida to increase the level of weed control (Rosskopf unpublished) and to improve control of soilborne pathogens (Butler et al., 2012; Stapleton et al., 2010). Using solarization film requires two applications of plastic or painting in order to reduce soil temperatures for crop establishment (Chellemi and Rosskopf, 2004). This presents additional cost, labor, and time. In addition to plastic removal, the application of CBL is perceived as a food safety risk due to the potential for *Salmonella* contamination (Gu et al., 2011). Although the stigma is present, previous studies have demonstrated that if composted CBL reaches a temperature of 65°C it becomes biocidal for gram negative bacteria, which includes *Salmonella* (Anthony and Nix, 1962; Murphy, 1990). Recently it was shown that *Salmonella* was not detected 18 hrs after the bacterium was artificially inoculated in a chicken litter compost pile; the temperature of the compost pile reached 64°C (Toth et al., 2011). A series of experiments were conducted to attempt to address these limitations.

MATERIALS AND METHODS

Plastic mulch

Multiple field trials have been conducted using various approaches to ASD. In one series of experiments, a "standard" ASD approach utilizing CBL at a rate to provide adequate nitrogen to the tomato crop, ~ 26 Mg dry matter ha^{-1} (Boyd Brothers, Live Oak, FL), and blackstrap molasses (Westway Feed Products, Clewiston, FL) was applied by spraying a diluted solution (1:1 with water) onto beds at a rate of 20 Mg ha^{-1} (wet basis; 8.2 Mg dry matter ha^{-1}). Following amendments, the beds were tilled to approximately 15 cm using a rotary cultivator and reformed. A 15-μm transparent polyethylene film (Polydak, Ginegar Plastic Products, Ginegar, Israel) was then pulled onto beds and two drip irrigation lines (30.5-cm emitter spacing) installed. Irrigation was applied to deliver approximately 5 cm. Two oxidation-reduction potential electrodes (Pt combination electrodes, Ag/AgCl reference, Sensorex, Garden Grove, CA) were installed at a 15-cm depth in each treatment prior to initial irrigation to evaluate presence of anaerobic soil conditions (indicated by redox potential; Eh) during the three-week treatment period. Electrodes were continuously monitored using an automatic data logging system (CR-1000 with AM 16/32 multiplexers, Campbell Scientific, Logan, UT) during the treatment period in order to calculate the accumulation of anaerobic conditions. To determine if the clear plastic was required, in one series of repeated trials, five plastics were compared. The "ASD-standard" clear Ginegar Polydak was compared to clear and white totally impermeable film (VaporSafe® TIF™ Raven Industries, Sioux Falls, SD), white virtually impermeable film (VIF, Guardian Agro, Grupo Olefinas, Guatemala), and white-on-black high density polyethylene (Hilex Poly AG1). ASD was applied as described above, with the only difference being the plastic used. Clear plastic was painted with a water-soluble white paint (Kool Grow, Cleveland, OH) after the ASD treatment period. Weeds were assessed weekly.

Microbial communities and soil pH

In order to observe the changes in microbial populations, soil samples were collected prior to ASD application, 24 hrs post application, and every 2 to 3 days during the 3-week treatment in two fields treated with "standard" ASD. The ASD process in field 1 was completed in immediate sequence, while there was a significant delay between plastic laying and irrigation application in field 2. Samples were taken by inserting a soil probe through the plastic mulch. As soon as the soil probe was extracted the hole was covered with tape that coordinated with the plastic, (e.g. clear tape was used for clear plastic). The pH of each soil sample was measured twice within 2 hrs after the soil samples were collected. Microbial DNA was extracted from the soil samples using Mobio PowerSoil DNA Isolation kit (Mo Bio Laboratories Inc., Carlsbad, CA, USA). Length heterogeneity polymerase chain reaction (lh-pcr) and universal bacteria primers amplified bacterial DNA. Amplicons from lh-pcr were read using an ABI 3730 sequencer and interpreted and annotated by Genemapper v5.0 (Applied Biosystems, Foster City, CA, USA). These results were analyzed by SIMPER and multidimensional (MDS) plots were created by programs included in the PRIMER-E software package v6.0 (Clarke et al., 2006). Changes in the microbial community were evaluated relative to the level of cumulative anaerobic activity and changes in soil pH.

Soil samples, CBL, and tomato fruit were tested for *Salmonella* using pcr and *Salmonella*-specific primers. Microbial DNA from pretreatment and post treatment soil and CBL were extracted using the same method as previously described. Harvested tomato fruits with the sepal removed were surface sterilized by washing in 70% ethanol and air-drying in a hood. A blender pulverized the tomato fruit and puree was divided into 2 parts; 40 ml was incubated overnight at 37°C, and 1 ml was added to 9 ml of peptone water (Thomason et al., 1977), used to enrich for gram negative bacteria, and then incubated overnight at 37°C. After incubation, 5 ml of the suspension was centrifuged for 2 min at 10,621 G-force, and the DNA of the sediment was extracted as previously described. Extracted *Salmonella* DNA (Norgen Biotek Corp, Ontario CA) was used as a positive control.

RESULTS AND DISCUSSION

There were no significant differences in the cumulative anaerobic activity under any of the plastic mulches (data not shown). Dominant weeds in this field were yellow nutsedge (*Cyperus esculentus*) and goosegrass (*Elusine indica*), although nutsedge coming through the plastic was the principal problem in the beds. There was a significant difference between the average density of nutsedge in each plastic-type (Figure 1), with the greatest numbers occurring in the HDPE and the VIF treatments. There were no significant differences between the two clear films and the opaque TIF. Nutsedge emergence was not correlated with cumulative anaerobic activity. Based on these results, it is apparent that ASD could be implemented using TIF instead of solarization. It appears that one mechanism of nutsedge suppression could be physical, which is likely more important than cumulative anaerobic condition.

In field trials assessing changes in microbial community composition, soil pH decreased in field 1 during ASD treatment, with the lowest at day 5 after application with a pH of 5.22, and returned to pretreatment pH of 6.71 at day 21 (Figure 2). The MDS plot of field 1 displays dramatic changes of the bacterial population during ASD treatment (Figure 3). In comparison, the soil pH for field 2 fluctuated throughout the treatment ranging between a pH of 6.03 to 7.01 (Fig 4). The MDS plot of field 2 showed few changes in the bacterial population throughout treatment (Fig 5). Changes observed at day 3 post-application are associated with a rain event. In field 1, ASD treatment resulted in substantial cumulative anaerobic activity, while in field 2, anaerobic conditions did not result from the treatment application (data not shown). The problems in field 2 could possibly due to the several hour delay in irrigation, allowing for aerobic decomposition of the added carbon source. The success or failure for a field to become "adequately anaerobic" for control of target pests could be related to the cropping history, which is a current area of investigation, but may also be related to completing the application as quickly as possible. In either case, significant change in soil pH and the microbial community was associated with anaerobic conditions.

ASD treatment was applied to two tomato fields, using the standard protocol, which included CBL. Samples of soil, CBL and tomatoes harvested from the field were tested by pcr with *Salmonella*-specific primers. Tomato fruit was sampled using vine-ripened and breaker stage fruit. The bacterium was not detected in tomato samples regardless if the tomato puree was enriched or not. *Salmonella* was not detected in any of the pretreatment or post treatment soil or CBL samples. The positive control, purified extracted *Salmonella* DNA, always amplified in the pcr.

REFERENCES

Allan, M. and Leon, T. 2013. IRF135, allylisothiocyanate (AITC) regulatory and development update. Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, MBAO, p. 1-1-1-2.

Andrews, W. A., Jacobson, A., Hammack, T. November 2011, posting date. Salmonella. In G. J. Jackson et al. (ed.), Bacteriological analytical manual online. Center for Food Safety and Applied Nutrition, U.S. Food and Drug Administration, Gaithersburg, MD. http://www.fda.gov/Food/ScienceResearch/LaboratoryMethods/BacteriologicalAnalyticalManualBAM/ucm070149.htm

Butler, D.M., Kokalis-Burelle, N., Muramoto, J., Shenna, C., McCollum, T.G., and Rosskopf, E.N. 2012. Impact of anaerobic soil disinfestation combined with soil solarization on plant-parasitic nematodes and introduced inoculum of soilborne plant pathogens in raised-bed vegetable production. Crop Protection 39:33-40.

Chellemi, D.O. and Rosskopf, E.N. 2004. Yield potential and soil quality under alternative crop production practices for fresh market pepper. Renewable Ag and Food Systems 19:168-175.

Clarke, KR, Gorley, RN, 2006. PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth.

Gu, G., Hu, J., Cevallos-Cevallos, J., M. Richardson, S.M., Bartz, J.A., and vvan Bruggen A.H.C. 2011. Internal colonization of Salmonella enterica serovar Typhimurium in tomato plants. PLoS ONE 6(11): e27340. doi:10.1371/journal.pone.0027340

Mowlick, S., Yasukawa, H., Inoue, T., Takehara, T., Kaku, N., Ueki, K., & Ueki, A. 2013. Suppression of spinach wilt disease by biological soil disinfestation incorporated with *Brassica juncea* plants in association with changes in soil bacterial communities. Crop Protection 54: 185-193.

Murphy, D. W., 1990. Disease transfer studies in a dead bird composter Proc. 1990 National Poultry Waste Management Symposium, pp.25-30.

Noling, J. and MacRae, A. 2010. New fumigant regulations coming in December. Florida Tomato Institute Proceedings. PRO53:28-30.

Shennan, C., Muramoto, J., Mazzola, M., Butler, D., Rosskopf, E., Kokalis-Burelle, N. Momma, K., Kobara, Y., and Lamers, J. 2014. Anaerobic Soil Disinfestation for Soil Borne Disease Control in Strawberry and Vegetable Systems: Current Knowledge and Future Directions. Acta Horticulturae: in press.

Stapleton, J.J., Summers, C.G., Mitchell, J.P., and Prather, T.S. 2010. Deleterious activity of cultivated grasses (Poaceae) and residues on soilborne fungal, nematode and weed pests. Phytoparastica 38:61-69.

Thomason, B. M., Dodd, D. J., and Cherry, W. B. 1977 Increased recovery of Salmonella from environmental samples enriched with buffered peptone water. Appl Environ Microbio. 34: 270-273.

Toth, J. D., Aceto, H. W., Rankin, S. C. Dou, Z. 2011 Survival characteristics of *Salmonella enteric* serovar Newport in the dairy farm environment. J. Dairy Sci. 94:5238–5246.

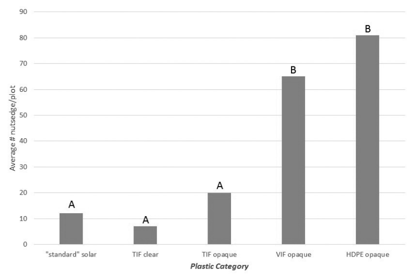


Figure 1. Average number of nutsedge (*Cyperus esculentus*) per 15-m plot at harvest. The "ASD-standard" clear Ginegar Polydak was compared to clear and white totally impermeable film (VaporSafe® TIF™ Raven Industries, Sioux Falls, SD), white virtually impermeable film (VIF, Guardian Agro, Grupo Olefinas, Guatemala), and high density polyethylene (Hilex Poly AG1). Bars with the same letter are not significantly different based on Fisher's Protected LSD (0.05).

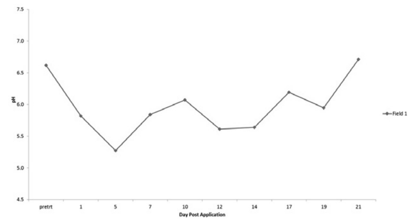


Figure 2. Soil pH during anaerobic soil disinfestation treatment in field 1. Data is the average of two combined samples from 0-15 cm and 15-30 cm from each plot.

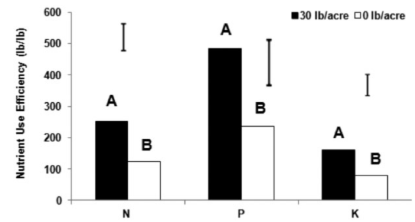


Figure 3. Multidimensional scaling plot of changes in the bacterial population during anaerobic soil disinfestation treatment in field 1 characterized using LH-PCR. Numbers associated with the data points are days following initial application of amendments (day 0 is pre-treatment).

Figure 4. Soil pH during anaerobic soil disinfestation treatment in field 2. Data is the average of two combined samples from 0-15 cm and 15-30 cm from each plot.

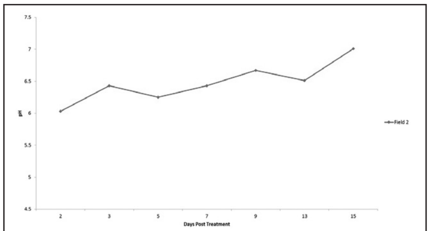


Figure 5. Multidimensional scaling plot of changes in the bacterial population during anaerobic soil disinfestation treatment in field 2 characterized using LH-PCR. Numbers associated with the data points are days following initial application of amendments (day 0 is pre-treatment).

Using Soil Fumigants with Totally Impermeable Film

Josh Freeman

University of Florida/IFAS, North Florida Research and Education Center, Quincy, FL, joshuafr@ufl.edu

INTRODUCTION

Soil fumigation remains the primary means of managing soil-borne pests in plasticulture tomato production. Now that methyl bromide (MBr) is no longer an available tool, producers must fully rely on other soil fumigants. Yellow nutsedge (*Cyperus esculentus* L.) and purple nutsedge (*Cyperus rotundus* L.) are among the most common and troublesome weeds in plasticulture production and require management strategies for successful control. An alternative fumigant that has successfully controlled nutsedge is dimethyl disulfide (DMDS) (Culpepper et al., 2008). New mulch film has been developed known as totally impermeable film that utilizes ethyl vinyl alcohol as a barrier layer. The use of this polymer decreases the permeability of mulch compared to the nylon polymers commonly used in virtually impermeable film (Chellemi et al., 2011). Decreased mulch permeability may allow for reduced fumigant application rates while maintaining pest control efficacy. Rate reductions of 25-50% have been demonstrated with other fumigants under highly retentive films (Fennimore and Ajwa, 2011). If application rates are reduced, buffer zones may be smaller and input costs could be less. One potential drawback of TIF could be increasing the already long plant-back period for a fumigant like DMDS. The goal of these experiments was to determine if application rates of DMDS could be reduced under TIF while maintaining pest control efficacy.

MATERIALS AND METHODS

Four field experiments were conducted at the Virginia Tech Eastern Shore Agricultural Research and Extension Center (ESAREC) in Painter, VA during the spring and fall of 2010 and 2011. Soil type at ESAREC is a Bojac sandy loam with 59% sand, 30% silt, and 11% clay. Soil was cultivated to a depth of 30 cm prior to fumigation. If necessary, overhead sprinkler irrigation was used to bring soil moisture capacity to between 50 and 75% field capacity before fumigant application. A 79:21 w/w formulation of DMDS:Pic (Arkema Inc., King of Prussia, PA) fumigant was shank applied using a single row combination bed press 30 in wide and 8 in high with three back swept shanks. Shanks were 8 in long and fumigant was released at the bottom of the shank. Experimental plots were single rows 78 ft long with a between row spacing of 6 ft. A single drip tape was deployed concurrently with the fumigant. Fumigant was applied on April 8 and June 14, 2010 and May 2 and June 14, 2011.

During all experiments, either a black (spring) or white on black (fall) formulation of 1.25 mil Blockade® VIF (Berry Plastics Corp., Evansville, IN) embossed polyethylene mulch containing a nylon barrier was used. The TIF mulch used was a black (spring) or white on black (fall) 1.8 mil Vaporsafe® TIF (Raven Industries Inc.,Sioux Falls, SD) polyethylene mulch containing an EVOH barrier layer.

The recommended broadcast application rate for DMDS:Pic under VIF film for nutsedge control in tomatoes is 60 gal/acre. Application rates specified for the following experiments are broadcast rates. A common rate used by vegetable producers would be 50 gal/acre and for the purposes of this research will be considered a standard rate. All experiments included a standard rate of DMDS:Pic (50 gal/acre) under VIF and TIF, a high rate (60 gal/acre) under VIF, three reduced rates (20 gal/acre, 30 gal/acre, 40 gal/acre) under TIF, and an nontreated control under TIF. Beginning in the fall of 2010 and for all subsequent experiments, a nontreated control under VIF was added. Experimental plots were arranged as a randomized complete block design with four replications.

A single row of twenty-five 4-5 week-old 'BHN 602' (BHN Seed, Immokalee, FL) tomato seedlings were transplanted into each plot spaced 18 in apart. Seedlings were transplanted on May 21, and July 13, 2010 and June 13 and July 25, 2011. Plants were staked and tied as needed. Insect and disease management measures were employed as needed based on commercial production recommendations for Virginia (Wilson et al. 2010). Tomato fruit were harvested at a mature green stage around 11 and 13 weeks after transplanting each season. Fruit were weighed and graded according to USDA standards (USDA, 1991). Emerged nutsedge was counted 10 weeks after tomato transplanting. Yield and nutsedge population data were subjected to analysis of variance and means separation with Duncan's multiple range test, when appropriate (SAS Institute, Cary, NC). Data from fall 2010 and 2011 will be presented here.

RESULTS AND DISCUSSION

Data from both seasons were pooled and no significant interaction between treatment and season was observed so data are presented together (Table 1). DMDS fumigation at all rates under both films controlled yellow nutsedge better than the nontreated VIF and TIF. The nontreated TIF managed nutsedge better than the nontreated VIF, 7.4 plants/ft^2 compared to 22.5 plants/ft^2, respectively. There were no differences in nutsedge population among fumigation treatments. All fumigation treatments maintained nutsedge populations below 1 plants/ft^2. There was no difference in yield of medium fruit among fumigation treatments. All the fumigated treatments provided greater tomato yields than the nontreated VIF and TIF. The nontreated TIF plots produced yields similar to fumigation treatments in several fruit size categories. Other than 30 gal/acre TIF, all fumigation treatments resulted in significantly greater total marketable tomato yield compared to the nontreated plots. Tomato plants in nontreated TIF plots produced significantly more total marketable yield than those in nontreated VIF plots.

Table 1. Effect of totally impermeable film (TIF) and virtually impermeable film (VIF) in combination with standard and reduced rates of dimethyl disulfide:chloropicrin (79:21 w/w) on yellow nutsedge population and tomato yield. Experiments were performed in Painter, VA during fall 2010 and 2011. Data presented are pooled over both seasons.

		Yields (lb/acre)[a]			
Treatment	**Emerged nutsedge ft^2**	**Medium**	**Large**	**Extra-large**	**Total marketable**
Untreated VIF	22.5a[b]	4,199b	5,922c	8,786d	18,908c
Untreated TIF	7.4b	5,336b	11,367b	20,332c	37,037b
20 gal/acre TIF	0.2c	7,745a	15,143a	25,479abc	48,368a
30 gal/acre TIF	0.1c	7,345a	13,870ab	22,144bc	43,360ab
40 gal/acre TIF	0.0c	7,716a	14,609a	26,299abc	48,625a
50 gal/acre TIF	0.0c	7,462a	15,664a	26,914ab	50,042a
50 gal/acre VIF	0.2c	7,375a	13,964a	28,730a	50,069a
60 gal/acre VIF	0.3c	6,941a	13,234ab	26,643ab	46,818a

[a] Yield estimates are based on two harvests from ten plants per plot.
[b] Values followed by the same letter do not differ at the 5% significance level by Duncan's multiple range test. Means are to be compared within columns. ns = not significant

The results from these experiments illustrate the potential of reducing fumigant use rates and maintaining pest control efficacy, even of a difficult weed such as yellow nutsedge. In both seasons, the reduced rates of 30 and 40 gal/acre under TIF increased total marketable tomato yield over the nontreated VIF. These rates also provided nutsedge control similar to that of 50 and 60 gal/acre under VIF. While the 50 gal/acre rate under TIF provided excellent nutsedge control, this combination would likely be economically prohibitive. Based on the current Paladin label, reducing the fumigant application rate from 60 to 30 gal/acre would reduce the buffer zone distance surrounding the field from 100 to 25 ft, on a 25 acre application block (Anonymous, 2012).

Based on current TIF prices, reducing fumigant use rates in combination with TIF will decrease fumigation costs compared to standard rates under VIF. These data illustrate that TIF may become a valuable tool for easing the transition from methyl bromide to alternative fumigants in the plasticulture production system while maintaining acceptable levels of pest control.

LITERATURE CITED

Anonymous. 2012. Paladin label. Available at: http://www.upi-usa.com/Paladin/pdf/PALDN_DFU_55050-4_3822CR1.pdf. Accessed: March 12, 2012.

Culpepper, S., L. Sosnoskie, K. Rucker, B. Tankersley, D. Langston, T. Webster, and W. Upchurch. 2008. DMDS or the 3-way: which is more effective in Georgia? Proc. 2008 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions. Available at: mbao.org/2008/Proceedings/007Culpepper SMB2008conferencesummary.pdf. Accessed: December 11, 2011.

Chellemi, D.O., H.A. Ajwa, D.A. Sullivan, R. Alessandro, J.P. Gilreath, and S.R. Yates. 2011. Soil fate of agricultural fumigants in raised-bed, plasticulture systems in the Southeastern United States. J. Environ. Qual. 40:1204-1214.

Fennimore, S.A. and H.A. Ajwa. 2011. Totally impermeable film retains fumigants, allowing lower application rates in strawberry. California Agriculture. 65:211-215.

USDA, 1991. United States Standards for Grades of Fresh Tomato. U.S. Dep. Agric., Agric. Marketing Serv. pp. 1-14. Available at: http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5050331. Accessed: December 9, 2011.

Wilson, H.P., T.P. Kuhar, S.L. Rideout, J.H. Freeman, M.S. Reiter, R.A. Straw, T.E. Hines, C.M Waldenmaier, H.B. Doughty, and U.T. Deitch. 2010. Virginia commercial vegetable production recommendations for 2012. Virginia Cooperative Extension. Publication 456-420.

Copper in a Copper Tolerant Environment: Questioning the Value of Copper for Managing Bacterial Leaf Spot and Speck of Tomato Strategies

Gary Vallad[1,2], H. Adkison[1], R. Willis[1], S. Newman[1], S. Timilsina[1,2], and J.B. Jones[1]

[1] University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL.

[2] University of Florida/IFAS, Department of Plant Pathology, Gainesville, FL, gvallad@ufl.edu

BACKGROUND

In 2013, we reported the results from a survey of 175 pathogenic strains of *Xanthomonas perforans* collected in 2011-12 from tomato fields and transplant production sites throughout Florida (Vallad et al. 2013). We presented evidence of two distinct groups of *X. perforans* strains, with one group exhibiting genetic features in common with *X. euvesicatoria* suggesting a recent genetic exchange had occurred between the two species. Characterization of the strains revealed the prevalence of copper-tolerance among strains and an increasing frequency of streptomycin resistance compared to a prior survey in 2006-07 (Horvath et al. 2013); in addition, all strains were sensitive to Kasumin 2L, which contains the antibiotic kasugamycin. We further demonstrated that the fungicide Quintec that contains the active ingredient quinoxyfen had no direct bactericidal activity against *X. perforans*, but enhanced the activity of copper in *in vitro* assays towards a specific subset of copper-tolerant strains. Efforts are still underway to register products like Kasumin 2L and Quintec for use in field production. Findings from these *in vitro* studies suggested the possibility of developing rotational strategies to limit bacterial leaf spot of tomato (BST) and limit the establishment of chemical resistant strains. However, due to the wide-spread prevalence of copper tolerance among *X. perforans* strains, simple rotations or tank mixtures of new products with current copper + mancozeb (Cu-mancozeb) programs is unlikely to prevent further development of resistant bacterial strains. Our current research efforts are focused on using an integrated approach of combining bactericidal products with plant defense activators, and other biological control agents to manage bactericide resistance and to improve overall control of bacterial spot. Although such strategies are employed to manage pesticide resistance among many fungal and insect pathogens, the lack of effective compounds has made this approach infeasible for managing BST.

MATERIALS & METHODS

Field trials were conducted in 2012 (fall) and 2013 (spring and fall) to test BST management programs using the grower Cu-mancozeb standard of Cuprofix Ultra 40D (copper sulfate; 2.5 lb/A) + Penncozeb 45DF (mancozeb;1.5 lb/A), Actigard (acibenzolar-*S*-methyl; 0.5 oz/A), or several other non-copper alternatives to include Firewall (streptomycin; 16 oz/A), Kasumin 2L (64 floz/A) or Quintec (6 floz/A), either alone or in two-way and three-way programs (Tables 1 and 2). Each trial also included a non-treated control, and trials in 2013 also included the biopesticides Regalia and Actinovate. Additional fungicides and insecticides were applied as needed to manage common foliar fungal pathogens, such as target spot and early blight, and insect pests. Each experimental plot consisted of three 25 ft long raised beds on 5 ft centers, with tomato var. ‘Charger’ or ‘HM1823’ planted on 1.5 ft spacing. Treatments were applied to plants on all three beds using a high-clearance tractor sprayer equipped with 8 hollow cone spray nozzles for each plant row, and calibrated to apply products in 60, 90 and 120 gal/A spray volumes at 210 psi. Each treatment was repeated 4 times within a randomized complete block design. Disease was initiated by infiltrating 2 to 3 lower true leaves of a single plant in the center of each plot with a 10^6 cfu/ml bacterial suspension. In 2012, a single copper-tolerant, streptomycin-sensitive strain of *X. perforans* was used to prepare inoculum, while both trials in 2013 used a mixture of

6 copper-tolerant *X. perforans* strains, two which were also streptomycin resistant. In both fall trials, natural outbreaks of bacterial speck also occurred. Each BST program was applied weekly throughout the season. The center 10 plants in the center bed of each 3-bed plot were individually rated every 7 to 14 days for the severity of bacterial spot and speck based on the Horsfall-Barratt scale until the first harvest. The center 10 plants in each plot were hand harvested at least once, graded for market size, and also rated for the incidence of fruit with symptoms of bacterial spot and speck.

RESULTS AND DISCUSSION

For fall 2012, all programs that received streptomycin performed better than those equivalent programs without streptomycin, exhibiting reduced foliar symptoms of BST. Weekly applications of Cu-mancozeb alone or in two-way programs with non-copper alternatives resulted in significantly higher AUDPC values, higher fruit incidence of BST, and lower yields compared to equivalent programs based on either Actigard alone or in two-way programs with non-copper alternatives (Tables 1 & 2).

Results for spring 2013 were similar. However, since BST was initiated with a mixture of strains that included 2 streptomycin resistant strains, programs using streptomycin alone failed to control BST. Similar to fall 2012, Cu-mancozeb applied alone or in two-way programs with non-copper alternatives resulted in significantly higher AUDPC values and higher fruit incidence of BST compared to similar programs based on Actigard alone or in two-way programs with non-copper alternatives; although programs had no effect on yield (Tables 1 & 2).

For fall 2013, the same mixture of 6 strains was used to initiate BST. However, unlike spring 2013, programs receiving streptomycin still performed well relative to equivalent programs without streptomycin. Once again, programs containing Cu-mancozeb applied alone or in two-way programs with non-copper alternatives resulted in significantly higher disease levels based on AUDPC values and lower yields compared to equivalent programs based on either Actigard alone or in two-way programs with non-copper alternatives (Tables 1 & 2).

Overall, the standard Cu-mancozeb program had the lowest yields in all three trials. In fall 2012, yields in the Cu-mancozeb treatment were statistically less than the non-treated control. In addition, the incidence of fruit with symptoms of bacterial spot and speck were highest in the Cu-mancozeb program, consistent with foliar ratings (data not shown). The results from the three field trials not only demonstrate the ineffectiveness of Cu-mancozeb programs in the presence of copper-tolerant *X. perforans* strains, but also the ability of the Cu-mancozeb to compromise the efficacy of non-copper alternatives when included in a program.

Programs containing the relatively inexpensive antibiotic streptomycin appeared to give the best level of disease control and improved yields, except when efficacy was compromised by insensitive strains; like what occurred during the spring 2013 trial. It should be emphasized that streptomycin is not labeled for field use, but was included to test the efficacy of rotational programs with other products for resistance management. In fact, several of the three-way BST programs consisting of Actigard, Regalia, streptomycin, kasugamycin, and quinoxyfen performed well over all seasons even in the presence of streptomycin insensitive strains and either maintained or improved tomato yields. Unfortunately, these three-way BST programs are quite costly ranging from $388 to $625 per a treated acre.

The best value for managing BST, based on current product availability, appeared to be Actigard alone. Although the Actigard program did not statistically improve tomato yields compared to the non-treated control, it did significantly reduce the incidence of diseased fruit in both fall seasons, comparable to the streptomycin programs (data not shown). The performance of the Actigard program was in line with previous findings (Huang et al. 2012).

REFERENCES:

Horvath, D.M., R.E. Stall, J.B. Jones, M.H. Pauly, G.E. Vallad, and J.W. Scott. 2012. GM tomatoes provide an effective solution for the control of bacterial spot disease and an alternative to crop protection compounds. PLoS One 7:e42036. doi: 10.1371/journal.pone.0042036.

Table 1. Effect of treatments on the severity of bacterial spot and speck based differences in the final severity (%) prior to harvest (DSf) and throughout the season based on the area under disease progress curve (AUDPC).

	Bacterial Spot Severity:					
	Fall 2012: 'Charger'		Spring 2013: 'HM1823'		Fall 2013: 'Charger'	
Chemical (apps.)[z]	DS_f(%)[y]	AUDPC[x]	DS_f(%)	AUDPC	DS_f(%)	AUDPC
Cu-Manc (1-10)	55.9bcd	1753a	97.0ab	2202ab	62.9ab	630a
Strep (1,3,5,7,9)	39.3f	929e	95.5bc	2105a-d	45.3def	439hij
Kas (1,3,5,7,9)	56.9abc	1423c	95.5bc	1934c-f	67.3a	562bcd
Quintec (1,3,5,7,9)	41.1f	1202d	95.5bc	1880d-f	58.7b	515def
Act (1-10)	50.4e	1247d	96.2ab	1920c-f	46.3def	431ijk
Non-treated Control	58.5ab	1486bc	97.0ab	2308a	46.5def	472fgh
Cu-Manc (1-10); Strep (1,3,5,7,9)	52.6cde	1551b	95.5bc	2069a-d	46.5def	524cde
Cu-Manc (1-10); Kas (1,3,5,7,9)	52.3de	1715a	95.5bc	2090a-d	64.2ab	567bc
Cu-Manc (1-10); Quin (1,3,5,7,9)	61.2a	1736a	96.2ab	1943b-f	56.9bc	577ab
Act (1-10); Strep (1,3,5,7,9)	30.5g	811f	94.4cd	1674gh	43.1f	397kl
Act (1-10); Kas (1,3,5,7,9)	46.4e	1214d	95.5bc	1951b-f	50.5cde	484efg
Act (1-10); Quin (1,3,5,7,9)	58.7ab	1428c	95.5bc	1919c-f	42.3f	456g-j
Cu-Manc (3,6,9); Strep (1,4,7); Kas (2,5,8)	56.0bcd	1439bc	95.5bc	1965b-e	64.4ab	518de
Act (1-10); Strep (1,3,5,7); Kas (2,4,6,8)	31.9g	792f	95.5bc	1862d-f	30.5g	356m
Act (1-10); Cu-Manc (3,6,9); Strep (1,4,7); Kas (2,5,8)	44.2ef	1248d	94.4cd	2007bcd	49.6de	457ghi
Act (1-10); Strep (1,4,7); Kas (2,5,8); Quin (3,6,9)	--	--	95.5bc	1731e-h	42.5f	393l
Act (1-10); Strep (2,5,8); Kas (2,5,8); Quin (2,5,8)	--	--	93.2d	1750e-h	51.1cd	459ghi
Act (1-10); Strep (2,4,6,8); Kas (2,6,10); Quin (4,8)	--	--	94.4cd	1596h	44.8ef	417jkl
Regalia (1-10); Strep (1,4,7); Kas (2,5,8); Quin (3,6,9)	--	--	95.5bc	1718f-h	41.4f	473fgh
Regalia (1-10); Cu-Manc (1-10)	--	--	97.7a	2173abc	63.5ab	543bcd
Actinovate (1-10); Cu-Manc (1-10)	--	--	--	--	60.1ab	530bcd
P =	< 0.0001	< 0.0001	0.0067	< 0.0001	< 0.0001	< 0.0001

[z] Cu-Manc = copper sulfate (Cuprofix Ultra 40D, 2.5 lb/A) + mancozeb (Penncozeb 75DF, 1.25 lb/A); Strep = streptomycin (Firewall, 16 oz/A); Kas = kasugamycin (Kasumin 2L, 64 floz/A); Quin = quinoxyfen (Quintec, 6 floz/A); Act = acibenzolar-*S*-methyl (Actigard, 0.5 oz/A); Regalia = extract of *Reynoutria sachalinensis* (Regalia, 2.5 qt/A); and Actinovate = *Streptomyces lydicus* WYEC 108 (Actinovate AG, 12 oz/A). Apps. refers to the timing of applications in weeks after planting.

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

Vallad, G.E., S. Timilsina, H. Adkison, N. Potnis, G. Minsavage, J. Jones, and E. Goss. 2013. A recent survey of Xanthomonads causing bacterial spot of tomato in Florida provides insights into management strategies. Proceedings from the 2013 Florida Tomato Institute, Naples, FL.

Table 2. Effect of treatments on the severity of bacterial spot and speck based differences the yield of extra (Ex.) large and total fruit.

	Tomato Yield (tons/A)					
	Fall 2012: 'Charger'		Spring 2013: 'HM1823'		Fall 2013: 'Charger'	
Chemical (apps.)[z]	**Ex. Large**	**Total**	**Ex. Large**	**Total**	**Ex. Large**	**Total**
Cu-Manc (1-10)	15.0c	34.3e	12.8	17.2	13.5c-f	21.5
Strep (1,3,5,7,9)	24.3a	48.5a	15.1	21.3	15.1a-e	21.9
Kas (1,3,5,7,9)	17.7bc	41.4bc	13.2	19.4	11.5f	19.4
Quintec (1,3,5,7,9)	19.3bc	41.8bc	16.3	22.2	15.4a-e	22.8
Act (1-10)	19.1bc	41.1bc	15.7	21.0	15.6a-e	21.7
Non-treated Control	21.7ab	43.5b	14.2	20.1	14.7a-f	21.6
Cu-Manc (1-10); Strep (1,3,5,7,9)	17.0bc	38.8cd	15.6	20.7	14.4a-f	23.4
Cu-Manc (1-10); Kas (1,3,5,7,9)	15.3c	36.5de	16.1	21.1	12.7def	21.6
Cu-Manc (1-10); Quin (1,3,5,7,9)	15.3c	38.2cde	16.3	21.2	13.3def	20.8
Act (1-10); Strep (1,3,5,7,9)	19.7abc	44.1b	16.0	22.2	17.6ab	25.1
Act (1-10); Kas (1,3,5,7,9)	19.7abc	41.2bc	15.8	21.9	14.2b-f	20.3
Act (1-10); Quin (1,3,5,7,9)	17.8bc	43.6b	16.0	22.3	14.5a-f	21.5
Cu-Manc (3,6,9); Strep (1,4,7); Kas (2,5,8)	19.1bc	40.9bcd	16.3	23.3	15.4a-e	22.0
Act (1-10); Strep (1,3,5,7); Kas (2,4,6,8)	19.2bc	43.6b	15.3	20.7	18.6a	26.6
Act (1-10); Cu-Manc (3,6,9); Strep (1,4,7); Kas (2,5,8)	19.0bc	40.9bcd	15.7	20.7	17.2abc	25.6
Act (1-10); Strep (1,4,7); Kas (2,5,8); Quin (3,6,9)	--	--	16.2	21.4	16.2a-d	24.0
Act (1-10); Strep (2,5,8); Kas (2,5,8); Quin (2,5,8)	--	--	14.9	20.7	17.2abc	25.1
Act (1-10); Strep (2,4,6,8); Kas (2,6,10); Quin (4,8)	--	--	16.4	21.7	17.5ab	25.6
Regalia (1-10); Strep (1,4,7); Kas (2,5,8); Quin (3,6,9)	--	--	14.7	20.7	12.4ef	21.6
Regalia (1-10); Cu-Manc (1-10)	--	--	15.2	20.2	14.5a-f	22.8
Actinovate (1-10); Cu-Manc (1-10)	--	--	--	--	13.4c-f	22.2
P =	0.0004	< 0.0001	0.6969	0.6949	0.0225	0.1321

[z] Cu-Manc = copper sulfate (Cuprofix Ultra 40D, 2.5 lb/A) + mancozeb (Penncozeb 75DF, 1.25 lb/A); Strep = streptomycin (Firewall, 16 oz/A); Kas = kasugamycin (Kasumin 2L, 64 floz/A); Quin = quinoxyfen (Quintec, 6 floz/A); Act = acibenzolar-*S*-methyl (Actigard, 0.5 oz/A); Regalia = extract of *Reynoutria sachalinensis* (Regalia, 2.5 qt/A); and Actinovate = *Streptomyces lydicus* WYEC 108 (Actinovate AG, 12 oz/A). Apps. refers to the timing of applications in weeks after planting.

Susceptibility of *Bemisia tabaci* to Group 4 Insecticides

Hugh A. Smith and Curtis A. Nagle

University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, hughasmith@ufl.edu

ABSTRACT

Populations of the silverleaf whitefly, *Bemisia tabaci* biotype B, are being collected from tomato fields in central and south Florida and tested for susceptibility to three neonicotinoid and one butenolide insecticide at the University of Florida's Gulf Coast Research and Education Center. Adult whitefly are tested for susceptibility to imidacloprid (Admire), thiamethoxam (Platinum), dinotefuran (Venom) and flupyridifurone (Sivanto) using a systemic cotton petiole bioassay. Each trial consists of four pesticides at six active ingredient concentrations (0.0, 1.2, 4.7, 18.8, 75.0, and 300 ppm) derived by serial dilution. To date, four field populations have been compared to a susceptible laboratory colony. There is considerable variability among populations tested with regard to susceptibility to Admire, Platinum, Venom and Sivanto. Data are presented for mortality 72 hrs after treatment. The highest LC_{50}s measured were for Admire and ranged from 7.84 to 23.56. The lowest LC_{50}s measured for a registered insecticide were for Venom, ranging from 0.18 to 1.05. LC_{50}s for Platinum ranged from 3.31 to 11.80. LC_{50}s for Sivanto ranged from 0.12 to 0.48. Resistance ratios for Admire ranged from 8.0 for a Balm population to 24.3 for a population near Vero Beach. Resistance ratios for Platinum ranged from 13.8 for a Balm population to 49 for a population from Homestead. Resistance ratios for Venom ranged from 1.2 to 7.5. For each site, the ranking of potency from least to most potent was Admire, Platinum, Venom, Sivanto.

BACKGROUND

Tomato yellow leaf curl virus (TYLCV) is a geminivirus that is persistently vectored by the silverleaf whitefly, *Bemisia tabaci* biotype B. TYLCV can cause up to 100% loss of the crop. Growers manage TYLCV by destroying crop residues and other virus reservoirs, by using reflective mulches and virus-resistant tomato varieties when appropriate (Schuster et al. 2008). Insecticide treatments are a key component of managing silverleaf whitefly and TYLCV. *Bemisia tabaci* has demonstrated the ability to develop resistance to many types of insecticide. Globally, the silverleaf whitefly is ranked among the top ten arthropod pests with regard to documented insecticide resistance (FAO 2012).

Since the early 1990s, when imidacloprid (Admire) first became available to Florida tomato growers, the neonicotinoid group of insecticides has played a central role in management of whitefly viruses. Schuster et al. (2009) documented widespread but uneven tolerance of the silverleaf whitefly to imidacloprid and thiamethoxam (Platinum) in Florida's tomato growing regions. Dinotefuran (Venom, Scorpion) received EPA registration in 2004. Periodic monitoring of whitefly susceptibility to neonicotinoids is necessary to inform growers and crop protection professionals regarding shifts in efficacy. Among new materials nearing registration for management of whitefly and TYLCV is flupyradifurone (Sivanto), a butenolide insecticide from Bayer Crop Science. Sivanto has a similar mode of action to neonicotinoids. It is described as comparatively safe for pollinators. Bayer expects to have Florida registrations for Sivanto in 2015. In order to monitor the efficacy of Sivanto over time, it is necessary to collect baseline susceptibility data on the insecticide before it is released.

A standard metric for evaluating and comparing the efficacy of insecticides is the LC_{50}, which is the concentration of an insecticide needed to kill 50% of test insects. LC_{50}s are measured in milligrams active ingredient per liter, which can also be expressed as parts per million (ppm). LC_{50}s are used to calculate the resistance ratio, which is the LC_{50} of a field population divided by the LC_{50} of a laboratory colony known to be susceptible to the insecticide being tested. LC_{50}s can also be used to calculate Relative Potency Estimates, which indicate how many times more effective one active ingredient is than another.

Table 1. LC_{50}s (ppm of ai.) for ***Bemisia tabaci*** populations after 72 hours of exposure to group 4 insecticides. Jan.-June, 2014.

	Insecticide Trade Name			
	Admire	**Sivanto**	**Platinum**	**Venom**
B. tabaci **population**	**----------------ppm of active ingredient ------------**			
Lab colony (susceptible)	0.97	0.03	0.24	0.14
Balm 1	7.84	0.21	3.31	0.61
Ruskin 1	14.86	0.34	8.62	0.51
Vero 1	23.56	0.12	3.63	0.18
Homestead 1	11.90	0.49	11.81	1.06

Table 2. Resistance ratios of ***Bemisia tabaci*** populations (compared to the lab colony) for group 4 insecticides after 72 hours of exposure. Jan.-June, 2014.

	Insecticide Trade Name			
B. tabaci **population**	**Admire**	**Sivanto**	**Platinum**	**Venom**
Balm 1	8.0	7.0	13.8	4.4
Ruskin 1	15.3	11.3	35.9	3.6
Vero 1	24.3	4.0	15.1	1.3
Homestead 1	12.2	16.3	49.2	7.6

Table 3. Relative median potency estimates of group 4 insecticides on ***Bemisia tabaci*** populations after 72 hours of exposure. Jan.-June, 2014.

Insecticide A	**Sivanto**	**Platinum**	**Venom**	**Sivanto**	**Venom**	**Sivanto**
Insecticide B	**Admire**	**Admire**	**Admire**	**Platinum**	**Platinum**	**Venom**
B. tabaci **population**	**No. of times more potent insecticide A is than insecticide B.**					
Lab colony (susceptible)	38.4	4.0	7.1	9.5	1.8	5.4
Balm 1	36.8	2.4	12.9	15.5	5.5	2.9
Ruskin 1	43.9	1.7	29.1	25.5	16.9	1.5
Vero 1	198.7	6.5	134.4	30.6	20.7	1.5
Homestead 1	24.5	1.0	11.2	24.3	11.2	2.2

MATERIALS AND METHODS

Each trial consisted of four pesticides at six active ingredient concentrations (0.0, 1.2, 4.7, 18.8, 75.0, and 300 ppm) derived by serial dilution. All treatments were replicated four times. Populations of whitefly were established from end of season commercial tomato fields. Lanai tomatoes on which field populations were established were confined in cages in growth rooms at GCREC with cotton plants. F_2 and F_3 populations were allowed to establish on cotton, and these are the populations that were tested.

Phase one: Cotton leaves from 3 wk old plants were removed and their petioles immersed in solutions in individual 50 ml. Erlenmeyer flasks and placed evenly on a lab bench at about 73° F for about 24 hours, with a fan running to provide air circulation.

Phase two: Cotton leaves were removed from solutions, petioles trimmed to 1/8th to ¼ inch and placed in standard, 4 inch diameter glass Petri dishes. Over about 2 hours, all experimental units were prepared as follows: 12-14 whitefly adults from the test population were aspirated into a glass medicine dropper vial, chilled in a freezer for 1.5 min. and deposited onto the leaf inside the Petri dish. The 24 Petri dishes of a replicate were stacked in four layers (pesticides) of six dishes (concentrations) each within a clear plastic storage box.

Data were recorded after 24, 48, and 72 hours of exposure, as the number of 'live', 'moribund' (having movement but not looking normal) or 'dead' whiteflies in a dish by removing the dishes from a box and examining them using a dissecting microscope. The 72 hour data were also compiled by taking the dishes apart and poking adults which were in doubt as to their status. Probit analysis was carried out using SPSS version 22 software.

RESULTS

Population testing began in January 2014. Analysis of four field colonies and the susceptible colony have been carried out as of June 30. Testing of additional populations is ongoing.

The data presented are for mortality 72 hours after treatment. LC_{50}s are listed in Table 1. The highest LC_{50}s measured were for Admire and ranged from 7.84 to 23.56. The lowest LC_{50}s measured for a registered insecticide were for Venom, ranging from 0.18 to 1.05. LC_{50}s for Platinum ranged from 3.31 to 11.80. LC_{50}s for Sivanto ranged from 0.12 to 0.48.

Resistance ratios are presented in Table 2. Resistance ratios for Admire ranged from 8.0 for a Balm population to 24.3 for a population near Vero Beach. Resistance ratios for Platinum ranged from 13.8 for a Balm population to 49 for a population from Homestead. Resistance ratios for Venom ranged from 1.2 to 7.5. There is considerable variability among populations tested with regard to susceptibility to Admire, Platinum, Venom and Sivanto. Resistance ratios calculated for Admire and Platinum are within the range of values calculated by Schuster et al. (2009), who presented results based on 24 hours after treatment. Data for Sivanto are provided for comparative purposes. Sivanto is not yet available for use.

The relative potencies of Sivanto, Platinum and Venom compared to Admire are presented by population in Table 3. For each site, the ranking of potency from least to most potent was Admire, Platinum, Venom, Sivanto.

REFERENCES

FAO 2012. Guidelines on prevention and management of pesticide resistance. http://www.eppo.int/PPPRODUCTS/resistance/FAO_RMG_Sept_12.pdf

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

Schuster, D. J., R. S. Mann, M. Toapanta, R. Cordero, S. Thompson, S. Cyman, A. Shurtleff, and R. F. Morris II. 2009. Monitoring neonicotinoid resistance in biotype B of *Bemisia tabaci* in Florida. Pest Management Science. www.interscience.wiley.com/journal/ps.

A Feasibility Study of Using Surfactant to Increase Nutrient-Use Efficiency for Tomato Production

Guodong Liu[1], Monica Ozores-Hampton[2], Eugene McAvoy[3], Ben Hogue[1], and Crystal Snodgrass[4]
[1] University of Florida/IFAS, Horticultural Sciences Department, Gainesville, FL.
[2] University of Florida/IFAS, Southwest Florida Research and Education Center, Immokalee, FL.
[3] University of Florida/IFAS, Hendry County Extension, LaBelle, FL.
[4] University of Florida/IFAS, Manatee County Extension, 1303 17 St W, Palmetto, FL, guodong@ufl.edu

INTRODUCTION

Most soils used for commercial crop production in Florida are sandy in nature. These sandy soils are often water repellent once they are dry. Water-repellent soils are unable to effectively retain water, which may simply pool on the surface or move down preferred pathways, leaving large volumes of soil dry even when a large volume of water is applied. Thus, managing water and nutrients in sandy soils is often challenging. This water-repellency, characteristic of sandy soils, can lower the profitability of commercial tomato production.

The properties of the outer surface of the organic coatings on soil particles determine water repellency. Amphipathic compounds are key constituents of the organic components of the outer layer of soil particles. These compounds have both polar and nonpolar components—they attract water at one end and repel it at the other. There are a few possible mechanisms responsible for water repellency in sandy soils (Horne and McIntosh, 2003; Hallett, 2008): (1) in the wetted state, the amphipathic compounds usually have their polar (water-attracting) ends pointing outwards. (2) Under moist conditions, the functional groups in the organic compounds are ionized and water-loving. (3) However, these amphipathic compounds may present water-repellent ends on the soil particle surface when soil is dry. The soil then becomes water repellent. Water repellency can pose challenges to growers. These challenges include: (1) Rapid leaching of applied agrichemicals; (2) Water and nutrient availability; (3) Uneven distribution of nutrients and water; (4) High soil evaporation; (5) Runoff (6); Soil erosion and (7) Low productivity (Doerr and Thomas 2000; Wahl 2008; Hall 2009).

Water repellency in soils can be alleviated if a surfactant is applied. A surfactant is a *surf*ace-*act*ive *agent,* i.e., a wetting agent. It, in a small quantity, distinctly affects the surface characteristics of a system. A surfactant consists of a water-loving head group and a water-repellent tail, which is usually a long-chain hydrocarbon. It has an affinity for either oils or water and so acts as a wetting agent by introducing a degree of continuity between water and soil particles. A surfactant can be used to reduce the surface tension of a liquid, such as water, the interfacial tension between two liquids or that between a liquid and a solid, e.g., water and soil. This property allows a surfactant to be mixed or dispersed readily in water or other liquids. The reduction of the surface tension of water allows a surfactant to penetrate and wet soils more easily and evenly. Thus, a surfactant can promote the absorption and retention of moisture in soil.

As an amphipathic compound, a surfactant's chemical structural characteristics determine its compatibility to both hydrophilic and lipophilic materials in soil. Thus, surfactants can react with water-repellent soil particles and convert the water repellency making it more attractive to water. Therefore, surfactants can significantly improve sandy soil by enhancing the soil's water retention and nutrient-holding ability (Ghebru et al., 2007). A surfactant increases potato petiole nitrate nitrogen (NO_3-N) by 28.9% from 4.5 to 5.8 g/kg 75 days after emergence (Arriaga, Lowery, and Kelling, 2009). With surfactants, vegetable crops can obtain water and nutrients significantly more efficiently (Sarvaš 2003). These effects of surfactants on soil quality may enhance yield and profitability for commercial tomato production in sandy soils. Stocksorb 660 can hold 216 g water per 1 g of Stocksorb 660 and can form a polymer gel or a hydrogel after adsorbing water (Ghebru et al., 2007). A hydrogel is a network of polymer chains that is highly absorbent and can retain many times its weight in water. When applied with a fertilizer and incorporated into soil, the hydrogel and fertilizer in the soil solution remain in the root zone to be used by the plant. Hence, this material provides the dual benefit of a surfactant and enhanced water retention. The dual benefit may make Stocksorb 660 more effective than a simple surfactant.

MATERIALS & METHODS

This trial was conducted at Plant Science Research and Education Center, Citra, FL to investigate the effects of potassium polyacrylate (Stocksorb 660) on tomato (var. 'Phoenix') production. The randomized complete block design was used with three replications. Every plot had 12 tomato plants. Thirty lb/acre of Stocksorb 660 were mixed with N as urea, 160; P2O5 as triple super phosphate, 83 and K2O as muriate of potash, 250 lb/acre and applied pre-plant. The control received no Stocksorb 660 application. Fertilization and field practices were the same in both of the treatment and control. The maximum plant heights from ground to the plant top were measured using a ruler 8 weeks after planting. The stem diameters at 3 inches above ground were measured by using a Haglöf Aluminum Tree Calipers (Item#: 105042, Ben Meadows Company, Janesville, WI) on the same day when the plant heights were measured. Nutrient use efficiency (NUE) was defined as follows:

$$NUE(b\ /b\ ) = \frac{Y_f - Y_0}{F}$$

Where TY_f and YT_0: tomato yield (lb/acre) with and without fertilization; F: fertilization rate (lb/acre) of N, P_2O_5, or K_2O.

Data were analyzed using one-way ANOVA method (SAS Institute, Cary, NC), and was considered significant at $p < 0.05$. After running the SAS program, the critical ranges ($LSD_{2,\ 0.05}$) of Duncan's Multiple Range Test were used to detect the difference significance between two means (Hubbard, 2001).

RESULTS AND DISCUSSION

The Stocksorb 660 treated plants were 15% greater in height and stem diameter than the control (Figure 1). In addition, Stocksorb 660 application produced significantly greater marketable tomato yields than the control (Figure 2). Similarly, the nutrient use efficiencies of the treatment were significantly greater than the control (Figure 3). The positive effects of Stocksorb 660 on tomato yield may have resulted from its very high water-retention capacity (Ghebru et al., 2007). Surfactant application may be an effective technology to optimize water use and crop yield and quality in sandy soils (Oostindie et al., 2012).

Trials with simple surfactants are planned for the future.

ACKNOWLEDGEMENTS

Evonic Industries provided Stocksorb 660.

FOR FURTHER READING

Arriaga, F. J., B. Lowery, K. A. Kelling. 2009. "Surfactant impact on nitrogen utilization and leaching in potatoes." *American Journal of Potato Research*. 86(5): 383-390.

Ghebru, M. G., E. S. duToit and J. M. Steyn. 2007. "Water and nutrient retention by Aquasoil® and Stockosorb® polymers." *South African Journal of Plant and Soil* 24(1): 32-36.

Hallett, P. D. 2008. "A brief overview of the causes, impacts and amelioration of soil water repellency: a review." *Soil and Water Research 3*(Special Issue 1): S21-S29.

Horne, D. J. and J. C. McIntosh. 2003. "Hydrophobic compounds in sands from New Zealand." In: *Soil Water Repellency: Occurrence, Consequences, and Amelioration* (eds. C.J. Ritsema and L.W. Dekker). ELSEVIER SCIENCE B.V. Amsterdam, The Netherlands. Pp. 25-36.

Hubbard MR, 2001. Statistical Quality Control for the Food Industry (2nd edition). Aspen Publishers, Inc, Caithersburg, MD, USA.

Oostindie, K., L. W. Dekker, J. G. Wesseling, C. J. Ritsema, and D. Moore. 2012. "Influence of a single soil surfactant application on potato ridge moisture dynamics and crop yield in a water repellent sandy soil." I. (ISHS) 938:341-346.

http://www.actahort.org/books/938/938_44.htm

Sarvaš, M. 2003. "Effect of desiccation on the root system of Norway spruce (Picea abies [L.] Karst.) seedlings and a possibility of using hydrogel STOCKOSORB® for its protection." *Journal of Forest Science* 49(11): 531-536.

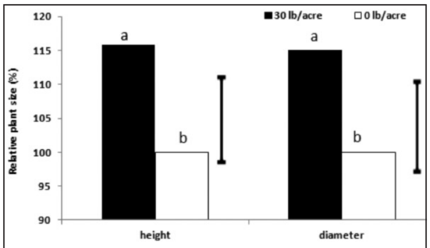


Figure 1. The treatment was significantly greater in both plant height and stem diameter than the control. The bars are the LSD values of plant heights and stem diameters, respectively. P < 0.10

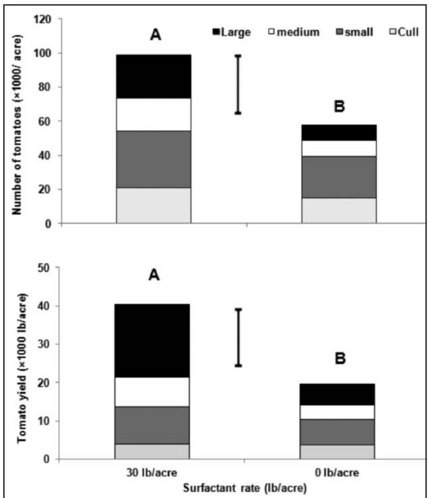


Figure 2. Differences in number of tomatoes and in tomato yield with and without applying surfactant. The bars are the LSD values of tomato yields and number of tomatoes, respectively. P < 0.05

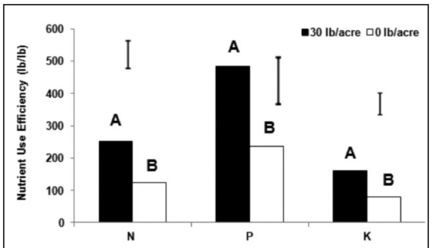


Figure 3. Yield differences nutrient use efficiency of tomatoes with and without applying surfactant. The bars are the LSD values of N, P_2O_5 and K_2O use efficiencies, respectively. P < 0.05

Pre-emergence Herbicides for Use in Tomato

Nathan S. Boyd[1] and P. Dittmar[2]

[1] University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL.
[2] University of Florida, Horticultural Sciences Department, Gainesville, FL, nsboyd@ufl.edu

INTRODUCTION

Purple and yellow nutsedge (*Cyperus rotundus* and *Cyperus esculentus*) are the worst weeds that occur in commercial tomato fields in Florida. They are especially problematic due to their ability to penetrate the plastic mulches used in plasticulture vegetable production systems. In fact, previous research in Georgia found that plastic mulches can promote purple nutsedge growth and in 16 weeks, yellow and purple nutsedge are capable of producing 66 and 365 tubers/plant (Webster 2005). Both species impact crop yield and quality with dense populations causing yield reductions up to 51% in tomato (Gilreath and Santos, 2004).

There are few nutsedge management options for vegetables due in part to the historical reliance on methyl bromide. However, several pre-emergence herbicides with activity on nutsedge such as Dual Magnum, Eptam, Sandea, and Reflex are registered for use in tomato in Florida. Dittmar (2013) reported that Reflex and Dual Magnum provided significant early season control of nutsedge but required post-transplant applications of Sandea to sustain adequate season-long control. Additional research is needed to identify a reliable nutsedge management plan for tomato.

MATERIALS AND METHODS

An experiment was conducted at the Gulf Coast Research and Education Center (GCREC) to evaluate crop tolerance and efficacy on purple nutsedge of multiple pre-emergence herbicides and tank mixes in tomato. The experiment was set up as a randomized complete block with four blocks and 18 treatments (Table 1). Raised beds (32 inch base and 8 inch height) on five foot centers were fumigated with 275 lbs of Pic-Clor 60 on January 15, 2014. Herbicides were applied on the same day following fumigation. Immediately after the herbicide application double drip tapes were placed offset 10 cm from each side of the bed center and buried 1.2 cm from the bed surface. All beds were covered with VIF plastic mulch. On February 18, 2014, tomato seedlings (CV. Charger and Florida47) were transplanted with 61 cm spacing February 18, 2014.

Tomato damage ratings were taken 2, 4, and 8 weeks after transplant using a 0-10 scale where 0 is no damage and 10 is complete death. The number of purple nutsedge shoots emerging through the plastic were counted weekly and the tomatoes were harvested on May 14 and June 5, 2014. Data was analyzed in SAS using Proc Mixed with block as the random factor and the repeated statement used for data collected on more than one time point. Varieties were analyzed separately.

RESULTS AND DISCUSSION

Eptam alone caused minor tomato damage to both varieties but caused much more serious damage when combined with Dual Magnum or Reflex (Table 2). Tomato yields tended to be lower where mixes containing Eptam were applied but were not always significantly lower than the untreated control. Eptam may be safe under LDPE mulches but is much more likely to cause damage under VIF mulches. The remaining herbicides or herbicide tank mixes were safe for use in tomato.

In the experiment where the Charger variety was grown, Eptam, Sandea, Sandea+League, Eptam+Dual, Reflex+Dual, and Reflex+Dual+Devrinol tended to provide the greatest reduction in purple nutsedge density (Table 3). In the experiment where Florida47 was grown Eptam, Sandea, Eptam+Dual tended to provide the greatest reduction in purple nutsedge density. Given the damage level observed with Eptam, we conclude that pre-emergence applications or tank mixes of Dual Magnum, Sandea, and Reflex should be further evaluated to identify the optimal herbicide regime for purple nutsedge.

Table 1. Herbicide treatments applied under the plastic on January 15 following fumigation at the Gulf Coast Research and Education Center.

Herbicide Treatment	Rate (per acre)
Untreated Control	-
Devrinol DF-XT	4.0 lb
Dual Magnum	1.0 lb
Eptam	3.0 pt.
Goal	1.0 lb
League	4.0 oz
Matrix	4.0 oz
Reflex	1.5 pt
Sandea	1.0 oz
Sandea + Dual Magnum	1.0 oz + 1.0 lb
Matrix + Dual Magnum	4.0 oz + 1.0 lb
Eptam + Dual Magnum	3.0 pt + 1.0 lb
Reflex + Dual Magnum	1.5 pt + 1.0 lb
Devrinol DF-XT + Dual Magnum	4.0 lb + 1.0 lb
Eptam + Dual Magnum + Devrinol DF-XT	3.0 pt + 1.0 lb + 4.0 lb
Reflex + Dual Magnum + Devrinol DF-XT	1.5 pt + 1.0 lb + 4.0 lb
Eptam + Reflex	3.0 pt + 1.5 pt.
Eptam + Reflex + Dual Magnum	3.0 pt + 1.5 pt. +1.0 lb

Table 2. Tomato damage and yield with different pre-emergence herbicides applied under a plastic mulch immediately after fumigation at the Gulf Coast Research and Education Center in the fall of 2014.

	Tomato Damage[1]		Tomato Yield	
	Charger	FL47	Charger	FL47
Herbicide			-----metric ton/ha-----	
Untreated Control	0d[2]	0d	47.8bcdef	56.6ab
Devrinol	0d	0d	62.4abcd	52.6ab
Dual	1cd	0d	59.5abcde	56.2ab
Eptam	2bc	2c	43.5def	52.7ab
Goal	0d	0d	66.0abc	50.2abc
Matrix	1cd	0d	50.7bcdef	53.5ab
Reflex	0de	1d	64.6abc	53.3ab
Sandea	0d	0d	60.8abcde	60.8a
League	0d	0d	59.1abcdef	57.4ab
Sandea + Dual	0d	1d	60.0abcde	51.0abc
Matrix + Dual	1cd	0d	67.9ab	56.9ab
Eptam + Dual	6a	4b	45.7cdef	37.3abc
Reflex + Dual	1cd	1d	52.8bcdef	51.9abc
Devrinol + Dual	1cd	0d	61.4abcde	55.0ab
Eptam + Dual + Devrinol	5a	5b	42.4ef	24.7bc
Reflex + Dual+ Devrinol	1cd	1d	75.8a	51.2abc
Eptam + Reflex	6a	7a	39.3f	26.1abc
Eptam + Reflex	3b	6a	49.4bcdef	16.4c

[1] Tomato was rated on a 0-10 scale where 0 is no damage and 10 is complete death.
[2] Means within columns followed by different letters are significantly different at $p<0.05$.

A range of additional grass and broadleaf weeds commonly emerge in planting holes in tomato and can hinder tomato growth and yield. Inadequate broadleaf and grass emergence occurred in this experiment to evaluate efficacy but based on authors experience and information contained within herbicide labels we have listed susceptibility of some of the most common weed species to registered herbicides (Table 4). Pre-emergence herbicide selection should be based upon the known historical occurrence of problem weed species within a given field.

ACKNOWLEDGMENTS

This research would not have been possible without the financial support of the Southern Integrated Pest Management Center and the hard work of Julie Franklin, Amy Hays, and Mike Sweat.

REFERENCES

Dittmar, P. J. 2014. Weed Control Strategies in Tomato. The Florida Tomato Proceedings. Pg. 24. http://swfrec.ifas.ufl.edu/docs/pdf/veg-hort/tomato-institute/proceedings/ti13_proceedings.pdf. Accessed June 2014.

Webster, T. M. 2005. Mulch type affects growth and tuber production of yellow nutsedge (*Cyperus esculentus*) and purple nutsedge (*Cyperus rotundus*). Weed Sci. 53:834-838.

Gilreath, J. P. and Santos, B. M. 2004. Methyl bromide alternatives for weed and soilborne disease management in tomato (*Lycopersicon esculentum*). Crop Protection 23:1193-1198.

Table3. Nutsedgecountsfollowingapplicationofpre-emergenceherbicidesappliedunderaplasticmulchimmediatelyafterfumigationattheGulfCoastResearchandEducationCenterinthefallof2014.

	NutsedgeCounts	
	Charger	FL47
Herbicide	---------#/m²----------	
UntreatedControl	6.7ab[1]	2.7g
Devrinol	5.1bcdef	6.9bcde
Dual	3.9bcde	14.6a
Eptam	4.5bcd	2.9g
Goal	7.0abc	6.5def
Matrix	6.3abc	6.4cdef
Reflex	4.8bcd	6.8def
Sandea	0.6gh	3.9efg
League	9.3a	10.5ab
Sandea+Dual	2.9cdefg	5.6def
Matrix+Dual	2.5bcdef	7.8cdef
Eptam+Dual	0.7h	2.8g
Reflex+Dual	2.3defg	12.3abc
Devrinol+Dual	2.0defg	8.4bcd
Eptam+Dual+Devrinol	2.1defgh	5.2defg
Reflex+Dual+Devrinol	1.5efgh	6.0fg
Eptam+Reflex	2.4fgh	54.5defg
Eptam+Reflex	2.6defg	5.7defg

[1] Means within columns followed by different letters are significantly different at p<0.05.

Table 4. Efficacy of various pre-emergence herbicides on common weed species in tomato fields. It is important to follow all label guidelines.

Weed Species	Devrinol DF-XT	Dual Magnum	Eptam	Goal	Matrix	Prowl	Reflex	Sandea
Grasses and Sedges								
Crabgrass	S[1]	S	S	SD	-	S	SD	-
Crowsfootgrass	-	-	-	S	-	S	-	-
Goosegrass	S	S	S	S		S	SD	-
Purple Nutsedge	-	SD	SD	-	-	-	SD	S
Yellow Nutsedge	-	SD	S	-	SD	-	SD	S
Broadleaf Weeds								
Eclipta	-	SD	S	S	S	-	S	S
Evening primrose	S	S	S	S	S	S	-	S
Filaree, redstem	-	-	-	S	-	-	-	-
Lambsquarters	S	S	S	S	SD	S	S	S
Nightshade, American black	-	-	S	S	SD	-	S	S
Purslane, Common	S	SD	S	S	S	S	S	SD
Pusley, Florida	S	S	S	S	-	S	-	SD
Amaranthus (pigweeds)	S	S	S	S	S	S	S	S

[1] The letter S represents 'susceptible' and 'SD' represents suppressed.

Tomato Varieties for Florida

Eugene McAvoy[1] and Monica Ozores-Hampton[2]

[1]Hendry County Extension Service, LaBelle, FL. [2]University of Florida/IFAS, SWFREC, Immokalee, FL, gmcavoy@ufl.edu

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

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

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

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

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

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

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

CURRENT VARIETY SITUATION

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

TOMATO VARIETIES FOR COMMERCIAL PRODUCTION

The following varieties are currently

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

LARGE FRUITED VARIETIES

1. LARGE FRUITED AND BEEFSTAKE TYPES

Amelia. Main season. Determinate vigorous, jointed hybrid. Fruit are firm and aromatic suitable for green or vine ripe. Good crack resistance. Resistance: Fusarium wilt (races 1, 2, and 3), Verticillium wilt (race 1), and Root-knot nematode. Intermediate resistance: Tomato spotted wilt and Gray leaf spot.

Bella Rosa. Midseason. Determinate. "Hot set" variety with good flavor. Medium to tall vine. Large to extra-large, deep globed shaped fruit with firm, uniform green fruits well suited for mature green or vine-ripe production. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), and Verticillium wilt (race 1). Intermediate resistance: Tomato spotted wilt and Gray leaf spot.

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

BHN 730. Fall through winter. Determinate. Intended for mature green production. Strong bush that produces well even on poor soils and smooth fruit. Resistance: Fusarium wilt (races 1 and 2), Fusarium crown rot, Verticillium wilt (race 1), and Bacterial speck.

BHN 975. Early fall. Hot set tomato for early fall mature green production in Florida. Strong vine and smooth large fruit. Resistance: Fusarium wilt (races 1 and 2), Fusarium crown rot, and Verticillium wilt (race 1).

Charger. Midseason. Determinate. Suited for fall and early summer production. Vigorous plant with good vine cover. Extra-large, smooth, deep oblate fruit with excellent firmness, color and good flavor. Resistance: Alternaria stem canker, Fusarium wilt (races 1, 2, and 3), and Verticillium wilt (race 1). Intermediate resistance: Gray leaf spot and Tomato yellow leaf curl virus.

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

Florida 47. Late midseason. Determinate, jointed hybrid. Uniform green, globe shaped fruit. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), and Gray leaf spot. (Note growers are moving away from Florida 47 as improved varieties become available, and it is no longer the predominate variety in the industry).

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

HM 1823. Early season. Determinate. Round tomato with strong plant habit. Good fruit cover deep, smooth, globe-shaped fruit with high yield potential and excellent size, color, and firmness. Resistance: Fusarium wilt (races 1 and 2), Fusarium crown rot, and Verticillium wilt (race 1). Intermediate resistance: Gray leaf spot.

HM 8849 CR. Early season. Determinate. Strong plant and good leaf cover. Fruit extra-large, smooth and slightly flattened globe shape. Resistance: Fusarium wilt (races 1 and 2), Fusarium crown and root rot, Verticillium wilt (race 1), and Gray leaf spot.

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

Quincy. Full season for North Florida. Determinate. Large to extra-large, excellent quality, firm, deep oblate shaped fruit, and uniformly colored. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), Tomato spotted wilt, and Gray leaf spot.

Raceway (STM9203). Main season. Determinate. Vigorous with good vine cover, suited for light pruning. Mostly extra-large, smooth, deep oblate fruit with great firmness and color. Gassing and vine ripe. Resistance: Alternaria stem canker, Fusarium crown and root rot, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1). Intermediate resistance: Gray leaf spot.

Rally. Midseason. Determinate. Large, very smooth, globe shaped fruit with excellent firmness. Excellent quality fruit with good flavor and color for the premium markets. Vigorous with good vine cover, suited for light pruning. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Fusarium crown and root rot, Verticillium wilt (race 1) and Tomato mosaic (races 0, 1, and 2). Intermediate resistance: Gray leaf spot and Tomato yellow leaf curl.

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

Redline. Main season. Determinate. Spring, tall plant with good cover. Good fruit quality for vine ripe or mature green production. Resistance: Fusarium wilt (races 1, 2, and 3), Verticillium wilt (race 1), Tomato spotted wilt, and Gray leaf spot.

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

RidgeRunner. Medium. Determinate. Bush for the mature green market. Tall plant that performs best in warm season conditions. Resistance: Fusarium wilt (races 1 and 2), Fusarium Crown Rot, Verticillium (Race 1), and Tomato yellow leaf curl.

Rocky Top. Midseason. Determinate. 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: Fusarium wilt (races 1, 2, and 3), Verticillium wilt (race 1), and Gray leaf spot.

Sanibel. Main season. Determinate. Large, firm, smooth fruit with light green shoulder and a tight blossom end. Used widely in Homestead. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), Root knot nematodes, and Gray leaf spot.

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

Security 28. Early season. Determinate. Plant with a medium vine and good leaf cover adapted to different growing conditions and produces extra-large, firm, round fruit. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), Gray leaf spot. Intermediate resistance: Tomato yellow leaf curl.

SevenTY III. Midseason. Determinate. Variety is best for spring production. Vigorous bush with good plant cover. It has good gray wall tolerance. Resistance: Fusarium wilt (races 1, 2, and 3) and Verticillium wilt (Race 1). Intermediate resistance: Tomato yellow leaf curl.

Solar Fire. Early season. Determinate, jointed hybrid. Plant has good fruit setting ability in high temperatures. Fruit are large, flat-round, smooth, and firm, with light green shoulder. Blossom scars are smooth. Resistance: Fusarium wilt (races 1, 2, and 3) and Verticillium wilt (race 1). Intermediate resistance: Gray leaf spot.

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

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

Tasti-Lee. Midseason. Determinate, jointed hybrid. Fruit are uniform green with a high lycopene content and deep red interior color due to the crimson gene. Targeted at the premium tomato market with moderate heat-tolerance. Resistance: Fusarium wilt (races 1, 2, and 3), Verticillium wilt (race 1), and Gray leaf spot.

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

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

Volante. Midseason. Determinate. "Hot set" variety with medium to tall vine. Fruit are extra-large and large, deep globed shaped with very firm, uniform green fruits well suited for mature green or vine-ripe production. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1). Intermediate resistance: Tomato spotted wilt and Gray leaf spot.

2. PLUM TYPE VARIETIES

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

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

Monticello. Early-medium. Determinate. Uniform fruit size and a unique blocky shape with an improved disease resistance package for North Florida. Large firm fruit with good interior quality and small blossom end scar. Resistance: Fusarium wilt (races 1 and 2), Bacterial speck, Verticillum wilt (race 1), Root know nematode, Tomato spotted wilt virus, and Gray leaf spot.

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 great firmness at the red stage. Resistance: Alternaria stem canker, Fusarium wilt (race 1), Verticillium wilt (race 1), Tomato spotted wilt, and Gray leaf spot.

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

Sunoma. Main season. Determinate. Plant maintains fruit size through multiple harvests and has good fruit cover. Fruit are medium-large, elongated and cylindrical. Resistance: Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), Root-knot nematodes, Tomato mosaic, and Gray leaf spot. Intermediate resistance: Bacterial speck (race 0).

Supremo. Midseason. Determinate. Mid compact plant with early maturity. Uniform predominately extra-large fruit. Suited for concentrated harvests for vine ripe and mature green markets. Resistance: Fusarium wilt (races 1, 2 and 3), Bacterial speck (race 0), Verticillium wilt (race 1), and Root-knot nematode. Intermediate resistance: Tomato spotted wilt.

Tachi. Midseason. Determinate. Mid compact plant with classic saladette shape. Uniform predominately extra-large fruit. Wide adaptability and suited for concentrated harvests for vine ripe and mature green markets. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), and Root-knot nematode. Intermediate resistance: Tomato spotted wilt.

3. CHERRY TYPE VARIETIES

BHN 268. Early to midseason. Determinate. Medium to tall bush with high yields an extra firm cherry tomato that holds, packs and ships well. Resistance: Fusarium wilt (race 1) and Verticillium wilt (race 1).

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

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

Sweet Treats. Early main season. Indeterminate. Strong, vigorous plant with wide adaptability. Deep pink, firm, globe shaped fruit with outstanding flavor potential. Strong against cracking. Resistance: Fusarium wilt (race 1 and 2), Leaf mold (races A-E), and Tomato mosaic (races 0 and 1). Intermediate resistance: Fusarium crown and root rot and Gray leaf spot.

4. GRAPE TOMATOES

Amai. Early main season. Indeterminate. Smooth uniform fruit, 1-2 gr more than Sweet Hearts. Uniform sizing. Dark red, firm, elongated grape-shaped fruit. High yield potential. Resistance: Fusarium wilt (race 1), Leaf mold (races A-E), and Tomato mosaic (races 0, 1, and 2). Intermediate resistance: Root-knot nematode and Gray leaf spot.

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

BHN 1022. Fall and spring. Determinate. Very firm fruit with heat tolerance and great shelf life. Resistance: Fusarium wilt (race 3) and Tomato spotted wilt.

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

Cupid. Early season. Indeterminate. Vigorous bush with oval shaped fruit that have an excellent red color and a sweet flavor. Resistance: Alternaria stem canker, Fusarium wilt (race 1), and Gray leaf spot. Intermediate resistance: Bacterial speck (race 0).

Jolly Girl. Early season. Determinate. Extended market life with firm, flavorful grape shaped fruits which resist green shoulders. High brix. Resistance: Verticillium wilt (race 1) and cracking. Intermediate resistance to Fusarium wilt (race 1 and 2).

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

St. Nick. Mid-early season. Indeterminate. Oblong, grape shaped fruit. High brix with brilliant red color and good flavor. Resistance: unknown.

Smarty. 69 days. Indeterminate. Vigorous bush with short internodes. Plants are 25% shorter than Santa. Good flavor, sweet. Resistance: Fusarium wilt (races 1 and 2) and Verticillium wilt (race 1).

Sweethearts. Early to main season. Indeterminate. Bush with intermediate internodes, high yield potential, and wide adaptability. Brilliant red, firm, elongated grape-shaped fruit with good flavor and shelf life. Crack resistance and high brix. Resistance: Fusarium wilt (race 1), Leaf mold (A-E), Tobacco mosaic (races 0, 1, and 2). Intermediate resistance: Gray leaf spot.

Tami G. Early season. Indeterminate. Medium tall bush with mall fruits with nice shape. Resistance: unknown.

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

Fertilizer and Nutrient Management for Tomato

Monica Ozores-Hampton

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/acre N rate on 6-ft centers is the same as 240 lbs/acre N rate on 5-ft centers and a 170 lbs/acre N rate on 7-ft centers. This example is for illustration purposes, and only 5 and 6 ft centers are commonly used for tomato production in Florida.

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

LIMING

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

Calcium (Ca) and magnesium (Mg) levels should be also corrected according to the soil test. If both elements are "low", and lime is needed, then broadcast and incorporate dolomitic limestone ($CaCO_3$, $MgCO_3$). Where calcium alone is deficient, "hi-cal" ($CaCO_3$) limestone should be used. Adequate Ca is important for reducing the severity of blossom-end rot. Research shows that a Mehlich-I (double-acid) index of 300 to 350 ppm Ca would be indicative of adequate soil-Ca. On limestone soils, add 30-40 lbs/acre of Mg in the basic fertilizer mix. It is best to apply lime several months prior to planting. However, if time is short, it is better to apply lime any time before planting than not to apply it at all. Where the pH does not need modification, but Mg is low

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

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

[z] 1 A = 7,260 linear bed feet per acre (6-ft bed spacing); for soils testing "low" in Mehlich 3 potassium (K_2O).

[y] applied using the modified broadcast method (fertilizer is broadcast where the beds will be formed only, and not over the entire field). Pre-plant fertilizer cannot be applied to double/triple crops because of the plastic mulch; hence, in these cases, all the fertilizer has to be injected.

[x] This fertigation schedule is applicable when no N and K_2O are applied preplant. Reduce schedule proportionally to the amount of N and K_2O applied pre-plant. Fertilizer injections may be done daily or weekly. Inject fertilizer at the end of the irrigation event and allow enough time for proper flushing afterwards.

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

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

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

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

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

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

[q] Supplemental amount for each leaching rain

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

(below 15 ppm, Mehlich-3 soil test index), apply magnesium sulfate or potassium-magnesium sulfate.

Changes in soil pH may take several weeks to occur when carbonate-based liming materials are used (calcitic or dolomitic limestone). Oxide-based liming materials (quick lime -CaO- or dolomitic quick lime -CaO, MgO-) are fast reacting and rapidly increase soil pH. Yet, despite these advantages, oxide-based liming materials are more expensive than the traditional liming materials, and therefore are not routinely used. The increase in pH induced by liming materials is not due to the presence of Ca or Mg. Instead, it is the carbonate (CO_3) and oxide (O) part of $CaCO_3$ and CaO, respectively, that raises the pH. Through several chemical reactions that occur in the soil, carbonates and oxides release OH- ions that combine with H^+ to produce water. As large amounts of H^+ react, the pH rises. A large fraction of the Ca and/or Mg in the liming materials gets into solution and binds to the sites that are freed by H^+ that have reacted with OH^-.

FERTILIZER-RELATED PHYSIOLOGICAL DISORDERS

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

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

Factors that impair the ability of tomato plants to obtain water will increase the risk of BER. These factors include damaged roots from flooding, mechanical damage or nematodes, clogged drip emitters, inadequate water applications, alternating dry-wet periods, and even prolonged overcast periods. Other causes for BER include high fertilizer rates, especially potassium and nitrogen. Calcium levels in the soil should be adequate when the Mehlich-3 index is 300 to 350 ppm, or above. In these cases, added gypsum (calcium sulfate) is unlikely to reduce BER. Foliar sprays of Ca are unlikely to reduce BER because Ca does not move out of the leaves to the fruit.

Gray Wall. Blotchy ripening (also called gray wall) of tomatoes is characterized by white or yellow blotches that appear on the surface of ripening tomato fruits, while the tissue inside remains hard. The affected area is usually on the upper portion of the fruit. The etiology of this disorder has not been fully established, but it is often associated with high N and/or low K, and aggravated by excessive amount of N. This disorder may be at times confused with symptoms produced by the tobacco mosaic virus. Gray wall is cultivar specific and appears more frequently on older cultivars. The incidence of gray wall is less with drip irrigation where small amounts of nutrients are injected frequently, than with systems where all the fertilizer is applied 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/acre) manganese -3, copper -2, iron -5, zinc -2, boron -2, and molybdenum -0.02. Micronutrients may be supplied from oxides or sulfates. Growers using micronutrient-containing fungicides need to consider these sources when calculating fertilizer micronutrient needs.

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

FERTILIZER APPLICATION

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

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

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

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

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

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

SOURCES OF N-P_2O_5-K_2O.

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

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

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

SAP TESTING AND TISSUE ANALYSIS

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

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

For both nutrient monitoring tools, the quality and reliability of the measurements are directly related 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

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

				N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
				%						ppm					
Tomato	MRM[z] leaf	5-leaf stage	Deficient	<3.0	0.3	3.0	1.0	0.3	0.3	40	30	25	20	5	0.2
			Adequate range	3.0 5.0	0.3 0.6	3.0 5.0	1.0 2.0	0.3 0.5	0.3 0.8	40 100	30 100	25 40	20 40	5 15	0.2 0.6
			High	>5.0	0.6	5.0	2.0	0.5	0.8	100	100	40	40	15	0.6
	MRM leaf	First flower	Deficient	<2.8	0.2	2.5	1.0	0.3	0.3	40	30	25	20	5	0.2
			Adequate range	2.8 4.0	0.2 0.4	2.5 4.0	1.0 2.0	0.3 0.5	0.3 0.8	40 100	30 100	25 40	20 40	5 15	0.2 0.6
			High	>4.0	0.4	4.0	2.0	0.5	0.8	100	100	40	40	15	0.6
			Toxic (>)								1500	300	250		
	MRM leaf	Early fruit set	Deficient	<2.5	0.2	2.5	1.0	0.25	0.3	40	30	20	20	5	0.2
			Adequate range	2.5 4.0	0.2 0.4	2.5 4.0	1.0 2.0	0.25 0.5	0.3 0.6	40 100	30 100	20 40	20 40	5 10	0.2 0.6
			High	>4.0	0.4	4.0	2.0	0.5	0.6	100	100	40	40	10	0.6
			Toxic (>)										250		
Tomato	MRM leaf	First ripe fruit	Deficient	<2.0	0.2	2.0	1.0	0.25	0.3	40	30	20	20	5	0.2
			Adequate range	2.0 3.5	0.2 0.4	2.0 4.0	1.0 2.0	0.25 0.5	0.3 0.6	40 100	30 100	20 40	20 40	5 10	0.2 0.6
			High	>3.5	0.4	4.0	2.0	0.5	0.6	100	100	40	40	10	0.6
	MRM leaf	During harvest period	Deficient	<2.0	0.2	1.5	1.0	0.25	0.3	40	30	20	20	5	0.2
			Adequate range	2.0 3.0	0.2 0.4	1.5 2.5	1.0 2.0	0.25 0.5	0.3 0.6	40 100	30 100	20 40	20 40	5 10	0.2 0.6
			High	>3.0	0.4	2.5	2.0	0.5	0.6	100	100	40	40	10	0.6

[z] MRM=Most recently matured leaf.

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

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

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

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

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

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/ae266

Santos, B. M., E.J. McAvoy, M. Ozores-Hampton, G.E. Vallad, P. J. Dittmar, S.E. Webb, H.A. Smith, and S.M. Olson. 2013. Tomato production in Florida. EDIS, HS739, http://edis.ifas.ufl.edu/pdffiles/cv/cv13700.pdf

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/pdffiles/HS/HS32800.pdf

Water Management for Tomato

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

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

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

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

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

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

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.

TABLE 2. Summary of irrigation management guidelines for tomato.

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

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

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

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.

TOMATO IRRIGATION REQUIREMENT

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

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

IRRIGATION SCHEDULING FOR TOMATO

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

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

SOILS MOISTURE MEASUREMENT

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

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

It is necessary to monitor SWT at two soil depths when tensiometers are used. A shallow 6-inch depth is useful at the beginning of the season when tomato roots are near that depth. A deeper 12-inch depth is used to monitor SWT during the rest of the season. Comparing SWT at both depths is useful to understand the dynamics of soil moisture. When both SWT are within the 4-8 cb range (close to field capacity), this means that moisture is plentiful in the rooting zone. This may happen after a large rain, or when tomato water use is less than the irrigation applied. When the 6-inch-depth SWT increases (from 4-8 cb to 10-15cb) while SWT at 12-inch-depth remains within

TABLE 4. Historical Penman-method reference ET (ETo) for four Florida locations (gallons/acre/day).

Month	Tallahassee	Tampa	West Palm Beach	Miami
January	1,630	2,440	2,720	2,720
February	2,440	3,260	3,530	3,530
March	3,260	3,800	4,340	4,340
April	4,340	5,160	5,160	5,160
May	4,890	5,430	5,160	5,160
June	4,890	5,430	4,890	4,890
July	4,620	4,890	4,890	4,890
August	4,340	4,620	4,890	4,620
September	3,800	4,340	4,340	4,070
October	2,990	3,800	3,800	3,800
November	2,170	2,990	3,260	2,990
December	1,630	2,170	2,720	2,720

[z] Assuming water application over the entire area with 100% efficiency

TABLE 5. Estimated maximum water application (in gallons per acre and in gallons/100 lft) in one irrigation event for tomato grown on 6-ft centers (7,260 linear bed feet per acre) on sandy soil (available water holding capacity 0.75 in/ft and 50% soil water depletion). Split irrigations may be required during peak water requirement.

Wetting width (ft)	Gal/100 ft to wet depth (ft)			Gal/acre to wet depth (ft)		
	1	1.5	2	1	1.5	2
1.0	24	36	48	1,700	2,600	3,500
1.5	36	54	72	2,600	3,900	5,200

4-8 cb, the upper part of the soil is drying, and it is time to irrigate. If the 6-inch-depth SWT continues to rise above 25cb, a water stress will result; plants will wilt, and yields will be reduced. This should not happen under adequate water management.

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

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

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

GUIDELINES FOR SPLITTING IRRIGATION

For sandy soils, a one square foot vertical section of a 100-ft long raised bed can hold approximately 24 to 30 gallons of water. 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 60 gallons/100ft, and 2½ 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

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/pdffiles/SS/SS42900.pdf

Weed Control in Tomato

Nathan S. Boyd[1] and Peter J. Dittmar[2]

[1] University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL.
[2] University of Florida/IFAS, Horticultural Sciences Dept., Gainesville, FL, nsboyd@ufl.edu

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

Active ingredient lb. a.i./A	Trade name product/A	Weeds controlled / remarks
		*** PREPLANT / PREEMERGENCE ***
Carfentrazone **up to 0.031**	(Aim) 1.9 EW up to 2 fl. oz. (Aim) 2.0 EC up to 2 fl. oz.	Emerged broadleaf weeds. Apply as a preplant burndown for emerged broadleaf weeds.
EPTC **2.6**	(Eptam) 7 E 3 pt.	Annual broadleaf, annual grass, and yellow/purple nutsedge. Labeled for transplanted tomatoes grown on low density mulch. Do not use under high density, VIF, or metalized mulches. Do not transplant until 14 days after application. A 24(c) special local needs label in Florida.
Flumioxazin **up to 0.128**	(Chateau) 51 WDG up to 4 oz.	Annual broadleaf and grass weeds. Apply to row middles of raised plastic mulched beds that are at least 4 in. higher than the treated row middle and 24 in. bed width. Label is a Third-Party registration (TPR, Inc.). Use without a signed authorization and waiver of liability is a misuse of the product. Tank mix with a burndown herbicide to control emerged weeds.
Fomesafen **0.25 - 0.38**	(Reflex) 2 EC 1.0 - 1.5 pt.	Broadleaf weeds and yellow/purple nutsedge. Suppression of some annual and perennial grasses. Label is a 24(C) local indemnified label and a waiver of liability must be signed for use. Transplanted crop only. May be applied to bareground production 7 days before transplanting or to plastic mulched beds following bed formation but prior to laying plastic. Use shields or hooded sprayers if applying to row middles and prevent contact with the plastic mulch.
Glyphosate	(various formulations) consult labels	Emerged broadleaf and grass weeds. Apply as a preplant burndown. Consult label for individual product directions.
Halosulfuron **0.024 - 0.05**	(Sandea, Profine) 75 DF 0.5 - 1.0 oz.	Broadleaf weeds and yellow/purple nutsedge suppression. Do not exceed 2 applications of halosulfuron per 12 month period.
Imazosulfuron **0.19-0.3**	(League) 4.0-6.4 oz	Broadleaf weeds and yellow/purple nutsedge. Apply pre-transplant just prior to installation of plastic mulch. May transplant 1 day after application. PHI 21 days.
Lactofen **0.25 - 0.5**	(Cobra) 2 EC 16 - 32 fl. oz.	Broadleaf weeds. Label is a Third-Party registration (TPR, Inc.). Use without a signed authorization and waiver of liability is a misuse of the product. Apply to row middles only with shielded or hooded sprayers. Cobra contacting green foliage or fruit can cause excessive injury. Drift of Cobra treated soil particles onto plant can cause contact injury. Limit of 1 PRE and 1 POST application per growing season. PHI 30 days.
***S*-metolachlor** **1.0 - 1.3**	(Brawl, Dual Magnum, Medal) 7.62 EC 1.0 - 1.33 pt. if organic matter less then 3%	Annual broadleaf and grass weeds and suppression of yellow nutsedge. Apply to bed tops pre-transplant just prior to laying the plastic. May also be used in row middles. Research has shown that the 1.33 pt. may be too high in some Florida soils except in row middles. Use on a trial basis.
Metribuzin **0.25 - 0.5**	(Sencor DF, TriCor DF) 75 WDG 0.33 - 0.67 lb. (Sencor 4, Metri) 4 F 0.5 - 1.0 pt.	Controls small emerged weeds. Apply preplant in transplanted tomatoes only. Incorporate to a depth of 2-4 inches. Maximum of 1.0 lb. a.i./A within a season. Avoid application for 3 days following cool, wet, or cloudy weather to reduce possible crop injury. PHI 7 days.

Labels change frequently. Be sure to read a current product label before applying any chemical.		
Active ingredient lb. a.i./A	**Trade name product/A**	**Weeds controlled / remarks**
Napropamide **t**	(Devrinol DF XT) 50 DF 2.0 - 4.0 lb.	Annual broadleaf and grass weeds. For direct-seed or transplanted tomatoes. Apply to well worked soil that is moist enough to permit thorough incorporation to a depth of 2 in. Incorporate same day as applied.
Oxyfluorfen **0.25 - 0.5**	(Goal 2 XL) 2 EC 1.0 - 2.0 pt. (GoalTender) 4 E 0.5 - 1.0 pt.	Broadleaf weeds. Must have a 30-day treatment-planting interval for transplanted tomatoes. Apply as a preemergence broadcast to preformed beds or banded treatment. Mulch may be applied any time during the 30-day interval.
Paraquat **0.5 - 1.0**	(Gramoxone) 2 SL 2.0 - 4.0 pt. (Firestorm) 3 SL 1.3 - 2.7 pt.	Emerged broadleaf and grass weeds. Apply as a preplant burndown treatment.
Pelargonic acid	(Scythe) 4.2 EC 3 - 10% v/v	Emerged broadleaf and grass weeds. Apply as a preplant burndown treatment or post transplant with shielded or hooded sprayers. Product is a contact, nonselective, foliar applied herbicide with no residual control.
Pendimethalin **0.48 - 0.72**	(Prowl $H_2$0) 3.8 1.0 - 1.5 pt.	May be applied pretransplant to bed tops just prior to laying the plastic mulch or to row middles. Do not exceed 3.0 pt./A per year. PHI 70 days.
Pyraflufen **0.001 - 0.003**	(ETX Herbicide) 0.208 EC 0.3 - 1.25 fl. oz.	Emerged broadleaf weeds. Apply as a preplant burndown treatment.
Rimsulfuron **0.03 - 0.06**	(Martix FNV, Matrix SG, Pruvin) 25 WDG 2.0 - 4.0 oz.	Annual broadleaf and grass weeds. Suppression of yellow nutsedge. Requires 0.5-1 in. of rainfall or irrigation within 5 days of application for activation. May be applied as a sequential treatment with a PRE and POST application not exceeding 0.06 lb. a.i./A in a single season.
Tifluralin **0.5**	(Treflan, Trifluralin) 4 EC 1 pt. (Treflan, Trifluralin) 10 G 5 lb.	Annual broadleaf and grass weeds. Do not apply in Dade County. Incorporate 4 in. or less within 8 hr. of application. Results in Florida are erratic on soils with low organic matter and clay contents. Note label precautions against planting noncrop within 5 months. Do not apply after transplanting.
	***** POSTTRANSPLANT *****	
Carfentrazone **up to 0.031**	(Aim) 1.9 EW up to 2 fl. oz. (Aim) 2.0 EC up to 2 fl. oz.	Emerged broadleaf weeds. Apply as a hooded application to row middles only. May be tank mixed with other herbicides. PHI 0 days.
Clethodim **0.09 - 0.25** **0.07 - 0.25**	(Arrow, Select) 2 EC 6 - 16 fl. oz. (Select Max) 1 EC 9 - 32 fl. oz.	Perennial and annual grass weeds. Use higher rates under heavy grass pressure or larger grass weeds. Consult label for required surfactant. PHI 20 days.
DCPA **6.0 - 7.5**	(Dacthal) W-75 8 - 10 lb. (Dacthal) 6 F 8 - 10 pt.	Apply to weed-free soil 6-8 wk. after crop is established and growing rapidly or to moist soil in row middles after crop establishment. Note label precautions against replanting non-registered within 8 months.
Diquat **0.5**	(Reglone Dessiccant) 1 qt.	Broadleaf and grass weeds. Apply to row middles only. Maximum of 2 applications per season. Prevent drift to crop. PHI 30 days.
Halosulfuron **0.024 - 0.05**	(Sandea, Profine) 75 DF 0.5 - 1.0 oz.	Broadleaf weeds and yellow/purple nutsedge. Apply 14 days after transplant but before first bloom. Following first bloom apply with shielded or hooded applicator. May be applied to row middles with shielded or hooded sprayer. Do not exceed 2 oz per 12 month period. PHI 30 days.
Imazosulfuron **0.19-0.3**	(League) 4.0-6.4 oz	Apply post emergence 3 to 5 days after transplant through to early bloom. Only apply if no pre-transplant application was made. PHI 21 days.
Lactofen **0.25 - 0.5**	(Cobra) 2 EC 16 - 32 fl. oz.	Broadleaf weeds. Apply to row middles only with shielded or hooded sprayers. Cobra contacting green foliage or fruit can cause excessive injury. Drift of Cobra treated soil particles onto plants can cause contact injury. Limit of 1 PRE and 1 POST application per growing season. PHI 30 days.
***S*-metolachlor** **1.0 - 1.3**	(Brawl, Dual Magnum, Medal) 7.62 EC 1.0 - 1.33 pt.	Annual broadleaf and grass weeds and yellow nutsedge. Apply to row middles. Label rates are 1.0-1.33 pt./A if organic matter is less than 3%. Research has shown that the 1.33 pt. may be too high in some Florida soils except in row middles. Use on a trial basis. PHI 60 days for rates 1.67 pt. or less/A. PHI90 days for rates 1.68-2.0
Metribuzin **0.25 - 0.5**	(Sencor DF, TriCor DF) 75 WDG 0.33 - 0.67 lb. (Sencor 4, Metri) 4 F 0.5 - 1.0 pt.	Controls small emerged weeds. Apply after transplants are established or direct-seeded plants reach 5-6 true leaf stage. Apply in single or multiple applications with a minimum of 14 days between treatments. Maximum of 1.0 lb. a.i./A within a season. Avoid application for 3 days following cool, wet, or cloudy weather to reduce possible crop injury. PHI 7 days.
Paraquat **0.5**	(Gramoxone) 2 SL 2 pt. (Firestorm) 3 SL 1.3 pt.	Emerged broadleaf and grass weeds. Direct spray over emerged weeds 1-6 in. tall in row middles between mulched beds. Use a nonionic surfactant. Use low pressure and shields to control drift. Do not apply more than 3 times per season. PHI 30 days.
Pelargonic acid	(Scythe) 4.2 EC 3 - 10% v/v	Emerged broadleaf and grass weeds. Direct spray to row middles. Product is a contact, nonselective, foliar applied herbicide with no residual control. May be tank mixed with several soil residual compounds. Has a greenhouse and growth structure label.
Pendimethalin **0.48 - 0.72**	(Prowl $H_2$0) 3.8 1.0 - 1.5 pt.	Broadleaf and grass weeds. May be applied post transplant to row middles if previously untreated. Do not exceed 3.0 pt./A per year. PHI 70 days.

Labels change frequently. Be sure to read a current product label before applying any chemical.		
Active ingredient lb. a.i./A	**Trade name product/A**	**Weeds controlled / remarks**
Rimsulfuron **0.02 - 0.03**	(Matrix FNV, Matrix SG, Pruvin) 25 WDG 1.0 - 2.0 oz.	Broadleaf and grass weeds. May be applied as a sequential treatment with a PRE and POST application not exceeding 0.06 lb. a.i./A in a single season. Requires 0.5-1.0 in. of rainfall or irrigation within 5 days of application for activation. For POST weed control, include a COC or NIS. PHI 45 days.
Sethoxydim **0.19 - 0.28**	(Post) 1.5 EC 1.0 - 1.5 pt.	Controls growing grass weeds. A total of 4.5 pt./A applied in one season. Include a COC. Unsatisfactory results may occur if applied to grasses under stress. PHI 20 days.
Trifloxysulfuron **0.005 - 0.009**	(Envoke) 75 DG 0.1 - 0.2 oz.	Broadleaf and nutsedge control. Direct spray solution to the base of transplanted tomato plants. Apply at least 14 days after transplanting and before fruit set. PHI 45 days.
	***** POSTHARVEST *****	
Diquat **0.5**	(Reglone Dessiccant) 2.0 pt.	Minimum of 35 gal./A. Include a NIS. Thorough coverage is required.
Paraquat **0.62 - 0.94**	(Gramoxone) 2 SL 2.4 - 3.75 pt. (Firestorm) 3 SL 1.6 - 2.5 pt.	Broadcast spray over the top of the plants after the last harvest. Use a nonionic surfactant. Thorough coverage is required to ensure maximum herbicide burndown. Do not use treated crop for human or animal consumption.

Tomato Fungicides

Gary E. Vallad

University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

TOMATO FUNGICIDES

Products sorted by disease and then in order by FRAC group corresponding to the mode of action.
Biopesticides and other alternative products labeled for disease management are listed in a separe table for convenience. (Updated June 2014).

Gary E. Vallad, University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

BE SURE TO READ A CURRENT PRODUCT LABEL BEFORE APPLYING ANY PRODUCT.

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

TOMATO FUNGICIDES continued

Products sorted by disease and then in order by FRAC group corresponding to the mode of action.
Biopesticides and other alternative products labeled for disease management are listed in a separe table for convenience. (Updated June 2014).

Gary E. Vallad, University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

BE SURE TO READ A CURRENT PRODUCT LABEL BEFORE APPLYING ANY PRODUCT.

Pertinent Diseases or Pathogens	Fungicide Group[1]	Chemical (active ingredients)	Max. Rate/Acre		Min. Days to		Remarks[2]
			Applic.	Season	Harvest	Reentry	
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0 0	4 hr 4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group.
	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
(suppression)	19	Ph-D WDG Oso 5% SC (polyoxin D zinc salt)	6.2 oz 13 fl oz	31.0 oz 78 fl oz	0 0	4 hr 4 hr	Alternate with a non-FRAC code 19 fungicide.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	Limit is 4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Bacterial canker	M1	**(copper compounds)** **Many brands available:** Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	**SEE INDIVIDUAL LABELS**		1	Varies by product from 4 hr to 2 days.	Mancozeb enhances the bactericidal effect of fix copper compounds.
(suppression)	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
Bacterial spot and Bacterial speck	M1	**(copper compounds)** **Many brands available:** Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	**SEE INDIVIDUAL LABELS**		1	Varies by product from 4 hr to 2 days.	Mancozeb enhances the bactericidal effect of fix copper compounds.
	M3	**(mancozeb)** **Many brands available:** Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate FL, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	SEE INDIVIDUAL LABELS		5	1	Bacterial spot control only when tank mixed with a copper fungicide.
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lb	112 lb	5	2	
(suppression)	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
	25	Agri-mycin 17 Ag Streptomycin Bac-Master (streptomycin sulfate)	200 ppm	-	-	0.5	See label for details. For transplant production only. Many isolates are resistant to streptomycin.
	P	Actigard (acibenzolar-S-methyl)	0.75 oz	4.75 oz	14	0.5	Begin applications within one week of transplanting or emergence. Make up to 8 weekly, sequential applications.
Black mold (*Alternaria* spp.)	3	Mentor (propiconazole)	8 oz /100 gal or /50,000 lb of fruit	-	-	-	Apply as a post-harvest dip, drench, or high-volume spray for the post-harvest control of certain rots. See label for details.
	7	Endura (boscalid)	12.5 oz	25 oz	0	0.5	Alternate with non-FRAC code 7 fungicides, see label
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential applications before rotating with another effective fungicide from a different FRAC group. See label for additional instructions pertaining to greenhouse useage.

Products sorted by disease and then in order by FRAC group corresponding to the mode of action.
Biopesticides and other alternative products labeled for disease management are listed in a separe table for convenience. (Updated June 2014).

Gary E. Vallad, University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

BE SURE TO READ A CURRENT PRODUCT LABEL BEFORE APPLYING ANY PRODUCT.

Pertinent Diseases or Pathogens	Fungicide Group[1]	Chemical (active ingredients)	Max. Rate/Acre Applic.	Max. Rate/Acre Season	Min. Days to Harvest	Min. Days to Reentry	Remarks[2]
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 1 year plant back restriction for certain off label crops.
	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Botrytis, Gray Mold	M5	**(chlorothalonil)** Many brands available: Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential applications before switching to another effective fungicide with a different mode of action. See label for additional instructions pertaining to greenhouse useage.
(suppression)	7	Endura (boscalid)	12.5 oz	25 oz	0	0.5	Alternate with non-FRAC code 7 fungicides.
	9	Scala SC (pyrimethanil)	7 fl oz	35 fl oz	1	0.5	Use only in a tank mix with another effective non-FRAC code 9 fungicide; Has a 30 day plant back with off label crops.
	9 & 12	Switch 62.5WG (cyprodinil + fludioxonil)	14 oz	56 oz per year	0	0.5	After 2 appl. Alternate with non-FRAC code 9 or 12 fungicides for next 2 applications. Has a 30 day plant back with off label crops.
(suppression)	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential appl. Allowed. Limit is 6 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
(suppression)	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	14	Botran 75 W (dichloran)	1 lbs per 100 gal.	5.33 lb	10	0.5	Greenhouse use only. Limit is 4 applications. Seedlings or newly set transplants may be injured.
	19	Ph-D WDG Oso 5% SC (polyoxin D zinc salt)	6.2 oz 13 fl oz	31.0 oz 78 fl oz	0 0	4 hr 4 hr	Alternate with a non-FRAC code 19 fungicide.
Buckeye rot	M1 + 4	Ridomil Gold Copper (copper hydroxide + mefenoxam)	2 lb	6 lb	14	2	Limited to 3 apps per season. Tankmix with mancozeb.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential appl. Allowed. Limit is 6 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group, see label.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
(suppression)	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	See label

TOMATO FUNGICIDES continued

Products sorted by disease and then in order by FRAC group corresponding to the mode of action.
Biopesticides and other alternative products labeled for disease management are listed in a separe table for convenience. (Updated June 2014).

Gary E. Vallad, University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

BE SURE TO READ A CURRENT PRODUCT LABEL BEFORE APPLYING ANY PRODUCT.

Pertinent Diseases or Pathogens	Fungicide Group[1]	Chemical (active ingredients)	Max. Rate/Acre Applic.	Max. Rate/Acre Season	Min. Days to Harvest	Min. Days to Reentry	Remarks[2]
Early blight	M1	**(copper compounds)** **Many brands available:** Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	**SEE INDIVIDUAL LABELS**		1	Varies by product from 4 hr to 2 days.	Mancozeb or maneb enhances bactericidal effect of fix copper compounds. **See label for details.**
	M3	(mancozeb) **Many brands available:** Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate FL, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	**SEE INDIVIDUAL LABELS**		5	1	
	M3	Ziram 76DF (ziram)	4 lbs	23.7 lb	7	2	Do not use on cherry tomatoes.
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lb	112 lb	5	2	
	M5	(chlorothalonil) **Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	4 & M5	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	3 lb	12 lb	14	2	Limit is 4 appl./crop.
	7	Endura (boscalid)	12.5 oz	25 oz	0	0.5	Alternate with non-FRAC code 7 fungicides.
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential applications before switching to another effective fungicide with a different mode of action. See label for additional instructions pertaining to greenhouse useage.
	9	Scala SC (pyrimethanil)	7 fl oz	35 fl oz	1	0.5	Use only in a tank mix with another effective non-FRAC code 9 fungicide ; Has a 30 day plant back with off label crops.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	9 & 12	Switch 62.5WG (cyprodinil + fludioxonil)	14 oz	56 oz per year	0	0.5	After 2 apps. alternate with non-FRAC code 9 or 12 fungicides for next 2 applications. Has a 30 day plant back with off label crops.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential apps. allowed. Limit is 6 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Flint (trifloxystrobin)	4 oz	16 oz	3	0.5	Limit is 5 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Evito Aftershock (fluoxastrobin)	5.7 fl oz	22.8 fl oz	3	0.5	Limit is 4 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Reason 500 SC (fenamidone)	8.2 oz	24.6 lb	14	0.5	Must alternate with a fungicide from a different FRAC group. See supplemental label for restrictions and details.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 1 year plant back restriction for certain off label crops.

TOMATO FUNGICIDES continued

Products sorted by disease and then in order by FRAC group corresponding to the mode of action.
Biopesticides and other alternative products labeled for disease management are listed in a separe table for convenience. (Updated June 2014).

Gary E. Vallad, University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

BE SURE TO READ A CURRENT PRODUCT LABEL BEFORE APPLYING ANY PRODUCT.

Pertinent Diseases or Pathogens	Fungicide Group[1]	Chemical (active ingredients)	Max. Rate/Acre		Min. Days to		Remarks[2]
			Applic.	Season	Harvest	Reentry	
	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
	19	Ph-D WDG Oso 5% SC (polyoxin D zinc salt)	6.2 oz 13 fl oz	31.0 oz 78 fl oz	0 0	4 hr 4 hr	Alternate with a non-FRAC code 19 fungicide.
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	
	28	Previcur Flex (propamocarb hydrochloride)	1.5 pt	7.5 pt	5	0.5	Must tank mix with chlorothalonil or mancozeb.
	28	Promess (propamocarb hydrochloride)	1.5 pt	7.5 pt	5	0.5	Must tank mix with chlorothalonil or mancozeb.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	Limit is 4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Late blight	M1	**(copper compounds)** **Many brands available:** Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	**SEE INDIVIDUAL LABELS**		1	Varies by product from 4 hr to 2 days.	
	M3	**(mancozeb)** **Many brands available:** Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	**SEE INDIVIDUAL LABELS**		5	1	
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lb	112 lb	5	2	
	M5	(chlorothalonil) **Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	SEE INDIVIDUAL LABELS		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	4 & M3	Ridomil MZ 68 WP (mefenoxam + mancozeb)	2.5 lb	7.5 lb	5	2	Limit is 3 apps./crop.
	4 & M1	Ridomil Gold Copper 64.8 W (mefenoxam + copper hydroxide)	2 lb	6 lb	14	2	Limit is 3 apps./crop. Tank mix with mancozeb fungicide.
	4 & M5	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	3 lb	12 lb	14	2	Limit is 4 apps./crop.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential appl. Allowed. Limit is 6 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Flint (trifloxystrobin)	4 oz	16 oz	3	0.5	Limit is 5 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Evito Aftershock (fluoxastrobin)	5.7 fl oz	22.8 fl oz	3	0.5	Limit is 4 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Reason 500 SC (fenamidone)	8.2 oz	24.6 lb	14	0.5	Must alternate with a fungicide from a different FRAC group.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
(suppression)	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	7	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.

TOMATO FUNGICIDES continued

Products sorted by disease and then in order by FRAC group corresponding to the mode of action.
Biopesticides and other alternative products labeled for disease management are listed in a separe table for convenience. (Updated June 2014).

Gary E. Vallad, University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

BE SURE TO READ A CURRENT PRODUCT LABEL BEFORE APPLYING ANY PRODUCT.

Pertinent Diseases or Pathogens	Fungicide Group[1]	Chemical (active ingredients)	Max. Rate/Acre		Min. Days to		Remarks[2]
			Applic.	Season	Harvest	Reentry	
	19	Oso 5% SC (polyoxin D zinc salt)	13 fl oz	78 fl oz	0	4 hr	Alternate with a non-FRAC code 19 fungicide.
	21	Ranman (cyazofamid)	2.75 oz	16oz	0	0.5	Limit is 6 apps./crop.
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	
	27	Curzate 60DF (cymoxanil)	5 oz	30 oz per year	3	0.5	Must tank mix with another effective product.
	28	Previcur Flex (propamocarb hydrochloride)	1.5 pt	7.5 pt	5	0.5	Must tank mix with Chlorothalonil or mancozeb.
	28	Promess (propamocarb hydrochloride)	1.5 pt	7.5 pt	5	0.5	Must tank mix with Chlorothalonil or mancozeb.
	33	Aliette 80 WDG (fosetyl-al)	5 lb	20lb	14	0.5	See label for warnings concerning the use of copper compounds.
	33	Alude (mono- and di-potassium salts of phosphorous acid)	1.5 qt/ acre/ 25 gal	-	-	4 hr	For transplants only.
	40	Forum (dimethomorph)	6 oz	30 oz	4	0.5	Only 2 sequential appl. See label for details
	40	Revus (mandipropamid)	8 fl oz	32 fl oz	1	4 hr	Supplemental label; No more than 2 sequential appl.; See label
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants. See label
	43	Presidio (Fluopicolide)	4 fl oz	12 fl oz/ per season	2	0.5	4 apps per season; no more than 2 sequential apps. 10 day spray interval; Tank mix with another labeled non-FRAC code 43 fungicide; 18 month rotation with off label crops; see label.
	45 & 40	Zampro (ametoctradin + dimethomorph)	14 fl oz	42 fl oz	4	0.5	Addition of a spreading or penetrating adjuvant is recommended to improve performance. Limit of 3 applications per season.
Leaf mold	M3	**(mancozeb)** **Many brands available:** Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	**SEE INDIVIDUAL LABELS**		5		
	M5	**(chlorothalonil)** **Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group.
	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
	19	Oso 5% SC (polyoxin D zinc salt)	13 fl oz	78 fl oz	0	4 hr	Alternate with a non-FRAC code 19 fungicide.
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Grey leaf spot	M1	**(copper compounds)** **Many brands available:** Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	**SEE INDIVIDUAL LABELS**		1	Varies by product from 4 hr to 2 days.	Mancozeb or maneb enhances bactericidal effect of fix copper compounds.

TOMATO FUNGICIDES continued

Products sorted by disease and then in order by FRAC group corresponding to the mode of action.
Biopesticides and other alternative products labeled for disease management are listed in a separe table for convenience. (Updated June 2014).

Gary E. Vallad, University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

BE SURE TO READ A CURRENT PRODUCT LABEL BEFORE APPLYING ANY PRODUCT.

Pertinent Diseases or Pathogens	Fungicide Group[1]	Chemical (active ingredients)	Max. Rate/Acre Applic.	Max. Rate/Acre Season	Min. Days to Harvest	Min. Days to Reentry	Remarks[2]
	M3	**(mancozeb)** **Many brands available:** Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	**SEE INDIVIDUAL LABELS**		5	1	
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lb	112 lb	5	2	
	M5	(chlorothalonil) **Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	4 & M5	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	3 lb	12 lb	14	2	Limit is 4 apps./crop.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	11	Flint (trifloxystrobin)	4 oz	16 oz	3	0.5	Limit is 5 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 1 year plant back restriction for certain off label crops.
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Phytophthora crown rot, Phytophthora root rot (*Phytophthora* spp.)	4	Ridomil Gold SL Ultra Flourish (mefenoxam)	1 pt 2 pt	3 pt 6 pt	28 7	2* 2*	Do not apply more than 6 lb mefenoxam/A per crop to the soil. *There is a reentry interval exemption if material is soil-injected or soil-incorporated.
	4	Metastar 2E (metalaxyl)	2 qt	6 qt	2	28	Soil applied by drip injection.
	11	Reason 500 SC (fenamidone)	8.2 oz	24.6 lb	14	0.5	Must alternate with a fungicide from a different FRAC group. *(Phytophthora capsici*-suppression only)
	14	Terramaster 4EC (etridiazole)	7 fl oz	27.4 fl oz	3	0.5	Greenhouse use only.
	21	Ranman (cyazofamid)	2.75 fl oz	16.5 fl oz	0		Apply to the base of plant at the time of transplanting. Make additional applications on a 7 to 10 day schedule if conditions are favorable for disease.
	28	Previcur Flex (propamocarb hydrochloride)	**SEE LABEL**		5	0.5	GREENHOUSE APPLICATION: 6 apps/crop cycle. Do not mix with other products. Can cause phytotoxicity if applied in intense sunlight.
	33	Aliette 80 WDG Linebacker WDG (fosetyl-aluminum)	5 lb	2 lb	14	0.5	See label for warnings concerning the use of copper compounds.
	33	Alude (mono- and di-potassium salts of phosphorous acid)	1.5 qt/ acre/ 25 gal	-	-	4 hr	For transplants only.
	43	Presidio (fluopicolide)	4 fl oz	12 fl oz	2	0.5	4 apps per season; no more than 2 sequential apps. 10 day spray interval; Tank mix with another labeled non-FRAC code 43 fungicide; 18 month rotation with off label crops.
	45 & 40	Zampro (ametoctradin + dimethomorph)	14 fl oz	42 fl oz	4	0.5	Addition of a spreading or penetrating adjuvant is recommended to improve performance. Limit of 3 applications per season.

TOMATO FUNGICIDES continued

Products sorted by disease and then in order by FRAC group corresponding to the mode of action.
Biopesticides and other alternative products labeled for disease management are listed in a separe table for convenience. (Updated June 2014).

Gary E. Vallad, University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

BE SURE TO READ A CURRENT PRODUCT LABEL BEFORE APPLYING ANY PRODUCT.

Pertinent Diseases or Pathogens	Fungicide Group[1]	Chemical (active ingredients)	Max. Rate/Acre		Min. Days to		Remarks[2]
			Applic.	Season	Harvest	Reentry	
Powdery mildew	M2	**(sulfur)** **Many brands available:** Cosavet DF, Kumulus DF, Micro Sulf, Microfine Sulfur, Microthiol Disperss, Sulfur 6L, Sulfur 90W, Super Six, That Flowable Sulfur, Tiolux Jet, Thiosperse 80%, Wettable Sulfur, Wettable Sulfur 92, Yellow Jacket Dusting Sulfur, Yellow Jacket Wettable Sulfur	**SEE INDIVIDUAL LABELS**		1	1	Follow label closely, may cause leaf burn if applied during high temperatures.
	3	Rally 40WSP Nova 40 W Sonoma 40WSP (myclobutanil)	4 oz	1.25 lb	0	1	Note that a 30 day plant back restriction exists.
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential applications before switching to another effective fungicide with a different mode of action. See label for additional instructions pertaining to greenhouse useage.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	9 & 12	Switch 62.5WG (cyprodinil + fludioxonil)	14 oz	56 oz per year	0	0.5	After 2 apps alternate with non-FRAC code 9 or 12 fungicides for next 2 applications. Has a 30 day plant back with off label crops.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential apps. allowed. Limit is 6 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Flint (trifloxystrobin)	4 oz	16 oz	3	0.5	Limit is 5 apps/crop; must alternate or tank mix with a fungicide from a different FRAC group.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 1 year plant back restriction for certain off label crops.
	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	19	Ph-D WDG Oso 5% SC (polyoxin D zinc salt)	6.2 oz 13 fl oz	31 oz 78 fl oz	0 0	4 hr 4 hr	Alternate with a non-FRAC code 19 fungicide.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Pythium diseases (*Pythium spp.*)	4	Ridomil Gold GR Ridomil Gold SL Ultra Flourish (mefenoxam)	20 lb 2 pt 2 pt	40 lb 3 pt 6 pt	28 7 7	2* 2* 2	*There is a reentry interval exemption if material is soil-injected or soil-incorporated.
	4	Metastar 2E (metalaxyl)	2 qt	6 qt	28	2	Soil applied by drip injection.
	14	Terramaster 4EC (etridiazole)	7 fl oz	27.4 fl oz	3	0.5	Greenhouse use only.
	21	Ranman (cyazofamid)	3 fl oz/ 100 gal	-	0	-	For greenhouse transplant production; make a single application to the seedling tray 1 week prior up to the time of transplanting. Do not use any surfactant.
	28	Previcur Flex (propamocarb hydrochloride)	**SEE INDIVIDUAL LABELS**		5	0.5	GREENHOUSE APPLICATION: 6 apps/crop cycle. Do not mix with other products. Can cause phytotoxicity if applied in intense sunlight.
	28	Previcur Flex (propamocarb hydrochloride)	1.5 pts/ treated acre	7.5 pt/ treated acre	5	0.5	(Root rots and seedling diseases) Applied to lower portion of plant and soil, or as a soil drench or drip irrigation.

TOMATO FUNGICIDES continued

Products sorted by disease and then in order by FRAC group corresponding to the mode of action.
Biopesticides and other alternative products labeled for disease management are listed in a separe table for convenience. (Updated June 2014).

Gary E. Vallad, University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

BE SURE TO READ A CURRENT PRODUCT LABEL BEFORE APPLYING ANY PRODUCT.

Pertinent Diseases or Pathogens	Fungicide Group[1]	Chemical (active ingredients)	Max. Rate/Acre		Min. Days to		Remarks[2]
			Applic.	Season	Harvest	Reentry	
	28	Promess (propamocarb hydrochloride)	1.5 pt	7.5 pt	5	0.5	Must tank mix with chlorothalonil or mancozeb.
	33	Alude (mono- and di-potassium salts of phosphorous acid)	1.5 qt/ acre/ 25 gal	-	-	4 hr	For transplants only.
Rhizoctonia root rot, Rhizoctonia fruit rot (*Rhizoctonia solani*)	M5	**(chlorothalonil)** **Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	7	Fontelis (penthiopyrad)	1.0 - 1.6 fl oz/ 1000 row-ft	24 fl oz	0	0.5	Apply at-plant, pre-plant incorporated, in-furrow, as a transplant drench, or by drip irrigation.
(suppression)	11	Cabrio (pyraclostrobin)	16 oz	96 oz	0	0.5	Limit is 2 sequential applications before alternating to another effective fungicide from a different FRAC group.
(suppression)	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	7	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	14	Blocker 4F Terraclor 75 WP (PCNB)	**SEE INDIVIDUAL LABELS**		Soil treatment at planting	0.5	See label for application type and restrictions
	14	Par-Flo 4F (PCNB)	12 fl oz per 100 gal.	2 app.	Soil drench	0.5	Limited to only container-grown plants in nurseries or greenhouse.
Septoria leaf spot	M1	**(copper compounds)** **Many brands available:** Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	**SEE INDIVIDUAL LABELS**		1	Varies by product from 4 hr to 2 days.	
	M3	**(mancozeb)** **Many brands available:** Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	**SEE INDIVIDUAL LABELS**		5		
	M3	Ziram 76DF (ziram)	4 lbs	23.7 lb	7	2	Do not use on cherry tomatoes.
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lbs	112 lb	5	2	
	M5	(chlorothalonil) **Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	4 & M5	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	3 lb	12 lb	14	2	Limit is 4 apps./crop.
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential apps. before switching to another effective fungicide with a different mode of action. See label for additional instructions pertaining to greenhouse useage.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential appl. Allowed. Limit is 6 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.

TOMATO FUNGICIDES continued

Products sorted by disease and then in order by FRAC group corresponding to the mode of action.
Biopesticides and other alternative products labeled for disease management are listed in a separe table for convenience. (Updated June 2014).

Gary E. Vallad, University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

BE SURE TO READ A CURRENT PRODUCT LABEL BEFORE APPLYING ANY PRODUCT.

Pertinent Diseases or Pathogens	Fungicide Group[1]	Chemical (active ingredients)	Max. Rate/Acre		Min. Days to		Remarks[2]
			Applic.	Season	Harvest	Reentry	
	11	Flint (trifloxystrobin)	4 oz	16 oz	3	0.5	Limit is 5 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Reason 500 SC (fenamidone)	8.2 oz	24.6 lb	14	0.5	Must alternate with a fungicide from a different FRAC group.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Up to a 1 year plant back restriction for certain off label crops.
	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Sour Rot (*Geotrichum candidum*)	3	Mentor (propiconazole)	8 oz /100 gal or /50,000 lb of fruit	-	-	-	Apply as a post-harvest dip, drench, or high-volume spray for the post-harvest control of certain rots. See label for details.
Southern blight	7	Fontelis (penthiopyrad)	1.0 - 1.6 fl oz/ 1000 row-ft	24 fl oz	0	0.5	Apply at-plant, pre-plant incorporated, in-furrow, as a transplant drench, or by drip irrigation.
	11	Evito Aftershock (fluoxastrobin)	5.7 fl oz	22.8 fl oz	3	0.5	Limit is 4 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
(suppression)	11	Cabrio (pyraclostrobin)	16 oz	96 oz	0	0.5	Limit is 2 sequential applications before alternating to another effective fungicide from a different FRAC group.
(suppression)	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	14	Blocker 4F Terraclor 75 WP (PCNB)	**SEE INDIVIDUAL LABELS**		Soil treatment at planting	0.5	See label for application type and restrictions.
(suppression)	19	Oso 5% SC (polyoxin D zinc salt)	13 fl oz	78 fl oz	0	4 hr	Alternate with a non-FRAC code 19 fungicide.
Target spot	M5	**(chlorothalonil) Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	4 & M5	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	3 lb	12 lb	14	2	Limit is 4 appl./crop.
	7	Endura (boscalid)	12.5 oz	25 oz	0	0.5	Alternate with non-FRAC code 7 fungicides.
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential apps. before switching to another effective fungicide with a different mode of action. See label for additional instructions pertaining to greenhouse useage.
	9	Scala SC (pyrimethanil)	7 fl oz	35 fl oz	1	0.5	Use only in a tank mix with another effective non-FRAC code 9 fungicide; has a 30 day plant back with off label crops.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps./season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential appl. Allowed. Limit is 6 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.

TOMATO FUNGICIDES continued

Products sorted by disease and then in order by FRAC group corresponding to the mode of action.
Biopesticides and other alternative products labeled for disease management are listed in a separe table for convenience. (Updated June 2014).

Gary E. Vallad, University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

BE SURE TO READ A CURRENT PRODUCT LABEL BEFORE APPLYING ANY PRODUCT.

Pertinent Diseases or Pathogens	Fungicide Group[1]	Chemical (active ingredients)	Max. Rate/Acre		Min. Days to		Remarks[2]
			Applic.	Season	Harvest	Reentry	
	11	Evito Aftershock (fluoxastrobin)	5.7 fl oz	22.8 fl oz	3	0.5	Limit is 4 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 1 year plant back restriction for certain off label crops.
	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Timber Rot, Sclerotinia stem rot, or White mold (*Sclerotinia sclerotiorum*)	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
(suppression)	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential apps. allowed. Limit is 6 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
(suppression)	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.

[1] FRAC code (fungicide group): Number (1 through 46) and letters (U and P) are used to distinguish the fungicide mode of action groups. All fungicides within the same group (with same number or letter) indicate same active ingredient or similar mode of action. This information must be considered for the fungicide resistance management decisions. U = unknown, or a mode of action that has not been classified yet and is typically associated with another number; P = host plant defense inducers. Source: FRAC Code List 2014; http://www.frac.info/ (FRAC = Fungicide Resistance Action Committee).

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

Tomato Biopesticides and Other Disease Control Products

Gary E. Vallad

University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

TOMATO BIOPESTICIDES AND OTHER DISEASE CONTROL PRODUCTS.

Ordered alphabetically by commercial name. (Updated June 2014).

Gary E. Vallad, University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

Product (active ingredient), Fungicide Group[1]	Pertinent Diseases or Pathogens	Minimum Days to:		OMRI Listed	Remarks[2]
		Harvest	Reentry		
Actinovate (*Streptomyces lydicus* WYEC 108), NC	*Alternaria* spp., Anthracnose, Botrytis, *Erwinia* spp., *Fusarium* spp., Powdery Mildew, Pseudomonas spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp., *Sclerotinia* spp., Southern Blight, Verticillium spp., *Xanthomonas* spp.	0	1 hr	Yes	See label for specific rates and application recommendations.
AgriPhage (bacteriophage), NC	Bacterial spot, Bacterial speck	0	0	No	Bacterial strains must be characterized preiodically by manufacturer to correctly formulate the bacteriophage mixture.

TOMATO BIOPESTICIDES AND OTHER DISEASE CONTROL PRODUCTS. continued

Ordered alphabetically by commercial name. (Updated June 2014).

Gary E. Vallad, University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

Product (active ingredient), Fungicide Group[1]	Pertinent Diseases or Pathogens	Minimum Days to: Harvest	Minimum Days to: Reentry	OMRI Listed	Remarks[2]
Armicarb 100 **Eco-mate Armicarb "O"** (potassium bicarbonate), NC	Anthracnose, Botrytis, Phoma, Powdery mildew, Septoria leaf spot	0	4 hr	No	See label for specific rates and application recommendations.
BioCover (Oil, petroleum)	Powdery mildew	0	4 hr	No	See label for specific rates, application recommendations, and precautions regarding use with other pesticides.
BIO-TAM (*Trichoderma asperellum* strain ICC 012 + *Trichoderma gamsii* strain ICC 080) NC	*Fusarium* spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp., *Sclerotinia* spp., *Sclerotium rolfsii*, *Thielaviopsis basicola*, and *Verticillium* spp.	-	1 hr	Yes	See label for additional rates and recommendations for transplant production and details for specific diseases. Check label for product incompatibility with certain chemical fungicides.
Cease (*Bacillus subtilis* strain QST 713), 44	Bacterial spot, Bacterial speck, Botrytis, Early Blight, Late Blight, Powdery mildew, Target spot, Rhizoctonia spp., Pythium spp., Fusarium spp., Verticillium spp., Phytophthora spp.	0	4 hr	Yes	For foliar applications mix with copper compounds or other effective fungicides. Compatible with soil drench and in-furrow applications. See label for specific rates and application recommendations.
Contans WG (*Coniothyrium minitans* strain CON/M/91-08)	*Sclerotinia sclerotiorum*	0	4 hr	Yes	See label for specific rates and application recommendations.
Double Nickel 55 **Double Nickel LC** (*Bacillus amyloliquefaciencs* strain D747), 44	*Alternaria* spp., Anthracnose, Bacterial diseases, Botrytis, Early blight, Late blight, *Phytophthora* spp., Powdery mildew, *Pythium* spp., Rhizoctonia, Fusarium spp., Rhizoctonia, Phytophthora spp., Pythium spp.	0	4 hr	Yes	See label for additional rates and recommendations for foliar and soil application rates and details for specific diseases. Use as a soil drench at transplant and periodically throughout the season. Can also be used as a seed treatment. See label for details.
Glacial Spray Fluid (Oil, petroleum), NC	Powdery mildew	0	4 hr	Yes	See label for specific rates, application recommendations, and precautions regarding use with other pesticides.
JMS Stylet-Oil **Organic JMS Stylet-Oil** (paraffinic oil), NC	Potato Virus Y, Tobacco Etch Virus, Cucumber Mosaic Virus	0	4 hr	Yes, but only for one label.	See label for specific rates, application recommendations, and precautions regarding use with other pesticides.
Kaligreen (potassium bicarbonate), NC	Powdery mildew	0	4 hr	Yes	See label for specific rates and application recommendations.
Milstop (potassium bicarbonate), NC	Anthracnose, *Alternaria* spp., Botrytis, Powdery mildew	0	1 hr	Yes	See label for specific rates and application recommendations.
Oxidate 2.0 (mono- and di-potassium salts of phosphorous acid + hydrogen peroxide), 33 + NC	*Alternaria* spp., Anthracnose, Bacterial diseases, Botrytis, Early blight, Late blight, *Phytophthora* spp., Powdery mildew, *Pythium* spp., Fusarium spp., Rhizoctonia	0	1 hr for enclosed areas; until spray dries in open field areas.	No	See label for additional rates and recommendations for transplant production and details for specific diseases. Use as a soil drench at transplant and periodically throughout the season. Can also be used as a seed treatment.
OxiPhos (hydrogen peroxide), NC	Bacterial diseases, Late blight, *Phytophthora* spp., Pythium spp.	0	4 hr	No	See label for recommedations for rates, application methods, and details for specific diseases.
(potassium phosphite; mono- and di-potassium salts of phosphorous acid), 33 **Many brands available:** Alude, Appear, Confine Extra T&O, Fosphite, Fungi-Phite, Helena Prophyt, K-Phite 7LP AG, Phorcephite, Phostrol, Rampart, Reveille	*Alternaria spp., Anthracnose, Bacterial diseases, Fusarium* spp., Late blight, Leaf blights caused by *Cercospora* and *Septoria* spp., *Phytophthora* spp., Powdery mildew, *Pythium* spp., *Rhizoctonia* spp., Root rots	0	4 hr	No	See label for details, specific recommendations, and precautions for tank mixing with copper-based fungicides.
PlantShield HC (*Trichoderma harzianum* Rifai strain KRL-AG2), NC	*Fusarium* spp., Rhizoctonia, *Pythium* spp.	0	4 hr	Yes	Can be applied to plant as a direct drench, furrow spray, chemigation, or in transplant starter solution. See label for details.
Purespray Green (Oil, petroleum)	Powdery mildew	0	4 hr	Yes	See label for specific rates, application recommendations, and precautions regarding use with other pesticides.
Regalia SC (extract of *Reynoutria sachalinensis*), P	Bacterial canker , Bacterial speck, Bacterial spot, Botrytis, Early blight, Phytophthora spp., Powdery mildew, Target spot, Late blight	0	4 hr	Yes	Tank mix with other effective fungicides for improved disease control under heavy pressure. See label for details.
RootShield Granular (Trichoderma harzianum Rifai strain KRL-AG2), NC	*Fusarium* spp., Rhizoctonia, *Pythium* spp.	0	0	Yes	Granular formulation can be applied in furrow in the field, or to greenhouse planting mix. See label for details.
RootShield WP (*Trichoderma harzianum* Rifai strain KRL-AG2), NC	*Fusarium* spp., Rhizoctonia, *Pythium* spp.	0	Until spray has dried.	Yes	Can be applied as a greenhouse soil drench, or by chemigation in field and greenhouse operations. In furrow or transplant starter solution.

TOMATO BIOPESTICIDES AND OTHER DISEASE CONTROL PRODUCTS. continued

Ordered alphabetically by commercial name. (Updated June 2014).

Gary E. Vallad, University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, gvallad@ufl.edu

Product (active ingredient), Fungicide Group[1]	Pertinent Diseases or Pathogens	Minimum Days to: Harvest	Minimum Days to: Reentry	OMRI Listed	Remarks[2]
Serenade ASO **Serenade Max** (*Bacillus subtilis* strain QST 713), 44	Bacterial speck, Bacterial spot, Botrytis, Early Blight, Late Blight, Powdery mildew, Target spot	0	4 hr	Yes	For foliar applications mix with copper compounds or other effective fungicides for improved disease control. See label for details.
Serenade Soil (Bacillus subtilis strain QST 713), 44	*Fusarium* spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp., *Verticillium* spp.	0	4 hr	Yes	Formulation compatible with soil drench, in-furrow, and chemigation applications. Mix with other effective fungicides for improved disease control. See label for details.
Sil-Matrix (potassium silicate), NC	Broad spectrum fungicide	0	4 hr	No	Must be used in a rotational program with other fungicides when conditions are conducive for disease development. See label for details.
Soilgard 12G (Gliocladium virens GI-21), NC	Fusarium root and crown rot, *Phytophthora capsici, Pythium* spp., Rhizoctonia, *Sclerotinia* spp., *Sclerotium* spp.	0	0	Yes	For best results apply to transplants or as a drench during transplanting. Subsequent applications can be made as drench, directed spray, or by chemigation. Chemical fungicides should not be mixed with or applied to soil or plant media at the same time as SoilGard 12G. See label for details.
Sonata (*Bacillus pumilus* QST 2808), NC	Early Blight, Late Blight, Powdery mildew	0	4 hr	Yes	Mix or alternate with other effective fungicides for improved disease control. See label for details.
Sporatec (oils of clove, rosemary and thyme), NC	Bacterial spot, Botrytis, Early blight, Gray mold, Late blight, Powdery mildew	0	0	Yes	Exercise care when applying. Begin applications once disease is observed. Use of a spreader and/or penetrant adjuvant recommended for improved performance. Do not apply when temps are above 90ºF. See label for details. Ingredients are exempt from FIFRA.
Taegro ECO (*Bacillus amyloliquefaciencs* strain FZB24), NC	Foliar diseases: Powdery mildew, Pseudomonas spp., Xanthomonas spp.; Soilborne diseases: *Fusarium* spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp., *Sclerotinia* spp.	-	1 day	No	See label for specific instructions regarding soil injected, spray, or incorporated applications. Maximum of 12 applications per season. For best efficacy, product should be applied prior to disease or disease establishment. May be applied to greenhouse produced crops.
Tenet (*Trichoderma asperellum* ICC 012; *Trichoderma gamsii* ICC 080), NC	*Fusarium* spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp., *Sclerotium rolfsii*, *Sclerotinia* spp., *Thielaviopsis basicola*, and *Verticillium* spp.	0	1 hr	Yes	For best results apply 1 week prior to planting, with 2 or more additional applications throughout the production cycle. May be applied through fertigation systems in combination with most common fertilizers. Can be applied to fumigated soil after fumigant has dissipated. Tenet has no curative activity. See label for details regarding application and fungicide incompatibility.
Terraclean (hydrogen dioxide), NC	Soilborne plant pathogens caused by species of *Fusarium, Phytophthora, Pythium,* and *Rhizoctonia*	0	0	No	Can be applied by flood irrigation, drip irrigation, or as a soil drench. See label for application details and instructions regarding applications with liquid fertilizer mixtures.
Trilogy (clarified hydrophobic extract of neem oil), NC	*Alternaria* spp., Anthracnose, Botrytis, Early blight, Powdery mildew	0	4 hr	Yes	See label for specific rates, application recommendations, and precautions regarding use with other pesticides.
Vacciplant (laminarin), P	Anthracnose, Bacterial speck, Bacterial spot, Early blight, Phytophthora blight, Powdery mildew	0	4 hr	No	Start applications preventively, when weather conditions are favorable for disease development. Repeat applications until disease conditions end. Add a labeled copper product to VacciPlant if the disease symptoms appear.

[1] FRAC code (fungicide group): Number (33 and 44) and letters (NC and P) are used to distinguish the fungicide mode of action groups. All fungicides within the same group (with same number or letter) indicate same active ingredient or similar mode of action. This information must be considered for the fungicide resistance management decisions. However, products with NC or P are considered low risk and don't require any rotation unless specifically directed on the label. NC = not classified, includes mineral oils, organic oils, potassium bicarbonate, and other materials of biological origin; P = host plant defense inducers. Source: FRAC Code List 2014; http://www.frac.info/ (FRAC = Fungicide Resistance Action Committee).

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

Selected Insecticides Approved for Use on Insects Attacking Tomatoes

Hugh A. Smith [1] and Susan E. Webb [2]

[1] University of Florida/IFAS, Gulf Coast Research and Education Center, Wimauma, FL, hughasmith@ufl.edu
[2] University of Florida/IFAS, Entomology and Nematology Dept., Gainesville, FL.

SELECTED INSECTICIDES APPROVED FOR USE ON INSECTS ATTACKING TOMATOES

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

Trade Name (Common Name)	Rate (product/acre)	REI (hours)	Days to Harvest	Insects	MOA Code[1]	Notes
Acramite 50WS (bifenazate)	0.75-1.0 lb	12	3	twospotted spider mite	un	One application per season. Field grown only.
Actara (thiamethoxam)	2.0-5.5 oz	12	0	aphids, Colorado potato beetle, flea beetles, leafhoppers, stinkbugs, whitefly	4A	Maximum of 11 oz/acres per season.
Admire Pro (imidacloprid)	7-10.5 fl oz (for rates for other brands, see labels)	12	21	aphids, Colorado potato beetle, flea beetles, leafhoppers, thrips (foliar feeding thrips only), whitefly	4A	Most effective if applied to soil at transplanting. Admire Pro limited to 10.5 fl oz/acre.
Admire Pro (imidacloprid)	0.6 fl oz per 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 per 10,000 plants	12	21	aphids, whitefly	4A	Planthouse: 1 application. See label.
Agree WG (*Bacillus thuringiensis* subspecies *aizawai*)	0.5-2.0 lb	4	0	armyworms, hornworms, loopers, tomato fruitworm	11A	Apply when larvae are small for best control. Can be used in greenhouse. OMRI-listed[2].
***Agri-Mek SC** (abamectin)	1.75-3.5 fl oz	12	7	broad mite, Colorado potato beetle, *Liriomyza* leafminers, spider mite, *Thrips palmi*, tomato pinworm, tomato russet mite	6	Do not make more than 2 sequential applications. Do not apply more than 10.25 fl oz per acre per season.
***Agri-Mek 0.15 EC** (abamectin)	8.0-16.0 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	3A	**Do not use on cherry tomatoes.** Do not apply more than 1.2 lb ai/acre per season (76.8 oz). Not recommended for control of vegetable leafminer in Florida.
***Asana XL (0.66EC)** (esfenvalerate)	2.9-9.6 fl oz	12	1	beet armyworm (aids in control), cabbage looper, Colorado potato beetle, cutworms, flea beetles, grasshoppers, hornworms, potato aphid, southern armyworm, tomato fruitworm, tomato pinworm, whitefly, yellowstriped armyworm	3A	Not recommended for control of vegetable leafminer in Florida. Do not apply more than 0.5 lb ai per acre per season, or 10 applications at highest rate.
Assail 70WP (acetamiprid)	0.6-1.7 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.
Assail 30 SG	1.5-4.0 oz					
***Athena** (abamectin, bifenthrin)	7-17 fl oz	12	7	tomato pinworm, broad mite, carmine spider mite, tomato russet mite, twospotted spider mite, leafminer spp. (adult), psyllids, thrips (adult), whitefly (adult), aphids, armyworms, cabbageworm, corn earworm, Colorado potato beetle, cucumber beetle (adult), cutworms, tobacco budworm	3A, 6	Do not apply more than 33.5 fl oz per acre in a growing season after transplanting.
Avaunt (indoxacarb)	2.5-3.5 oz	12	3	beet armyworm, hornworms, loopers, southern armyworm, tomato fruitworm, tomato pinworm, suppression of leafminers	22	Do not apply more than 14 ounces of product per acre per crop. Minimum spray interval is 5 days.
Aza-Direct (azadirachtin)	1-2 pts, up to 3.5 pts, if needed	4	0	aphids, beetles, caterpillars, leafhoppers, leafminers, mites, stink bugs, thrips, weevils, whitefly	un	Antifeedant, repellant, insect growth regulator. OMRI-listed[2].
Azatin XL (azadirachtin)	5-21 fl oz	4	0	aphids, beetles, caterpillars, leafhoppers, leafminers, thrips, weevils, whitefly	un	Antifeedant, repellant, insect growth regulator.
***Baythroid XL** (beta-cyfluthrin)	1.6-2.8 fl oz	12	0	beet armyworm(1), cabbage looper, Colorado potato beetle, dipterous leafminers(2), flea beetles, hornworms, potato aphid, southern armyworm(1), stink bugs, tomato fruitworm, tomato pinworm, variegated cutworm, thrips (except *Thrips palmi*), whitefly adults(2)	3A	(1) 1st and 2nd instars only (2) Suppression Do not apply more than 16.8 fl oz per acre per season.
Belay 50 WDG (clothianidin)	1.6-2.1 oz (foliar application)	12	7	aphids, Colorado potato beetle, flea beetles, leafhoppers, leafminers (suppression), Lygus, stink bugs, whiteflies (suppression)	4A	Do not apply more than 6.4 oz per acre per season. Do not use an adjuvant. Toxic to bees. Do not release irrigation water from the treated area.

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

Trade Name (Common Name)	Rate (product/acre)	REI (hours)	Days to Harvest	Insects	MOA Code[1]	Notes
Belay 50 WDG (clothianidin)	4.8-6.4 oz (soil application)	12	Apply at planting	aphids, Colorado potato beetle, flea beetles, leafhoppers, leafminers (suppression), Lygus, foliar feeding thrips, whiteflies (suppression)	4A	Do not apply more than 6.4 oz per acre per season. See label for application instructions. Do not release irrigation water from the treated area.
Beleaf 50 SG (flonicamid)	2.0-2.8 oz	12	0	aphids, plant bugs	9C	Do not apply more than 8.4 oz/acre per season. Begin applications before pests reach damaging levels.
Belt SC (flubendiamide)	1.5 fl oz	12	1	beet armyworm, cabbage looper, cutworm species, fall armyworm, southern armyworm, tomato fruitworm, tomato hornworm, tomato pinworm, yellow striped armyworm	28	Do not apply more than 1.5 oz per acre per 3-day interval. Do not apply more than 4.5 oz per acre per crop season.
Biobit HP (*Bacillus thuringiensis* subspecies *kurstaki*)	0.5-2.0 lb	4	0	caterpillars (will not control large armyworms)	11A	Treat when larvae are young. Good coverage is essential. Can be used in the greenhouse. OMRI-listed[2].
***Brigade 2EC** (bifenthrin)	2.1-5.2 fl oz	12	1	aphids, armyworms, corn earworm, cutworms, flea beetles, grasshoppers, mites, stink bug spp., tarnished plant bug, thrips, whitefly	3A	Make no more than 4 applications per season. Do not make applications less than 10 days apart.
CheckMate TPW-F (pheromone)	1.2-6.0 fl oz	0	0	tomato pinworm	--	For mating disruption - See label for details.
Closer SC (sulfoxaflor)	1.5-4.5 fl oz	12	1	aphids, plant bugs, whitefly, thrips (suppression only)	4C	Do not apply more than 4 times per crop or more than two times in succession. Maximum of 17 fl oz per acre per year.
Confirm 2F (tebufenozide)	6-16 fl oz	4	7	armyworms, black cutworm, hornworms, loopers	18	Product is a slow-acting IGR that will not kill larvae immediately. Do not apply more than 64 fl oz per acre per season.
Coragen (chlorantraniliprole)	3.5-7.5 fl oz	4	1	beet armyworm, Colorado potato beetle, fall armyworm, hornworms, leafminer larvae, loopers, southern armyworm, tomato fruitworm, tomato pinworm	28	Can be applied by drip chemigation or as a soil application at planting. See label for details. Do not apply more than 15.4 fl oz per acre per crop.
Courier 40SC (buprofezin)	9.0-13.6 fl oz	12	1	leafhoppers, mealybugs, planthoppers, whitefly nymphs	16	Apply when a threshold is reached of 5 whitefly nymphs per 10 leaflets from the middle of the plant. Product is a slow-acting IGR that will not kill nymphs immediately. No more than 2 applications per season. Allow at least 5 days between applications.
Crymax WDG (*Bacillus thuringiensis* subspecies *kurstaki*)	0.5-2.0 lb	4	0	armyworms, loopers, tomato fruitworm, tomato hornworm, tomato pinworm	11A	Use high rate for armyworms. Treat when larvae are young.
***Danitol 2.4 EC** (fenpropathrin)	10.67 fl oz	24	3 days, or 7 if mixed with Monitor 4	beet armyworm, cabbage looper, fruitworms, potato aphid, silverleaf whitefly, stink bugs, thrips, tobacco hornworm, tomato pinworm, twospotted spider mite, yellowstriped armyworm	3A	Use alone for control of fruitworms, stink bugs, tobacco hornworm, twospotted spider mites, and yellowstriped armyworms. Tank-mix with Monitor 4 for all others, especially whitefly. Do not apply more than 0.8 lb ai per acre per season. Do not tank mix with copper.
Deliver (*Bacillus thuringiensis* subspecies *kurstaki*)	0.25-1.5 lb	4	0	armyworms, cutworms, loopers, tomato fruitworm, tomato pinworm	11A	Use higher rates for armyworms. OMRI-listed[2].
***Diazinon AG500; *50 W** (diazinon)	**AG500:** 1-4 qt **50W:** 2-8 lb	48	preplant	cutworms, mole crickets, wireworms	1B	Incorporate into soil - see label.
Dimethoate 4 EC (dimethoate)	0.5-1.0 pt	48	7	aphids, leafhoppers, leafminers	1B	Will not control organo-phosphate-resistant leafminers.
DiPel DF (*Bacillus thuringiensis* subspecies *kurstaki*)	0.5-2.0 lb	4	0	caterpillars	11A	Treat when larvae are young. Good coverage is essential. Can be used for organic production.
Durivo (thiamethoxam, chlorantraniliprole)	10-13 fl oz	12	30	aphids, beet armyworm, Colorado potato beetle, fall armyworm, flea beetles, hornworms, leafhoppers, loopers, southern armyworm, thrips, tomato fruitworm, tomato pinworm, whitefly, yellowstriped armyworm	4A, 28	Several methods of soil application – see label.
***Endigo ZC** (lambda-cyhalothrin, thiamethoxam)	4.0-4.5 fl oz	24	5	aphids, blister beetles, cabbage looper, Colorado potato beetle, cucumber beetle adults, cutworms, fall, southern, and yellowstriped armyworm (1st and 2nd instars), flea beetles, grasshoppers, hornworms, leafhoppers, plant bugs, stink bugs, tomato fruitworm, vegetable weevil adult	3A, 4A	Do not exceed a total of 19.0 fl oz per acre per season. See label for limits on each active ingredient.
Entrust (spinosad)	0.5-2.5 oz	4	1	armyworms, Colorado potato beetle, flower thrips, hornworms, *Liriomyza* leafminers, loopers, tomato fruitworm, tomato pinworm	5	Do not apply more than 9 oz per acre per crop. OMRI-listed[2]. For thrips, rotate to other class of effective insecticide after 2 applications of a Group 5 insecticide for at least 2 applications.
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 3 weeks and eliminated after 8 to 10 weeks. May be applied by ground equipment or aerially.

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

Trade Name (Common Name)	Rate (product/acre)	REI (hours)	Days to Harvest	Insects	MOA Code[1]	Notes
Exirel (cyantraniliprole)	7-20.5 fl oz	12	1	tomato fruitworm, tomato pinworm, tomato hornworm, armyworms, Colorado potato beetle, green peach aphid, potato aphid, thrips	28	Do not apply more than 0.4 lb ai/acre per crop whether applications are made to soil or foliarly.
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 apply more than 5.5 oz/acre per crop. (FL-040006) 24(c) label for growing transplants also (FL-03004).
***Gladiator** (avermectin B1 & zeta-cypermethrin)	10-19 fl oz	12	7	armyworms, corn earworm, cutworms, hornworms, tobacco budworm, tomato fruitworm, tomato pinworm, cucumber beetle, flea beetle, Colorado potato beetle, leafhoppers, aphids, brown stink bug, *Liriomyza* leafminers, broad mite, spider mites, tomato russet mite, *Thrips palmi*.	3A, 6	Do not apply more than 57 fl oz/acre per 12 month cropping year.
Grandevo (*Chromobacterium subtsugae*)	1.0-3.0 lb	4	0	armyworms, hornworms, loopers, tomato fruitworm, tomato pinworm, variegated cutworm, aphids, mites, thrips, whiteflies	--	Thorough coverage is necessary for effective control.
***Hero** (bifenthrin & zeta-cypermethrin)	4.0-10.3 fl oz	12	1	armyworms, cabbage looper, Colorado potato beetle, cucumber beetle, cutworms, flea beetles, grasshoppers, hornworms, leafhoppers, stink bugs, tobacco budworm, tomato fruitworm, tomato pinworm, vegetable leafminer, twospotted spider mite, thrips, whiteflies	3A	Check label for maximum seasonal totals for bifenthrin and zeta-cypermethrin containing products.
Intrepid 2F (methoxyfenozide)	4-16 fl oz	4	1	beet armyworm, cabbage looper, fall armyworm, hornworms, southern armyworm, true armyworm, yellowstriped armyworm, suppression of tomato fruitworm and tomato pinworm	18	Do not apply more than 64 fl oz per acre per season. Product is a slow-acting IGR that will not kill larvae immediately.
Javelin WG (*Bacillus thuringiensis* subspecies *kurstaki*)	0.12-1.5 lb	4	0	most caterpillars, but not *Spodoptera* species (armyworms)	11A	Treat when larvae are young. Thorough coverage is essential. OMRI-listed[2].
Kanemite 15 SC (acequinocyl)	31 fl oz	12	1	twospotted spider mite	20B	Do not use less than 100 gal per acre. Make no more than 2 applications at least 21 days apart.
***Karate with Zeon** (lambda-cyhalothrin)	0.96-1.92 fl oz	24	1	beet armyworm, fall armyworm, yellowstriped armyworm, cabbage looper, cutworms, hornworms, tobacco budworm, tomato fruitworm, tomato pinworm, aphids, Colorado potato beetle, cucumber beetle, flea beetles, grasshoppers, leafhoppers, leafminers, spider mites, stink bugs, thrips (except western flower thrips), whiteflies.	3A	Do not apply more than 0.36 lb ai/acre per season.
Knack IGR (pyriproxyfen)	8-10 fl oz	12	7	immature whitefly	7C	Apply when a threshold is reached of 5 nymphs per 10 leaflets from the middle of the plant. Product is a slow-acting IGR that will not kill nymphs immediately. Make no more than two applications per season. Treat whole fields.
***Lannate LV,** ***Lannate 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).
***Leverage 360** (beta-cyfluthrin & imidacloprid)	3.8-4.1 fl oz	12	0	aphids, early instar beet armyworm and yellow-striped armyworm, cabbage looper, Colorado potato beetle, leafhoppers, thrips (except *Thrips palmi*), stink bugs, tarnished plant bug, tomato fruitworm, tomato hornworm, tomato pinworm, variegated cutworm.	3A, 4A	Maximum allowed per crop season: 15.4 fl oz/acre.
Malathion 5 **Malathion 8 F** (malathion)	1.0-2.5 pt 1.5-2 pt	12	1	aphids, *Drosophila*, spider mites	1B	8F can be used in greenhouse.
Met52 EC (*metarhizium anispoliae* strain F52)	drench: 40-80 fl oz; foliar: 0.5 pint – 2 qt	4 (0 if no contact) see label	0	thrips, whiteflies, mites	un	
***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-listed[2].
Mycotrol O (*Beauvaria bassiana* strain GHA)	0.5 quart-1 quart/100 gallons	4	0	whitefly, aphids, thrips	un	OMRI-listed[2].

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

Trade Name (Common Name)	Rate (product/acre)	REI (hours)	Days to Harvest	Insects	MOA Code[1]	Notes
***Mustang** (zeta-cypermethrin)	2.4-4.3 oz	12	1	beet armyworm, cabbage looper, Colorado potato beetle, cutworms, fall armyworm, flea beetles, grasshoppers, green and brown stink bugs, hornworms, leafminers, leafhoppers, *Lygus* bugs, plant bugs, southern armyworm, tobacco budworm, tomato fruitworm, tomato pinworm, true armyworm, yellowstriped armyworm. Aids in control of aphids, thrips and whitefly.	3A	Not recommended for vegetable leafminer in Florida. Do not make applications less than 7 days apart. Do not apply more than 0.3 lb ai per acre per season.
Neemix 4.5 (azadirachtin)	4-16 fl oz	12	0	aphids, armyworms, hornworms, psyllids, Colorado potato beetle, cutworms, leafminers, loopers, tomato fruitworm (corn earworm), tomato pinworm, whitefly	un	IGR, feeding repellant. OMRI-listed[2].
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.
PFR-97 (*Isaria fumosorosea* Apopka strain 97)	1.0-2.0 lbs	4	0	aphids, broad mites, rust mites, spider mites, leafminers, thrips, whiteflies	un	Repeat applications at 3-10 days are needed to maintain control. OMRI listed[2]
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 WP** (permethrin)	3.2-12.8 oz	12	0	beet armyworm, cabbage looper, Colorado potato beetle, dipterous leafminers, granulate cutworm, hornworms, southern armyworm, tomato fruitworm, tomato pinworm	3A	Do not apply to cherry or grape tomatoes (fruit less than 1 inch in diameter). Do not apply more than 0.6 lb ai per acre per season.
***Proaxis Insecticide** (gamma-cyhalothrin)	1.92-3.84 fl oz	24	5	aphids(1), beet armyworm(2), blister beetles, cabbage looper, Colorado potato beetle, cucumber beetles (adults), cutworms, hornworms, fall armyworm(2), flea beetles, grasshoppers, leafhoppers, plant bugs, southern armyworm(2), spider mites(1), stink bugs, thrips(1), tobacco budworm, tomato fruitworm, tomato pinworm, vegetable weevil (adult), whitefly(1), yellowstriped armyworm(2)	3A	(1) Suppression only. (2) First and second instars only. Do not apply more than 2.88 pints per acre per season.
***Proclaim** (emamectin benzoate)	2.4-4.8 oz	12	7	beet armyworm, cabbage looper, fall armyworm, hornworms, southern armyworm, tobacco budworm, tomato fruitworm, tomato pinworm, yellowstriped armyworm	6	Do not apply more than 28.8 oz/acre per season.
Provado 1.6F (imidacloprid)	3.8-6.2 fl oz	12	0	aphids, Colorado potato beetle, leafhoppers, whitefly	4A	Do not apply to crop that has been already treated with imidacloprid or thiamethoxam at planting. Maximum per crop per season 19 fl oz per acre.
Pyganic Crop Protection EC 5.0 (pyrethrins)	4.5-18.0 fl oz	12	0	aphids, beetles, caterpillars, grasshoppers, leafhoppers, leafminers, mites, plant bugs, thrips, whiteflies	3A	Pyrethrins degrade rapidly in sunlight. Thorough coverage is important. OMRI-listed[2].
Radiant SC (spinetoram)	5-10 fl oz.	4	1	armyworms (except yellowstriped), Colorado potato beetle, flower thrips, hornworms, *Liriomyza* leafminers, loopers, *Thrips palmi*, tomato fruitworm, tomato pinworm	5	Maximum of 34 fl oz per acre per season. For thrips, if additional treatment is needed after two applications, switch to an alternate mode of action (not group 5) for at least two applications.
Requiem 25EC (extract of *Chenopodium ambrosioides*)	2-4 qt	4	0	chilli thrips, Eastern flower thrips, Florida flower thrips, green peach aphid, *Liriomyza* leafminers, melon thrips, potato aphid, western flower thrips, silverleaf whitefly	un	Begin applications before pests reach damaging levels. Limited to 10 applications per crop cycle.
Rimon 0.83EC (novaluron)	9.0-12.0 fl oz	12	1	armyworms, Colorado potato beetle, foliage feeding caterpillars, loopers, tomato fruitworm, tomato hornworm, tomato pinworm, stink bugs, thrips, whiteflies (immatures only)	15	Do not apply more than 36 fl oz per acre per season. Minimum of 7 days between applications.
Safari 20 SG (dinotefuran)	7.0-14.0 oz	12	1	aphids, leafminers, whiteflies	4A	**For transplant production only**. Can be applied as foliar spray or soil drench.
Scorpion 35SL (dinotefuran)	Foliar: 2-7 fl oz Soil: 9-10.5 oz	12	Foliar: 1 Soil: 21	Colorado potato beetle, cucumber beetles, flea beetles, leafhoppers, leafminers, stink bugs, thrips, whiteflies, aphids	4A	Do not use on cherry or grape tomatoes. Do not combine soil application with foliar application, use only one application method.
Sevin 80S **Sevin XLR Plus; Sevin 4F** (carbaryl)	**80S:** 5/8-2 1/5 lb **XLR Plus; 4F:** 0.5-2.0 qt	12	3	Colorado potato beetle, cutworms, fall armyworm, flea beetles, lace bugs, leafhoppers, plant bugs, tomato fruitworm, tomato hornworm, tomato pinworm, Suppression of thrips and stinkbugs.	1A	Do not apply more than seven times. Do not apply a total of more than 10 lb or 8 qt per acre per crop.
10% Sevin Granules (carbaryl)	20 lb	12	3	ants, centipedes, crickets, cutworms, earwigs, grasshoppers, millipedes, sowbugs, springtails	1A	Maximum of 4 applications, not more often than once every 7 days.
Sulfur (many brands)	See label	24	see label	tomato russet mite, twospotted spider mite	--	May burn fruit and foliage when temperature is high. Do not apply within 2 weeks of an oil spray or EC formulation.
Synapse WG (flubendiamide)	2.0-3.0 oz	12	1	armyworms, hornworms, loopers, tomato fruitworm, tobacco budworm	28	Do not apply more than 9 oz/acre per season.

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

Trade Name (Common Name)	Rate (product/acre)	REI (hours)	Days to Harvest	Insects	MOA Code[1]	Notes
Trigard (cyromazine)	2.66 oz	12	0	Colorado potato beetle (CPB) suppression, leafminers	17	No more than 6 applications per crop. Does not control CPB adults. Most effective against 1st & 2nd instar larvae.
Ultra-Pure Oil, **Saf-T-Side, SuffOil-x** **JMS Stylet-Oil** (oil, insecticidal)	0.25-1.0 gal/100 gal 1-2 gal/100 gal 3.0-6.0 qt/ 100 gal	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:** 1.0-4.0 oz	12	1	cucumber beetles, grasshoppers, stink bugs, suppression of green peach and potato aphids	4A	Use only one application method (soil or foliar). Limited to three applications per season. Toxic to honeybees.
Venom Insecticide (dinotefuran)	**soil:** 5.0-6.0 oz	12	21	Colorado potato beetle, flea beetles, grasshoppers, leafhoppers, leafminers, thrips, whiteflies, suppression of green peach and potato aphids	4A	Use only one application method (soil or foliar). Must have supplemental label for rates over 6.0 oz/acre.
Verimark (cyantraniliprole)	5.0-13.5 fl oz	4	1	armyworms, loopers, tomato fruitworm, tomato pinworm, flea beetles, green peach aphid, potato aphid, leafminers, thrips	28	Do not apply more than 0.4 lb ai/acre per crop whether applications are made to soil or foliarly.
Vetica (flubendiamide, buprofezin)	12.0-17.0 fl oz	12	1	armyworms, cabbage looper, cutworms, garden webworm, saltmarsh caterpillar, tobacco budworm, tomato hornworm, tomato fruitworm, tomato pinworm, suppression of leafhoppers, mealybugs, and whiteflies	28, 16	Do not apply more than 3 times per season or apply more than 38 fl oz per acre per season. Same classes of active ingredients as Belt, Synapse, Coragen (all group 28), and Courier (group 16).
Voliam Flexi (thiamethoxam, chlorantraniliprole)	4.0-7.0 oz	12	1	aphids, beet armyworm, Colorado potato beetle, fall armyworm, flea beetles, hornworms, leafhoppers, loopers, southern armyworm, stink bugs, tobacco budworm, tomato fruitworm, tomato pinworm, whitefly, yellowstriped armyworm, suppression of leafminer	4A, 28	Do not use in greenhouses or on transplants. Do not use if seed has been treated with thiamethoxam or if other Group 4A insecticides will be used. Highly toxic to bees. Do not exceed 14 oz per acre per season, or 0.172 lb ai of thiamethoxam-containing products or 0.2 lb ai of chlorantraniliprole-containing products per acre per season.
***Voliam Xpress** (lambda-cyhalothrin, chlorantraniliprole)	5.0-9.0 fl oz	24	5	aphids, armyworms, Colorado potato beetle, cucumber beetle adults, flea beetles, leafhoppers, leafminers, stink bugs, thrips (suppression - does not include Western flower thrips), tobacco budworm, tomato fruitworm, tomato pinworm, whiteflies (suppression)	3A, 28	Do not apply more than 31.0 fl oz Voliam Xpress or equivalent of lambda-cyhalothrin or chlorantraniliprole containing products per acre per season.
***Vydate L** (oxamyl)	**foliar:** 2.0-4.0 pt	48	3	aphids, Colorado potato beetle, *Liriomyza* leafminers (suppression), , whiteflies (suppression)	1A	Do not apply more than 32 pts per acre per season.
***Warrior II** (lambda-cyhalothrin)	0.96-1.92 fl oz	24	5	aphids(1), beet armyworm(2), cabbage looper, Colorado potato beetle, cutworms, fall armyworm(2), flea beetles, grasshoppers, hornworms, leafhoppers, leafminers(1), plant bugs, southern armyworm(2), stink bugs, thrips(3), tomato fruitworm, tomato pinworm, whitefly(1), vegetable weevil adults, yellowstriped armyworm(2)	3A	(1) suppression only (2) for control of 1st and 2nd instars only. Do not apply more than 0.36 lb ai per acre per season. (3)Does not control Western flower thrips.
Xentari DF (*Bacillus thuringiensis* subspecies *aizawai*)	0.5-2 lb	4	0	caterpillars	11A	Treat when larvae are young. Thorough coverage is essential. May be used in the greenhouse. Can be used in organic production. OMRI-listed[2].

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

[1] Mode of Action codes for vegetable pest insecticides from the Insecticide Resistance Action Committee (IRAC) Mode of Action Classification v.7.3 February 2014. http://www.irac-online.org/wp-content/uploads/MoA-classification.pdf

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

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

*** Restricted Use Only**

Nematicides Registered for Use on Florida Tomato

Joseph W. Noling
University of Florida/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/1000Ft/Chisel
FUMIGANT NEMATICIDES					
Methyl Bromide[1,3] 50-50	300-480 lb	12"	3	250 lb	6.8-11.0 lb
Chloropicrin EC[1]	300-500 lb	Drip applied	See label for use guidelines and additional considerations		
Chloropicrin[1]	300-500 lb	12"	3	150-200 lb	6.9-11.5 lb
Dimethyl Disulfide[1]	35-51 gal	12"	3	17.5 – 25.5	102-149 fl oz
PIC Clor 60[1]	19.5 – 31.5 gal	12"	3	20-25 gal 250-300 lb	117- 147 fl oz
Telone II[2]	9 -18 gal	12"	3	6 -9.0 gal	35-53 fl oz
Telone EC[2]	9 -18 gal	Drip applied	See label for use guidelinesand additional considerations		
Telone C-17[2]	10.8-17.1 gal	12"	3	10.8-17.1 gal	63-100 fl oz
Telone C-35[2]	13-20.5 gal	12"	3	13-20.5 gal	76-120 fl oz
Telone Inline[2]	13-20.5 gal	Drip applied	See label for use guidelineand additional considerations		
Metam sodium	50-75 gal	5"	6	25-37.5 gal	73-110 fl oz
Metam potassium 30-62 gal5"615-31.0 gal44-91 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%. Some crop and specific Florida county uses of Dimethyl Disulfide (DMDS) now required totally impermeable mulch film (TIF).
2. The manufacturer of Telone II, Telone EC, Telone C-17, Telone C-35, and Telone Inline has restricted use only on soils that have a relatively shallow hard pan or soil layer restrictive to downward water movement (such as a spodic horizon) within six feet of the ground surface and are capable of supporting seepage irrigation regardless of irrigation method employed. Crop use of Telone products do not apply to the Homestead, Dade county production regions of south Florida. Higher label application rates are possible for fields with cyst-forming nematodes. Consult manufacturers label for personal protective equipment and other use restrictions which might apply.
3. As a grandfather clause, it is still possible to continue to use methyl bromide on any previous labeled crop as long as the methyl bromide used comes from existing supplies produced prior to January 1, 2005. A critical use exemption (CUE) for continuing use of methyl bromide was not awarded for tomato, pepper and eggplant for calendar year 2014. As of January 1, 2014, **<u>all of the prior approved CUE uses of methyl bromide for these crops finally came to an end in Florida</u> .** Specific, certified uses and labeling requirements for any methyl bromide acquired for field use must now be certified and labeled as coming from existing stock from distributors prior to grower purchase and use in these crops. Methyl bromide products purchased and farm delivered as CUE stock before December 31, 2013 are still available for future use. Product formulations are subject to change and availability.
4. Rate/acre estimated for row treatments to help determine the approximate amounts of chemical needed per acre of field. If rows are closer, more chemical will be needed per acre; if wider, less. Reduced rates are possible with use of gas impermeable mulches.

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 June 30, 2014 as a reference for the commercial Florida tomato grower. The mentioning of a chemical or proprietary product in this publication does not constitute a written recommendation or an endorsement for its use by the University of Florida, Institute of Food and Agricultural Sciences, and does not imply its approval to the exclusion of other products that may be suitable. Products mentioned in this publication are subject to changing Environmental Protection Agency (EPA) rules, regulations, and restrictions such as requirements for buffer zones, fumigant management plans (FMP), post application summary reports, mandatory good agricultural practices, and EPA approved certified applicator fumigant product training. Additional products may become available or approved for use.

NOTES:

NOTES: