FLORIDA TOMATO INSTITUTE PROCEEDINGS

SEPTEMBER 5,2007

Compiled by:
Alicia Whidden, UF/IFAS, Hillsborough County Extension Service, Seffner
Phyllis Gilreath, UF/IFAS, Manatee County Extension Service, Palmetto
Eric Simonne, UF/IFAS, Horticultural Sciences Department, Gainesville

CITRUS+ VEGETABLE

UNIVERSITY OF FLORIDA IFAS EXTENSION

THE GROWER

2007 FLORIDA TOMATO INSTITUTE

Ritz Carton • Naples, Florida • September 5, 2007 **PRO 524**

Moderator: *Alicia Whidden, Hillsborough County Extension Service, Seffner*

9:00 **Welcome** – Joan Dusky, Associate Dean & Professor, UF/IFAS, Gainesville

9:10 **State of the Industry** – Reggie Brown, Florida Tomato Committee, Maitland

9:20 **CUE and Fumigant Assessment Update** – Mike Aerts, FFVA, Maitland

9:40 **Critical Issues for the Tomato Industry: Preventing a Rapid Postharvest Breakdown of Fruit –** Jerry Bartz, Gainesville **PAGE 4**

9:50 **Food Safety Update and TGAP Program** – Martha Roberts, UF/IFAS, Tallahassee

10:20 **Results of Latest BMP Trials** – Monica Ozores-Hampton, UF/IFAS, SWFREC, Immokalee **PAGE 8**

10:50 **Recent Developments and Release Outlook from the University of Florida Tomato Breeding Program** – Jay Scott, UF/IFAS, GCREC, Balm **PAGE 13**

11:10 **Western Flower Thrips: on the Move?** – Joe Funderburk, UF/IFAS, NFREC, Quincy **PAGE 16**

11:30 **Lunch and Visit Information Cafe**

Moderator: *Phyllis Gilreath, Manatee County Extension Service, Palmetto*

1:00 **Got Gas? Keep it Under Wraps** – Jim Gilreath, PhytoServices, Myakka City **PAGE 20**

1:20 **Whitefly Resistance Update** – Dave Schuster, UF/IFAS, GCREC, Balm **PAGE 23**

1:40 **Small Viruses That Cause Big Problems in Tomatoes** – Jane Polston, UF/IFAS, Gainesville **PAGE 29**

2:00 **Industry New Product Updates** – TBA

3:00 **Adjourn and Visit Information Cafe**

CONTROL GUIDES

CRITICAL ISSUES FOR THE TOMATO INDUSTRY: PREVENTING A RAPID POSTHARVEST BREAKDOWN OF FRUIT

J. A. Bartz[1], S. A. Sargent[2] and P. R. Gilreath[3]
[1]UF/IFAS, Plant Pathology Dept., Gainesville, softbart@ufl.edu
[2]UF/IFAS, Horticultural Sciences Dept., Gainesville, sasa@ufl.edu
[3]UF/IFAS, Manatee County Extension Service, Palmetto, phyllisg@ufl.edu

What is rapid fruit breakdown? Rapidly growing lesions become visible within 12 to 18 hours after harvest and continue to develop among packed fruit in the ripening room. The lesions produce large amounts of fluid leading to wet patches appearing on the exterior of the cartons and the spread of decay within the box. Affected fruit are out-of-grade either prior to shipment or upon arrival at the receiver.

BRIEF HISTORY

Severe outbreaks of postharvest decay have occurred sporadically in the Florida and eastern U.S. tomato production areas for the past several years. During the summer of 2006, the problem was persistent in the production areas of Virginia and Maryland. In October, extensive losses occurred at the beginning of the harvest season in north Florida but disappeared within a few days. The decay losses feature a rapid breakdown of green fruit where lesions can appear within 18 hours of harvest. At the time ripening rooms are opened, packers observe lesions on fruit surfaces along with a release of fluids. Wet spots may appear on the lower part of cartons where the fluid has leak.

Growers suggest that a condition called "tender fruit" leads to decay losses. The term "tender fruit" does not have a scientific definition, but to growers it means enhanced bruising during harvest. In 1964, R. S. Cox observed a field disorder, shoulder pox, on tomatoes produced in the lower east coast of Florida, which he attributed to the combination of tender fruit, cool moist weather and the application of certain pesticides. However, rapid fruit breakdown has usually occurred during or after warm, moist weather, which is also a likely promoter of fruit tenderness. A quick change in the weather from very warm, dry conditions to cooler temperatures featuring heavy fogs has also been associated with tender fruit. Conditions leading to tender fruit likely coincide with wet fields and moist plant canopies. This wetness promotes an increase in the populations of decay pathogens on the plants, and insect wounds and other types of injuries lead to infections. Moisture on fruit at the time of harvest readily disperses the pathogens to wounds. The common recommendation for avoiding decay issues associated with wet fields is "don't harvest if the plants have free moisture on them." However, at times, this may not be a viable option for growers either due to price, crop maturity or labor issues.

The following guide is intended as a quick checklist of suggestions for minimizing rapid breakdown of tomato fruit. This breakdown is normally caused by two postharvest diseases, bacterial soft rot and sour rot. Key symptoms and causes about each type of disease follow.

SOFT ROT BACTERIA (BACTERIAL SOFT ROT)

- Are found in all humid growing areas and exist in highest populations on plants and in surface water.
- May cause lesions at injuries on stems or petioles if the canopy remains wet for several days.
- Are dispersed to tomato fruit via rain splash, storms, insects, equipment, and the hands of field crews during harvest.
- Infect fruit equally well at any stage of maturity or ripeness.
- Cannot cause decay on healthy tissue – they enter via wounds or are forced into fruit by water.
- Rapidly disintegrate fruit tissues and usually produce cloudy fluids and an unpleasant aroma.
- Their infection first becomes visible as a water-soaking of wounds or portions of wounds including cuticle cracks, surface cracks, stem punctures, insect wounds, abrasions, etc.
- If internalized (forced into the fruit), cause lesions beside or beneath the stem scar, the attached stem (fruit still on plant) or beneath the blossom-end scar (Figs. 1-3).
- Become internalized when fruit are harvested wet (wet stem scars absorb bacteria), exposed to rainfall after harvest or submerged too long or deeply in dump tank water.
- A white yeast-like fungus may grow over the surface of the bacterial soft rot lesions (see sour rot section below).
- Decaying fruit collapse within a few days after disease onset, depending on the storage temperature.
- The contact of healthy fruit with the cloudy fluid from decaying fruit will spread the disease among packed fruit in cartons or among fruit still on the plant.
- Initial water soaking and disintegration of tissues can become visible within 12 h of inoculation, particularly among fruit stored at higher temperatures (>80°F).
- The disease is favored by moist conditions (dry wounds may remain free of disease for several days) and develops most rapidly at 77 to 97°F.
- Onset of the disease is delayed up to

3 days among fruit stored at 70˚F as compared with those stored at 86˚F.

SOUR ROT PATHOGENS (SOUR ROT)

- Include certain Geotrichum species as well as bacteria that produce lactic acid.
- Have been isolated from the soil, plant debris, decaying tissues, garbage, and sewage as well as from the canopies of healthy plants (although the latter had only small populations).
- Are dispersed from sources to tomato fruit by splashing rainfall, field crews, equipment, and insects -- including fruit flies and those causing surface injuries.
- Cannot cause fruit decay unless they get into wounds or inside fruit (see soft rot bacteria for a description of internal lesions).
- Initial symptoms appear as a water-soaking of tissues in or around the edges of wounds including the stem scar, open blossom-end pore or scar, cuticle cracks, etc. (Figs. 4-6).
- Lesions do not enlarge as rapidly as those produced by soft rot bacteria.
- The minimum interval between inoculation of wounds and the beginning of water soaking is unclear but appears to take longer than soft rot.
- The liquid seeping out of sour rot lesions is generally clear and has a distinctive sour odor or no odor at all.
- Lesions usually become covered by a white yeast-like growth within 24 hours of exposure to air (Figs. 4 & 5).
- Warm moist conditions favor disease development (optimum = 86˚F).
- Green tomatoes have been described as being resistant to sour rot except if weakened by chilling injury. With exposure to air, sour rot lesions on tender green fruit (Fig. 7) often become arrested (Fig. 8). However, red tomatoes are susceptible. The susceptibility of green fruit being gassed with ethylene, bruised green fruit or tender green Fruit is currently being investigated.
- Cracks in the fruit surface, including rain checks (Fig. 5) and cuticle cracks, may lead to infection particularly under moist conditions.
- It is unclear if sour rot infects the petioles, stems or leaves of the fruit, but increased populations of lactic acid bacteria have been associated with humid weather in the field.

PREVENTING LOSSES TO POSTHARVEST DECAY

- **Field practices.** Provisions should be made for insuring adequate drainage, particularly if unsettled weather might occur during the production season.
- Recommended disease and insect control practices should be used.
- If at all possible, fruit should not be harvested if the plants are wet, even if there are only a few droplets of free moisture on or at the edges of leaves as this will lead to the spread of decay pathogens among the fruit. Figs. 9 & 10 illustrate that wet stem scars rapidly internalize decay pathogens that contact the scar surface.
- Clean and disinfect all harvest containers prior to first harvest and periodically during the harvest season. Some packers clean and sanitize bins after each use.
- Immediately clean and disinfect any container that has been in contact with

Figure 1. Bacterial soft rot - internal lesion. Bacteria entered into fruit under the stem attachment Credits: S. R. Bartz

Figure 2. Bacterial soft rot - internal lesion. Bacteria entered through blossom-end scar of fruit. Credits: S. R. Bartz

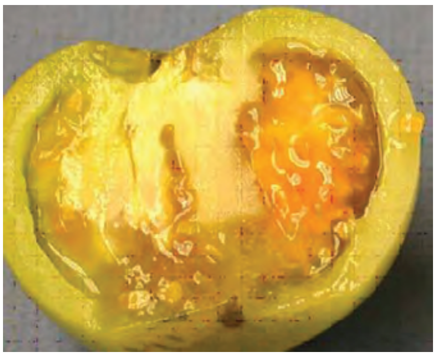


Figure 3. Bacterial soft rot - internal lesions. Internal view of bacterial soft rot that began at blossom and stem ends of fruit. Credits: S. R. Bartz

Figure 4. Rain check. Dark checked areas are a severe form of cuticle cracking that develops in wet weather. The cracks enable attack by postharvest pathogens. Credits: M. J. Mahovic

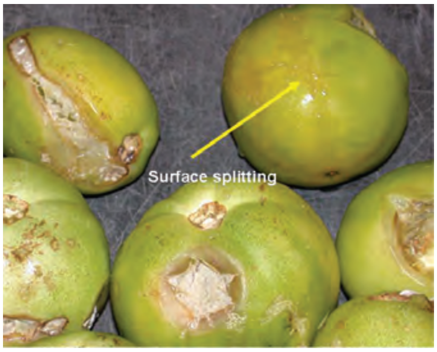


Figure 5. Sour rot - from natural outbreak. Dark rough areas are rain checks. Fruit (upper right) has surface splitting due to decay spread in the carton. Credits: M.J. Mahovic

decayed fruit.

- Teach harvest crews to avoid handling or picking partially decayed fruit.
- Require harvest crews to wear gloves so that the glove surfaces can be washed in chlorinated water immediately after encounters with decaying fruit, as well as periodically during the day (lunch breaks, etc.).
- Avoid mechanically injuring fruit during harvest and avoid excessive load shifting during transport to the packinghouse.
- Bins or gondolas of harvested tomatoes should not be exposed to rainfall or suffer prolonged exposure to direct sunlight; loads hauled from fields to distant packinghouses should be covered with a tarpaulin (Figs 9 & 10).
- **Postharvest practices.** The water in dump tanks and flumes should contain a minimum of 150 ppm free chlorine at pH 6.5 to 7.5 at the point where the fruit enter the water.
- Containers of chlorine products must be kept out of direct sunlight (heating causes a rapid loss of free chlorine) and should be stored in a cool, well-ventilated location.
- Flumes must be designed to avoid "dead" pockets, where fruit float in an eddy current are not floated promptly to the packing line elevator.
- Fruit should not be allowed to remain in the water more than 2 minutes.
- The water can be warmed 5 to 10 degrees above the fruit temperature to improve fruit handling and drying.
- The spray rinse on the fruit exiting the flume should contain some free chlorine so that the fruit carry active disinfectant down the moist part of the packing line.
- At this time it is not recommended to replace the chlorine spray with an organic acid or other natural product-based material because the efficacy of these products for preventing biofilm development (sliminess on sponge beds or other equipment) is unknown. Additionally, the ability of these products to control lactic acid bacteria or

Figure 8. Arrested sour rot lesions. Sour rot lesions in green fruit may become arrested when exposed to air. The decay will resume development as the fruit ripens. Credits: M. J. Mahovic

Figure 6. Sour rot - internal lesions from natural outbreak. Rough fruit became infected through blossom end scars and wounds. Tissues appear to be pickled with only a little evidence of fungal development at the surface. Credits: P. R. Gilreath

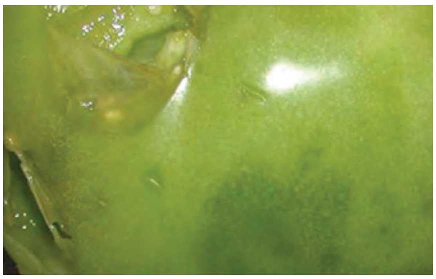


Figure 7. Sour rot infection in green tomato involves high water content. An apparent bruise with infection occurring at tiny cracks in the fruit surface is evidence that this fruit is tender, which likely means high water content. Credits: M. J. Mahovic

the sour rot yeast (two of the decay agents isolated from decaying fruit) is unknown.

- All injured tomatoes must be culled prior to packing.
- The packed fruit should be promptly cooled to 70°F or less, particularly when the fruit appear to be tender and field conditions and temperatures favor decay development. Stacked pallets should be placed so as to ensure that all boxes are exposed to the circulating air in the gas room.
- **If a harvest must be scheduled while the plants are wet or the fruit are tender, the following will reduce the decay risk:**
- Picking containers of fruit must be gently emptied into field bins or gondolas as wet and/or tender fruit are prone to bruising and abrasions that lead to infection.
- Fruit must be gently hauled from field to packinghouse - speeding over rough roads can cause excessive fruit bouncing and vibration, which leads to bruising injury.
- Rapidly removing field heat will slow decay development. Tomatoes cooled to 68°F or lower by forced-air cooling are unlikely to develop lesions quickly. The moving air dries moisture from stem scars and fruit surfaces, which decreases the chances for infection.
- Holding bins of tender fruit overnight to facilitate the disappearance of minor bruises is likely to favor growth of decay pathogens if the pulp temperature remains high (>85°F). However, if the fruit are cool (< 70°F), the overnight holding period should decrease decay risks (dry wounds and stem scars aren't as susceptible as wet ones).
- People responsible for culling fruit on the packing line must "cull tight" and remove all injured fruit, even those with minor surface cracks.
- Chlorine concentrations in dump tanks and flumes must be monitored carefully, and should not be excessive. Higher chlorine concentrations will not control decay any better than recommended levels.
- Bins of fruit harvested from wet fields contain leaves and other debris and the fruit will appear "grimy." Such loads have an unusually high chlorine demand and quickly depress active chlorine levels in the dump tank and flume.
- Maintaining adequate free chlorine concentration and pH in dump tank water during these periods requires vigilance. Frequent free-chlorine measurements are recommended, even if an automated oxidation-reduction measurement (ORP) system is in place. With the latter, false readings may occur due to fouled electrodes or other measurement problems.

Figure 9. Fruit picked during a shower and then dye added to wet stem scar. The dye was washed off after 2 minutes and the fruit was sliced. Note the green dye moving down vascular tissues from the stem scar (top). Credits: S. R. Bartz

Figure 10. Bacterial soft rot - internal lesion. Water - congested stem scar, such as was present in Figure 9, eliminated protection provided by a dry stem scar and enabled bacteria to enter fruit by capillary forces. Credits: S. R. Bartz

FOR MORE INFORMATION:

The Growers IPM Guide for Florida Tomato and Pepper Production. http://ipm.ifas.ufl.edu/resources/success_stories/T&PGuide/index.shtml

Identifying and Controlling Postharvest Tomato Diseases in Florida. EDIS publication HS866. http://edis.ifas.ufl.edu/HS131

Physiological, Nutritional and Other Disorders of Tomato Fruit. EDIS Publication HS-954. http://edis.ifas.ufl.edu/HS200

RESULTS OF NITROGEN BMP TOMATO TRIALS FOR THE 2006-2007 SEASON

Monica Ozores-Hampton[1], Eric Simonne[2], Eugene McAvoy[3], Fritz Roka[1], Pam Roberts[1], Phil Stansly[1], Sanjay Shukla[1], Kent Cushman[1] Morgan Kelly[1] Tom Obreza[4], Phyllis Gilreath[5], Darrin Parmenter[6]

[1]University of Florida/IFAS, SWFREC, Immokalee, FL. [2]University of Florida, Horticultural Sciences Department, Gainesville, FL. [3]Hendry County Extension Service. [4]University of Florida, Soil and Water Science Department, Gainesville, FL. [5]Manatee County Extension Service, [6]Palm Beach County Extension Service.

ABSTRACT.

Best management practices (BMPs) for Florida vegetable crops are a combination of nonstructural and structural practices which have been determined to be effective for reducing or preventing pollutant load in target watersheds. There are 49 BMPs in the Florida BMP manual (www.floridaagwaterpolicy.com) including an "Optimum fertilization management and application" section that adopts the University of Florida (UF/IFAS) N rate recommendations. Hence, N fertilizer recommendations and practices should reflect the different growing seasons, soil types, and irrigation systems used for tomato production. In partnership with tomato growers, the objectives of this project are to evaluate N fertilizer rate effects on plant growth, petiole N sap, fruit yield, and disease incidence. Data were subjected to ANOVA, T-test and Duncan Multiple Range Test as well as regression analysis. In the 2006-07 growing season, thirteen on-farm trials were conducted in the fall, winter and spring with N rates ranging from 200 to 330 lb/acre. Each trial included the UF-IFAS recommended rate and at least one grower-defined rate, except the multiple N rate study with eight N rates from 20 to 420 lb/acre at 60 lb/acre increments. Routine sap NO_3-N and K were above published sufficiency ranges in all the trials and seasons. In this dry season, IFAS and grower rates produced significant higher yield in first harvest of extra-large tomatoes and total yields in 1 and 2 out of 13 trials, respectively. The trend indicated an increase in total yield and first harvest extra-large and total extra-large fruit from 20 to 240 lb/acre N, but a plateau with higher rates of N. These results show that it may be possible to reduce N rates especially when the risk of rainfall is low (winter, spring and dry year), or when only two harvests are expected (late spring). Differences in yield under current fertilizer prices ($40 per 100 lb/acre of N) were much lower than traditional ANOVA, t-test and Duncan Multiple Range Test could detect (less than 300 boxes/acre of 25 lb box of tomato) due to the variability of weather conditions and the interaction with seasons and year. Together the cooperating farms represented 16,000 acres (80%) of staked tomato production in southern and eastern Florida and 310 acres under BMP experiments.

INTRODUCTION

Seventy percent of Florida tomato production is in the South Florida counties of Collier, Manatee and Palm Beach with approximately 41,200 acres in 2006 (NASS, 2006). Tomatoes are grown primarily in sandy soils. These crops are mostly grown in South Florida in the fall, winter or spring growing seasons under intensive irrigation and fertilizer management. Nitrogen (N) fertilizer management has become an issue of environmental concern for Florida vegetable growers following the adoption by the State of Florida of vegetable BMPs [Best Management Practices, (**www.floridaagwaterpolicy.com)**]. BMPs emphasize the need to better manage fertilizer, increase fertilizer efficiency, and reduce N loss to the environment. The optimum fertilization management and application section of the manual incorporates University of Florida (UF/IFAS) N rate recommendations. The most common method for producing tomato in South Florida is to use seepage-irrigation together with fumigated raised beds with polyethylene mulch. Therefore, nutrient management is tied to this unique irrigation system. Because the plastic mulch covers the soil surface, all fertilizers (N, P, K, and micronutrients) are applied preplant. Typically, fertilizer is applied as a "bottom mix" (or "cold mix") and a "top mix" (or "hot mix"). All the P and micronutrients, and 20% to 30% of the N and K are applied broadcast and incorporated in the bed as the bottom mix. The remaining N and K are applied in 1 or 2 grooves made on the top of the bed. Fertilizer in the "top mix" is slowly solubilized as the water moves up by capillarity (Olson et al., 2006a and b). While this system is simple and well established, growers often use N fertilizer rates above the UF/IFAS recommended rate because N may be lost by leaching or denitrification (Cockx and Simonne, 2003), but mostly as an inexpensive insurance if the market conditions remain favorable resulting in a longer-than-expected harvest season. When soluble fertilizers are leached by excessive rainfall (a leaching rainfall is defined as 3 inches of rain in 3 days or 4 inches in 7 days), UF-IFAS recommendations (Olson et al., 2006a and b) and vegetable BMPs (BMP 33I, p.96 of the BMP manual for vegetable and agronomic crops) allow for a supplemental application (per planted acre basis) of 30 lbs of N and 20 lbs of K_2O. Supplemental fertilizer applications should be made after a leaching rain, not before or preventively. While drip irrigation allows for easy in-season fertilizer application, crops grown with plastic mulch and seepage irrigation require a down-the-row application of fertilizer, done either manually or using a fertilizer wheel increasing the production cost.

Table 1. Experiment number, irrigation type, N rates evaluated, plot size, planting date, and number of harvests in the 2006-07 N management trials in southwestern and eastern Florida.

Trial number	Location	Season	Irrigation type	N rate (lb/acre)[z]	Experiment size (acres)	Planting date	Number of harvest
1	Collier	Fall	Seepage	200 and 260	21 (CRD)	Aug 31	3
2	Collier	Winter	Drip	200 and 300	35	Oct 16	3
3	Collier	Winter	Seepage	200, 250, 200+C[y]	1 (CRD)	Oct 17	3
4	Collier	Winter	Seepage	200 and 320	3 (CRD)	Oct 26	3
5	Collier	Winter	Seepage	200 and 260	21 (CRD)	Nov 15	3
6	Collier	Winter	Drip	200 and 300	50	Nov 27	3
7[x]	Palm Beach	Winter	Seepage	200 and 300	5.5 (CRD)	Nov 21	3
8[x]	Palm Beach	Winter	Seepage	200 and 300	5.5 (CRD)	Nov 24	3
9	Collier	Spring	Seepage	200 and 260	18 (CRD)	Feb 12	3
10	Manatee	Spring	Seepage	20 to 420	0.4 (CRD)	Feb 15	3
11	Manatee	Spring	Drip	225 and 330	19	Feb 19	3
12	Manatee	Spring	Drip	225 and 330	19	Feb 19	3
13	Manatee	Spring	Drip	225 and 330	13	Feb 19	3
Total	-	-	-	-	310	-	-

[z] based on 6-ft spacing

[y] C = Yard Waste compost 12 tons/acre

[x] 25 % of the total N slow release fertilizer in the hot-mix

BMP education is a slow process that requires the reconciliation of the rigor of science with the reality of vegetable production today (Simonne and Ozores-Hampton, 2006; Cantliffe et al., 2006). However, when BMP education is based on trust and a mutual commitment to the success of the project, a win-win situation develops where productivity, profitability, and environmental impact are integrated. Since the first 3 x 100-ft long bed demonstrations conducted in the 2003-2004 season by G. McAvoy and E. Simonne, a lot of trust has been developed between UF-IFAS, FDACS, and South Florida growers on nutrient management issues. This is best shown by the number and size of trials conducted in 2006-2007 (multiple rate trials, randomization and replication of the treatments, and 3-acre plots; Ozores-Hampton et al., 2006).

A 3-year project was initiated in southwest Florida in 2004-05 to 1) establish partnerships with selected tomato growers to evaluate the effects of N fertilization in commercial fields; 2) evaluate the effect of N fertilizer rate on plant growth, nutritional status, yield, disease and pest incidences, and crop market value; 3) determine the optimum N rate for tomato production; and 4) evaluate the cost effectiveness of selected N application rates. This paper reports the results of the 3rd year of this project and focuses on objectives (1) and (2).

MATERIALS AND METHODS

We conducted thirteen trials at five commercial farms in multiple locations and seasons (fall, winter and spring) during the 2006-2007 seasons (Table 1). Together the cooperating farms represented 16,000 acres (80%) of staked tomato production in southern and eastern Florida. Soils in the area have a sandy surface layer that is prone to leaching mostly Immokalee and EauGallie fine sand. Growing seasons are defined as fall with planting dates from 1 August to 15 Oct., winter from 15 Oct. to 15 Dec. and spring from 15 Dec. to 1 Feb. These seasons differ in rainfall patterns, temperatures and day length. For example, fall may bring hurricanes, leaching rains, and wide-ranging temperatures; winter brings cool temperatures and unpredictable freezes accompanying cold fronts; spring is typically dry with temperatures cool at the start and warm or hot at the end. Typical growing season lengths are 18, 20, and 16 weeks for fall winter and spring, respectively. Therefore, eight trials were done with seepage, two with drip and three with a combination seepage/drip irrigation. One trial was conducted in fall 2006, nine in the winter (2006-07) and four in spring 2007. Treatments consisted of N fertilizer rates ranging from 200 to 330 lb/acre N applied to seepage-irrigated tomatoes in a completely randomized experimental design with three replications (Table 1), except the multiple N rate study with eight N rates from 20 to 420 lb/acre at 60 lb/acre increments in a completely randomized block experimental design

Table 2. Initial multiple N fertilizer treatments for seepage irrigated tomatoes grown during spring 2007, Manatee County.

Treatments	Fertilizer Bottom mix (lb N/acre)	Fertilizer Hot mix (lb N/acre)	Fertilizer Total N Rate (lb N/acre)
1	20	0	20
2	20	40	60
3	20	100	120
4	20	160	180
5	20	220	240
6	20	280	300
7	20	340	360
8	20	400	420

Table 3. Summary of rainfall, number of leaching rain events and possible and applied supplemental N during 2006-07 tomato season.

Trial	Season	Number of days from planting to last harvest	Location	Total rainfall (inches)	Number of leaching rainfalls	Possible[Z] and applied supplemental N (lb/acre)
1	Fall	188	Collier	4.89	0	0/0
2	Winter	136	Collier	2.97	0	0/0
3	Winter	141	Collier	1.26	0	0/0
4	Winter	112	Collier	1.26	0	0/0
5	Winter	128	Collier	0.53	0	0/0
6	Winter	135	Collier	2.25	0	0/0
7	Winter	122	Palm Beach	13.37	1	30/0
8	Winter	120	Palm Beach	13.37	1	30/0
9	Spring	108	Collier	1.83	0	0/0
10	Spring	117	Manatee	10.38	1	30/0
11	Spring	113	Manatee	9.43	1	30/0
12	Spring	113	Manatee	9.43	1	30/0
13	Spring	113	Manatee	9.43	1	30/0

[Z] UF-IFAS supplemental fertilizer application is allowed after a leaching rain defined as 3 inches in 3 days or 4 inches in 7 days for tomatoes (Olson et al., 2005)

Figure 1. Effect of multiple N rates (trial 10) on NO_3-N sap on tomato during season 2006-07.

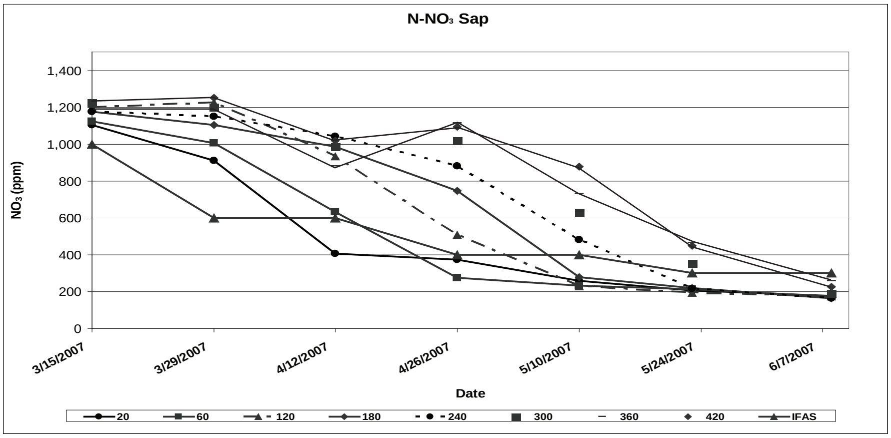
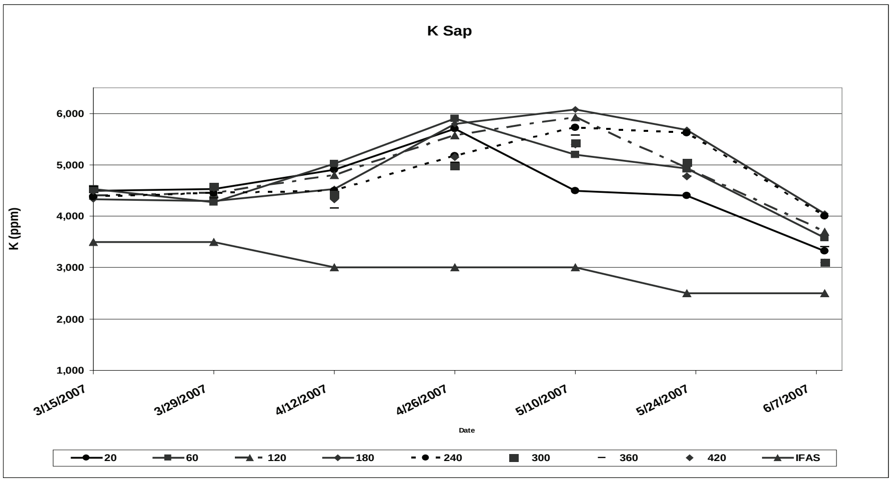
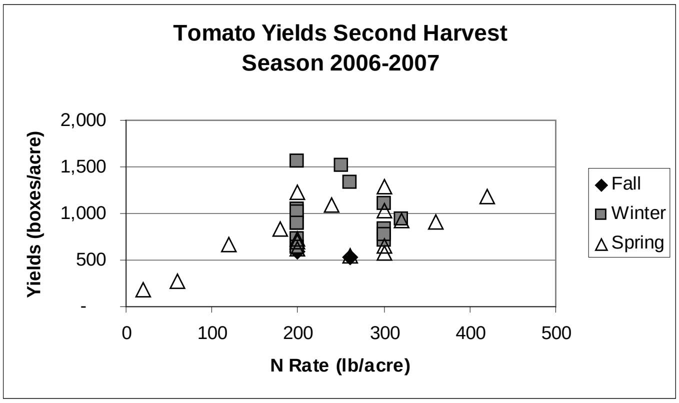


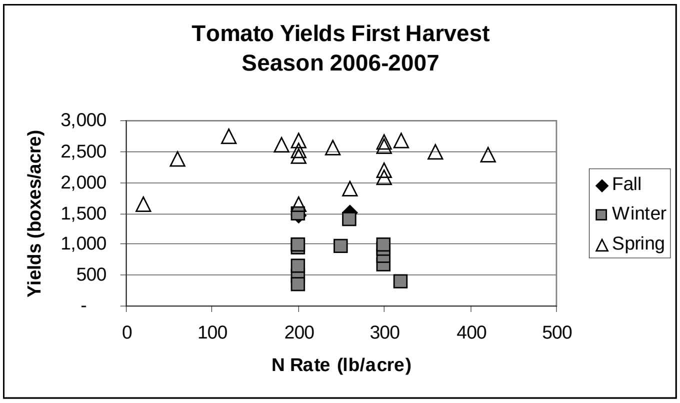
Figure 2. Effect of multiple N rates (trial 10) on K-sap on tomato during season 2006-07,

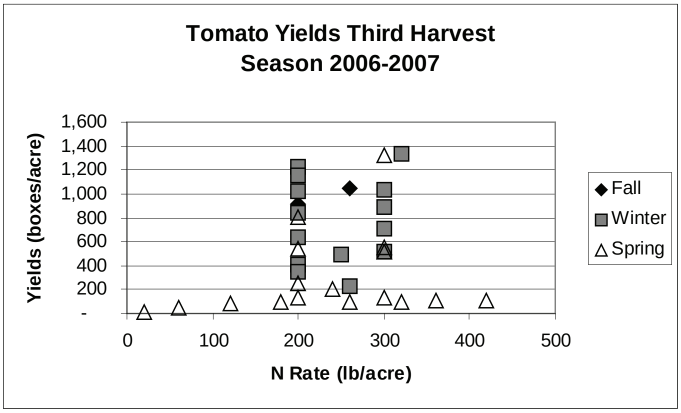


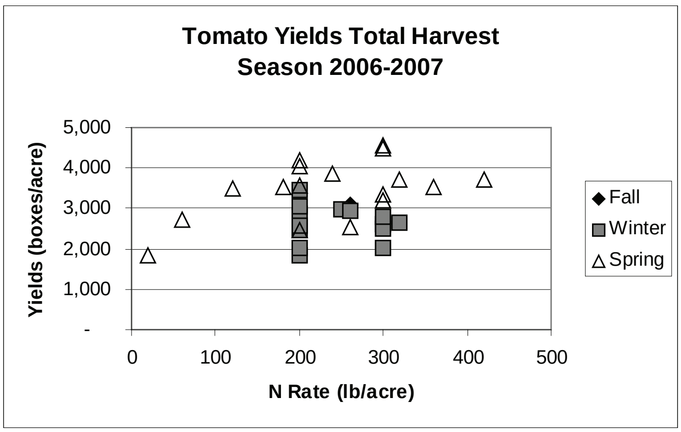
with four replications (Table 2). In drip-irrigated fields, there were two individual zones representing IFAS and grower N rates. At the seepage-irrigated fields, the UF-IFAS rates were achieved by changing the rate or composition of the hot mix and by applying custom-made blends to keep P, K and micronutrient rates constant. Hot-mix N and K fertilizer sources were water soluble nutrients, except trials 7 and 8 with a 25% slow release fertilizer. The trials represented diverse growing conditions found in Southwest and East Florida, and also included different varieties (mostly 'Florida 47' and 'Sebring'), plant densities (in-row spacing of 18 to 26 inches between plants; 5 or 6 ft bed centers), soil types (described above), and farm sizes (700 to 5,000 acres). Cooperators prepared beds, fumigated the soil, applied bottom and hot mixes and installed polyethylene mulch, transplanted, pruned, staked, irrigated and provided pest and disease control.

Data collection: Water table depth was recorded bi-weekly throughout the growing season. Beginning at first flower buds and continuing until third harvest, fresh petiole sap NO_3-N and K concentrations were measured bi-weekly using ion-specific meters (Cardi, Spectrum Technologies, Inc., Plainfield, IL) (Olson et al., 2005). Harvested plots were 15









First Harvest	N Rate	(boxes/acre) XL	L	M	Total
Trial			Fall		
1	200 and 260	ns	ns	IFAS	ns
			Winter		
2	200 and 300	GROWER	ns	GROWER	GROWER
3	200, 250, 200+C[y]	ns	IFAS	IFAS	ns
4	200 and 320	ns	ns	ns	ns
5[v]	200 and 260	ns	ns	ns	ns
6	200 and 300	GROWER	IFAS	ns	ns
7	200 and 300	ns	ns	ns	ns
8	200 and 300	ns	ns	ns	ns
			Spring		
9[v]	200 and 260	ns	ns	ns	ns
11	225 and 330	ns	ns	ns	ns
12	225 and 330	ns	ns	ns	ns
13	225 and 330	ns	ns	ns	ns

Second Harvest	N Rate	(boxes/acre) XL	L	M	Total
Trial			Fall		
1	200 and 260	ns	ns	ns	ns
			Winter		
2	200 and 300	ns	GROWER	GROWER	ns
3	200, 250, 200+C[y]	ns	ns	ns	ns
4	200 and 320	ns	GROWER	ns	ns
5[v]	200 and 260	ns	IFAS	ns	ns
6	200 and 300	ns	ns	IFAS	ns
7	200 and 300	ns	ns	ns	ns
8	200 and 300	ns	ns	ns	ns
			Spring		
9[v]	200 and 260	ns	ns	ns	ns
11	225 and 330	GROWER	ns	IFAS	ns
12	225 and 330	ns	ns	ns	ns
13	225 and 330	ns	ns	ns	ns

[z] 25-lb tomatoes/box
[y] XL = Extra-large (5x6 industry grade); L = Large (6x6); M = Medium (6x7)
[x] C = Yard waste compost 12 tons/acre
[w] growers, IfasSignificant and ns non-significant at P <0.01.
[v] Trials effected by TYLCV
Trial 10 not show in the tables.

to 22-ft long row segments of 10 plants. They were clearly marked to prevent unscheduled harvest by commercial crews. Marketable green and color tomatoes were graded in the field according to USDA specifications of number and weight of extra-large (5x6), large (6x6), and medium (6x7) fruit (USDA, 1997) of green and color. Yield data were subjected to analysis of variance (ANOVA) mean separation using Duncan's Multiple Range Test at the 5% level of significance as well as non-parametric analysis tests like binomial distribution and probability.

RESULTS AND DISCUSSION

Weather conditions and supplemental fertilizer applications. Overall, South Florida was hot and dry throughout the fall, and cool and dry during the winter and spring of 2006-2007. Rainfall recorded by the Florida Automated Weather Network (FAWN) and growers during the 2005-2006 season showed accumulations of 5, 0.5 to 13 and 10 inches for fall, winter and spring, respectively (Table 3). The IFAS tomato fertilizer recommendation allows supplemental N and K fertilizer applications in specific situations (Olson et al., 2006b), as does the BMP manual (Simonne and Hochmuth, 2003). Under this recommendation, 30 lb/acre of N can be added for each leaching rain event. Therefore, using fall/winter/spring 2006-07 as an example, a supplemental application of 30 lbs/acre of N fertilizer was permissible in two trials (7 and 8) in Palm Beach and four trials (10,11, 12 and 13) in Manatee due to three leaching rains. No fertilizer addition due to leaching rain was justified in the rest of the trials, so N fertilizer application consisted of the base 200 lbs/acre rate only (Olson et al., 2005). These results suggest that analysis and prediction of leaching rain frequency and timing would be valuable for Florida's vegetable growing areas.

Irrigation management. The BMP trial acreage was irrigated 80% by seepage and 20% by drip systems. The water table in the seepage-irrigated trials fluctuated between about 16 to 20 inches deep and tensiometer readings were between 4 and 8 kPa. In the drip-irrigated fields, water was applied daily at a volume estimated from the Weather Service Class A Pan evaporation combined with a crop coefficient.

Plant nutritional status. Petiole sap NO_3-N concentrations were above the UF-IFAS sufficiency threshold throughout the season in all thirteen locations and under all N treatments, except for the lower N rates in the multiple N rate trials (Figure 1). In general, in the multiple N rates (trial 10) the higher N rates produced tomato sap NO_3-N concentrations that were greater compared to the lower rates. Petiole sap K concentrations tended to be above the UF-IFAS sufficiency threshold during the season (Figure 2).

Yield response to N rates. In this dry season, IFAS and higher N rate produced significantly higher yield in first harvest of extra-large tomatoes (80% of the total harvest) and total yields in 1 and 2 out of 13 trials [Table 4 ($P<0.05$)], respectively. In general, during the season when soluble fertilizer was used there were between 90 to 300 boxes/acre more in total yields with higher N rates, although the differences were not significant [Figure 3 ($P<0.05$)]. At the highest prices during the season of $23/box, growers revenues would be $2,070 for 90 boxes/acre and $6,900 for 300 boxes/acre to off-set $20 to $45 in cost of extra fertilizer. Regression analysis of first and total harvest extra-large yields and total yields indicated a quadratic response to the multiple N rates in trial 10 (Figure 3). The trend indicated an increase in total yield and first harvest extra-large and total extra-large fruit from 20 to 240 lb/acre N, but a plateau with higher rates of N. There was no response to N treatment by other tomato size categories at first, second and third harvest or all harvests combined. These results show that it may be possible to reduce N rates especially when the risk of rainfall is low (winter, spring and dry year), or when only two harvests are expected (late spring).

Grower participation in the project. We would like to thank the growers participating in the project for their in-kind contribution and valuable inputs. The BMP trials are a popular on-farm research project where growers and IFAS cooperators work as a team. Together the cooperating farms represented 16,000 acres (80%) of staked tomato production in southern and eastern Florida and 310 acres under BMP experiments.

SUMMARY FOR THE 2006-2007 SEASONS:

a. On farm trials continue to be a grower preferred research method for N BMP studies. Extensive one-on-one grower contact was an effective means to engage growers in the implementation and outcome of this research and demonstration project.
b. Petiole sap NO_3-N and K concentrations throughout the season tended to be above the UF-IFAS sufficiency threshold for all N treatments and seasons.
c. In this a dry season, IFAS and grower rates produced significantly higher yield in first harvest of extra-large tomatoes and total yields in 1 and 2 out of 13 trials [Table 4 ($P<0.05$)], respectively. The trend indicated an increase in total yield and first harvest extra-large and total extra-large fruit from 20 to 240 lb/acre N, but a plateau with higher rates of N. These results show that it may be possible to reduce N rates especially when the risk of rainfall is low (winter, spring and dry year), or when only two harvests are expected (late spring).
d. Grower cooperator surveys during 2007 indicated that they would like to continue two more years of N-BMP studies for a total of five years of study. The main areas of interest are: testing grower vs. IFAS N rates under dry, moderate rainfall and wet years; testing N rates in different crops: cherry, grape, plum, peppers, etc.; testing P, K and minor elements with N; continue with the economics of N; fall, winter and spring studies with multiple N rates in different farms; more drip and N; and finally more data is needed in the early fall with high rainfall.

LITERATURE CITED

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. 2006. Review of nutrient management systems for Florida vegetable producers Proc. Fla. State Hort. Soc. 119:240-248.

Cockx, E.M. and E.H. Simonne. 2003. Reduction of the impact of fertilization and irrigation on processes in the nitrogen cycle in vegetable fields with BMPs. EDIS, HS 948, http://edis.ifas.ufl.edu/HS201.

Olson, S.M., Maynard, D.N., G.J. Hochmuth, C.S. Vavrina, W.M. Stall, T.A. Kucharek, S.E. Webb, T.G. Taylor, S.A. Smith, and E.H. Simonne. 2005. Tomato production in Florida, EDIS, HS-739, http://edis.ifas.ufl.edu/CV137.

Olson, S.M., E.H. Simonne, W.M. Stall, K.L. Pernezny, S.E. Webb, T.G. Taylor, S.A. Smith, and D.M. Parmenter. 2006a. Pepper production in Florida, pp. 331-343 In: S.M. Olson and E. Simonne (Eds.) 2006-2007 Vegetable Production Handbook for Florida, Vance Pub., Lenexa, KS.

Olson, S.M., W.M. Stall, M.T. Momol, S.E. Webb, T.G. Taylor, S.A. Smith, E.H. Simonne, and E. McAvoy. 2006b. Tomato production in Florida, pp. 407-426 In: S.M. Olson and E. Simonne (Eds.) 2006-2007 Vegetable Production Handbook for Florida, Vance Pub., Lenexa, KS.

Simonne, E.H. and G.J. Hochmuth. 2003. Supplemental fertilizer application for vegetable crops grown in Florida in the BMP era, EDIS HS-906, http://edis.ifas.ufl.edu/HS163

Simonne, E. And M. Ozores-Hampton. 2006. Challenges and opportunities for extension educators involved in best management practices. HortTechnology 16(3):403-407.

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

NSS, 2006. National Statistics Service. http://www.nss.usda.gov. – Incomplete reference

RECENT DEVELOPMENTS AND RELEASE OUTLOOK FROM THE UNIVERSITY OF FLORIDA TOMATO BREEDING PROGRAM

J.W. Scott[1], S.M. Olson[2], D.J Schuster[1], Yuanfu Ji[1], and W. Klassen[3]

[1]University of Florida/IFAS, IFAS, GCREC, Wimauma, FL. [2]University of Florida/IFAS, NFREC, Quincy, FL. [3]University of Florida/IFAS, TREC, Homestead,FL. jwsc@ufl.edu

INTRODUCTION.

When the senior author began as a University of Florida tomato breeder in 1981 there was another tomato breeder located at the Homestead station, Dr. Ray Volin. Ray moved on to the private sector a few years later and is presently with Western Seeds. By the time of this years' Tomato Institute there will once again be a second tomato breeder at the University of Florida thanks to an endowment from Paul Dimare. This position will be at the Gulf Coast Research & Education Center (GCREC) and has been filled by Dr. Jeremy Edwards. Jeremy had a job on the field crew at GCREC, later worked for me in the late 1990's before starting graduate school at Cornell. He is the first (and may quite possibly be the last) person to go from field crew to faculty at GCREC! We at GCREC are excited at the skills Dr. Edwards brings to the breeding program and anticipate increased outputs in the coming years. At present there is a lot going on in the breeding program which is beyond the scope of this report but some of the major issues of interest to the grower community will be covered.

FLA. 8153 IS RELEASED.

This hybrid was released in October, 2006 and seed production is underway and should be available from Florida Foundation Seed Producers in fall 2007. I can be contacted by those with interest in growing this variety. It features high lycopene due to the crimson (og^c) gene which also provides a deep red interior fruit color. Fla. 8153 has done well for overall flavor in numerous taste panels over the last four years. A marketing strategy for this variety has yet to be worked out. It was released as a field grown variety that could be branded to compete with greenhouse tomatoes in the supermarket. This would require a vine-ripe harvest system to insure proper maturity for optimal flavor. Fla. 8153 has a determinate vine and

Table 1. Marketable and extra large fruit yield and cull percentage for selected tomato cultivars at Gulf Coast Research and Education Center, Wimauma, FL Spring 2007z.

Tomato hybrids	Marketable yield (25 lb cartons/A) Total	Extra large	Culls (% by wt)
Fla. 8415	2896	1833 ab[y]	22 b
Fla. 8552	2852	2222 a	18 b
154	2842	2137 ab	28 ab
Fla. 8153	2782	1029 c	23 b
144	2679	1940 ab	26 ab
140	2679	2167 ab	25 b
Fla. 8314	2650	1436 bc	22 b
Crown Jewel	2605	1865 ab	29 ab
Florida 47	2567	2202 a	24 b
Fla. 8485	2563	1610 bc	30 ab
149	2528	2134 ab	33 ab
Phoenix	2525	2106 ab	24 b
Solar Fire	2430	1720 b	28 ab
Fla. 8413	2337	1832 ab	20 b
Sebring	2336	2056 ab	17 b
Sanibel	1824	1448 bc	48 a
	ns		

[z] Fruit harvested at vine ripe stage 3 times at weekly intervals.
[y] Mean separation in columns by Duncan's multiple range test at P≤ 0.05.

firm fruit that have consistently graded well (Tables 1,2). Fruit size is not as large as tomato varieties typically grown in Florida as seen at GCREC in spring 2007 (Table 1), but it had a good percentage of extra large fruit in the fall Quincy variety trial (Table 2).

POSSIBLE RELEASES.

Fla. 8413 has looked good on grower farms and in IFAS trials and is presently being widely tested for possible release perhaps in early 2008. This hybrid is a main season hybrid with a strong vine that has had a high percentage of large, marketable fruit with good firmness. Besides the normal disease resistances it may have resistance to fusarium crown and root rot. We have had some problems with the crown rot disease screen and the "resistant" parent may not actually be resistant. A test this fall should determine this one way or the other. The hybrid would have greater utility if it does have crown rot resistance, but even if it doesn't it has attributes that may merit release anyway. It did well in the spring 2007 trial at GCREC (Table 1). Flavor is good although it did not come out particularly good for overall flavor in a spring 2007 taste panel (data not shown). At present no negative attributes have been seen in this hybrid but further testing will be done to see if there are any serious drawbacks.

Fla. 8485 is a crimson, heat-tolerant hybrid that has performed well in recent trials (Table 1). It also did well for overall flavor in a spring 2007 taste panel (data not shown). Since it has not been widely tested considerably more testing is needed before a decision can be made for release. Florida still needs improved heat-tolerant tomato varieties.

Dr. Jim Strobel was the University of Florida tomato breeder at Homestead before Ray Volin. He moved on to several administrative positions including President of Mississippi College for Women before he retired a few years ago. He is now doing some more tomato breeding and we are cooperating on a project primarily to develop a new jointless hybrid aimed at Dade County and perhaps elsewhere in Florida. Several of these were trialed at GCREC this spring and performed well; they are designated 154, 144, 140, and 149 in Table 1. All of them have the crimson gene so will be high in lycopene. Flavor is also being emphasized in this material. Further testing will be done especially in Dade County in conjunction with Dr. Waldy Klassen.

In Table 1 also are two UF hybrids resistant to spotted wilt Fla. 8367 and Fla. 8363. These are being tested for possible release as well with primary testing in North Florida.

TYLCV RESISTANCE.

This project has been ongoing since 1990 in cooperation with Entomologist Dr.David Schuster. The focus is on utilization of resistance genes from the wild species *Solanum chilense*. We have developed tomato lines with genes from three accessions. The resistances are inherited additively meaning that for a hybrid to have adequate resistance requires the resistance to be bred into both parents. Furthermore, each parent requires two resistance genes and these factors increase the difficulty of developing resistant hybrids with horticultural attributes comparable to those of susceptible varieties presently being grown in Florida. The breeding process could be accelerated dramatically if molecular markers tightly linked to the resistance genes could be identified and used for marker assisted selection (MAS). This would allow for two backcrosses to be made per year without cumbersome inoculations and field screening. At present with field screening, only one backcross cycle can be made every two years. Development of such markers has been a goal of the program for many years now. The intensive work of Dr. Yuanfu Ji over the last three and one-half years has made some progress in making MAS a reality. Recently we have identified a resistance gene designated *Ty-3* in lines derived from two accessions; LA2779 and LA1932 (Ji et al., 2007). A reliable molecular marker that works in both backgrounds has also been identified. Our plan is to license this marker and large-round, plum, and cherry breeding lines from both sources to tomato breeders interested in using this resistance gene. The mentioned breeding lines are presently being harvested to provide data for this procedure but data are not available for this writing. We have still not found markers for the other genes. For lines from LA1932 we have evidence based on earlier lines with markers that the gene is located on the lower part of chromosome 6. However, new lines no longer have the markers of previous lines and the resistance gene is apparently in a region where we do not presently have marker coverage. Despite considerable testing we have not located the second gene from LA2779. We do know several regions of the genome where the gene is not located.

Several TYLCV resistant hybrids have also been tested over the last few years. Linkage drag (Scott, 2005) still hampers this project despite the fact that the breeding lines have had seven or more backcrosses from *S. chilense*. The parent lines being used do have some positive attributes and it is hoped that two parents will compliment the defects of each other and a commercially acceptable hybrid will emerge. Some hybrids have performed well but further testing is needed to determine if they actually have commercial potential.

Table 2. Marketable and extra large fruit yield and fruit size for tomato hybrids at North Florida Research and Education Center, Quincy, FL Fall 2006.

Tomato hybrid	Marketable Yield (25 lb cartons/A) Total	Extra large	Marketable (%)	Fruit wt (oz)
Quincy	2521 a[z]	1708 ab	84.6 a	6.2 bc
Bella Rosa	2217 ab	1802 a	79.3 ab	6.7 a-c
Fla. 8153	2154 ab	1527 a-c	80.6 ab	6.2 bc
RFT 4971	2077 ab	1445 a-c	83.8 a	6.3 bc
Fla. 8367	2072 ab	1610 a-c	81.0 ab	6.5 a-c
Phoenix	1971 ab	1489 a-c	77.6 ab	6.6 a-c
FL 91	1965 ab	1613 a-c	79.2 ab	6.6 a-c
Fla. 8363	1904 ab	1550 a-c	80.0 ab	6.7 a-c
Amelia	1887 ab	1525 a-c	70.9 ab	6.8 ab
NC 03289	1876 ab	1395 a-c	77.6 ab	6.4 bc
Fla. 8314	1870 ab	1364 a-c	73.8 ab	6.3 bc
Solar Fire	1731 ab	1321 a-c	74.3 ab	7.4 a
RFT 4974	1714 ab	1278 a-c	74.6 ab	6.6 a-c
HMX 5825	1692 ab	1154 a-c	76.4 ab	6.0 b-d
Crista	1577 ab	1178 a-c	76.1 ab	6.5 a-c
XTM 3301	1576 ab	1280 a-c	66.9 b	6.7 a-c
NC 056	1574 ab	1204 a-c	78.4 ab	6.4 bc
HA 3074	1540 ab	775 cd	69.1 b	5.3 d
Talladega	1511 ab	1136 a-c	67.2 b	6.4 bc
FL 47	1320 bc	955 b-c	76.0 ab	6.4 bc
HA 3617	498 c	305 d	47.4 c	5.9 cd

[z] Mean separation in columns by Duncan's multiple range test at P≤ 0.05.

BACTERIAL SPOT RESISTANCE.

With the present TYLCV threat looming, bacterial spot has become "that other disease" but it is still probably the most common disease problem that Florida tomato growers face. Breeding for this resistance has been a priority for my entire Florida career and still there have been no varieties released. Complex genetics and shifting races of the pathogen have been the bane of the breeding effort (Scott et al., 2003). The two races that we presently have in Florida are races T3 and T4. It is not known how prevalent race T4 is but by observation it appears well established. Ph.D. student Mr. Sam Hutton is studying the inheritance of resistance to race T4 and searching for molecular markers linked to the resistance genes. We have breeding lines with fair levels of resistance to T4 that are derived from three different sources; PI 114490, and *S. pimpinellifolium* accessions PI 128216 and PI 126932. The former two have shown resistance to T4 in recent testing but not the latter, which is confusing since breeding lines with this accession in their pedigree have been resistant (Scott et al., 2006). Our present thinking is that combining resistance genes from different sources may provide enhanced levels of resistance but this has to be demonstrated yet. Furthermore, there is evidence that a gene from PI 114490 has effects against multiple races (Yang et al., 2005) and such a gene may be useful in developing durable resistance that doesn't break down as new races of the pathogen emerge.

Fla. 8314 is a hybrid with T3 tolerance that has performed well in numerous grower and IFAS trials (Tables 1,2) but since it is not quite as large fruited as susceptible Florida varieties and since T4 has been widespread the decision has been made not to release it. Numerous hybrids with tolerance to races T3 and T4 have been tested in recent years. To date none have shown enough horticultural type or bacterial spot resistance. One new one, Fla. 8552 did well in the spring 2007 trial at GCREC and will be tested further. We also selected some promising inbreds in the spring and perhaps these will make good parents for hybrid varieties in the near future.

LITERATURE CITED.

Ji, Y, D.J. Schuster, and J.W. Scott. 2007. *Ty-3*, a begomovirus resistance locus near the *tomato yellow leaf curl virus* resistance locus *Ty-1* on chromosome 6 of tomato. Molecular Breeding (in press; presently on-line)

Scott, 2005. Perspcetives on tomato disease resistance breeding: past, present, and future. Acta Horticulturae 695:217-224.

Scott J.W, S. F. Hutton, J.B. Jones, D.M. Francis, and S.A. Miller. 2006 Resistance to bacterial spot race T4 and breeding for durable, broad range resistance to other races. Rept. Tomato Genetics Coop. 54:33-36.

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

Yang, W., S.A. Miller, J.W. Scott, J.B. Jones, and D.M. Francis. 2005. Mining tomato genome sequence databases for molecular markers: Application to bacterial resistance and marker assisted selection. Acta Horticulturae 695:241-249.

WESTERN FLOWER THRIPS: ON THE MOVE?

Joe Funderburk
UF/IFAS, North Florida Research & Education Center, Quincy, jef@ufl.edu

INTRODUCTION

There are over 5,000 described species of thrips (Thysanoptera). These insects are small with fringed wings and unique piercing, sucking mouthparts. About 87 species of thrips are pests of commercial crops due to the damage caused by feeding on developing flowers or vegetables which causes discoloration, deformities, and reduced marketability of the crop. Because of their small size, cryptic habits, and biological characteristics of rapid development, rapid mobility, high reproductive rate, and parthenogenesis (ability to reproduce without mating), some species of thrips are excellent invaders. Over 20 species are now cosmopolitan. Recent invasive species established in the landscape in Florida include the chilli thrips, *Scirtothrips dorsalis*, and a legume pest, *Megalurothrips mucanae*.

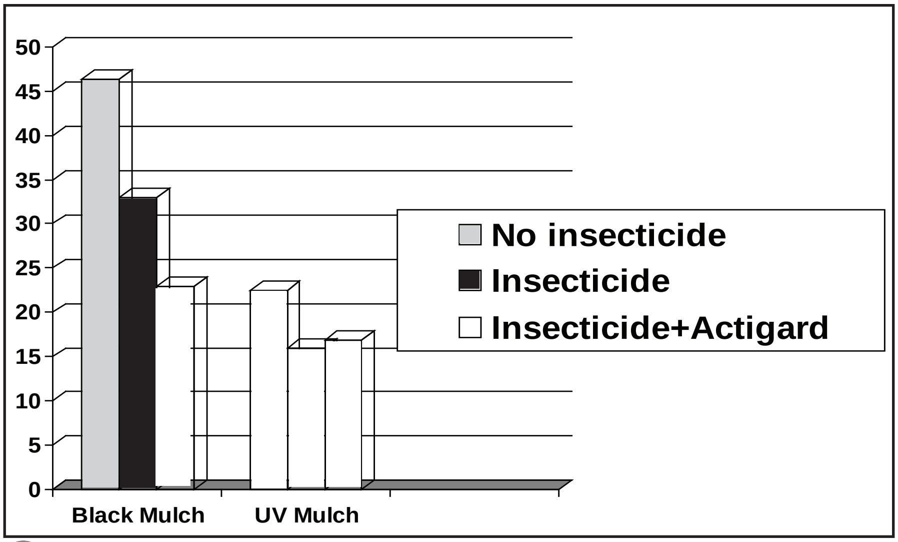
Global trade in ornamental greenhouse plants rapidly spread the western flower thrips, *Frankliniella occidentalis*, around the world in the 1980's. The species is native to the southwestern US and it is the key vector of *Tomato spotted wilt virus* (Kirk and Terry 2003). The western flower thrips was first found established in the landscape of northern Florida in 1985, and tomato plants infected with *Tomato spotted wilt virus* were first noted in 1986. The insect and the virus rapidly emerged as the key pest problems of tomato and other crops in northern Florida, but (until recently) they were not pests in most years of tomato and other crops in central and southern Florida.

The adults of the western flower thrips inhabit the flowers of tomato sometimes in large numbers where they feed on the pollen and flower tissues. The females lay eggs individually on the small developing fruit of the flower, and the larva hatches in about six days. A small dimple sometimes surrounded by a white halo remains on the developing fruit (Salguero Navas et al. 1991b). This damage can result in cull-out and lowering of grade of the harvested fruit, with tolerance based on price and demand in the marketplace. Direct feeding by the western flower thrips also can cause cosmetic fruit damage referred to as 'flecking' (Ghidiu et al. 2006)

Other species of flower thrips sometimes occur in large numbers in the flowers of tomato in Florida. The eastern flower thrips, *Frankliniella tritici*, is common in northern Florida but it is very rare in central and southern Florida. The Florida flower thrips, *Frankliniella bispinosa*, is common throughout the state, especially in central and southern Florida. These native species do not appear to cause dimples or flecking damage to the fruits, even when their numbers are very great. Tomato is a poor reproductive host for all thrips species in Florida, including the western flower thrips (Momol et al. 2004, Reitz et al. 2002). Many plant species growing in and around tomato fields are inhabited by the thrips adults (Chellemi et al. 1994). Some plant species serve as food hosts and not as reproductive hosts. The larvae of the common thrips are not distinguishable from one another, and there is inadequate information about the plant species serving as reproductive hosts. The tobacco thrips, *Frankliniella fusca*, occurs in low numbers in tomatoes, and *Franklinella shultzei*, occurs in low numbers in central and southern Florida. The eastern flower thrips is the only thrips species mentioned above that is not a potential vector of *Tomato spotted wilt virus*. Epidemics of tomato spotted wilt in northern Florida apparently are due primarily to western flower thrips, although in some rare cases other vector species are involved. Localized epidemics of the disease are rare in central and southern Florida.

The pest status of individual species obviously differs in tomato. The western flower thrips damages fruit and it is the key vector of *Tomato spotted wilt virus*. The eastern flower thrips is virtually a non-pest. It does not damage fruit, and it is an incapable vector of *Tomato spotted wilt virus*. The Florida flower thrips is not damaging to fruit. Although it is a

Figure 1. Effect of mulch type, insecticides, and insecticides plus Actigard on final incidence of tomato spotted wilt in an experiment conducted in 2000 in Quincy, Gadsden County, FL (adapted from Momol et al. 2004). The insecticides were Spintor and Monitor applied alternately on a weekly schedule for six weeks.

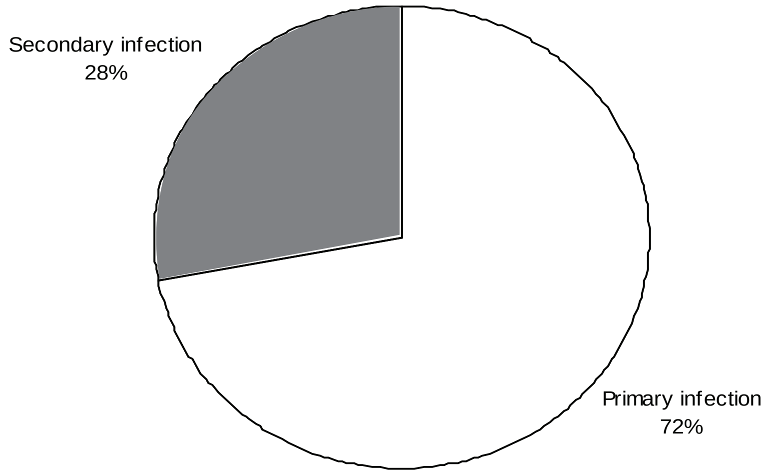


capable vector of *Tomato spotted wilt virus* (Avila et al. 2006), epidemics are rare in central and southern Florida where it is the predominate species. Despite the ability to distinguish the adults to species and the great differences in pest status, the numbers of the individual species are rarely determined in scouting programs.

The population dynamics of the individual species has been well studied in northern Florida (e.g., Salguero Navas et al. 1991a, Reitz et al., 2002, Momol et al. 2004), though such information in tomato in southern Florida is not well documented in the published literature. Based mostly on unpublished observations by university and private industry scientists, it is certain that the abundance and population dynamics of different thrips species in central and southern Florida differs greatly from northern Florida. The western flower thrips, in particular, has never (until recently) been found in abundance in central and southern Florida. A published study in pepper supports this conclusion (Hansen et al. 2003).

A lack of knowledge of the reproductive plant hosts serving as sources of thrips invading crop fields has hampered efforts to develop better management strategies for *Tomato spotted wilt virus*. The virus is acquired only by the larvae, and the adults can transmit to host plants. Usually primary spread of the disease is due to infections caused by incoming viruliferous adults to a crop (such as tomato) from outside sources that are usually host weed species. Adults persistently transmit, and their control with insecticides does not prevent transmission due to the short time of feeding for infection to occur (Momol et al. 2004). Secondary spread is caused by viruliferous adults that acquired the virus as larvae feeding on an already infected plant. For secondary spread, thrips need to colonize and reproduce on that season's crop. Secondary spread can be reduced with insecticides targeted against larval populations. Most viral infections in commercial tomato in northern Florida usually are the result of primary spread, although some secondary viral infections occur late in the season (Momol. et al. 2004) (Figure 2).

Figure 2. The percentage of final tomato spotted wilt incidence due to primary and secondary spread in an experiment conducted in 2000 in Quincy, Gadsden County, FL (adapted from Momol et al. 2004). These values were estimated based on the amount of



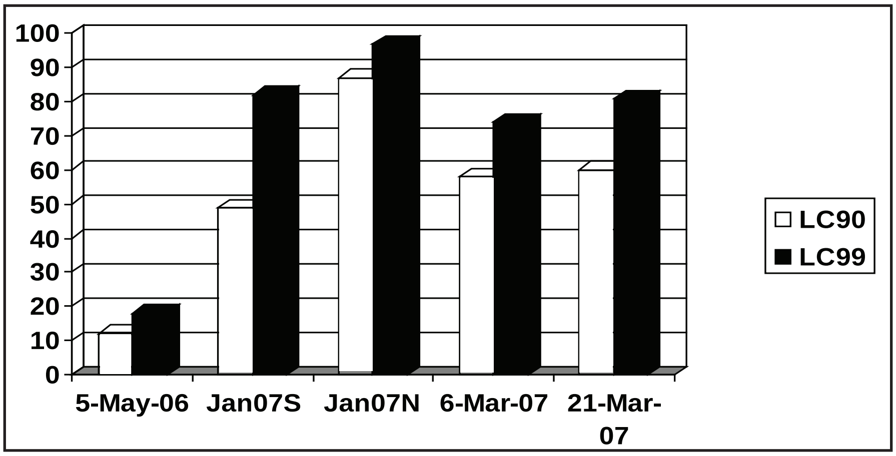
INTEGRATED PEST MANAGEMENT

Producers in northern Florida and other parts of the world responded to the threat of western flower thrips and *Tomato spotted wilt virus* by the calendar application (twice per week or more) of broad-spectrum highly toxic insecticides. Tomato growers applied insecticides an average 12.3 to 16.4 times per season in Georgia and northern Florida, respectively (Bauske et al. 1998). Yet research revealed that losses were the result of primary infections which were not prevented by such intensive insecticide use (Puche et al. 1995). Salguero Navas et al. (1994) established a threshold of one half of tomato flowers infested by western flower thrips to prevent dimpling and flecking. However, efforts to develop therapeutic strategies were hampered by the lack of a practical method to identify the thrips to species in scouting programs. Usually, most of the thrips in the flowers were non-pest species that are highly susceptible to most insecticides. The introduced population of western flower thrips was resistant to the available insecticides (Immaraju, et al. 1992).

Spinosad (Spintor, Dow Agro Sciences, Indianapolis, IN) is a natural macrocyclic lactone insect control product with a unique mode of action. In laboratory assays against un-exposed feral populations of *Frankliniella* species base-line toxicities were established (Eger et al. 1998). These assays showed that the insecticide was equally toxic to western flower thrips, eastern flower thrips, and Florida flower thrips. However, eastern flower thrips and Florida flower thrips are rapid re-colonizers, and sometimes there is an apparent lack of control for these species under field conditions (Ramachandran et al. 2001).

The benefits of other management tactics were investigated, and an effective, sustainable program developed that was adopted by tomato growers (Momol et al. 2004). Ultra-violet reflective mulch (aluminum layered) is very effective in reducing colonization of *Frankliniella* species thrips onto the tomato plants and in reducing the incidence of primary infections (Figure 1). Development of the larval instars is about 5 days, and weekly applications of insecticides is sufficient to prevent successful larval development and subsequent secondary spread of *Tomato spotted wilt virus*. Methamidophos (Monitor, Valent USA Corp., Walnut Creek, CA) and spinosad are in different chemical classes with different modes of action. Alternating applications for thrips control during the season is recommended as an integrated resistance management strategy. Few other insecticides are efficacious against the western flower thrips. Acibenozar-S-methyl (Actigard, Syngenta, Inc., Greensboro, NC) is an inducer of systemic resistance and it is has

Figure 3. Percent mortality of western flower thrips adults collected on five dates from fields on the same farm in southern Florida and exposed in the laboratory to concentrations of spinosad expected to kill 90 and 99 % (LC90 and LC99) of a susceptible population (Eger et al. 1998). Vegetable production on the farm ended in May 2006 and began again in October 2006. The data indicated a susceptible population was collected from a field not yet sprayed with spinosad in January (Jan07N) and varying levels of resistance were indicated from populations collected in fields previously sprayed with spinosad on each of the other sample dates.



some benefit in reducing the incidence of tomato spotted wilt.

Primary spread of *Tomato spotted wilt virus* accounts for most of the incidence of the disease in northern Florida, although secondary spread must also be managed especially mid- to late season (Momol et al. 2004, Figure 2). Cultivars resistant to *Tomato spotted wilt virus* with acceptable yield and fruit quality are available, and growers are rapidly adopting resistant cultivars in northern Florida. Strains of *Tomato spotted wilt virus* that have overcome resistance from the single-gene-dominate trait have appeared in other geographical areas (Rosello et al. 1998). An integrated approach therefore is recommended to reduce feeding by thrips and to manage the development of virus-resistant strains.

OUTBREAKS IN CENTRAL AND SOUTHERN FLORIDA

Populations of Florida flower thrips typically predominate in the agro-ecosystem on crops and the surrounding vegetation in central and southern Florida (Hansen et al. 2003). The only other thrips sometimes common in southern Florida is the melon thrips, *Thrips palmi*. The western flower thrips has been established for about two decades in central and southern Florida, as low population levels are detectable during at least some times of the year (Hansen et al. 2003). Several localized outbreaks from the western flower thrips have been noted recently in central and southern Florida. There also are indications of increased incidences of *Tomato spotted wilt virus* in vegetables and other crops, although epidemics have remained localized (S. Adkins, personal communication).

For example, a large population of western flower thrips was detected on a vegetable farm on the east coast of southern Florida in May 2006. The farm had sprayed on a calendar schedule many insecticides from different chemical classes including spinosad. The population of western flower thrips was very resistant to spinosad as determined by bioassay procedures reported in Eger et al. (1998) (Figure 3). Vegetable production on the farm ended for the summer months. The demographics of individual thrips species was monitored on this farm during the next production season that began in October of 2006. Populations of thrips during November and December were >95% Florida flower thrips. Bioassays of their populations showed expected susceptibility to spinosad (Figure 3). Populations of thrips shifted in January to >95% western flower thrips for the rest of the production season. The population was susceptible to spinosad in a field not yet sprayed with spinosad in January 2007. This indicated that the population of western flower thrips had reverted to normal susceptibility. In pepper fields treated with spinosad on the farm, bioassays revealed low levels of resistance, but not at the very resistant level documented at the end of the previous season. The farm had sprayed fewer insecticides of all chemical class during the November 2006 to May 2007 vegetable production season. Flecking and dimpling due to western flower thrips feeding and egg-laying activities was noted on tomato fruits for the first time on the farm. Bioassays of western flower thrips collected from several other farms in southern Florida revealed a mix of susceptible and resistant populations in 2007. Efforts currently are underway to implement integrated pest management programs for western flower thrips on farms in this production area in order to manage resistance to spinosad. In pepper, natural populations of minute pirate bugs are very effective in controlling thrips (Funderburk et al. 2000), and it is recommended that pepper growers use control tactics for thrips and other pests that conserve their populations. Pepper, unlike tomato, is an excellent reproductive host for thrips to develop and spread to other crops such as tomato. Minute pirate bugs do not inhabit tomato.

Chilli thrips is established in central Florida (Silagyi and Dixon 2006). It is listed as a 'reportable/actionable pest' which means that if detected on foreign cargo at US ports, the cargo must be treated before it can enter domestic commerce. There currently is no federal quarantine to restrict domestic spread but Florida has a state restriction. As a consequence, nurseries are attempting control with heavy insecticides. Personal observations have revealed very large populations of western flower thrips in nurseries in central Florida. Efforts are underway to better determine the extent of the pest status of western flower thrips in central and southern Florida nurseries. Populations of western flower thrips are induced by broad-spectrum insecticides (Funderburk et al. 2000). Replacement and resurgence of non-target pests such as western flower thrips as a result of broad-spectrum insecticides targeted against chilli thrips is related to the killing of natural enemies and competing thrips species and apparently to the beneficial effects of some insecticides especially pyrethroids on development and reproduction of western flower thrips populations. The recent outbreaks of western flower thrips in central and southern nursery and vegetable crops appear to be caused by efforts to control pests with calendar sprays of broad-spectrum insecticides. The outbreaks in ornamental and vegetable crops in central and southern Florida undoubtedly were in part a product of the droughts which favor survival of western flower thrips over the competing native thrips species

Populations of chilli thrips currently are susceptible to a broad range of commercial insecticides (Seal et al. 2005). However, heavy use of insecticides as a result of the Florida restriction on movement of infested plant material on nursery plants may result in the development and spread of resistant thrips populations. The chilli thrips will eventually be a pest of field pepper and other vegetable crops. Its pest status on individual vegetable crops such as tomato in Florida is not yet determined. A Chilli Thrips Task Force was formed with the objectives of conducting surveys to establish the spread of chillis thrips, developing domestic regulations to prevent spread to un-infested areas, and developing management plans. An Industry Group with representation from the vegetable industry in Florida is charged with giving feedback to the Technical Group about issues and concerns such as the development and spread of resistant thrips populations.

REFERENCES CITED

Avila, Y., J. Stavisky, S. Hague, J. Funderburk, S. Reitz, and T. Momol. 2006. Evaluation of *Frankliniella bispinosa* (Thysanopera: Thripidae) as a vector of the *Tomato spotted wilt virus* in pepper. Fla. Entomol. 89: 204-207.

Eger, Jr., J. E., J. Stavisky, and J. E. Funderburk. 1998. Comparative toxicity of spinosad to *Frankliniella* spp. (Thysanoptera: Thripidae), with notes on a bioassay technique. Fla. Entomol. 81: 547-551.

Funderburk, J., J. Stavisky, and S. Olson. Predation of *Frankliniella occidentalis* (Thysanoptera: Thripidae) in field peppers by *Orius insidiosus* (Hemiptera: Anthocoridae). Environ. Entomol. 29: 376-382.

Ghidiu, G. M., E. M. Hitchner, and J. E. Funderburk. 2006. Goldfleck damage to tomato fruit caused by feeding of *Frankliniella occidentalis* (Thysanoptera: Thripidae). Fla Entomol. 89: 279-281.

Hansen, E. A., J. E. Funderburk, S. R. Reitz, S. Ramachandran, J. E. Eger, and H. McAuslane. 2003. Within-plant distribution of *Frankliniella* species (Thysanoptera: Thripidae) and *Orius insidiosus* (Heteroptera: Anthocoridae) in field pepper. Environ. Entomol. 32: 1035-1044.

Immaraju, J. A., T. D. Paine, J. A. Bethke, K. L. Robb, and J. P. Newman. 1992. Western flower thrips (Thysanoptera: Thripidae) resistance to insecticides in coastal California greenhouses. J. Econ. Entomol. 85: 9-14.

Kirk, W. D. J., and L.I. Terry. 2003. The spread of the western flower thrips *Frankliniella occidentalis* (Pergande). Agric. For. Entomol. 5:301-310.

Momol, M. T., S. M. Olson, J. E. Funderburk, J. Stavisky, and J. J. Marois. 2004. Integrated management of tomato spotted wilt on field-grown tomatoes. Plant Dis. 88: 882-890.

Puche, H., R. D. Berger, and J. E. Funderburk. 1995. Population dynamics of *Frankliniella* thrips and progress of tomato spotted wilt virus. Crop Prot. 14:577-583.

Ramachandran, S., J. Funderburk, J. Stavisky, and S. Olson. 2001. Population abundance and movement of *Frankliniella* species and *Orius insidiosus* in field pepper. Agric. For. Entomol. 3:1-10.

Reitz, S. R. 2002. Seasonal and within plant distribution of *Frankliniella* thrips (Thysanoptera: Thripidae) in northern Florida. Fla. Entomol. 85:431-439.

Rosello, S., M. J. Diez, and F. Nuez. 1998. Genetics of tomato spotted wilt virus resistance coming from *Lycopersicon peruvianum*. Eur. J. Plant Pathol. 104: 499-509.

Salguero Navas, V. E., J. E. Funderburk, R. J. Beshear, S. M. Olson, and T. P. Mack. 1991a. Seasonal patterns of *Frankliniella* spp. (Thysanoptera: Thripidae) in tomato flowers. J. Econ. Entomol. 84: 1818-1822.

Salguero Navas, V. E., J. E. Funderburk, S. M. Olson, and R. J. Beshear. 1991b. Damage to tomato fruti by the western flower Thrips (Thysanoptera: Thripidae). J. Entomol. Sci. 26: 436-442.

Salguero Navas, V. E., J. E. Funderburk, T. P. Mack, R. J. Beshear, and S. M. Olson. 1994. Aggregation indices and sample size curves for binomial sampling of flower-inhabiting *Frankliniella* species (Thysanoptera: Thripidae) on tomato. J. Econ. Entomol. 87: 1622-1626.

Seal, D. R., M. Ciomperlik, and W. Klassen. 2005. Chilli thrips (castor thrips, Assam thrips, yellow tea thrips, strawberry thrips), *Scirtothrips dorsalis* Hood, provisional management guidelines. University of Florida, Florida Coop. Ext. Serv. EDIS Document ENY-725.

Silagyi, A. J., and W. N. Dixon. 2006. Assessment of Chili Thrips, *Scirtothrips dorsalis*, in Florida. Florida Coop. Agric. Pest Surv., Division of Plant Industry, FDACS, Gainesville.

GOT GAS? KEEP IT UNDER WRAPS: SOIL FUMIGATION OPTIONS FOR TOMATOES

James P. Gilreath
PhytoServices, Myakka City, FL • DrGilreath@aol.com

Since 1991 research and grower trials have been conducted in Florida to improve performance of methyl bromide formulations and potential alternatives to methyl bromide. Results of those studies have led to a better understanding of fumigant movement and retention in soil which has allowed growers to achieve good soilborne pest control with lower rates of methyl bromide and have enhanced performance of what previously were considered marginal products. Most of the research with reduced rates and barrier films was conducted at the Florida Soil Fumigation Experiment Farm which I established and operated for 2.5 years near Ruskin, Florida. This farm was a cooperative effort between my research program with the University of Florida and Deseret Farms of Ruskin. It was established to conduct research under real world conditions on an old tomato farm which was infested with nutsedge, Fusarium wilt, and nematodes. As such, it served to provide a well coordinated, scientifically valid research program for tomato as required by the CUE process under the Montreal Protocol and built much good will and understanding by hosting visitors from MBTOC as well as regulatory agencies. Most of the soil fumigant research in Florida was conducted at that farm during the time of its operation. Up to 50 acres were dedicated to tomato herbicide, fumigant and mulch film research during one season and acreage under production never dropped below 20, which is a sizeable area for research plots. The space provided by this farm allowed the use of large plots, not the small plots typical of most experiment stations. Staffed and operated almost exclusively with grant funds, the farm was closed after 2.5 years due to insufficient support from industry and federal programs. I left the University of Florida after making the decision to close the farm and spent much of the fall of 2006 moving equipment to the UF facility at Balm and cleaning up the farm provided by Deseret Farms. It was unfortunate that the tomato industry had to lose this program, but the lack of support made it impossible to continue.

Some of the advances developed at that farm included the use of greatly reduced rates of methyl bromide with metalized film and vif, improvements in fumigant application equipment via simple modifications of existing equipment which were critical to the application of reduced rates, and much of the development work for Midas (methyl iodide) and DMDS. Advances in application of K-Pam also were developed at this facility, to name just a few.

Many factors contribute to fumigant performance, including the fumigant itself, environmental conditions, mulch film selection and application equipment. There is little a grower can do about environmental conditions, other than water management and application timing in relation to soil temperature, and sometimes even that is not possible, so attention needs to be focused on what a grower can control.

MULCH FILM

Currently the price of methyl bromide (50/50 formulation) is about $3.80 a pound, resulting in a cost of approximately $760 per treated acre or $380 per row acre for 200 lb. per treated acre in 3 feet-wide beds. Combined with this is the cost of high barrier plastic mulch which is required for acceptable pest control with this formulation/rate of methyl bromide. The required high barrier film may be either one of the better metalized films or virtually impermeable film (vif), both of which cost substantially more than conventional low density polyethylene (ldpe) film (approximately $400 per row acre for vif). Today we have several sources of virtually impermeable film, including Pliant's Blockade, Klerk's Barricade, and IPM's Bromostop, as well as some metalized films (Canslit and Pliant) which are capable of greatly reducing the loss of methyl bromide through the film over time. This characteristic allows us to reduce our bromide rate to ½ or less of what we used in the past and still have good pest control with vif and metalized. Unfortunately, the greater retention of methyl bromide also means the fumigant will be held in the soil longer than normal, so we have to delay planting for at least 3 weeks on average. These films are more expensive than standard ldpe or hdpe, so some of the decrease in fumigant expense is offset by increased mulch expense. VIF and metalized films appear to work with all of the fumigants which are highly volatile, but they do not make much of a difference with products like Vapam and K-Pam, both of which form relatively weak gases. Among the products which have been shown to respond well are Midas (iodomethane or methyl iodide), Telone products, chloropicrin, and DMDS, an experimental fumigant. As a result of the higher cost of high barrier films, the cost for methyl bromide fumigation alone is about $780 per row acre. This higher cost makes some alternatives look more promising.

Not all vif mulches have the same handling characteristics, so you need to gain some experience with them before ordering large quantities. Also, please remember that not all metalized films restrict movement of fumigants the same. Canslit and the non-embossed Pliant metalized films have performed well under field conditions, but several other metalized films do not have the barrier properties of these two films. Make sure the film you choose meets your barrier needs.

EQUIPMENT MODIFICATIONS

Regardless of what fumigant a grower chooses, he must make certain that his equipment is set up correctly for the fumigant of choice and that it is operating properly. Highly volatile fumigants, such as methyl bromide, chloropicrin, Telone products and Midas (iodomethane or methyl iodide), require sufficient back pressure in the system all the way to the gas knives in order for the product to be applied uniformly and accurately. If attention to these details is insufficient, then even methyl bromide may result in poor performance. I have seen a lot of marginal fumigant performance due to lack of attention to this detail. Results can range from marginal to bad with methyl bromide and even worse with some other products, such as Midas. The difference in results between the two fumigants is related to differences in vapor pressure. Midas is less volatile than methyl bromide, so the lower vapor pressure means differences in fumigant distribution will be more greatly amplified with the lower pressure fumigant. Colored polypropylene tubing is available for distribution of fumigant from the flow divider on the bedder to the gas knives. The different colors (yellow, red and black) represent different flow capacities and it makes it easy to determine whether or not the flow capacity of the system is appropriate for the desired fumigant rate. Unfortunately, the red tubing which generally is considered acceptable for methyl bromide is not always the preferred tubing for other fumigants and, in some cases, may not be appropriate for methyl bromide, so growers need to pay close attention to this detail.

A 0 to 30 psi pressure gauge is a valuable addition at the flow divider as it allows a means of monitoring fumigant back pressure in the system. If there is not at least 15 to 20 psi of back pressure when measured at the flow divider, then the rate will not be consistent across all knives and pest control will suffer. With 3 row gas rigs, crop injury also may result due to one row receiving more fumigant than another. All of the tubing must be the same length from the flow divider to the knives or rates will vary as a result of friction loss inside the tubing. At present, I feel that yellow tubing is appropriate for Midas, chloropicrin and reduced rates of Telone products, and red tubing generally can be used for methyl bromide. Again, the final decision should be based upon the desired flow rate per tube and the fumigant. To determine this, you have to calculate what the flow rate per minute will be for each individual tube/line/gas knife and compare that to the capacity for each tubing type. For example, if you needed to flow 12 oz. per minute to each gas knife, yellow tubing would allow you to do so and maintain about 20 psi of back pressure, but if you tried to use red tubing, you would not be able to achieve even 10 psi and product would not flow uniformly to all of the gas knives. If it is not delivered uniformly, results will be non-uniform and control will suffer.

Another equipment-related consideration is the flow meter. When bromide rates were 350 lb./treated acre and higher, most growers had the correct flow meter for their situation, but the shift to greatly reduced rates means that the older flow meters may not be acceptable. The accuracy of most meters drops off greatly as they approach 10% and 90% of flow capacity. Applications requiring rates of 17% are not going to be as accurate as those in the 50% range and a smaller meter should be obtained. While Raven radar controlled units have improved rate accuracy and uniformity when applying higher rates, their performance has been less than stellar for the reduced rates of today. This is because the system was designed for higher flow rates and equipment changes are required to address the diminished flow of today's rates.

FUMIGANTS

Chloropicrin is going to be a component of any fumigant-based alternative program because chloropicrin is generally the most effective product against soilborne diseases. Unfortunately, chloropicrin is going through re-registration review at this time and, unless changed, current thinking about buffer zones will severely limit its use in many areas. It has long been believed that to be effective, the rate had to be about 120 lb./treated acre. This is true under low density and high density polyethylene films, but no one knows required rates under high barrier films like metalized film and VIF. I suspect the rate could be reduced to 80 lb./treated acre or less with no loss of disease control, based on some of my earlier research.

Midas or methyl iodide has an experimental use permit (EUP) at the present time and is being evaluated in 5 acre trials on a number of commercial farms throughout the southeastern USA. Results appear to be positive at this time and it is hoped that a full registration will come in the near future. The current formulation is a 50% blend with chloropicrin. The use rate is in the range of 120 to 160 lb./treated acre under metalized or vif mulch. Rates would have to be doubled to be effective under ldpe or hdpe film. Issues associated with Midas are mainly cost and planting delay requiring at least 3 weeks. Nutsedge control has been good in experiments when combined with vif or metalized film at about 150 lb./treated acre. Midas does not move in the soil as readily as methyl bromide and wet soil greatly impedes its distribution so greater attention to soil conditions at application are required. It can be applied with your existing gas rig, provided the tubing from the flow divider to the chisels is changed to provide sufficient back pressure so that uniformity of delivery results. Since this product is heavier than methyl bromide and not as volatile, flow rates will be lower and less back pressure will result in the system. The size of the tubing will depend upon the rate and ground speed, but the red tubing being fitted on gas rigs in order to accommodate reduced rates of methyl bromide may not be restrictive enough and I feel yellow tubing which has a 1/16 inch diameter interior is the more appropriate choice. You need to pay close attention to this back pressure issue.

DMDS or dimethyl disulfide will have a different trade name and will be available under an EUP in fall 2007. It will be combined with chloropicrin, but the concentration is not known at this time. Good control of nutsedge and other soilborne pests was attained with DMDS / chloropicrin mixture in trials in the Ruskin area using 74 gal/treated acre under vif and metalized films. Performance under ldpe and hdpe suffered greatly, so metalized or vif will be the only way to go with this product. Planting delay was not a major issue with the product, but odor was. It has a very pungent aroma that lingers for quite some time. DMDS can be applied with your existing gas rig, but you will probably require a larger capacity flow meter.

Vapam and K-Pam have a long history of erratic performance in Florida. They can be very effective, especially for weed control, but they require greater attention to application details than methyl bromide. Many different means of application have been tried and some folks have had great success with one particular method while others swear it does not work. It really depends upon the user and his attention to details and willingness to do what it takes to make it work. Currently, I see Vapam and K-Pam as weed control products in the bed, especially for nutsedge, and the most successful application procedure is one where the product is concentrated in the top 3 to 4 inches of the bed where most of the emerged nutsedge tubers are located. These products form very weak gases in the soil and this means they do not move much laterally. Since movement is so limited, you have to distribute the product uniformly throughout that shallow area of the bed or place it in shallow bands no more than about 5 inches apart. Previous attempts to do this using gas knives did not work because the large number of knives wrecked the bed. Today there is equipment available which uses small coulters mounted in a bedder to make narrow grooves into which the product is sprayed in streams, not fans, just ahead of the press pan. Results in trials have been quite good. This application equipment was evaluated on 2 farms in the Manatee - Ruskin area during spring 2007 and in large plot experiments. Nutsedge control varied from excellent to good, but the bed shoulders were a weak area, most likely due to equipment adjustments. Just like with Telone, methyl iodide and DMDS, an effective program requires chloropicrin for soilborne disease control. Combining K-Pam with Telone products or chloropicrin looks good and will probably be tested on more acreage in the area in the fall of 2007. Vapam and K-Pam effectiveness is not improved by use of high barrier films, so a grower can use the cheaper ldpe with these combinations and expect good performance.

DRIP IRRIGATION APPLICATION

So far I have discussed applications based primarily on standard application equipment, but delivery through the drip irrigation system is an option with some products, especially Vapam and K-Pam, provided you can wet most of the bed. Wetting more than about 60% of the bed requires the use of 2 drip tapes per bed, except in some areas with some clay in the soil. Research was conducted for several years to determine the effectiveness of drip delivery of K-Pam following application of Inline (drip) or chloropicrin (gas knives) under standard ldpe versus vif. What we found was that K-Pam did control nutsedge about the same under either film and did it with or without Inline or chloropicrin but there was some improvement in control when it followed either of these products. While film type did not influence K-Pam, it had a major effect on nutsedge control with Inline alone or in combination with K-Pam, but much less impact on performance of chloropicrin. The take home lesson from this study was that if you had a nutsedge problem, you could control it, but to do so with Inline + K-Pam required vif, whereas with Pic + K-Pam you could use ldpe.

The role of chloropicrin in these trials was researched separately and it was found that chloropicrin actually increased nutsedge tuber sprouting and emergence up to a rate of about 200 lb./treated acre and then it declined, but it never actually controlled nutsedge. From these results a management strategy was developed which utilized chloropicrin to stimulate nutsedge tuber sprouting, then apply K-Pam or Vapam 5 to 7 days later to kill those tubers which had begun to sprout. Finally we studied the effect of time of K-Pam application following chloropicrin application from the day of chloropicrin application out to 8 days after application. What we discovered was that timing was very important. Control of nutsedge was poor when K-Pam was applied from 0 to 4 days after chloropicrin. Six days after application provided improvement, but the greatest improvement occurred when we waited 8 days before applying the K-Pam through the drip tubing. Remember this if you choose to follow this program.

SUGGESTED FUMIGANT ALTERNATIVE PROGRAMS

1. **A combination of Telone C-35 and K-Pam or Vapam in the bed.**

   Let's assume that you are using standard LDPE polyethylene mulch. You would first inject Telone C-35 at about 26 gallons per treated acre in the bed with your gas rig. What about PPE? As long as there is no fertilizer hopper on the unit with people on it, it should not be a problem. (Another option to avoid excessive PPE is to put it out with gas knives on the pre-bedder.) You then follow this with Vapam or KPam at a rate of 75 or 60 gal/A, respectively, placed 3 inches in the bed top. This can be done using a new piece of equipment built by Mirusso Enterprises which consists of a bedder with a precision application system of up to 8 coulters (depending on bed width) mounted in the bedder. This gives more uniform application and thus more consistent results than past application methods. Follow this immediately with your plastic rig. If you use vif or metalized film, you still have to use about 26 gal of Telone C-35 in the bed in order to deliver enough chloropicrin to achieve the historical 120 lb. minimum rate. The rate of K-Pam or Vapam would remain the same regardless of film type.

   If you trust my educated guess about 80 lb. of chloropicrin being enough under vif, then you should be able to reduce the Telone C-35 rate to about 16 gal/treated acre and still have good soilborne disease and nematode control. That is your call.

2. **Broadcast application of Telone II followed by Chloropicrin in the bed (and K-Pam or Vapam in some situations)**.

   Broadcast application of Telone II would eliminate the PPE requirement for everyone except the tractor driver. (Please note that even though the driver may be in an enclosed cab, if the label specifies a particular respirator, this must still be worn.) Broadcasting

Telone II at 12 to 15 gallons per acre may be advantageous for nematode problems as it should give nematode control over the whole field. It will not, however, give significantly improved weed control in the row middles of the finished field. After waiting 7 days, follow with your bedding equipment and apply 120 lbs of chloropicrin in the bed. If you know you have significant nutsedge problems, you can either use Sandea (make sure it's labeled for the crop you are growing) after the nutsedge emerges through the plastic or use K-Pam or Vapam in the bed as described above in option #1.

If you are using high barrier film, you still need to use the 12 to 15 gal rate because you are not applying product in the bed. Again, if you trust my guess, you may wish to reduce the chloropicrin rate to no less than 80 lb. treated acre in the bed. Additional K-Pam or Vapam will need to be applied at 60 and 75 gal/treated acre, respectively. Your success with reduced rates of any product depends upon your attention to detail before and during application. If you are going to use reduced rates of these products, you should try it in several places on your own farm under your own soil, pest and cultural conditions. Please remember that for success with reduced rates you MUST adjust your application equipment by using smaller diameter tubing between the manifold and the chisels to compensate for reduced flow capacity and to increase back line pressure. If you do not, you will not get uniform application and coverage and will have problems later on.

3. **Application of Telone C-35 broadcast followed by additional chloropicrin in the bed.**

Telone C-35 would be applied at 20 to 24 gal per acre to supply enough 1,3-D (Telone II) and about 80 lb. of chloropicrin per acre, then additional chloropicrin would be applied to the bed no sooner than 7 days later. If using ldpe, apply 120 lb. of chloropicrin in the bed and reduce the rate to about 80 lb. under vif or metalized. You either can use Sandea to control nutsedge or apply K-Pam to the bed as described previously.

4. **A fourth alternative to consider is Midas.**

This is currently being trialed under a non crop-destruct Experimental Use Permit (EUP). Even though the price currently seems quite high, price is relative in comparison to the cost of other materials, which may change. The rate will vary depending upon the type of plastic you use and your pest pressure. One benefit is that Midas can be applied through your standard fumigation equipment and this one product alternative has shown good results in field trials. The PPE required is a half face respirator for all those in the field. If I were going to use Midas, I would apply it at a rate of 150 lb./treated acre under vif or metalized film.

WHITEFLY RESISTANCE UPDATE

David J. Schuster
UF/IFAS, Gulf Coast Research & Education Center, Wimauma, dschust@ufl.edu

INTRODUCTION

The silverleaf whitefly (SLWF), *Bemisia argentifolii* Bellows & Perring [also known as biotype B of the sweetpotato whitefly, *B. tabaci* (Gennadius)] and *Tomato yellow leaf curl virus* (TYLCV) remain the key pests of tomatoes in southern Florida. Insecticides, particularly the neonicotinoids (Admire Pro®, imidacloprid; Bayer CropScience, Research Triangle Park, NC; Assail®, acetamiprid; Cerexagri Inc., King of Prussia, PA; Platinum®, thiamethoxam; Syngenta Crop Protection, Inc., Greensboro, NC; and Venom®, dinotefuran, Valent U.S.A. Corp., Walnut Creek, CA), remain integral tools for the management of the pests. Because of the potential of the whitefly to develop resistance to the insecticides, a program to monitor the susceptibility of field populations of the SLWF to Admire and Platinum using a cut leaf petiole method was conducted from 2000 to 2006 (Schuster and Thompson 2001, 2004; Schuster et al. 2002, 2003, 2006). Susceptibility of the SLWF to Admire decreased from 2000 to 2003, increased in both 2004 and 2005, and then decreased tremendously in 2006. Susceptibility of the SWLF to Platinum decreased from 2003 to 2005 and then, as with Admire, susceptibility decreased dramatically in 2006. Because of the reduced susceptibility indicated in 2006, the resistance monitoring program was continued in 2007 and expanded to include the other neonicotinoids Assail and Venom.

Resistance was estimated in the laboratory using a cut leaf petiole bioassay method (Schuster and Thompson 2001, 2004; Schuster et al. 2002, 2003, 2006). Bioassays were conducted using adults reared from foliage infested with nymphs that had been collected from each crop field. Standard probit analyses (SAS Institute 1989) were used to estimate the LC_{50} values (the concentration estimated to kill 50% of the population) for a laboratory colony and for each field population. The laboratory colony used as a susceptible standard in this study has been

Table 1. Results of resistance bioassays of silverleaf whitefly populations collected from west central, southwest and southeast Florida to neonicotinoid insecticides, Spring 2007.

Population site	Crop	Generation Tested[1]	Admire		Assail		Platinum		Venom	
			LC_{50}	RS_{50}	LC_{50}	RS_{50}	LC_{50}	RS_{50}	LC_{50}	RS_{50}
GCREC/Lab	Tomato	----	0.38	----	0.58	----	1.36	----	0.32	----
Apollo Beach	Tomato	1st	2.75	7.3	----	----	13.8	10.1	1.25	4.0
Collier-2	Tomato	2nd	----	----	----	----	25.4	18.7	----	----
F1	Tomato	2nd	----	----	----	----	10.4	7.6	----	----
FM	Tomato	1st	2.13	5.6	----	----	6.58	4.8	----	----
Homestead	Tomato	2nd[2]	10.7	28.3	----	----	29.8	21.9	----	----
HomesteadB	Bean	2nd	----	----	----	----	4.37	3.2	----	----
HSRC	Tomato	2nd	----	----	----	----	3.83	2.8	----	----
Myakka-1	Tomato	2nd	----	----	----	----	6.15	4.5	----	----
Maykka-5	Tomato	1st	----	----	2.16	3.7	5.30	3.9	1.39	4.4
NECollier	Tomato	2nd[2]	32.5	85.8	----	----	31.1	22.9	----	----
P 1&2	Pepper	2nd	----	----	1.60	2.8	24.8	18.2	1.19	3.8
P 9	Potato	2nd	----	----	----	----	----	----	1.31	4.1
Parrish-1	Tomato	1st[3]	18.1	47.8	----	----	8.82	6.5	2.21	7.0
SWFREC	Watermelon	2nd	12.6	33.2	----	----	29.7	21.8	2.24	7.1
T 5	Tomato	2nd	----	----	----	----	----	----	1.70	5.4
T 6	Tomato	2nd	----	----	----	----	8.00	5.9	1.28	4.0
TG12N	Tomato	2nd	----	----	----	----	----	----	1.61	5.1
TomG#2	Tomato	1st	2.08	5.5	----	----	14.3	10.5	0.90	2.8
TR 3	Tomato	2nd	4.67	12.3	----	----	19.7	14.5	----	----

[1]The first generation would be those whitefly adults emerging from the foliage collected in the field. The second and third generations were reared on tomato plants in the laboratory that had not been treated with neonicotinoid.

[2]These populations were tested in the 3rd generation for Admire.

[3]This population was tested in the 2nd generation for Admire.

in continuous culture since the late 1980's without the introduction of whiteflies collected from the field and, therefore, would be expected to be particularly susceptible to insecticides. The relative susceptibility (RS_{50}) of each field population compared to the laboratory colony was calculated by dividing the LC_{50} values of the field populations by the LC_{50} value of the laboratory colony. Increasing values greater than one suggest decreasing susceptibility in the field population. While values approaching 8 could indicate decreasing susceptibility of the whiteflies, such variability is not unexpected when comparing field-collected insects with susceptible, laboratory-reared insects. Values of 10 or greater, especially those of 20 or higher, are sufficiently high to draw attention.

The average RS_{50} value for Admire for 2007 did not decrease from 2006 while that for Platinum decreased about 60% (Fig. 1). One population, NECollier, was particularly high for Admire with an RS_{50} value of 85.8 (Table 1). This is the highest RS_{50} ever identified in 8 years of monitoring, especially considering the population had been reared for two generations (3rd generation) in the lab without further exposure to Admire. Research in the past has indicated that reduced susceptibility declines as the whiteflies are reared on successive generations on plants not treated with Admire (Schuster and Thompson 2004). The NECollier population was also higher for Platinum. Some other populations were also high for both Admire and Platinum including Homestead, SWFREC (Southwest Florida Research & Education Center, Immokalee), and TR 3. However, there were two populations that were higher for Platinum but not Admire (Apollo Beach and TomG#2) and one that was higher for Admire but not Platinum (Parrish-1). These results may suggest that there isn't cross tolerance between the two neonicotinoids but that there may be simultaneous selection for tolerance. Previous monitoring had suggested a similar conclusion (Schuster and Thompson 2004). All 10 populations evaluated for susceptibility to Venom were susceptible, even some populations that were higher for Admire and/or Platinum. The two populations evaluated with Assail were susceptible, although one, P 1&2, was higher with Platinum.

Biotype Q of the sweetpotato whitefly is the most prevalent biotype in the Mediterranean region and has plagued greenhouse-grown crops in southern Spain for years. This biotype is resistant to many of the commonly used insecticides for managing whiteflies, including the pyrethroids, neonicotinoids, pymetrozine and insect growth regulators (Courier and Knack). Furthermore, resistance in biotype Q is more stable than that in biotype B, i.e. resistance does not diminish over time. Biotype Q has now been found in greenhouses and nurseries in 22 states including Florida. Although the biotype has not been detected in the field, it represents a new threat to vegetables and other crops in Florida. Strict adherence to management guidelines, especially those dealing with crop hygiene and cultural controls, is important in inhibiting or delaying the establishment of biotype Q in the field.

A Resistance Management Working Group was formed in 2003 to promote resistance management on a regional basis. The group modified previous resistance management recommendations (Schuster and Thompson 2001, 2004; Schuster et al. 2002, 2003) and met with growers to encourage their adoption. The Working Group consisted of University of Florida research and extension personnel, representatives of the chemical companies marketing neonicotinoid insecticides, representatives of commodity organizations, and commercial scouts. Because of the threat of biotype Q and decreased insecticide susceptibility demonstrated in 2006 (Schuster et al. 2006), the group was expanded and met in May, 2006 to once again discuss and revise the whitefly and resistance management recommendations. The recommendations include field hygiene and cultural practices which should be considered a high priority and should be included as an integral part of the overall strategy for managing whitefly populations, TYLCV incidence, and insecticide resistance. These practices will help reduce the onset of the initial infestation of whitefly and lower the initial infestation level during the cropping period, thus reducing insecticide use and selection pressure for insecticide resistance development. The recommendations also include insecticide use recommendations which help improve whitefly and resistance management.

RECOMMENDATIONS FOR MANAGEMENT OF WHITEFLIES, BEGOMOVIRUS, AND INSECTICIDE RESISTANCE FOR FLORIDA VEGETABLE PRODUCTION

A. Crop Hygiene.

Field hygiene should be a high priority and should be included as an integral part of the overall strategy for managing whitefly populations, TYLCV incidence, and insecticide resistance. These practices will help reduce the onset of the initial infestation of whitefly, regardless of biotype, and lower the initial infestation level during the cropping period.

1. Establish a minimum 2 month crop free period during the summer, preferably from mid-June to mid-August.
2. Disrupt the virus-whitefly cycle in winter by creating a break in time and/or space between fall and spring crops, especially tomato.
3. Destroy the crop quickly and thoroughly, killing whiteflies and preventing re-growth.
   a. Promptly and efficiently *destroy all vegetable crops* **within 5 days of final harvest** to decrease whitefly numbers and sources of plant begomoviruses like TYLCV.
   b. Use a contact desiccant ("burn down") herbicide in conjunction with a heavy application of oil (not less than 3% emulsion) and a non-ionic adjuvant to destroy crop plants and to kill whiteflies quickly.
   c. Time burn down sprays to avoid crop destruction during windy periods, especially when prevailing winds are blowing whiteflies toward adjacent plantings.
   d. Destroy crops block by block as harvest is completed rather than waiting and destroying the entire field at one time.

B. Other Cultural Control Practices.

Reduce overall whitefly populations, regardless of biotype, and avoid introducing whiteflies and TYLCV into crops by strictly adhering to correct cultural practices.

1. Use proper pre-planting practices.
   a. Plant whitefly and virus-free transplants.
      1) Do not grow vegetable transplants and vegetatively propagated ornamental plants (i.e. hibiscus, poinsettia, etc.) at the same location, especially if bringing in plant materials from other areas of the US or outside the US.
      2) Isolate vegetable transplants and ornamental plants if both are produced in the same location.
      3) Do not work with or manipulate vegetable transplants and ornamental plants at the same time.
      4) Practice worker isolation between vegetable transplants and ornamental crops.
      5) Avoid yellow clothing or utensils as these attract whitefly adults.
      6) Cover all vents and other openings with whitefly resistant screening (0.25 x 0.8 mm openings or less for passive ventilation, less for forced air ventilation). Use double doors with positive pressure. Cover roofs with UV absorbing films.
   b. Delay planting new fall crops as long as possible.
   c. Do not plant new crops near or adjacent to old, infested crops.
   d. Use determinant varieties of grape tomatoes to avoid extended crop season (see additional information below for list).
   e. Use TYLCV resistant tomato cultivars (see additional information below for list) where possible and appropriate, especially during historically critical periods of virus pressure. Whitefly control must continue even with use of TYLCV resistant cultivars because these cultivars can carry the virus.
   f. Use TYLCV resistant pepper cultivars (see additional information below for a source of a list) when growing pepper and tomato in close proximity.
   g. Use ultraviolet light reflective (aluminum) mulch on plantings that growers find are historically most commonly infested with whiteflies and infected with TYLCV.
2. Use proper post-planting practices.

a. Apply an effective insecticide to kill whitefly adults prior to cultural manipulations such as pruning, tying, etc.
b. Rogue tomato plants with symptoms of TYLCV at least until second tie. Plants should be treated for whitefly adults prior to roguing and, if nymphs are present, should be removed from the field, preferably in plastic bags, and disposed of as far from production fields as possible.
c. Manage weeds within crops to minimize interference with spraying and to eliminate alternative whitefly and virus host plants.
d. Dispose of cull tomatoes as far from production fields as possible. If deposited in pastures, fruit should be spread instead of dumped in a large pile to encourage consumption by cattle. The fields should then be monitored for germination of tomato seedlings, which should be controlled by mowing or with herbicides if present.
e. Avoid u-pick or pin-hooking operations unless effective whitefly control measures are continued.
f. Destroy old crops within 5 days after harvest, destroy whitefly infested abandoned crops, and control volunteer plants with a desiccant herbicide and oil.
g. Plant non-host cover crops such as Sudex to discourage weeds and volunteer crop plants from growing and being infested by whiteflies.

C. Insecticidal Control Practices.

1. **Delay resistance to neonicotinoid and other insecticides by using a proper whitefly insecticide program. *Follow the label!***
   a. On transplants in the production facility, do not use a neonicotinoid insecticide if biotype Q is present. If biotype B is present, apply a neonicotinoid **one time** 7-10 days before shipping. Use products in other chemical classes, including Fulfill, soap, etc. before this time.
   b. Use neonicotinoids in the field **only during the first six weeks of the crop**, thus leaving a neo nicotinoid-free period at the end of the crop.
   c. As control of whitefly nymphs diminishes following soil drenches of the neonicotinoid insecticide or after more than six weeks following trans planting, use rotations of in secticides of other chemical classes including insecticides effective against biotype Q. Consult the Cooperative Extension Service for the latest recommendations.
   d. Use selective rather than broad-spectrum control products where possible to conserve natural en emies and enhance biological control.
   e. Do not apply insecticides on weeds on field perimeters. These could kill whitefly natural en emies and, thus, interfere with biological control, as well as select for biotype Q, if present, which is more resistant to many insecticides than biotype B.
2. Soil applications of neonicotinoid insecticides for whitefly control.
   a. For best control, use a neonicotinoid as a soil drench at trans planting, preferably in the trans plant water.
   b. Soil applications of neonic otinoids through the drip irrigation system are inefficient and not recommended.
   c. Do not use split applications of soil drenches of neonicotinoid insecticides (i.e. do not apply at transplanting and then again later).
3. Foliar applications of neonicotinoid insecticides for whitefly control.
   a. Foliar applications, if used instead of or in addition to soil drenches at transplanting, **should be restricted to the first 6 weeks after transplanting.** Do not exceed the maximum active ingredient per season ac cording to the label.
   b. Follow scouting recommendations when using a foliar neonicotinoid insecticide program. Rotate to non-neonicotinoid 6 weeks and do not use any neonicotinoid class insecticides for the remaining cropping period.

D. Do unto your neighbor as you would have him do unto you.

1. Look out for your neighbor's welfare. This may be a strange or unwelcome concept in the highly competitive vegetable industry but it is in your best interest to do just that. Growers need to remember that, should the whiteflies develop full-blown resistance to insecticides, especially the neonicotinoids, it's not just the other guy that will be hurt—everybody will feel the pain! This is why the Resistance Management Working Group has focused on *encouraging region-wide cooperation in this effort.*
2. Know what is going on in the neighbor's fields.
   Growers should try to keep abreast of operations in upwind fields, especially harvesting and crop destruction, which both disturb the foliage and cause whitefly adults to fly. Now that peppers have been added to the list of TYLCV hosts, tomato growers will need to keep in touch with events in that crop as well.

FOR ADDITIONAL INFORMATION:

IRAC (Insecticide Resistance Action Committee) Website – http://www.irac-online.org.

More suggestions for breaking the whitefly/TYLCV cycle and a list of TYLCV resistant pepper cultivars can be found in articles by Dr. Jane Polston in the 2002 and 2003 Proceedings of the Florida Tomato Institute. TYLCV resistant tomato cultivars can be found in an article by Dr. Jay Scott in the 2004 Florida Tomato Institute Proceedings and in an article by Dr. Kent Cushman in the 2006 Florida Tomato Institute Proceedings. Information on determinant grape tomato cultivars can be found in an article by Dr. Eric Simmone in the 2006 Florida Tomato Institute Proceedings. All of these proceedings can be accessed via Adobe Acrobat™ at the Gulf Coast Research & Education Center website (http://gcrec.ifas.ufl.edu/vegetables.htm).

ACKNOWLEDGMENTS

The author wishes to express his appreciation to Sabrina Spurgeon and Aaron Shurtleff for conducting the 2007 bioassays; to Phil Stansly, Dak Seal, Henry Yonce, Sarah Hornsby and Leon Lucas for identifying and/or collecting whitefly samples for the 2007 monitoring; and to Bayer CropScience, Cerexagri Inc., Syngenta Crop Protection, Valent Agricultural Products and the Florida Tomato Committee for providing funding for the neonicotinoid resistance monitoring. Appreciation also is expressed to representatives of the Florida Tomato Committee, Florida Fruit and Vegetable Association, Bayer CropScience, Syngenta Crop Protection, Cerexagri Inc., Glades Crop Care, Agricultural Crop Consulting, Agri-Tech Services, KAC Agricultural Research, and Integrated Crop Management, and to UF/IFAS personnel Phyllis Gilreath, Alicia Whidden, Gene McAvoy, Jim Price and Phil Stansly for their participation in the Resistance Management Working Group and for their many contributions to the whitefly and resistance management recommendations.

REFERENCES CITED

SAS Instititute Inc. 1989. SAS/STAT User's Guide, Version 6, Fourth Edition, Vol. 2, SAS Institute Inc., Cary, NC.

Schuster, D. J. and S. Thompson. 2001. Monitoring susceptibility of the silverleaf whitefly to imidacloprid, pp. 16-18. *In* P. Gilreath and C. S. Vavrina [eds.], 2001 Fla. Tomato Institute Proc., Univ. Fla., Gainesville, PRO 518.

Schuster, D. J. and S. Thompson. 2004. Silverleaf whitefly resistance management update, pp. 19-25. *In* P. Gilreath and W. H. Stall [eds.], Fla. Tomato Institute Proc., Univ. Fla., Gainesville, PRO 521.

Schuster, D. J., S. Thompson, P. A. Stansly and J. Conner. 2002. Update on insecticides for whitefly and leafminer control, pp. 51-60. *In* P. Gilreath and C. S. Vavrina [eds.], 2002 Fla. Tomato Institute Proc., Univ. Fla., PRO 519.

Schuster, D. J., S. Thompson and P. R. Gilreath. 2003. What's up with all these whiteflies?, pp. 12-19. *In* P. Gilreath and W. H. Stall [eds.], Fla. Tomato Institute Proc., Univ. Fla., PRO 520.

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

SMALL VIRUSES THAT CAUSE BIG PROBLEMS IN TOMATO

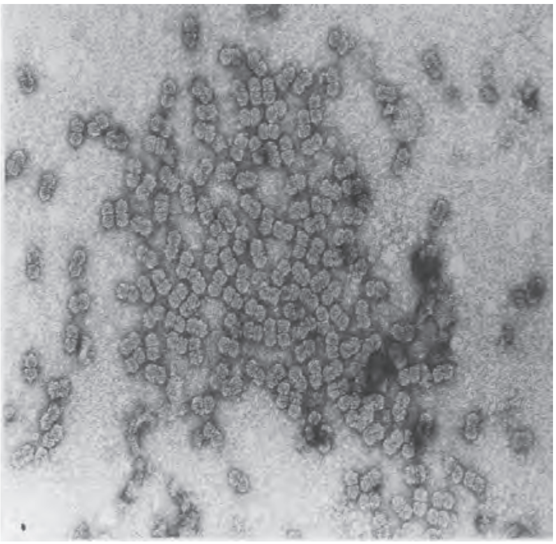
Jane E. Polston, Dept. of Plant Pathology,
University of Florida, Gainesville, FL 32607
jep@ufl.edu

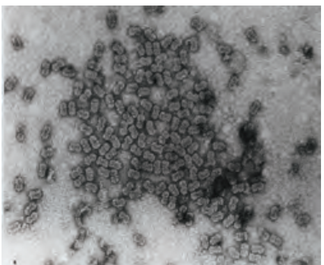
BEGOMOVIRUSES: THE LARGEST GENUS OF VIRUSES

Begomoviruses have become the largest genus of viruses with more than 140 approved species. There are more than 1,000 plant viruses known, and begomoviruses represent 10 - 15% of all known plant viruses. This huge increase in their number has occurred just in the last 15 years and they have become very important pathogens of plants.

The emergence of begomoviruses is due to several factors. One is the movement of known begomoviruses throughout the world through the commercial trade in plant material. Tomato transplants, which often show no symptoms of infection by begomoviruses, can easily be shipped long distances in very short periods of time. These plants are then put in the fields, and if the vector is present, the virus can easily spread to other tomato plants as well as to other crop and weed species, which allows the new virus to become established in the environment. Another factor in the emergence of begomoviruses in tomato is the increase in the global distribution of a whitefly vector which can feed and reproduce on tomato. This vector is capable of moving viruses present in the weeds (which previously had no way to infect tomato) into tomato plants and creating a new disease. Still another factor in the emergence of begomoviruses is the fact that new begomoviruses can come into being when different begomoviruses are present in the same plant at the same time. Begomoviruses can exchange parts of their DNA sequences and form new virus strains and new viruses.

Figure 1. Begomovirus particles as seen with an electron microscope





Close-up of a begomovirus showing the unique geminate ("twinned") particle

Tomato appears to be a very suitable host for begomoviruses. Approximately 95 begomoviruses have been reported to infect tomato. Begomoviruses infect tomato in many production areas throughout the tropics and subtropics. Almost 90% of these viruses have been found in symptomatic field plants, rather than as the result of artificial greenhouse host range experiments. To be considered an approved species, the complete sequence of the begomovirus must be determined and reported. However, only a partial genome sequence is known for a large number of the begomoviruses found in symptomatic plants; only 50 of these viruses have been approved as species. Table 1 lists the approved species known to infect tomato either experimentally (only in greenhouse transmission studies) or naturally (sequence came from infected field plants). Many of these viruses have only been identified within the last 10 years. Although the sequence of these viruses has been reported, there is a lag in the reporting of biological data (response to resistance genes, host range, ecology, and recognition of strains) for most of these viruses. It is expected that even more new begomoviruses will be added to this list, based in part on the long list of tentative species (45 reported to date).

All begomoviruses have a unique geminate particle morphology (Figure 1), and have the ability to be transmitted by the members of the *Bemisia tabaci* species complex (or were once able to in the case of a few). Begomoviruses can be divided into two groups – those with a monopartite genome (about 5,200 nt) and those with bipartite genomes (about 2,500 nt per component). Begomoviruses with monopartite genomes probably originated in the Old World, although at least one, *Tomato yellow leaf curl virus*, now occurs in the New World due to its recent spread across continents through the movement of infected plant material. The bipartite begomoviruses occur in both the Old and New Worlds; a center of origin for these is not known.

TOMATO CHLOROSIS VIRUS (TOCV): AN OLD VIRUS CAUSING NEW PROBLEMS

Tomato chlorosis virus or ToCV is another whitefly transmitted virus, but it is very different from TYLCV or other begomoviruses (Figure 2). ToCV belongs to the genus Criniviruses. These viruses are all transmitted by whiteflies. There are two viruses in this genus that can infect tomato, ToCV

Table1. List of Approved Species of Begomoviruses Known to Infect Tomato

Begomovirus	Acronym	Begomovirus	Acronym
Abutilon mosaic virus	AbMV	*Tomato golden mosaic virus*	TGMV
Ageratum yellow vein virus	AYVV	*Tomato golden mottle virus*	ToGMoV
Bean calico mosaic virus	BCMoV	*Tomato leaf curl Bangalore virus*	ToLCBV
Bean dwarf mosaic virus	BDMV	*Tomato leaf curl Bangladesh virus*	ToLCBDV
Chino del tomate virus	CdTV	*Tomato leaf curl Gujarat virus*	ToLCGV
Cotton leaf curl Alabad virus	CLCuAV	*Tomato leaf curl Karnataka virus*	ToLCKV
Cotton leaf curl virus Kokhran	CLCuKV	*Tomato leaf curl Laos virus*	ToLCLV
Cotton leaf curl Multan virus	CLCuMV	*Tomato leaf curl Malaysia virus*	ToLCMV
Honeysuckle yellow vein mosaic virus	HYVMV	*Tomato leaf curl New Delhi virus*	ToLCNDV
Papaya leaf curl virus	PaLCuV	*Tomato leaf curl Sri lanka virus*	ToLCSLV
Pepper golden mosaic virus	PepGMV	*Tomato leaf curl Taiwan virus*	ToLCTWV
Pepper hausteco virus	PHYVV	*Tomato leaf curl Vietnam virus*	ToLCVV
Pepper leaf curl Bangladesh virus	PepLCBV	*Tomato leaf curl virus*	ToLCV
Potato yellow mosaic virus	PYMV	*Tomato mosaic Havana virus*	ToMHV
Potato yellow mosaic Panama virus	PYMPV	*Tomato mottle Taino virus*	ToMoTV
Potato yellow mosaic Trinidad virus	PYMTV-[TT]	*Tomato mottle virus*	ToMoV
Sida golden mosaic Costa Rica virus	SiGMCRV	*Tomato rugose mosaic virus*	ToRMV
Sida yellow vein virus	SiYVV	*Tomato severe leaf curl virus*	ToSLCV
Sida golden mosaic virus	SiGMV	*Tomato severe rugose virus*	ToSRV
Tobacco curly shoot virus	TbCSV	*Tomato yellow leaf curl china virus*	TYLCCNV
Tobacco leaf curl Japan virus	TbLCJV	*Tomato yellow leaf curl Gezira virus*	TYLCGV
Tobacco leaf curl Kochi virus	TbLCKoV	*Tomato yellow leaf curl Malaga virus*	TYLCMalV
Tobacco leaf curl Yunnan virus	TbLCYNV	*Tomato yellow leaf curl Sardinia virus*	TYLCSV
Tobacco leaf curl Zimbabwe virus	TbLCZV	*Tomato yellow leaf curl Thailand virus*	TYLCTHV
Tomato chlorotic mottle virus	ToCMV	*Tomato yellow leaf curl virus*	TYLCV

Viruses with gray backgrounds were found in naturally occurring in tomato. All others are the result of greenhouse experiments

and *Tomato infectious chlorosis virus* or TiCV. Only ToCV has been found in Florida and has been known here since 1989.

ToCV and TiCV cause very similar symptoms in tomato. The symptoms are unusual for those caused by viruses because they are first observed on older leaves, gradually advancing toward the top of the plant. The symptoms Of ToCV resemble those of nutrient deficiencies, particularly magnesium or nitrogen, and consist of a yellowing of the areas between the veins, leaf brittleness, and rolling of leaves. As the plant ages, interveinal necrotic flecking or bronzing may be observed as well. The effect of ToCV on yield has not been established; however, TiCV has been shown to reduce fruit size and number and to cause premature senescence.

Like Begomoviruses, TICV is only transmitted by the *Bemisia tabaci* species complex. However, unlike the Begomoviruses, TiCV is transmitted in a semi-persistent manner. It can only be acquired by the feeding of an adult whitefly on an infected plant, and can only be transmitted for a period of up to five days.

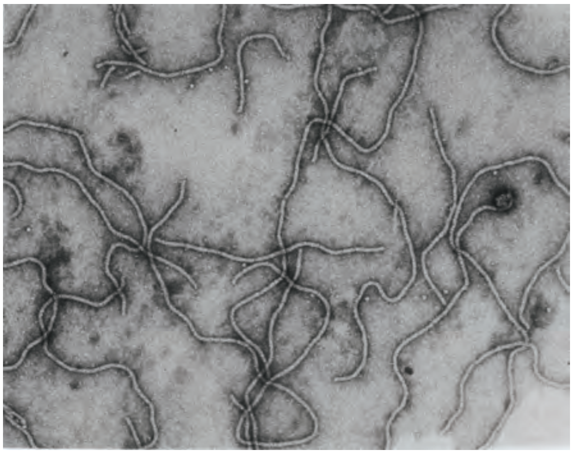
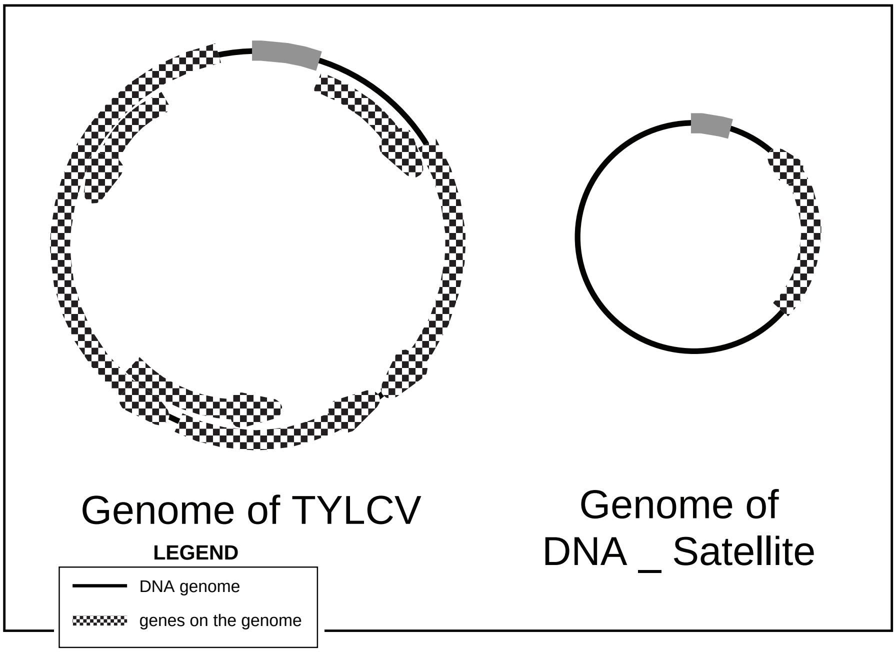


Figure 2. Image of Crinivirus particles from the electron microscope showing the long flexuous rod shape. (Image courtesy of ICTV Descriptions)

The geographic distribution of both TICV and ToCV appears to be increasing. ToCV is widespread in field tomato production in Florida and other areas of the southeastern US, Israel, and Puerto Rico. TICV has been reported from the U.S. (California, North Carolina), Mexico, Central and Southern Europe, and Taiwan. In the U.S., ToCV and TICV are primarily a problem for field tomato, but they are found in greenhouse production facilities in other parts of the world. TICV is readily found in tomato fields in production in California and Mexico. Although these viruses have the potential to cause yield losses in both field and greenhouse tomatoes, in most years and locations they cause only minor losses.

Detection of ToCV (as with all other Criniviruses) is very difficult. The virus is located in the phloem, it is not evenly distributed within the plant, and it occurs in very low amounts. The proteins it produces are also present in low amounts, so ELISA and similar techniques are unreliable. Also, it does not cause easily recognized inclusions. ToCV has a very long and unstable particle shape and its RNA genome is harder to work with than DNA viral ge-

Figure 3. Diagram of the Genomes of Tomato yellow leaf curl virus and a DNA ß satellite showing the differences in sizes of the genomes and number of genes.



nomes. PCR and nucleic acid hybridization are the best techniques to utilize, but because the virus is present in such low amounts in the plant it can be missed even by such highly sensitive techniques.

A BIG CONCERN, BUT NOT OUR PROBLEM YET: DNA SS (BETA) SATELLITES

"Great fleas have little fleas, Upon their backs to bite 'em, And little fleas have lesser fleas, and so, ad infinitum." A. DeMorgan, 1806-1871

Although begomoviruses by themselves are bad enough from an economic perspective, the damage they cause can be intensified by the presence of "parasitic" sequences of DNA known as DNA ß satellites. DNA ß satellites are much smaller than begomoviruses (approximately 1,400 nt in their genome) and share no sequence homology with begomoviruses (Figure 3). These satellites are single stranded circular DNAs that completely depend upon a monopartite begomovirus for replication, movement, and transmission to new hosts. DNA ß satellites have been found in cotton, tomato, pepper, and a few weed hosts primarily in the Old World; they have not yet been found in the New World. Many of the diseases caused by monopartite begomoviruses in this area of the world have been found to involve a DNA ß satellite.

More than 100 DNA ß satellites have been reported, and fortunately all of these have been found in the Old World (primarily in Asia). The DNA ß satellite genome encodes one gene (ßC1) which suppresses the plants' ability to resist the begomovirus. By decreasing the plants' resistance, the DNA ß satellites 1) increase the severity of symptoms caused by the begomoviruses and 2) increase the amount of begomovirus in the plants. When they are present, the DNA ß satellites are the main determinant of symptom severity in the infected host.

In addition, new diseases can arise from mixtures of begomoviruses and DNA ß satellites. DNA ß satellites can turn off normal resistance mechanisms, and this can allow the begomovirus to replicate in a plant that is immune, highly resistant, or moderately resistant to the begomovirus in the absence of the DNA ß satellite.

The presence of DNA ß satellites and their role in increasing symptom severity was first found in begomoviruses that infect cotton. However, the number of diseases in tomato that are attributable to DNA ß satellites are increasing rapidly -- reports of the involvement of DNA ß satellites in tomato diseases have come from China, India, Pakistan, and Mali. It is likely that the number of begomoviruses associated with DNA ß satellites will increase, and that DNA ß satellites may be found to play a greater role in the creation of new diseases in tomato as well as other crops.

TOMATO VARIETIES FOR FLORIDA

Stephen M. Olson[1] and Eugene McAvoy[2]
[1]North Florida Research & Education Center, University of Florida, Quincy; *smolson@ufl.edu*
[2]Hendry County Extension, University of Florida, Labelle; *gmcavoy@ufl.edu*

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

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

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

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

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

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

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

CURRENT VARIETY SITUATION

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

TOMATO VARIETY TRIAL RESULTS

Table 1 shows results of spring trials for 2005 and Table 2 shows results of fall trial of 2005 conducted at the North Florida Research and Education Center, Quincy.

TOMATO VARIETIES FOR COMMERCIAL PRODUCTION

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

LARGE FRUITED VARIETIES

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

Bella Rosa. Heat tolerant determinate type. Produces large to extra-large, firm, uniformly green and shaped fruit. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1,2), Tomato spotted wilt. (Sakata)

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

BHN 640. Early-midseason maturity. Fruit are globe shape but tend to slightly elongate, and green shouldered. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1,2,3), Gray leaf spot, and Tomato spotted wilt. (BHN).

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

Crown Jewel. Uniform fruit have a deep oblate shape with good firmness, quality and uniformly-colored shoulders. Determinate with medium-tall bush. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1,2) Fusarium crown rot, Alternaria stem canker and Gray leaf spot. (Seminis)

Flora-Lee. It was released for the premium tomato market. A midseason, determinate, jointed hybrid with moderate heat-tolerance. Fruit are uniform green with a high lycopene content and deep red interior color due to the crimson gene. Resistant: Fusarium wilt (race 1,2,3), Verticillium wilt (race 1), and Gray leaf spot. **For Trial.**

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

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

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

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

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

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

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

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

Sebring. A late midseason determinate, jointed hybrid with a smooth, deep oblate, firm,

Table 1. Tomato variety trial results, spring 2006. NFREC-Quincy, FL.

Entry	Source	Marketable Yield (25 lb cartons/a)			Marketable (%)	Fruit wt. (oz)
		Large	Extra large	Total		
Quincy	Seminis	308 a-d[z]	2585 a	2956 a	84.3 a-c	7.2 bc
Fla 8367	GCREC	320 a-c	2164 ab	2565 ab	81.6 b-d	6.8 b-e
BHN 444	BHN	299 b-e	2167 ab	2542 ab	82.4 a-d	7.1 b-d
SVR 01420224	Seminis	288 b-e	2047 b	2415 bc	84.0 a-d	7.0 b-e
NC 056	NCS	297 b-e	2043 b	2379 bc	82.8 a-d	6.9 b-e
Amelia	Harris Moran	223 c-f	2082 b	2371 bc	87.0 ab	7.1 b-d
BHN 602	BHN	303 b-e	2011 b	2368 bc	85.1 a-c	7.1 b-d
SVR 01408580	Seminis	279 b-e	1988 b	2329 bc	83.0 a-d	7.1 b-d
NC 0392	NCS	284 b-e	1962 bc	2307 b-d	82.8 a-d	7.0 b-d
SVR 01409432	Seminis	206 ef	2021 b	2267 b-d	86.0 a-c	7.3 ab
HMX 5825	Harris Moran	398 a	1717 bc	2249 b-d	83.4 a-d	6.5 e
Crista	Harris Moran	212 d-f	1877 bc	2129 b-d	85.0 a-c	7.2 bc
SVR 01721400	Seminis	161 f	1935 bc	2127 b-d	87.1 a	7.8 a
NC 03289	NCS	274 b-e	1763 bc	2098 b-d	83.6 a-d	6.8 b-e
BHN 640	BHN	352 ab	1667 bc	2096 b-d	82.2 a-d	6.6 de
NC 0377	NCS	265 b-e	1709 bc	2043 b-d	86.6 ab	6.8 b-e
Bella Rosa	Sakata	221 d-f	1700 bc	1975 cd	80.9 cd	6.8 b-e
Talladega	Syngenta	249 c-f	1465 c	1773 d	78.7 d	6.6 de

[z] Mean separation by Duncan's Multiple Range Test, 5 % level.

Comments: In-row spacing 20 inches, between row spacing 6 ft., Drip irrigation under black polyethylene mulch, Fertilizer applied 195-60-195 lbs/A of N-P2O5-K2O. Transplanted 22 March 2006

thick walled fruit. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1,2,3), Fusarium crown rot and Gray leaf spot. (Syngenta)

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

Solimar. A midseason hybrid producing globe-shaped, green shouldered fruit. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), Alternaria stem canker, gray leaf spot. (Seminis).

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

Talledega. Midseason. Fruit are large to extra-large, globe to deep globe shape. Determinate bush. Has some hot-set ability. Performs well with light to moderate pruning. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1,2), Tomato spotted wilt and Gray leaf spot. (Syngenta Rogers Seed)

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

PLUM TYPE VARIETIES

BHN 410. Midseason. Large, smooth, blocky, jointless fruit tolerant to weather cracking. Compact to small bush with concentrated high yield. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1,2), Bacterial speck (race 0) and Gray leaf spot. (BHN Seed)

BHN 411. Midseason. Large, smooth, jointless fruit is tolerant to weather cracks and has reduced tendency for graywall. Compact plant with concentrated fruit set. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1,2), Bacterial speck (race 0) and Gray leaf spot. (BHN Seed)

BHN 485. Midseason. Large to extra-large, deep blocky, globe shaped fruit. Determinate, vigorous bush with no pruning recommended. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1,2,3) and Tomato spotted wilt. (BHN Seed)

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

Monica. Midseason. Fruit are elongated, firm, extra-large and uniform green color. Vigorous bush with good cover. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1,2), Bacterial speck (race 0) and Gray leaf spot. (Sakata)

Plum Dandy. Medium to large determinate plants. Rectangular, blocky, defect-free fruit for fresh-market production. When grown in hot, wet conditions, it does not set fruit well and is susceptible to bacterial spot. For winter and spring production in

Florida. Resistant: Verticillium wilt, Fusarium wilt (race 1), Early blight, and rain checking. (Harris Moran).

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

CHERRY TYPE VARIETIES

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

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

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

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

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

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

Table 2. Tomato variety trial results, fall 2006. NFREC-Quincy, FL.

Entry	Source	Marketable Yield (25 lb cartons/a)				Marketable (%)	Fruit wt. (oz)
		Medium	Large	Ex-large	Total		
Quincy	Seminis	215 ab[z]	596 a	1708 ab	2521 a	84.6 a	6.2 bc
Bella Rosa	Sakata	104 cd	310 b-d	1802 a	2217 ab	79.3 ab	6.7 a-c
Flora-Lee	GCREC	167 bc	460 a-c	1527 a-c	2154 ab	80.6 ab	6.2 bc
RFT 4971	Syngenta	176 a-c	456 a-c	1445 a-c	2077 ab	83.8 a	6.3 bc
Fla. 8367	GCREC	146 b-d	315 b-d	1610 a-c	2072 ab	81.0 ab	6.5 a-c
Phoenix	Seminis	124 b-d	357 b-d	1489 a-c	1971 ab	77.6 ab	6.6 a-c
FL 91	Seminis	81 cd	271 cd	1613 a-c	1965 ab	79.2 ab	6.8 ab
Fla. 8363	GCREC	62 d	292 b-d	1550 a-c	1904 ab	80.0 ab	6.7 a-c
Amelia	Harris Moran	79 cd	281 b-d	1525 a-c	1887 ab	70.9 ab	6.8 ab
NC 03289	NCS	135 b-d	346 b-d	1395 a-c	1876 ab	77.6 ab	6.4 bc
Fla. 8314	GCREC	152 b-d	353 b-d	1364 a-c	1870 ab	73.8 ab	6.3 bc
Solar Fire	Harris Moran	76 cd	333 b-d	1321 a-c	1731 ab	74.3 ab	7.4 a
RFT 4974	Syngenta	104 cd	330 b-d	1278 a-c	1714 ab	74.6 ab	6.6 a-c
HMX 5825	Harris Moran	143 b-d	394 a-c	1154 a-c	1692 ab	76.4 ab	6.0 b-d
Crista	Harris Moran	99 cd	299 b-d	1178 a-c	1577 ab	76.1 ab	6.5 a-c
XTM 3301	Sakata	58 d	237 cd	1280 a-c	1576 ab	66.9 b	6.7 a-c
NC 056	NCS	120 b-d	249 cd	1204 a-c	1574 ab	78.4 ab	6.4 bc
HA 3074	Hazera	262 a	502 ab	775 cd	1540 ab	69.1 b	5.3 d
Talladega	Syngenta	89 cd	285 b-d	1136 a-c	1511 ab	67.2 b	6.4 bc
FL 47	Seminis	89 cd	274 cd	955 b-d	1320 bc	76.0 ab	6.4 bc
HA 3617	Hazera	59 d	133 d	305 d	498 c	47.4 c	5.9 cd

[z] Mean separation by Duncan's Multiple Range Test, %5 level.

Comments: In-row spacing 20 in., between row spacing 6 ft., Drip irrigation under white on black polyethylene mulch. Fertilizer applied 195-60-195 lb/a of N-P2O5-K2O. Transplanted 31 July 2006.

GRAPE TOMATOES

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. Resistant: Verticillium wilt (race 1), root-knot nematodes and Tomato mosaic. ((Harris Moran)

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

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

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

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

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

WATER MANAGEMENT FOR TOMATO

E.H. Simonne

UF/IFAS Horticultural Sciences Department, Gainesville, esimonne@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

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

Water Management Level	Rating	Irrigation scheduling method
0	None	Guessing (irrigate whenever)
1	Very low	Using the >feel and see= method
2	Low	Using systematic irrigation (example: 2 hrs every day)
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 water moisture, determining rainfall contribution to soil moisture, and having a guideline for splitting irrigation. In addition, BMPs have some record keeping requirements

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

TOMATO WATER REQUIREMENT

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

By definition, ETo represents the water

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

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

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

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

Typical CF values for fully-grown tomato should not exceed 0.75 (Locascio and Smajstrla, 1996). A third method for estimated tomato crop water requirement is to use modified Bellani plates also known as atmometers. A common model of atmomter used in Florida is the $ET_{gage.}$ 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 0.2inch/day, rain water wets the canvas which interferes with the flow of water out of the atmometers, and decreases the reliability of the measurement.

TOMATO IRRIGATION REQUIREMENT.

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

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

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

IRRIGATION SCHEDULING FOR TOMATO

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

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

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

Tomato Growth Stage	Plasticulture
1	0.30
2	0.40
3	0.90
4	0.90
5	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)

SOIL 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-in depth is useful at the beginning of the season when tomato roots are near that depth. A deeper 12-in depth is used to monitor SWT during the rest of the season. Comparing SWT at both depth 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 irrigation applied. When the 6-in SWT increases (from 4-8 cb to 10-15cb) while SWT at 12-in remains within 4-8 cb, the upper part of the soil is drying, and it is time to irrigate. If the 6-in 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-in depth remaining with the 4-8 cb range, but the 12-in reading showing a SWT of 20-25 cb 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-in 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 not a new method for measuring soil moisture but its use in vegetable production has been limited in the past. The recent availability of inexpensive equipment ($400 to $550/unit) has increased the potential of this method to become practical for tomato growers. A TDR unit is comprised of three parts: a display unit, a sensor, and two rods. Rods may be 4 inches or 8 inches in length based on the depth of the soil. Long rods may be used in all the sandy soils of Florida, while the short rods may be used with the shallow soils of Miami-Dade county.

The advantage of TDR is that probes need not being buried permanently, and readings are available instantaneously. This means that, unlike the tensiometer, 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. Preliminary tests with TDR probes have shown that best soil monitoring may be achieved by placing the probe vertically, approximately 6 inches away from the drip tape on the opposite side of the tomato plants. For fine sandy soils, 9% to 15% appears to be the adequate moisture range. Tomato plants are exposed to water stress when soil moisture is below 8%. Excessive irrigation may result in soil moisture above 16%.

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

Units for Measuring Irrigation Water. When overhead and seepage irrigation were the dominant methods of irrigation, acre-inches or vertical amounts of water were used as units for irrigations recommendations. There are 27,150 gallons in one 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 was wetted.

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

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

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

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

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

IRRIGATION AND BEST MANAGEMENT PRACTICES

As an effort to clean impaired water bodies, federal legislation in the 70's, followed by state legislation in the 90's and state rules since 2000 have progressively shaped the Best Management Practices (BMP) program for vegetable production in Florida. Section 303(d) of the Federal Clean Water Act of 1972 required states to identify impaired water bodies and establish Total Maximum Daily Loads (TMDL) for pollutants entering these water bodies. In 1987, the Florida legislature passed the Surface Water Improvement and Management Act requiring the five Florida water management districts to develop plans to clean up and preserve Florida lakes, bays, estuaries, and rivers. In 1999, the Florida Watershed Restoration Act defined a process for the development of TMDLs. More recently, the "*Florida vegetable and agronomic crop water quality/quantity Best Management Practices*" manual was adopted by reference and by rule 5M-8 in the Florida Administrative Code on Feb.9, 2006 (FDACS, 2005). The manual which is available at www.floridaagwater-policy.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

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

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

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

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

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

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:

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

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

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

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

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

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

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

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

Simonne, E.H, M.D. Dukes, and D.Z. Haman. 2006. Principles of irrigation management for vegetables, pp.33-39. In: S.M. Olson and E. Simonne (eds) 2006-2007 Vegetable Production Handbook for Florida, Vance Publ., Lenexa, KS.

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

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

FERTILIZER AND NUTRIENT MANAGEMENT FOR TOMATO

E.H. Simonne

UF/IFAS Horticultural Sciences Department, Gainesville, esimonne@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 lab uses methodologies calibrated and extractants suitable for Florida soils. When used with the percent sufficiency philosophy, routine soil testing helps adjust fertilizer applications to plant needs and target yields. In addition, the use of routine calibrated soil tests reduces the risk of over-fertilization. Over fertilization reduces fertilizer efficiency and increases the risk of groundwater pollution. Systematic use of fertilizer without a soil test may also result in crop damage from salt injury.

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

Fertilizer rates can be simply and accurately adjusted to row spacings other than the standard spacing (6-ft centers) by expressing the recommended rates on a 100 linear bed feet (lbf) basis, rather than on a real-estate acre basis. For example, in a tomato field planted on 7-ft centers with one drive row every six rows, there are only 5,333 lbf/A (6/7 x 43,560 / 7). If the recommendation is to inject 10 lbs of N per acre (standard spacing), this becomes

Table 1. Fertilization recommendations for tomato grown in Florida on sandy soils testing very low in Mehlich-1 potassium (K2O).

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

[z] 1 A = 7,260 linear bed feet per acre (6-ft bed spacing); for soils testing >very low= in Mehlich 1 potassium (K2O).

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

[x] This fertigation schedule is applicable when no N and K2O are applied preplant. Reduce schedule proportionally to the amount of N and K2O applied preplant. Fertilizer injections may be done daily or weekly. Inject fertilizer at the end of the irrigation event and allow enough time for proper flushing afterwards.

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

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

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

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

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

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

[q] Supplemental amount for each leaching rain

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

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

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

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

The increase in pH induced by liming materials is not due to the presence of calcium or magnesium. Instead, it is the carbonate (ACO_3") and oxide (AO≅) part of $CaCO_3$ and "CaO", respectively, that raises the pH. Through several chemical reactions that occur in the soil, carbonates and oxides release OH- ions that combine with H^+ to produce water. As large amounts of H^+ react, the pH rises. A large fraction of the Ca and/or Mg in the liming materials gets into solution and binds to the sites that are freed by H^+ that have reacted with OH^-.

FERTILIZER-RELATED PHYSIOLOGICAL DISORDERS

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

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

Factors that impair the ability of tomato plants to obtain water will increase the risk of BER. These factors include damaged roots from flooding, mechanical damage or nematodes, clogged drip emitters, inadequate water applications, alternating dry-wet periods, and even prolonged overcast periods. Other causes for BER include high fertilizer rates, especially potassium and nitrogen.

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

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

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

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

FERTILIZER APPLICATION

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

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

				N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
				%						ppm					
Tomato	MRM[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.

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

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

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

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

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

SOURCES OF N-P_2O_5-K_2O.

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

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

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

SAP TESTING AND TISSUE ANALYSIS

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

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

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

Florida Department of Agriculture and Consumer Services. 2005. Florida

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

	Sap concentration (ppm)	
Stage of growth	**NO_3-N**	**K**
First buds	1000-1200	3500-4000
First open flowers	600-800	3500-4000
Fruits one-inch diameter	400-600	3000-3500
Fruits two-inch diameter	400-600	3000-3500
First harvest	300-400	2500-3000
Second harvest	200-400	2000-2500

Vegetable and Agronomic Crop Water Quality and Quantity BMP Manual. http://www.floridaagwaterpolicy.com/PDFs/BMPs/vegetable&agronomicCrops.pdf

Gazula, A., E. Simonne and B. Boman. 2007. Update and outlook for 2007 of Florida=s BMP program for vegetable crops, EDIS HSXXX (In press).

Gilbert, C.A and E.H. Simonne. 2005. Update and outlook for 2005 of Florida=s BMP program for vegetable crops, EDIS HS1013, http://edis.ifas.ufl.edu/HS256.

Hochmuth, G. 1994. Plant petiole sap-testing for vegetable crops. Univ. Fla. Coop. Ext. Circ. 1144, http://edis.ifas.ufl.edu/cv004

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

Maynard, D.N., and G.J. Hochmuth. 1997. Knott=s Handbook for vegetable growers. 4th ed. Wiley Interscience, New York.

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

Olson, S.M.,W.M. Stall, M.T. Momol, S.E. Webb, T.G. Taylor, S.A. Smith, E.H. Simonne, and E. McAvoy. 2006. Tomato production in Florida, pp. 407-426 In: S.M. Olson and E. Simonne (Eds.) 2006-2007 Vegetable Production Handbook for Florida, Vance Pub., Lenexa, KS.

Simonne, E.H. and G.J. Hochmuth. 2006. Soil and fertilizer management for vegetable production in Florida, pp. 3-15 In: S.M. Olson and E. Simonne (Eds.) 2006-2007 Vegetable Production Handbook for Florida, Vance Pub., Lenexa, KS.

Simonne, E., D. Studstill, B. Hochmuth, T. Olczyk, M. Dukes, R. Munoz-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.

Simonne, E.H. and G.J. Hochmuth. 2003. Principles of irrigation and fertilization management for vegetable crops grown in Florida in the BMP era: Introduction. EDIS HS897, http://edis.ifas.ufl.edu/HS154.

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

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

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

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

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

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

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

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

[q] Supplemental amount for each leaching rain

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

UPDATE AND OUTLOOK FOR FLORIDA'S BMP PROGRAM FOR VEGETABLE CROPS

Aparna Gazula[1], Eric Simonne[1], and Brian Boman[2]
University of Florida, IFAS, [1]Horticultural Sciences Department and [2]IRREC, Ft. Pierce
esimonne@ufl.edu

The BMPs developed for vegetable crops grown in Florida are described in a manual titled "Water Quality/Quantity Best Management Practices for Florida Vegetable and Agronomic Crops". The manual, which is electronically accessible at <http://www.floridaagwaterpolicy.com>, was adopted by reference in Rule No 5M-8.004 of the Florida Administrative Code on February 8, 2006. (The Florida Administrative Code is the official compilation of the rules and regulations of Florida regulatory agencies.) The purpose of this rule is to achieve pollutant reduction through the implementation of non-regulatory and incentive based programs which may be determined to have minimal individual or cumulative adverse impacts to the water resources of the state.

BMPs are defined in s. 373.4595(2)(a), F.S. as "practices or combinations of practices determined by the coordinating agencies, based on research, field-testing, and expert review, to be the most effective and practicable on-location means, including economical and technological considerations, for improving water quality in agricultural and urban discharges". The 5M-8 rule includes information about the approved BMP's, presumption of compliance, notice of intent to implement, and record keeping. The statutory benefits for enrolling in the BMP program are: (1) obtaining a presumption of compliance with water quality standards (s. 403.067 (7)(d) Florida Statutes.), (2) receiving a waiver of liability from the reimbursement of costs and damages associated with the evaluation, assessment, or remediation of nutrient contamination of ground water (s. 376.307), and (3) eligibility for cost-share programs (s. 570.085 (1)). (The Florida Statutes are the codified, statutory laws of the state of Florida which are approved by the Florida

Table 1. Table of contents and corresponding BMPs of the "Water Quality/Quantity Best Management Practices for Florida Vegetable and Agronomic Crops"

Sections: General Area / Area of Application	Contents of Section: BMPs
1. Introduction	Outlines the history and purpose of the program.
2. BMP Evaluation and Implementation	Gives a general outline and how to use the manual, including information on developing a BMP implementation plan. In this section, there are decision tree flow charts and a geographic region map designed to help growers identify BMPs applicable to their operations.
3. Pesticide Management	Explains integrated pest management and how to manage pesticides.
4. Conservation Practices and Buffers	Aquatic ecosystems and the practices necessary to help protect water quality by preventing leaching runoff.
5. Erosion Control and Sediment Management	Techniques that help prevent movement of soil from agricultural fields.
6. Nutrient and Irrigation Management Pages 75-130, Sections 26-42	Soil testing and pH, water table observation wells, precision agriculture, crop establishment, double cropping in plasticulture system, proper use of organic fertilizer materials, controlled-release fertilizers, optimum fertigation management/application, chemigation/fertigation, tissue testing, water supply, tailwater recovery, tailwater refuse, and waterborne plant pathogens, irrigation system maintenance and evaluation, irrigation scheduling, frost and freeze protection, water control structures.
7. Water Resources Management	Update industry on the most common irrigation and storm water management techniques available to date. In this section, there is a subsection focusing on plasticulture.
8. Seasonal or Temporary Farming Operations	BMPs to address issues related to seasonal farming.
9. Glossary	Definitions of words used within manual.
10. Appendices	A. BMP Checklist, NOI Form, BMP Effectiveness Summary B. Tables • Typical Bed Spacings • Conversion of Fertilizer Rates • Irrigation Application Rates for Cold Protection • Precipitation Rates by Nozzle Flow Rate and Sprinkler Spacing C. Soil testing information D. Incentive programs for agriculture E. Federal Department of Agriculture and Consumer Services (FDACS), http://www.doacs.state.fl.us/

Table 2 Record keeping requirements for the Florida vegetable BMP program.

BMP Number	BMP Title	Record keeping requirement
5	Pesticide Equipment Calibration	Record calibration dates for future reference.
6	Well Head Protection	Maintain records of well construction.
26	Soil Testing/Soil pH	Record or sketch where soil samples were taken within each area.
26	Soil Testing/Soil pH	Record date, rate of application, materials used, and method of lime application.
26	Soil Testing/Soil pH	Keep the soil testing lab report for each field and crop as well as information about the soil testing lab and the soil test method used.
33	Optimum Fertilization Management/Application	Keep records of the fertilizers used, the amounts applied, and dates of application.
34	Chemigation/Fertigation	On a regular basis, record the flow rate and pressure of the injection device and irrigation pump(s), as well as the energy consumption of the power unit for the irrigation pump.
39	Irrigation System Maintenance and Evaluation	Record the flow rate, pressure delivered by the pump, and energy consumption of the power unit frequently enough to gain an understanding of system performance.
40	Irrigation Scheduling	Keep records of irrigation amounts applied and total rainfall received. Flag values where rainfall rate or duration exceeds the definition of a leaching rainfall event
49	Seasonal or Temporary Farming Operations	Keep permanent records of crop history.
49	Seasonal or Temporary Farming Operations	Keep records of flooded field including the duration, water level, and water quality analyses.

Legislature and signed into law by the Governor of Florida). The BMP program for vegetables applies to the whole state of Florida, except for the Lake Okeechobee Priority Basin (rule 5M-3 F.A.C.) and the EAA and C-139 basin (under rule 40E-63, F.A.C.) where pre-existing regulations are already in place.

THE FUTURE IS HERE, BUT THE CLOCK IS TICKING!

The BMP programs for all major agricultural commodities of Florida have been developed under the provisions of the 1999 Florida Watershed Restoration Act (FWRA .s. 403.067 F.S.). The FWRA specifically outlines the process for the Florida Department of Environmental Protection (FDEP) to develop and implement total maximum daily loads (TMDLs) for impaired waters of the state. Section 303(d) of the Clean Water Act requires states to submit lists of surface waters that do not meet applicable water quality standards and to establish TMDLs for these waters on a prioritized schedule. TMDLs are defined as the maximum amount of a pollutant that a waterbody can receive and still meet the water quality standards as established by the Clean Water Act of 1972.

The purpose of the FWRA was to better coordinate the numerous pollution control efforts that were implemented prior to 1999 and develop a standard to address future water quality issues. The FWRA requires that TMDLs be developed for all pollution sources "agricultural and urban" to ensure water quality standards are achieved. The FWRA affects all Floridians; thus, in order to effectively implement the TMDL program the FDEP coordinates its efforts with a variety of entities including the Florida Department of Agriculture and Consumer Services, the Water Management Districts, the local Soil and Water Conservation Districts, the environmental community, the agricultural community, as well as concerned citizens.

BMP measures are not regulatory or enforcement-based, they are strictly voluntary. As part of the BMP implementation, growers perform an environmental assessment of their operations. This process identifies which BMPs should be considered to achieve the greatest economic and environmental benefit. The adopted BMPs may be a single practice or grouping of practices that, when implemented, are designed to improve water quality. The BMPs that are selected for each parcel of land with a tax ID are specified on a *Notice of Intent to Implement* and submitted to FDACS. If the practices are not yet implemented, the dates when they will be implemented are included on the *Notice of Intent*. Once enrolled in the BMP program, landowners must maintain records and provide documentation regarding the implementation of all BMPs (i.e. fertilizer application dates and amounts or design and construction details of a water control structure).

One of the most innovative elements of the FWRA and the associated agricultural BMP program is the *Presumption of Compliance* with water quality standards to landowners who voluntarily implement adopted BMPs that have been verified to be effective by FDEP. This component of the FWRA provides a powerful incen-

Table 3. Contact Information for Mobile Irrigation Labs (MIL) of Florida (current as of April 2007; contact NRCS office for updated information)

County	Contact	Address	Phone & Fax
Lee	Garry Bailey	3434 Hancock Bridge Parkway	Phone: 239-995-5678 ext. 3
	garry.bailey@fl.nacdnet.net	Suite 209B	FAX: 239-997-7557
	James (Nik) Nikolich	North Fort Myers, FL 33903	
	nik.nikolich@fl.nacdnet.net		
Website: http://www.lee-county.com/utilities/Mobile%20Irrigation%20Lab/Mobile%20Irrigation%20Lab.htm			
Miami-Dade	Robert Perez	South Dade SWCD	Phone: 305-242-1288
	rperez@southdadeswcd.org	1450 N Krome Ave., Suite 104	FAX: 305-242-1292
	Michelle Codallo	Florida City, FL 33034	
	mcodallo@southdadeswcd.org		
	Don Grimsley		
	don@southdadeswcd.org		
Website: http://www.southdadeswcd.org/Mobile%20Irrigation%20Lab.htm			
Collier	Mark Siverling	14700 Immokalee Rd.	Phone: 239-455-4100
Hendry	mark.siverling@fl.nacdnet.net	Naples, FL 34120	Cell: 239-961-4292
Charlotte	Jovino Marquez		FAX: 239-455-2693
Glades			
Website: http://www.collierswcd.org/Page315.html			
Broward	Willie Rojas	6191 Orange Drive, Suite 6181-P	Phone: 954-873-7594
	browardmil@aol.com	Davie, FL 33314	954-584-1306
			FAX: 954-792-4919
			954-792-3996
Website: http://ci.ftlaud.fl.us/public_services/water/pdf/Mobile%20Irrigation%20Laboratory.pdf			
Broward	David DeMaio	Palm Beach SWCD	Phone: 561-683-2285 ext. 3
Palm Beach	ddemaio@pbswcd.org	750 South Military Trail Suite G	561-385-1240
		West Palm Beach, Florida 33415	FAX: 561-683-8205
Website: http://www.pbswcd.org/AgMobileIrrigationLab.htm			
Broward	David Legg	Natural Resources Consulting Services,	FAX: 561-649-5627
Palm Beach	dlegg1149@bellsouth.net	3344 Palomino Dr.	Cell: 561- 385-1240
		Lake Worth, FL, 33462	
Columbia	Doug Ulmer	Suwannee River RC&D Council	Phone: 386-364-4278
Suwannee	Andy Schrader	234 Court Street, S.E.	FAX: 386-364-1558
Hamilton		Live Oak, FL 32060	
Jefferson			
Madison			
Lafayette			
Taylor			
Website: http://www.kineticnet.net/flrcd/suwannee.html			

* For counties not listed in the table contact your local NRCS District Conservationist for the mobile irrigation lab closest to your location.

tive to encourage landowners to enroll in the BMP programs since landowners are protected from cost recovery by the state if water quality standards are not met. This unique approach to addressing water quality concerns has been well received by the environmental and agricultural communities alike and as a result is becoming the primary method for addressing water quality concerns. In addition, growers enrolled in the BMP program become eligible for cost-sharing funds to implement specific BMP practices.

In approximately 2 years, the Florida Legislature will assess the success of this non-regulatory program by examining the participation and enrolment of agricultural operations on a regional and commodity basis. By participating in BMP programs, growers are telling the Florida Legislature that the Florida agriculture industry has endorsed the challenge to remain in business while minimizing environmental impact. By making the BMP program a success, growers are also telling the Florida legislature that there is no need for a more stringent regulatory program.

How to sign up for the program? Participation in the program requires that applicable BMPs are implemented and documented as noted in the manual (Table 1). Parcels of lands may be enrolled in the vegetable BMP program by:

(1) completing the "BMP checklist" (page A-5 of the manual),

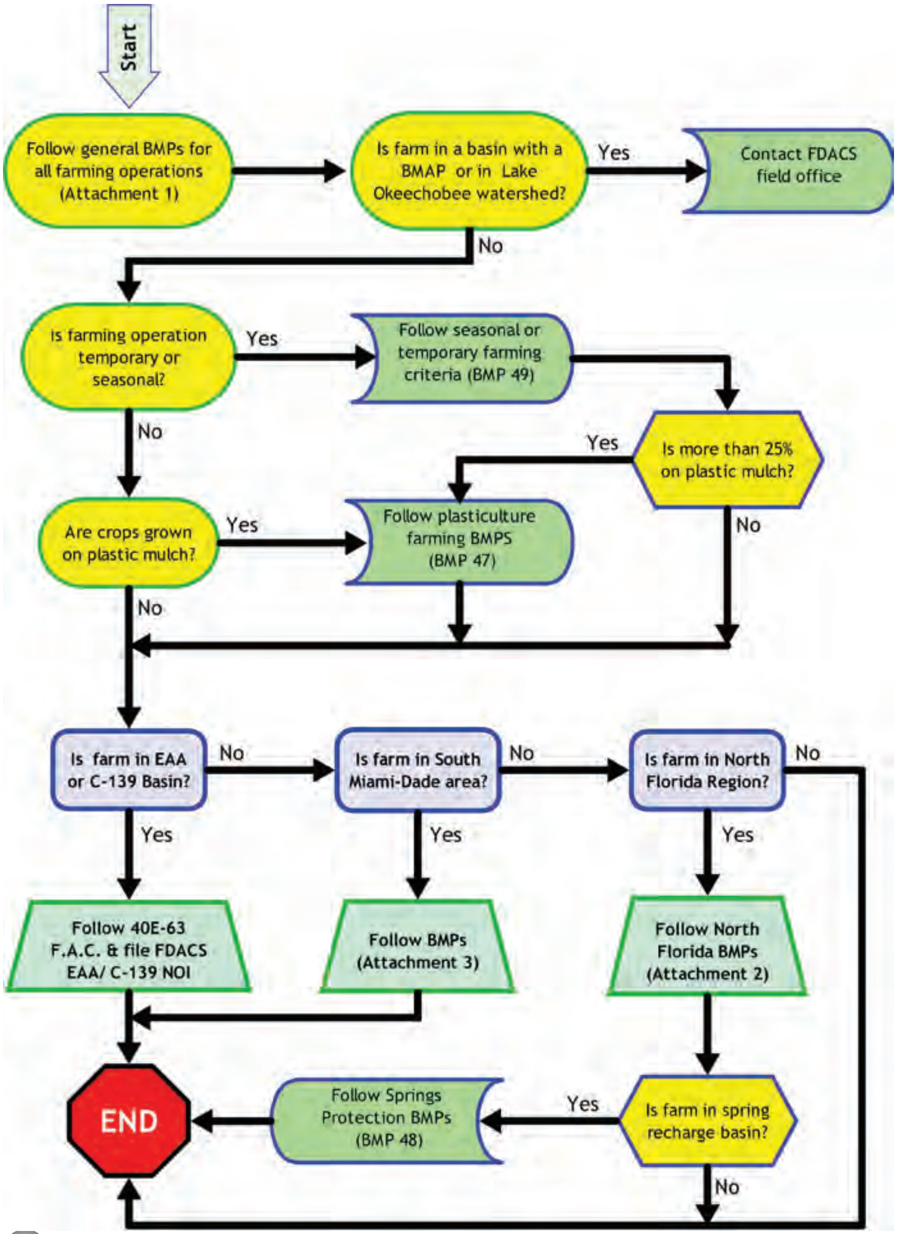
(2) completing the "Vegetable production Best Management Practices Checklist" if applicable (pages A1-A3 of the BMP manual),

(3) submitting a "Notice of Intent to Implement" to FDACS, and

(4) keeping these documents and those required by the program (Table 2) on file for possible later inspection.

The BMP checklist (found on page A-1 of the BMP manual) is designed to assist vegetable growers in identifying appropriate BMPs for their specific site and growing conditions. It should be used together with the decision tree flow chart (found on pages 7-8 of the BMP manual). Growers should check the boxes corresponding to the BMPs they are already implementing, and identify the year they plan to implement other applicable BMPs not yet implemented. It should be noted that BMP 33 "Optimum fertilization management/application" (found on pages 93-98 of the BMP manual) has to be a part of all BMP plans.

Fig. 1. Decision tree in the "BMP Evaluation and Implementation Section" of the "Water Quality/Quantity Best Management Practices for Florida Vegetable and Agronomic Crops" used to select BMPs for specific cropping systems and geographical areas of Florida.



IMPLEMENTATION TEAMS ARE AVAILABLE TO PROVIDE ONE-ON-ONE HELP

Vegetable growers and land owners who need one-on-one help to complete the BMP checklist and/or *Notice of Intent to Implement* may contact their UF/IFAS County Extension Agent (go to http://solutionsforyourlife.ufl.edu/map/index.html for the addresses of all counties of Florida) or visit the FDACS web site at http://www.floridaagwaterpolicy.com/PDF/Maps/OawpBmpImpTeams070220.pdf for contact information on the BMP implementation team member in your area. In addition, implementation team members may conduct on-farm demonstrations of selected BMPs and assist in locating cost-share funds to partially offset the cost of BMP implementation.

ON-LINE BMP RESOURCES AVAILABLE FROM VEGETABLE BMP WEBSITE

The "Best Management Practices for the Florida Vegetable Industry" web site (http://www.imok.ufl.edu/bmp/vegetable/) was developed as a quick resource for growers, Extension educators, implementation team members and all those involved in the BMP process. Currently, the site is organized in four sections regularly updated:

1. The BMP manual for vegetables and agronomic crops accessible on-line.
2. Background documents on how to participate in the BMP program. Among others, this section contains the BMP checklist for self evaluation of current BMP adoption.
3. A list of selected UF/IFAS on-line Extension publications applicable to the state-wide BMP program and interim measures.
4. Additional BMP-related resources.

This section contains a link to a series of frequently asked question regarding BMPs, and how to locate and contact the implementation teams.

HOW TO SELECT BMPS THAT APPLY TO SPECIFIC FARMING OPERATIONS?

BMP selection for vegetable farms is based on parcel location and type of production system. Based on the decision tree flow chart of the manual (p.7-8 of the BMP manual), regions of Florida with specific BMP requirements are (1) areas where a BMAP/TMDL has been established, (2) North Florid region, (3) springs recharge basins, (4) EAA or the C139 basin, (4) south Miami-Dade county, and (5) Okeechobee watershed priority basins (Fig.1). Recognized production systems are bare ground or plastic culture, drip or seepage irrigation, and permanent or temporary farming operations. Growers and/or land owners should assess their operation and complete the "Candidate BMP checklist" (found on page A-5 of the BMP manual).

Vegetable growers who follow nutrient management option 2 in BMP 33 "Optimum fertilization management/application" (found on pages 93-98 of the BMP manual) should fill up the "Vegetable production Best Management Practices Checklist" (found on pages A-1 to A-3 of the BMP manual). Option 2 (page 93 of manual) deals with production systems that use IFAS published fertilizer recommendations as a general starting point. When these rates are exceeded, growers are expected to "employ additional nutrient and irrigation BMPs to negate possible environmental impacts".

THE FREE MOBILE IRRIGATION LABS (MIL) CAN HELP IMPROVE IRRIGATION SYSTEMS

The mission of the MIL is to improve irrigation management by making customized recommendations to improve the performance of an irrigation system (overhead, drip, or other) and encourage better water management practices. Composed of 1 to 2 qualified irrigation technicians, MILs visit farms and test pump flow rates, drip emitter and sprinkler pressures and flow rates, and estimate irrigation uniformity (Table 3). MIL services are available free of charge and they provide a confidential irrigation system evaluation with recommendations regarding system upgrades, irrigation scheduling, and other maintenance items.

Fig. 2. Sample BMP list that may apply to fields equipped with drip or seepage irrigation in South Florida.

BMP Question	Drip	Seep
1. Integrated Pesticide Management		
IPM practices are utilized (soil preparation, crop rotation, resistant varieties, modified irrigation methods, cover crops, augmenting beneficial insects, etc.).	Y	Y
Scouting is used to monitor pest populations in order to decide when control measures are needed. (Insects, disease, weeds, nematodes, etc.)	Y	Y
Varieties are selected based on factors such as maturity, lodging resistance, climate, market value, yield potential, and pest resistance.	Y	Y
Spray/dust drift to other crops and off-site areas is minimized.	Y	Y
Classes of insecticide and fungicide are alternated to prevent resistance buildup.	Y	Y
Pesticide applications are coordinated with soil moisture, weather forecast, and irrigation.	Y	Y
2. Pesticide Mixing and Loading Activities		
Mix and load operations are conducted at locations well away from ground water wells and surface water bodies (or berms or mounds are used to keep spills out of surface waters if such areas cannot be avoided).	Y	Y
Properly constructed and maintained permanent or portable mix/load facilities are used. Or, mixing and loading operations are conducted at random locations in the field.	Y	Y
Nurse tanks are used to transport clean water to the field in order to fill the sprayer.	Y	Y
A check valve or air gap separation is ALWAYS used to prevent backflow into the water source.	Y	Y
Adequate headspace (usually 10%) is left when filling the tank.	Y	Y
3. Spill Management		
Appropriate personal protective equipment (PPEs) as indicated on the Material Safety Data Sheet or label are ALWAYS used when handling pesticides.	Y	Y
Pesticide spills are properly contained and cleaned up.	Y	Y
Employees receive periodic spill response training.	Y	Y
4. Pesticide Application Equipment Wash Water and Container Management		

Required personal protective equipment are ALWAYS worn when conducting rinse operations.	Y	Y
Empty containers are pressure-rinsed or triple-rinsed and the rinse water is added to the sprayer.	Y	Y
Pesticide containers are properly disposed or recycled after cleaning.	Y	Y
All application equipment is washed on a mixing/loading pad or at random areas in the field.	Y	Y
5. Pesticide Equipment Calibration ***(Recordkeeping)***		
Equipment is calibrated at appropriate intervals based use, on spray coverage, and nozzle replacement.	Y	Y
The flow rates of all nozzles on the sprayer are checked.	Y	Y
6. Wellhead Protection ***(Recordkeeping)***		
Wells are sited as far as possible from septic tanks or chemical mixing areas.	Y	Y
Abandoned or flowing wells are properly plugged or valved before constructing any new wells. The procedures provided by the Water Management District are used to plug wells.	Y	Y
Backflow prevention devices are used when fertigating or chemigating.	Y	Y
Wellheads and pads are inspected regularly for leaks or cracks and if needed, repairs are made promptly.	Y	Y
No agrichemicals in the well house and no mixing within 100 ft of any well.	Y	Y
7. Wetland Protection		
Wetlands (>1ac=35 ft wide, 1/2-1 ac=50 ft wide) and perennial watercourses (i.e., creeks, rivers, min 25 ft buffer) have appropriate undisturbed upland buffers.	Y	Y
The use of pesticides and fertilizers around wetlands is limited and spray drift into wetlands is minimal.	Y	Y
8. Grassed Waterways		
The bottom and side slopes of grassed waterways are maintained to preserve their function and integrity.	Y	Y
Side slopes are not be steeper than 2:1, and are be designed to accommodate equipment crossing.	Y	Y
Tillage equipment is lifted and sprayers are shut off when crossing waterways.	Y	Y
9. Filter Strips		
Filter strip vegetation is suited to the climate and soil types of the area.	Y	Y
Heavy equipment use and grazing are avoided when filter strips are saturated.	Y	Y
Invasive plant species are controlled.	Y	Y
Rills or gullies that have formed have been repaired.	Y	Y
10. Field Borders		
Field borders (strips of permanent vegetation at the edge of or around fields) are established, maintained, and are wide enough so equipment can turn around.	Y	Y
Waterbars, berms, or mounds are used (if needed) to break up or redirect concentrated water flow within the borders.	Y	Y
11. Riparian Buffers		
Riparian buffers (areas of trees/shrubs) are used adjacent to natural water bodies (35+ ft wide).	Y	Y
Riparian buffers consist of two or more woody or herbacious species, with individual plants suited to the seasonal variation of soil moisture conditions.	Y	Y
The riparian buffer is maintained, dead trees or shrubs removed and replaced, and undesirable vegetation is controlled.	Y	Y
12. Contour Farming		
Row direction is established as closely as possible to the natural contour (most effective when slopes are between 2 and 10 percent).	NA	NA
The established contour line is followed for all tillage and planting operations.	NA	NA
Farming operations begin on the contour baselines and proceed both up and down the slope in a parallel pattern until patterns meet.	NA	NA
Sod turn strips are established on sharp ridge points or other areas, as needed, where contour row curvature becomes too sharp to keep machinery aligned with rows during field operations.	NA	NA
13. Land Leveling		
The design and layout for leveling land is based on a detailed engineering survey, design and layout.	Y	Y
Leveling operations are conducted in such a manner to minimize erosion.	Y	Y
Exposed areas of highly permeable soils (that can inhibit proper distribution of water over the field) are not left after leveling work is finished.	Y	Y
14. Soil Survey		
Grower is familiar with the basic characteristics of each soil series that is identified on the property.	Y	Y
The information from the soil survey is used to help make farm-management decisions related to irrigation, fertilization, erosion control, etc.	Y	Y
15. Sediment Basins		
Sediment basins constructed upstream of control structures are used to trap sediment and debris in runoff water.	Y	Y
Accumulated sediment is removed before it significantly reduces the capacity of the basin.	Y	Y
16. Access Roads		
Road widths are consistent with the type and size of vehicles.	Y	Y
Perennial vegetative cover on road banks is maintained.	Y	Y
Soils are stabilized with vegetation or armor around the ends of pipes to prevent erosion when crossing conveyance systems.	Y	Y
Access roads are sloped towards field production areas.	Y	Y
17. Critical Area Plantings		
Highly erodible areas are stabilized by well-maintained vegetation.	Y	Y
Plants are non-invasive species that are suited to the soil and climate.	Y	Y
18. Diversions/Terraces		
Diversions or terraces are used where appropriate to divert runoff water away from cropland.	NA	NA
19. Temporary Erosion Control Measures		

Temporary erosion control measures (e.g. straw bale barrier, silt fence erosion-control blankets, gabions-wire mesh containers filled with stone, or floating turbidity barriers) are used to minimize sediment transport from disturbed areas.	Y	Y
20. Raised Bed Preparation		
Old crop residues are plowed down well in advance (6-8 weeks) of crop establishment.	Y	Y
Bed height is determined by the amount of drainage needed in the field (excessively high beds are prone to rapid drying and can be difficult to re-wet).	Y	Y
Drip tube is appropriately located considering the soils, bed geometry, and crop.	Y	NA
Fertilizer rates and placement are appropriate so that leaching is minimized.	Y	Y
Plastic mulch is properly removed and recycled or legally disposed.	Y	Y
21. Grade Stabilization Structures		
Stabilization structures are used and maintained in areas that are prone to erosion due to changes in flow velocity or water level.	Y	Y
22. Ditch Construction and Maintenance		
Ditches are set back appropriate distances from wetlands.	Y	Y
Ditch spacings, depths, and side-slopes are consistent with soil types.	Y	Y
Ditches are cleaned when necessary and vegetation is maintained on side slopes.	Y	Y
Accumulated aquatic weeds are routinely removed.	Y	Y
23. Conservation Tillage		
Where appropriate, conservation tillage (no-till, strip-till, ridge-till, mulch till, and seasonal-till) are used to reduce soil erosion.	NA	NA
Required % of residue or groundcover being maintained.	NA	NA
24. Cover Crops		
A cover crop that is suitable for the climate, soil type, cropping system, and specific goals (i.e., nutrient uptake, nitrogen fixation, etc.) is used to protect the land from erosion until the main crop is planted.	Y	Y
25. Conservation Crop Rotation		
Crops are adapted to the local climate and soil conditions and grown in a planned, recurring sequence.	NA	NA
Alternate crops to break the pest cycle and/or allow the use of a variety of IPM strategies.	NA	NA
26. Soil Testing / Soil pH ***(Recordkeeping)***		
Soil pH is tested regularly (every 2-3 years) and if needed, amendments are used to maintain soil pH between 6.0 and 6.5 for most crops.	Y	Y
27. Water Table Observation Wells		
Water table observation wells are used to monitor water table levels as a tool to aid irrigation and drainage decisions.	Y	Y
28. Precision Agriculture		
Precision application technology is used where appropriate to apply site-specific inputs (fertilizer, seed, pesticides, etc.) in order to minimize potential for leaching and runoff of applied materials.	NA	NA
29. Crop Establishment		
Weather forecasts and season are considered when planning for crop establishment.	Y	Y
Soil moisture measurement devices (such as tensiometers) and/or water table observation wells are used so that over-watering of fields is minimized.	Y	Y
30. Double Cropping in Plasticulture Systems		
Soil samples are used to determine residual fertilizer available from first crop and rates for the second crop are adjusted accordingly.	NA	NA
Soil moisture is maintained at appropriate levels between removal of the first crop and planting of the second crop.	NA	NA
31. Proper Use of Organic Fertilizer Materials		
Application rates are based on laboratory analysis of product and on individual crop requirements.	NA	NA
Fertilizer spreaders are calibrated and excessive material is not applied.	NA	NA
Uncomposted animal manure is not spread on cropland.	NA	NA
32. Controlled-Release Fertilizer		
Controlled-release fertilizers (CRFs) are applied at lower rates than that recommended rate for soluble fertilizers.	NA	NA
The CRF's release time is matched with the crop nutrient needs.	NA	NA
Do not exceed the recommended fertilization rate.	NA	NA
33. Optimum Fertilization Management/Application ***(Recordkeeping)***		
(1) IFAS published fertilizer recommendations are used (which include provisions for supplemental nutrient applications) or alternate recommendations that are supported by other credible research institutions are used; or	Y	Y
(2) IFAS published fertilizer application recommendations are used as a general starting point. If these rates are exceeded, additional nutrient and irrigation BMPs are used minimize environmental impacts; or	Y	Y
(3) For farming operations in basins that have a Total Maximum Daily Load (TMDL) for nutrients (issued by the Dept. of Environmental Protection), all recommendations set forth in the Basin Management Action Plan (BMAP) are followed.	NA	NA
Fertilizer application equipment is calibrated accurately and fertilizer is applied at the appropriate rate and position with respect to the plant's root zone.	Y	Y
A calibrated micronutrient soil test is conducted every to 2 to 3 years. Micronutrients are applied only when a specific deficiency has been clearly diagnosed.	Y	Y
A calibrated soil test is used to determine P fertilizer needs. Required P is applied P to the root zone.	Y	Y
The Linear Bed Foot system is used, where appropriate.	Y	Y
When using drip irrigation, no more than 20-40% of the N and K is applied as a cold mix in the bed.	Y	NA
Where possible, applications of the mobile nutrients are split to reduce leaching losses.	Y	Y
Supplemental fertilizer applications after leaching rainfall events is limited to less than 30 lbs. N per acre and 20 lbs K_20 per acre	Y	Y
Plant tissue analysis or sap tests are that fall below the sufficiency ranges are used as a basis for supplemental fertilizer applications.	Y	Y
34. Chemigation / Fertigation ***(Recordkeeping)***		

When the production system permits, chemigation and fertigation is utilized to apply frequent, low rates of fertilizers and agrichemicals to the crop via irrigation.	Y	NA
When chemigating or fertigating, over-irrigation resulting in chemical leaching is avoided.	Y	NA
Materials are injected only after the irrigation system is brought up to full pressure and the system is operated long enough after completion of injection to flush system.	Y	NA
Split applications are used whed the required injection period would result in water and fertilizer moving below the plant root zone.	Y	NA
All chemicals applied through the irrigation system are appropriately labeled chemigation use.	Y	NA
35. Tissue Testing ***(Recordkeeping)***		
Tissue sampling is used regularly to diagnose plant nutrient status and fertilizer applications are adjusted according to results.	Y	Y
36. Water Supply		
Seepage losses on reservoir-supplied sources are reduced by lining dikes with appropriate materials or construction techniques.	NA	NA
Backflow devices are used to ensure that the water source does not become contaminated from chemigation activities.	Y	Y
37 & 38. Tailwater Recovery		
Where appropriate, tailwater recovery systems are used to collect and re-use irrigation water or rainfall that runs off cropped areas.	NA	NA
39. Irrigation System Maintenance and Evaluation ***(Recordkeeping)***		
Irrigation system uniformity is periodically checked (can utilize Mobile Irrigation Lab, or MIL).	Y	Y
Flow meters and pressure gauges are used to determine existing operating parameters and to properly manage the irrigation system.	Y	Y
Irrigation water quality is tested at least once each year.	Y	Y
Manufacturers maintenance recommendations are followed for pumps, filters, valves, injection equipment, etc.	Y	Y
40. Irrigation Scheduling ***(Recordkeeping)***		
Soil moisture content is measured and used to determine effectiveness of irrigation schedules.	Y	Y
Irrigation schedules are adjusted for time of year, plant size, and soil moisture status. (Irrigation application may need to be split into 2 or 3 daily applications).	Y	Y
Irrigation and fertilization are managed together, especially if liquid fertilizer is being applied through the irrigation system.	Y	Y
Excess irrigations are avoided.	Y	Y
41. Frost and Freeze Protection		
Over-application and potential offsite runoff is minimized by not initiating irrigation events too soon, or continuing protection after all the ice has melted.	Y	Y
Computers, satellite, etc. are used to access regional weather data.	Y	Y
42. Water Control Structures		
Riser-board control structures (which facilitate deposition of sediments and their accompanying nutrients or pesticides upstream) are used at outfall locations.	NA	NA
43. Flood Protection		
A water management/drainage plan has been developed to deal with potential flooding resulting from high rainfall events (e.g. tropical storms or hurricanes).	Y	Y
44. Ponds/Reservoirs and Ditches		
Detention ponds/reservoirs are used to capture and temporarily store stormwater runoff.	Y	Y
Culverts are maintained free of debris.	Y	Y
Sediment sumps are used and maintained in ditches at pump stations and where the velocity of the water creates erosion problems.	NA	NA
Vegetative cover on dikes and berms is mowed and properly maintained.	NA	NA
45. Farm Pond		
Vegetative cover of farm ponds (used for irrigation water supply and/or for holding and treating runoff water) is maintained by mowing or burning and nuisance or exotic species are controlled.	NA	NA
Pond size <1acre and <14' deep, with 4:1 side slopes.	NA	NA
46. Fields and Beds		
Soil type, field slope, and crop characteristics are considered when laying out rows with regard to length and alignment.	Y	Y
If plastic mulch is used, drip irrigation is used.	Y	NA
Fields with persistent drainage problems are leveled or re-graded to improve stormwater management.	Y	Y
47. Plasticulture Farming		
Depressional areas are utilized as catchment areas.	Y	Y
Tillage practices are appropriate to minimize the development of plow pans.	Y	Y
Where practical, inter-row cover crops such as grasses or legumes are used to reduce runoff.	Y	Y
Plastic mulch and tubing is not left on farm fields unduly long after harvest.	Y	Y
Undesirable weed species growing in holes in the plastic mulch are controlled.	Y	Y
48. Springs Protection		
Conservation buffer setbacks (buffer areas of perennial vegetation) are established and maintained for springs, spring runs, functional sinks, or other conduits.	NA	NA
49. Seasonal or Temporary Farming Operations ***(Recordkeeping)***		
Crops on a particular piece of land are alternated to break the pest and disease cycles and to allow for the use of a variety of Integrated Pest Management control strategies.	NA	NA
All agricultural surface water management system features are restored to equivalent, pre-development, hydrologic conditions when the farming is completed.	NA	NA
Soil tests are used and fertilizer recommendations are followed to avoid over fertilizing.	NA	NA
Plastic mulch and tubing is removed within 30 days after harvest of the last crop.	NA	NA
Recommended rotation intervals including prescribed fallow periods are used for each 5-year rotation interval (2- year farming period, no more than 4 seasons; 3-year farming period, no more than 1 season per year).	NA	NA

Fig.3. Example of a Candidate BMP Checklist found on page A-5 of the BMP manual for vegetables based on answers provided in the BM P questionnaire (see Fig. 2)

Candidate BMP Checklist

Instructions: Using the *Florida Vegetable and Agronomic Crops Best Management Practices Checkl*ist, check "yes" for all BMPs currently practiced and "no" for BMPs not currently implemented. For those BMPs that will be implemented in future years, enter the year you plan initiate the BMP in the "year" column. Enter N/A in the "year" column if the practice is not applicable to your operation or if it conflicts with other BMPs that have been implemented.

Pesticide Management

Yes	No	Year		BMP
X			1	Integrated Pest Management
X			2	Pesticide Mixing and Loading
X			3	Spill Management
X			4	Pesticide App. Eq. Washwater and Container Mgmt.
X			5	Pesticide Equipment Calibration

Conservation Practices and Buffers

Yes	No	Year		BMP
X			6	Well Head Protection
X			7	Wetlands Protection
X			8	Grassed Waterways
X			9	Filter Strips
X			10	Field Borders
X			11	Riparian Buffers
		NA	12	Contour Farming
X			13	Land Leveling
X			14	Soil Survey

Erosion Control & Sediment Mgmt

Yes	No	Year		BMP
X			15	Sediment Basins
X			16	Access Roads
X			17	Critical Area Plantings
		NA	18	Diversions/Terraces
X			18	Temporary Erosion Control Measures
4/5		NA	20	Raised Bed Preparation
X			21	Grade Stabilization Structures
X			22	Ditch Construction and Maintenance
		NA	23	Conservation Tillage
X			24	Cover Crops
		NA	25	Conservation Crop Rotation

Nutrient and Irrigation Management

Yes	No	Year		BMP
X			26	Soil Testing/Soil pH
X			27	Water Table Observation Wells
	X		28	Precision Agriculture
X			29	Crop Establishment
		NA	30	Double Cropping in Plasticulture Systems
		NA	31	Proper Use of Organic Fertilizer Materials
		NA	32	Controlled-Release Fertilizers
9/11		NA	33	Optimum Fertilization Management/ Application
		NA	34	Chemigation/Fertigation
X			35	Tissue Testing
1/2		NA	36	Water Supply
		NA	37	Tailwater Recovery
		NA	38	Tailwater Reuse and Waterborne Plant Pathogens
X			39	Irrigation System Maintenance and Evaluation
X			40	Irrigation Scheduling
X			41	Frost and Freeze Protection
		NA	42	Water Control Structures

Water Resources Management

Yes	No	Year		BMP
X			43	Flood Protection
2/4		NA	44	Ponds/Reservoirs and Ditches
		NA	45	Farm Ponds
2/3		NA	46	Fields and Beds
X			47	Plasticulture Farming
		NA	48	Springs Protection

Seasonal or Temporary Farming

Yes	No	Year		BMP
Y			49	Plasticulture Farming

WEED CONTROL IN TOMATO

William M. Stall[1] and James P. Gilreath[2]
[1]UF/IFAS Horticultural Sciences Department, Gainesville, wmstall@ufl.edu
[2]PhytoServices, Myakka City, FL DrGilreath@aol.com

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

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

Disking is probably the least expensive weed control procedure for fallow fields. Where weed growth is mostly grasses, clean cultivation is not as important as in fields infested with nightshade and other disease and insect hosts. In the latter situation, weed growth should be kept to a minimum throughout the year. If cover crops are planted, they should be plants which do not serve as hosts for tomato diseases and insects. Some perimeter areas are easily disked, but berms and field

Table 1. Chemical weed controls: tomatoes.

Herbicide	Labeled Crops	Time of Application to Crop	Rate (lbs. AI./Acre) Mineral	Rate (lbs. AI./Acre) Muck
Carfentrazone (Aim)	Tomato	Preplant, Directed-Hooded row-middles	0.031	0.031
Remarks: Aim may be applied as a preplant burndown treatment and /or as a post-directed hooded application to row middles for the burndown of emerged broadleaf weeds. May be tank mixed with other registered herbicides. May be applied up to 2 oz (0.031 lb ai). Use a quality spray adjuvant such as crop oil concentrate (coc) or non-ionic surfactant at recommended rates.				
Clethodim (Select 2 EC)	Tomatoes	Postemergence	0.9-.125	---
Remarks: Postemergence control of actively growing annual grasses. Apply at 6-8 fl oz/acre. Use high rate under heavy grass pressure and/or when grasses are at maximum height. Always use a crop oil concentrate at 1% v/v in the finished spray volume. Do not apply within 20 days of tomato harvest.				
DCPA (Dacthal W-75)	Established Tomatoes	Posttransplanting after crop establishment (non-mulched)	6.0-8.0	---
Remarks: Controls germinating annuals. Apply to weed-free soil 6 to 8 weeks after crop is established and growing rapidly or to moist soil in row middles after crop establishment. Note label precautions of replanting non-registered crops within 8 months.				
Glyphosate (Roundup, Durango Touchdown, Glyphomax)	Tomato	Chemical fallow Preplant, pre-emergence, Pre transplant	0.3-1.0	---
Remarks: Roundup, Glyphomax and touchdown have several formulations. Check the label of each for specific labeling directions.				
Halosulfuron (Sandea)	Tomatoes	Pre-transplant, Postemergtence, Row middles	0.024 - 0.036	---
Remarks: A total of 2 applications of Sandea may be applied as either one pre-transplant soil surface treatment at 0.5-0.75 oz. product; one over-the-top application 14 days after transplanting at 0.5-0.75 oz. product; and/or postemergence applications(s) of up to 1 oz. product (0.047 lb ai) to row middles. A 30-day PHI will be observed. For postemergence and row middle applications, a surfactant should be added to the spray mix.				
S-Metolachlor (Dual Magnum)	Tomatoes	Pretransplant, Row middles	1.0 - 1.3	---
Remarks: Apply Dual Magnum preplant non-incorporated to the top of a pressed bed as the last step prior to laying plastic. May also be used to treat row-middles. Label rates are 1.0-1.33 pts/A if organic matter is less than 3%. Research has shown that the 1.33 pt may be too high in some Florida soils except in row middles. Good results have been seen at 0.6 pts to 1.0 pints especially in tank mix situations under mulch. Use on a trial basis.				
Metribuzin (Sencor DF) (Sencor 4)	Tomatoes	Postemergence, Posttransplanting after establishment	0.25 - 0.5	---
Remarks: Controls small emerged weeds after transplants are established direct-seeded plants reach 5 to 6 true leaf stage. Apply in single or multiple applications with a minimum of 14 days between treatments and a maximum of 1.0 lb ai/acre within a crop season. Avoid applications for 3 days following cool, wet or cloudy weather to reduce possible crop injury.				
Metribuzin (Sencor DF) (Sencor 4)	Tomatoes	Directed spray in row middles	0.25 - 1.0	---
Remarks: Apply in single or multiple applications with a minimum of 14 days between treatments and maximum of 1.0 lb ai/acre within crop season. Avoid applications for 3 days following cool, wet or cloudy weather to reduce possible crop injury. Label states control of many annual grasses and broadleaf weeds including, lambsquarter, fall panicum, amaranthus sp., Florida pusley, common ragweed, sicklepod, and spotted spurge.				

Table 1. Chemical weed controls: tomatoes.

Herbicide	Labeled Crops	Time of Application to Crop	Rate (lbs. AI./Acre)	
			Mineral	Muck
Napropamid (Devrinol 50DF)	Tomatoes	Preplant incorporated	1.0 - 2.0	---
Remarks: Apply to well worked soil that is dry enough to permit thorough incorporation to a depth of 1 to 2 inches. Incorporate same day as applied. For direct-seeded or transplanted tomatoes.				
Napropamid (Devrinol 50DF)	Tomatoes	Surface treatment	2.0	---
Remarks: Controls germinating annuals. Apply to bed tops after bedding but before plastic application. Rainfall or overhead-irrigate sufficient to wet soil 1 inch in depth should follow treatment within 24 hours. May be applied to row middles between mulched beds. A special Local Needs 24(c) Label for Florida. Label states control of weeds including Texas panicum, pigweed, purslane, Florida pusley, and signalgrass.				
Oxyfluorfen (Goal 2XL) (Goaltender)	Tomatoes	Fallow bed	0.25 - 0.5	
Remarks: Must have a 30 day treatment-planting interval for transplanted tomatoes. Apply as a preemergence broadcast or banded treatment at 1-2 pt/A or ½ to 1 pt/A for Goaltender to preformed beds. Mulch may be applied any time during the 30-day interval.				
Paraquat (Gramoxone Inteon) (Firestorm)	Tomatoes	Premergence; Pretransplant	0.62 - 0.94	---
Remarks: Controls emerged weeds. Use a non-ionic spreader and thoroughly wet weed foliage.				
Paraquat (Gramoxone Inteon)	Tomatoes	Post directed spray in row middle	0.47	---
Remarks: Controls emerged weeds. Direct spray over emerged weeds 1 to 6 inches tall in row middles between mulched beds. Use a non-ionic spreader. Use low pressure and shields to control drift. Do not apply more than 3 times per season.				
Paraquat (Gramoxone Inteon)	Tomato	Postharvest dessication	0.62-0.93	0.46-0.62
Remarks: Broadcast spry over the top of plants after last harvest. Label for Boa states use of 1.5-2.0 pts while Gramoxone label is from 2-3 pts. Use a nonionic surfactant at 1 pt/100 gals to 1 qt/100 gals spray solution. Thorough coverage is required to ensure maximum herbicide burndown. Do not use treated crop for human or animal consumption.				
Pelargonic Acid (Scythe)	Fruiting Vegetable (tomato)	Preplant, Preemergence, Directed-Shielded	3-10% v/v	---
Remarks: Product is a contact, nonselective, foliar applied herbicide. There is no residual control. May be tank mixed with several soil residual compounds. Consult the label for rates. Has a greenhouse and growth structure label.				
Rimsulfuron (Matrix)	Tomato	Posttransplant and directed-row middles	0.25 - 0.5 oz.	---
Remarks: Matrix may be applied preemergence (seeded), postemergence, posttransplant and applied directed to row middles. May be applied at 1-2 oz. product (0.25-0.5 oz ai) in single or sequential applications. A maximum of 4 oz. product per acre per year may be applied. For post (weed) applications, use a non-ionic surfactant at a rate of 0.25% v/v. for preemergence (weed) control, Matrix must be activated in the soil with sprinkler irrigation or rainfall. Check crop rotational guidelines on label.				
Sethoxydim (Poast)	Tomatoes	Postemergence	0.188 - 0.28	---
Remarks: Controls actively growing grass weeds. A total of 42 pts. product per acre may be applied in one season. Do not apply within 20 days of harvest. Apply in 5 to 20 gallons of water adding 2 pts. of oil concentrate per acre. Unsatisfactory results may occur if applied to grasses under stress. Use 0.188 lb ai (1 pt.) to seedling grasses and up to 0.28 lb ai (12 pts.) to perennial grasses emerging from rhizomes etc. Consult label for grass species and growth stage for best control.				
Trifloxysulfuron (Envoke)	Tomatoes(transplanted)	Post directed	0.007-0.014	
Remarks: Envoke can be applied at 0.1 to 0.2 oz product/A post-directed to transplanted tomatoes for control of nutsedge, morningglory, pigweeds and other weeds listed on the label. Applications should be made prior to fruit set and at least45 days prior to harvest. A non-ionic surfactant should be added to the spray mix.				
Trifluralin (Treflan HFP) (Treflan TR-10) (Trifluralin 4EC)	Tomatoes (except Dade County)	Pretransplant incorporated	0.5	---
Remarks: Controls germinating annuals. Incorporate 4 inches or less within 8 hours of application. Results in Florida are erratic on soils with low organic matter and clay contents. Note label precautions of planting non-registered crops within 5 months. Do not apply after transplanting.				

ditches are not and some form of chemical weed control may have to be used on these areas. We are not advocating bare ground on the farm as this can lead to other serious problems, such as soil erosion and sand blasting of plants; however, where undesirable plants exist, some control should be practiced, if practical, and replacement of undesirable species with less troublesome ones, such as bahiagrass, might be worthwhile.

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

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

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

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

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

POSTHARVEST VINE DESSICATION

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

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

TOMATO FUNGICIDES AND OTHER DISEASE MANAGEMENT PRODUCTS (UPDATED JUNE 2007)

TIM MOMOL AND LAURA RITCHIE
UF/IFAS, NFREC, QUINCY, FL
TMOMOL@UFL.EDU

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

Chemical	Fungicide Group[1]	Maximum Rate / Acre / Applic.	Maximum Rate / Acre / Season	Min. Days to Harvest	Pertinent Diseases or Pathogens	Remarks[2]
Manex 4 F (maneb)	M3	2.4 qts.	16.8 qts.	5	Early blight, Late blight, Gray leaf spot Bacterial spot[3]	See label
Dithane, Manzate or Penncozeb 75 DFs (mancozeb)	M3	3 lbs.	22.4 lbs.	5		
Maneb 80 WP (maneb)	M3	3 lbs	21 lbs.	5		
Dithane F 45 or Manex II 4 FLs (mancozeb)	M3	2.4 pts.	16.8 qts.	5		
Dithane M-45, Penncozeb 80, or Manzate 80 WPs (mancozeb)	M3	3 lbs.	21 lbs.	5		
Maneb 75 DF (maneb)	M3	3 lbs.	22.4 lbs.	5		See label for details
Bonide Mancozeb FL (mancozeb)	M3	5 tsp/ gal		5	Anthracnose, Early blight, Gray leaf spot, Late blight, Leaf mold, Septoria leaf spot	See label for details.
Ziram (ziram)	M3	4 lbs	24 lbs	7	Anthracnose, Early blight, Septoria leaf spot	Do not use on cherry tomatoes. See label for details.
Equus 720, Echo 720, Chloro Gold 720 6 Fls (chlorothalonil)	M5	3 pts. or 2.88 pts.	20.1 pts.	2	Early blight, Late blight, Gray leaf spot, Target spot	Use higher rates at fruit set and lower rates before fruit set, see label
Echo 90 DF or Equus 82.5DF (chlorothalonil)	M5	2.3 lbs.		2		

Ridomil Gold Bravo 76.4 W (chlorothalonil +mefenoxam)	4 / M5	3 lbs.	12 lbs	14	Early blight, Late blight, Gray leaf spot, Target Spot	Limit is 4 appl./crop, see label
Amistar 80 DF (azoxystrobin)	11	2 ozs	12 ozs	0	Early blight, Late blight, Sclerotinia Powdery mildew, Target spot, Buckeye rot	Limit is 2 seqential appl. or 6 application total. Alternate or tank mix with a multi-site effective fungicide (FRAC code M), see label
Quadris (azoxystrobin)	11	6.2 fl.ozs.	37.2 fl.ozs.	0		
Cabrio 2.09 F (pyraclostro-bin)	11	16 fl oz	96 fl oz	0		
Flint (trifloxystro-bin)	11		16 oz	3	Early blight, Late blight, Gray leaf spot	See label for details
Evito (fluoxastrobin)	11	5.7 fl oz	22.8 fl oz	3	Early blight. Late blight, Southern blight, Target spot	Limit is 4 appl/crop
Reason 500SC (fenamidone)	11	5.5-8.2 oz	24.6 lb	14	Early blight, Late blight, Septoria leaf spot	See label for details
Ridomil Gold EC (mefenoxam)	4	2 pts. / trtd. acre	3 pts / trtd / acre	28	Pythium diseases	See label for details
Ultra Flourish (mefenoxam)	4	2 qts	3 qts		Pythium and Phytophthora rots	See label for details
Ridomil MZ 68 WP (mefenoxam + mancozeb)	4 / M3	2.5 lbs.	7.5 lbs.	5	Late blight	Limit is 3 appl./crop, see label
Ridomil Gold Copper 64.8 W (mefenoxam + copper hydroxide)	4 / M1	2 lbs.		14	Late blight	Limit is 3 appl. /crop. Tank mix with maneb or mancozeb fungicide, see label
JMS Stylet-Oil (paraffinic oil)		3 qts.			Potato Virus Y, Tobacco Etch Virus, CMV	See label for restrictions and use (e.g. use of 400 psi spray pressure)
Aliette 80 WDG (fosetyl-al)	33	5 lbs.	20 lbs.	14	Phytophthora root rot	Using potassium carbonate or Diammonium phosphate, the spray of Aliette should be raised to a pH of 6.0 or above when applied prior to or after copper fungicides, see label
Bravo Ultrex (chlorothalonil)	M5	2.6 lbs.	18.3 lbs	2	Early blight, Late blight, Gray leaf spot, Target spot, Botrytis, Rhizoctonia fruit rot, Leaf mold	Use higher rates at fruit set, see label
Bravo Weather Stik (chlorothalonil)	M5	2.75 pts.	20 pts	2		
Botran 75 W (dichloran)	14	1 lb.	4 lbs.	10	Botrytis	Greenhouse use only. Limit is 4 applications. Seedlings or newly set transplants may be injured, see label
Nova 40 W (myclobutanil)	3	4 ozs.	1.25 lbs.	0	Powdery mildew	Note that a 30 day plant back restriction exists, see label
Sulfur (many brands)	M2			1	Powdery mildew	Follow label closely, it may cause phytotoxicity.
Actigard (acibenzolar-S-methyl)	P	0.75 oz.	4 ozs.	14	Bacterial spot Bacterial speck Tomato spotted wilt – a viral disease (use in combination of UV-reflective mulch and vector thrips specific insecticides.	Do not use highest labeled rate in early sprays to avoid a delayed onset of harvest. See label for details.
ManKocide 61.1 DF (mancozeb + copper hydroxide)	M3 / M1	5 lbs.	112 lbs.	5	Bacterial spot, Bacterial speck, Late blight, Early blight, Gray leaf spot	See label
Gavel 75DF (mancozeb + zoaximide)	M3 / 22	2.0 lbs	16 lbs	5	Buckeye rot Early blight Gray leaf spot Late blight Leaf mold	See label
Previcur Flex (propamocarb hydrochloride)	28	1.5 pints (see Label)	7.5 pints	5	Late blight	Only in a tank mixture with chlorotalonil, maneb or mancozeb, see label
Curzate 60DF (cymoxanil)	27	5 oz	30 oz per 12 month	3	Late Blight	Do not use alone, see label for details
Tanos (famoxadone + cymoxanil)	11 / 27	8 oz	72 oz	3	Early blight, Late blight, Target spot, Bacterial spot (suppression)	See label for details
Acrobat 50 WP (dimethomorph)	15	6.4 oz	32 oz	4	Late blight	See label for details
Forum (dimethomorph)	15	6 oz	30 oz	4	Late blight	See label for details
K-phite (Phosphorous acid)	33	2 qts/ 100 gal.		0	*Phythophthora* sp. (root rot) *Pythium* sp. (Damping-off)	Dosage given is for drip application. See label for restrictions and details

Scala SC (pyrimethanil)	9	7 fl oz 0.27 lbs	35 fl oz 1.4 lbs	1	Early blight Botrytis	Use only in a tank mix with another effective fungicide (non FRAC code 9), see label
Endura (boscalid)	7	3.5 oz	21	0	Target spot (*Corynespora cassiicola*), Early Blight (*Alternaria solani)*	Alternate with non-FRAC code 7 fungicides, see label
Terraclor 75 WP (PCNB)	14	See Label	See Label	Soil treatment at planting	Southern blight (*Sclerotium rolfsii*)	See label for application type and restrictions
Fix (Copper +mancozeb or maneb)	M1 / M3			5	Bacterial spot Bacterial speck	Mancozeb or maneb enhances bactericidal effect of fix copper compounds. See label for details.
Kocide 101 or Champion 77 WPs (copper hydroxide)	M1	4 lbs.		2	Anthracnose Bacterial speck Bacterial Spot Early blight Grey leaf mold Grey leaf spot Late blight Septoria leaf spot	Mancozeb or maneb enhances bactericidal effect of fix copper compounds. See label for details.
Kocide 4.5 LF (copper hydroxide)	M1	2.66 pts		1		
Kocide 2000 53.8 DF (copper hydroxide)	M1	3 lbs.		1		
Champ 57.6 DP (copper hydroxide)	M1	1.3 lbs		1		
Basicop 53 WP (copper hydroxide)	M1	4 lbs.		1		
Kocide 61.4 DF(copper hydroxide)	M1	4 lbs				
Cuprofix Disperss 36.9 DF(copper hydroxide)	M1	6 lbs				
Nu Cop 50WP (copper hydroxide)	M1	4 lb				
Bonide Liquid Copper (copper salts)	M1	6 tsp/ gal		0		
Allpro Exotherm Termil (20 % chlorothalonil)	M5	1 can / 1000 sq. ft.		7	Botrytis, Leaf mold, Late blight, Early blight Gray leaf spot, Target spot	Greenhouse use only. Allow can to remain overnight and then ventilate. Do not use when greenhouse temperature is above 75 F. See label for details.
Terramaster 4EC (etridiazole)	14	7 fl oz	27.4 fl oz	3	Pythium and Phytophthora root rots	Greenhouse use only. See label for details
Ranman (cyazofamid)	21	2.1-2.75 oz	16 oz	0	Late Blight	Limit is 6 appl./crop, see label
Agri-mycin 17 (streptomycin sulfate)	25	200 ppm			Bacterial spot	See label for details
Ag Streptomycin (streptomycin sulfate)	25	200 ppm				
Topsin M WSB (thiophanate methyl)	1	1 lb.	3.5 lb.	2	White mold	Section 18 exemption through April 12, 2008
AgriPhage (bacteriophage)	Biological material				Bacterial speck Bacterial spot	See label for details
Serenade Serenade ASO Serenade Max Sonata (*Bacillus subtilis*)	Biological material	See label	See label	0	Bacterial spot	mix with copper compounds, see label

[1]FRAC code (fungicide group): Numbers (1-37) and letters (M, U, P) are used to distinguish the fungicide mode of action groups. All fungicides within the same group (with same number or letter) indicate same active ingredient or similar mode of action. This information must be considered for the fungicide resistance management decisions. M = Multi site inhibitors, fungicide resistance risk is low; U = Recent molecules with unknown mode of action; P = host plant defense inducers. Source: http://www.frac.info/ (FRAC = Fungicide Resistance Action Committee).

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

SELECTED INSECTICIDES APPROVED FOR USE ON INSECTS ATTACKING TOMATOES

Susan Webb, *UF/IFAS Entomology and Nematology Department, Gainesville, sewe@ufl.edu*

Trade Name (Common Name)	Rate (product/acre)	REI (hrs)	Days to Harvest	Insects	MOA Code[1]	Notes
Acramite-50WS (bifenazate)	0.75-1.0 lb	12	3	twospotted spider mite	2	One application per season.
Admire 2F (imidacloprid) **Admire Pro**	16-24 fl oz 7-10.5 fl oz	12	21	aphids, Colorado potato beetle, flea beetles, leafhoppers, thrips (foliar feeding thrips only), whiteflies	4A	Most effective if applied to soil at transplanting. Limited to 24 oz/acre. Admire Pro limited to 10.5 fl oz/acre.
Admire 2F (imidacloprid) **Admire Pro**	1.4 fl oz/1000 plants 0.6 fl oz/1000 plants	12	0 (soil)	aphids, whiteflies	4A	Greenhouse Use: 1 application to mature plants, see label for cautions.
Admire 2F (imidacloprid) **Admire Pro**	0.1 fl oz/1000 plants 0.44 fl oz/10,000 plants	12	21	aphids, whiteflies	4A	Planthouse: 1 application. See label.
Agree WG (*Bacillus thuringiensis* subspecies *aizawai*)	0.5-2.0 lb	4	0	lepidopteran larvae (caterpillar pests)	11B1	Apply when larvae are small for best control. Can be used in greenhouse. OMRI-listed[2].
***Agri-Mek 0.15EC** (abamectin)	8-16 fl oz	12	7	Colorado potato beetle, *Liriomyza* leafminers, spider mite, tomato pinworms, 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 cutworms, hornworms, southern armyworm, tomato fruitworm, tomato pinworm, vegetable leafminer	3	**Do not use on cherry tomatoes.** Do not apply more than 1.2 lb ai/acre per season (76.8 oz). Not recommended for control of vegetable leafminer in Florida.
***Asana XL (0.66EC)** (esfenvalerate)	2.9-9.6 fl oz	12	1	beet armyworm (aids in control), cabbage looper, Colorado potato beetle, cutworms, flea beetles, grasshoppers, hornworms, potato aphid, southern armyworm, tomato fruitworm, tomato pinworm, whiteflies, yellowstriped armyworm	3	Not recommended for control of vegetable leafminer in Florida. Do not apply more than 0.5 lb ai per acre per season, or 10 applications at highest rate.
Assail 70WP (acetamiprid) **Assail 30 SG**	0.6-1.7 oz 1.5-4.0 oz	12	7	aphids, Colorado potato beetle, thrips, whiteflies	4A	Do not apply to crop that has been already treated with imidacloprid or thiamethoxam at planting. Begin applications for whiteflies when first adults are noticed. Do not apply more than 4 times per season or apply more often than every 7 days.
Avaunt (indoxacarb)	2.5-3.5 oz	12	3	beet armyworm, hornworms, loopers, southern armyworm, tomato fruitworm, tomato pinworm, suppression of leafminers	22	Do not apply more than 14 ounces of product per acre per crop. Minimum spray interval is 5 days.
Aza-Direct (azadirachtin)	1-2 pts, up to 3.5 pts, if needed	4	0	aphids, beetles, caterpillars, leafhoppers, leafminers, mites, stink bugs, thrips, weevils, whiteflies	18B	Antifeedant, repellant, insect growth regulator. OMRI-listed[2].
Azatin XL (azadirachtin)	5-21 fl oz	4	0	aphids, beetles, caterpillars, leafhoppers, leafminers, thrips, weevils, whiteflies	18B	Antifeedant, repellant, insect growth regulator.

***Baythroid 2** (cyfluthrin) ***Baythroid XL** (beta-cyfluthrin)	1.6-2.8 fl oz	12	0	beet armyworm[1], cabbage looper, Colorado potato beetle, dipterous leafminers, European corn borer, flea beetles, hornworms, potato aphid, southern armyworm[1], stink bugs, tomato fruitworm, tomato pinworm, variegated cutworm , western flower thrips, whitefly[2]	3	[1] Ist and 2nd instars only [2] suppression Do not apply more than 0.26 lb ai per acre per season. (Baythroid 2) or 0.132 lb (Baythroid XL). Maximum number of applications: 6.
Beleaf 50 SG (flonicamid)	2.0-2.8 oz	12	0	aphids, plant bugs	9C	Do not apply more than 8.4 oz/acre per season. Begin applications before pests reach damaging levels.
Biobit HP (*Bacillus thuringiensis* subspecies *kurstaki*)	0.5-2.0 lb	4	0	caterpillars (will not control large armyworms)	11B2	Treat when larvae are young. Good coverage is essential. Can be used in the greenhouse. OMRI-listed[2].
BotaniGard 22 WP, ES (*Beauveria bassiana*)	**WP:** 0.5-2 lb/100 gal **ES:** 0.5-2 qts 100/gal	4	0	aphids, thrips, whiteflies	--	May be used in greenhouses. Contact dealer for recommendations if an adjuvant must be used. Not compatible in tank mix with fungicides.
***Capture 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, whiteflies	3	Make no more than 4 applications per season. Do not make applications less than 10 days apart.
CheckMate TPW, TPW-F (pheromone)	**TPW:** 200 dispenser **TPW-F:** 1.2-6.0 fl oz	0	0	tomato pinworm	--	For mating disruption - See label. TPW formulation. OMRI-listed[2].
Confirm 2F (tebufenozide)	6-16 fl oz	4	7	armyworms, black cutworm, hornworms, loopers	18A	Product is a slow-acting IGR that will not kill larvae immediately. Do not apply more than 1.0 lb ai per acre per season.
Courier 40SC (buprofezin)	9-13.6 fl oz	12	1	whitefly nymphs	16	See label for plantback restrictions. 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. No more than 2 applications per season. Allow at least 28 days between applications.
Crymax WDG (*Bacillus thuringiensis* subspecies *kurstaki*)	0.5-2.0 lb	4	0	caterpillars	11B2	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 mites, yellowstriped armyworm	3	Use alone for control of fruitworms, stink bugs, tobacco hornworm, twospotted spider mites, and yellowstriped armyworms. Tank-mix with Monitor 4 for all others, especially whitefly. Do not apply more than 0.8 lb ai per acre per season. Do not tank mix with copper.
Deliver (*Bacillus thuringiensis* subspecies *kurstaki*)	0.25-1.5 lb	4	0	caterpillars	11B2	Use higher rates for armyworms. OMRI-listed[2].
***Diazinon AG500; 4E; *50 W** (diazinon)	**AG500, 4E:** 0.5-1.5 pts **50W:** 0.5-1.5 lb	24	1	aphids, beet armyworm, banded cucumber beetle, *Drosophila*, fall armyworm, dipterous leafminers, southern armyworm	1B	Will not control organophosphate-resistant leafminers. Do not apply more than five times per season.
	AG500, 4E: 1-4 qts **50W:** 2-8 lb	24	preplant	cutworms, mole crickets, wireworms		
Dimethoate 4 EC, 2.67 EC (dimethoate)	**4EC:** 0.5-1.0 pt **2.67:** 0.75-1.5 pt	48	7	aphids, leafhoppers, leafminers	1B	Will not control organophosphate-resistant leafminers.
DiPel DF (*Bacillus thuringiensis* supspecies *kurstaki*)	0.5-2.0 lb	4	0	caterpillars	11B2	Treat when larvae are young. Good coverage is essential. OMRI-listed[2].
Endosulfan 3EC (endosulfan)	0.66-1.33 qt	24	2	aphids, blister beetle, cabbage looper, Colorado potato beetle, flea beetles, hornworms, stink bugs, tomato fruitworm, tomato russet mite, whiteflies, yellowstriped armyworm	2	Do not exceed a maximum of 3.0 lb active ingredient per acre per year or apply more than 6 times. Can be used in greenhouse.

Entrust (spinosad)	0.5-2.5 oz	4	1	armyworms, Colorado potato beetle, flower thrips, hornworms, *Liriomyza* leafminers, loopers, other caterpillars, tomato fruitworm, tomato pinworm	5	Do not apply more than 9 oz per acre per crop. OMRI-listed[2].
Esteem Ant Bait (pyriproxyfen)	1.5-2.0 lb	12	1	red imported fire ant	7C	Apply when ants are actively foraging.
Extinguish ((S)-methoprene)	1.0-1.5 lb	4	0	fire ants	7A	Slow-acting IGR (insect growth regulator). Best applied early spring and fall where crop will be grown. Colonies will be reduced after three weeks and eliminated after 8 to 10 weeks. May be applied by ground equipment or aerially.
Fulfill (pymetrozine)	2.75 oz	12	0 - if 2	green peach aphid, potato aphid, suppression of whiteflies	9B	Do not make more than four applications. (FL-040006) 24(c) label for growing transplants also (FL-03004).
Intrepid 2F (methoxyfenozide)	4-16 fl oz	4	1	beet armyworm, cabbage looper, fall armyworm, hornworms, southern armyworm, tomato fruitworm, true armyworm, yellowstriped armyworm	18A	Do not apply more than 64 fl oz 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)	11B2	Treat when larvae are young. Thorough coverage is essential. OMRI-listed[2].
Kelthane MF 4 (dicofol)	0.75-1.5 pt	12	2	tomato russet mites, twospotted and other spider mites	20	Do not apply more than twice a season or more than 1.6 pts per year.
Knack IGR (pyriproxyfen)	8-10 fl oz	12	14 7 - SLN No FL-200002 or FL-000002	immature whiteflies	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
Kryocide (cryolite)	8-16 lb	12	14	armyworm, blister beetle, cabbage looper, Colorado potato beetle larvae, flea beetles, hornworms, tomato fruitworm, tomato pinworm	9A	Minimum of 7 days between applications. Do not apply more than 64 lbs per acre per season.
***Lannate LV, *SP** (methomyl)	**LV:** 0.75-3.0 pt **SP:** 0.25-1.0 lb	48	1	aphids, armyworms, 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).
Lepinox WDG (*Bacillus thuringiensis* subspecies *kurstaki*)	1.0-2.0 lb	12	0	for most caterpillars, including beet armyworm (see label)	11B2	Treat when larvae are small. Thorough coverage is essential.
Malathion 8 F (malathion)	1.5-2 pt	12	1	aphids, *Drosophila*, mites	1B	Can be used in greenhouse.
***Monitor 4EC** (methamidophos) [24(c) labels] FL-800046 FL-900003	1.5-2 pts	96	7	aphids, fruitworms, leafminers, tomato pinworm[(1)], whiteflies[(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.
M-Pede 49% EC (Soap, insecticidal)	1-2% V/V	12	0	aphids, leafhoppers, mites, plant bugs, thrips, whiteflies	--	OMRI-listed[2].
***Mustang Max** (zeta-cypermethrin)	2.24-4.0 oz	12	1	beet armyworm, cabbage looper, Colorado potato beetle, cutworms, fall armyworm, flea beetles, grasshoppers, green and brown stink bugs, hornworms, leafminers, leafhoppers, *Lygus* bugs, plant bugs, southern armyworm, tobacco budworm, tomato fruitworm, tomato pinworm, true armyworm, yellowstriped armyworm. Aids in control of aphids, thrips and whiteflies.	3	Not recommended for vegetable leafminer in Florida. Do not make applications less than 7 days apart. Do not apply more than 0.15 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, whiteflies	18B	IGR, feeding repellant. OMRI-listed[2].
NoMate MEC TPW (pheromone)		0	0	tomato pinworm	--	For mating disruption - See label.

Oberon 2SC (spiromesifen)	7.0-8.5 fl oz	12	7	broad mite, twospotted spider mite, whiteflies (eggs and nymphs)	23	Maximum amount per crop: 25.5 fl oz/ acre. No more than 3 applications.
Platinum (thiamethoxam)	5-8 fl oz	12	30	aphids, Colorado potato beetles, flea beetles, whiteflies	4A	Soil application. See label for rotational restrictions.
***Pounce 25 W** (permethrin)	3.2-12.8 oz	12	0	beet armyworm, cabbage looper, Colorado potato beetle, dipterous leafminers, granulate cutworm, hornworms, southern armyworm, tomato fruitworm, tomato pinworm	3	Do not apply to cherry or grape tomatoes (fruit less than 1 inch in diameter). Do not apply more than 1.2 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), whiteflies[1], yellowstriped armyworm[2]	3	[1] Suppression only. [2] First and second instars only. Do not apply more than 2.88 pints per acre per season.
***Proclaim** (emamectin benzoate)	2.4-4.8 oz	48	7	beet armyworm, cabbage looper, fall armyworm, hornworms, southern armyworm, tobacco budworm, tomato fruitworm, tomato pinworm, yellowstriped armyworm	6	No more than 28.8 oz/acre per season.
Prokil Cryolite 96 (cryolite)	10-16 lb	12	14	blister beetle, cabbage looper, Colorado potato beetle larvae, flea beetles, hornworms	9A	Minimum of 7 days between applications. Do not apply more than 64 lbs per acre per season. Not for cherry tomatoes.
Provado 1.6F (imidacloprid)	3.8 oz	12	0	aphids, Colorado potato beetle, leafhoppers, whiteflies	4A	Do not apply to crop that has been already treated with imidacloprid or thiamethoxam at planting. Maximum per crop per season 19 fl oz per acre.
Pyrellin EC (pyrethrin + rotenone)	1-2 pt	12	12 hours	aphids, Colorado potato beetle, cucumber beetles, flea beetles, flea hoppers, leafhoppers, leafminers, loopers, mites, plant bugs, stink bugs, thrips, vegetable weevil, whiteflies	3, 21	
Sevin 80S; XLR; 4F (carbaryl)	**80S:** 0.63-2.5 **XLR; 4F:** 0.5-2.0 A	12	3	Colorado potato beetle, cutworms, fall armyworm, flea beetles, lace bugs, leafhoppers, plant bugs, stink bugs[1], thrips[1], tomato fruitworm, tomato hornworm, tomato pinworm, sowbugs	1A	[1] suppression Do not apply more than seven times. Do not apply a total of more than 10 lb or 8 qt per acre per crop.
SpinTor 2SC (spinosad)	1.5-8.0 fl oz	4	1	armyworms, Colorado potato beetle, flower thrips, hornworms, *Liriomyza* leafminers, loopers, *Thrips palmi*, tomato fruitworm, tomato pinworm	5	Do not apply to seedlings grown for transplant within a greenhouse or shadehouse. Leafminer and thrips control may be improved by adding an adjuvant. Do not apply more than three times in any 21 day period. Do not apply more than 29 oz per acre per crop.
Sulfur (many brands)	See label	24	see label	tomato russet mite	--	
***Telone C-35** (dichloropropene + chloropicrin)	See label	5 days (See label)	preplant	garden centipedes (symphylans), wireworms	--	See supplemental label for restrictions in certain Florida counties.
***Telone II** (dichloropropene)						
Trigard (cyromazine)	2.66 oz	12	0	Colorado potato beetle (suppression of), leafminers	17	No more than 6 applications per crop. Does not control CPB adults. Most effective against 1st & 2nd instar larvae.
Trilogy (extract of neem oil)	0.5-2.0% V/V	4	0	aphids, mites, suppression of thrips and whiteflies	18B	Apply morning or evening to reduce potential for leaf burn. Toxic to bees exposed to direct treatment. OMRI-listed[2].
Ultra Fine Oil, JMS Stylet-Oil, and others (oil, insecticidal)	3-6 qts/100 gal (JMS)	4	0	aphids, beetle larvae, leafhoppers, leafminers, mites, thrips, whiteflies, aphid-transmitted viruses (JMS)	--	Do not exceed four applications per season. Organic Stylet-Oil is OMRI-listed[2].

Venom Insecticide (dinotefuran)	**foliar:** 1-4 oz **soil:** 5-6 oz	12	**foliar:** 1 **soil:** 21	Colorado potato beetle, flea beetles, leafhoppers, leafminers, thrips, whiteflies	4A	Use only one application method (soil or foliar). Limited to three applications per season. **Do not use on grape or cherry tomatoes.**
***Vydate L** (oxamyl)	**foliar:** 2-4 pt	48	3	aphids, Colorado potato beetle, leafminers (except *Liriomyza trifolii*), whiteflies (suppression only)	1A	Do not apply more than 32 pts per acre per season.
***Warrior** (lambda-cyhalothrin)	1.92-3.84 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, whiteflies(1), yellowstriped armyworm(2)	3	(1) suppression only (2) for control of 1st and 2nd instars only. Do not apply more than 0.36 lb ai per acre per season. (3)Does not control western flower thrips.
Xentari DF (*Bacillus thuringiensis* subspecies *aizawai*)	0.5-2 lb	4	0	caterpillars	11B1	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.5.2 September, 2006.

1A. Acetylcholine esterase inhibitors, Carbamates
1B. Acetylcholine esterase inhibitors, Organophosphates
2A. GABA-gated chloride channel antagonists
3. Sodium channel modulators
4A. Nicotinic Acetylcholine receptor agonists/antagonists, Neonicotinoids
5. Nicotinic Acetylcholine receptor agonists (not group 4)
6. Chloride channel activators
7A. Juvenile hormone mimics, Juvenile hormone analogues
7C. Juvenile hormone mimics, Pyriproxifen
9A. Compounds of unknown or non-selective mode of action (selective feeding blockers), Cryolite
9B. Compounds of unknown or non-selective mode of action (selective feeding blockers), Pymetrozine
9C. Compounds of unknown or non-selective mode of action (flonicamid)
11B1. Microbial disruptors of insect midgut membranes, *B.t.* var *aizawai*
11B2. Microbial disruptors of insect midgut membranes, *B.t.* var *kurstaki*
12B. Inhibitors of oxidative phosphorylation, disruptors of ATP formation, Organotin miticide
15. Inhibitors of chitin biosynthesis, type 0, Lepidopteran
16. Inhibitors of chitin biosynthesis, type 1, Homopteran
17. Molting disrupter, Dipteran
18A. Ecdysone agonist/disruptor (methoxyfenozide, tebufenozide)
18B. Ecdysone agonist/disruptor (azadirachtin)
20. Site II electron transport inhibitors
21. Site I electron transport inhibitors
22. Voltage-dependent sodium channel blocker
23. Inhibitors of lipid biosynthesis
25. Neuronal inhibitors

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

*** Restricted Use Only**

NEMATICIDES REGISTERED FOR USE ON FLORIDA TOMATO

Joseph W. Noling

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

	Row Application (6' row spacing - 36" bed)[4]				
Product	Broadcast (Rate)	Recommended ChiselSpacing	Chisels (per Row)	Rate/Acre	Rate/1000 Ft/Chisel
FUMIGANT NEMATICIDES					
Methyl Bromide[3] 67-33	225-375 lb	12"	3	112-187 lb	5.1-8.6 lb
Methyl Bromide 50-50	300-480 lb	12"	3	150-240 lb	6.8-11.0 lb
Chloropicrin[1]	300-500 lb	12"	3	150-250 lb	6.9-11.5 lb
Telone II[2]	9-12 gal	12"	3	4.5-9.0 gal	26-53 fl oz
Telone C-17	10.8-17.1 gal	12"	3	5.4-8.5 gal	31.8-50.2 fl oz
Telone C-35	13-20.5 gal	12"	3	6.5-13 gal	22-45.4 fl oz
Metham Sodium	50-75 gal	5"	6	25-37.5 gal	56-111 fl oz

NON-FUMIGANT NEMATICIDES

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

1. If treated area is tarped, dosage may be reduced by 33%.
2. The manufacturer of Telone II, Telone C-17, and Telone C-35 has restricted use only on soils that have a relatively shallow hard pan or soil layer restrictive to downward water movement (such as a spodic horizon) within six feet of the ground surface and are capable of supporting seepage irrigation regardless of irrigation method employed. Crop use of Telone products do not apply to the Homestead, Dade county production regions of south Florida. Higher label application rates are possible for fields with cyst-forming nematodes. Consult manufacturers label for personal protective equipment and other use restrictions which might apply.
3. As a grandfather clause, it is still possible to continue to use methyl bromide on any previous labeled crop as long as the methyl bromide used comes from existing supplies produced prior to January 1, 2005. A critical use exemption (CUE) for continuing use of methyl bromide for tomato, pepper, eggplant and strawberry has been awarded for calendar years 2005 through 2008. Specific, certified uses and labeling requirements for CUE acquired methyl bromide must be satisfied prior to grower purchase and use in these crops. Product formulations are subject to change and availability.
4. Rate/acre estimated for row treatments to help determine the approximate amounts of chemical needed per acre of field. If rows are closer, more chemical will be needed per acre; if wider, less. Reduced rates are possible with use of gas impermeable mulches.

Rates are believed to be correct for products listed when applied to mineral soils. Higher rates may be required for muck (organic) soils. Growers have the final responsibility to guarantee that each product is used in a manner consistent with the label. This information was compiled by the author as of June 25, 2007 as a reference for the commercial Florida tomato grower. The mention of a chemical or proprietary product in this publication does not constitute a written recommendation or an endorsement for its use by the University of Florida, Institute of Food and Agricultural Sciences, and does not imply its approval to the exclusion of other products that may be suitable. Products mentioned in this publication are subject to changing Environmental Protection Agency (EPA) rules, regulations, and restrictions. Additional products may become available or approved for use.

NOTES

NOTES

NOTES

NOTES