2004 FLORIDA TOMATO INSTITUTE

Ritz Carton • Naples, Florida • September 8, 2004 **PRO 521**

Morning Moderator: *Ed Skvarch, St. Lucie County Extension Service, Ft. Pierce*

9:00 **Welcome and Opening Remarks** - Jack Rechcigl, Director, GCREC, Bradenton

9:10 **The "State of the Florida Tomato" Address** - Reggie Brown, Florida Tomato Committee, Orlando

9:20 **Outlook for Florida Tomatoes Under FTAA and Future Marketing Issues** - John VanSickle, UF , Food & Resource Economics Department, Gainesville, **pg. 2**

9:40 **Methyl Bromide CUE : What Did We Get and What's Next?** - Mike Aerts , FFVA, Orlando

10:00 **Results of Preliminary Fertilization Rate Trials in SW Florida** - Gene McAvoy, UF, Hendry County Extension Service, LaBelle

10:20 **Drip Irrigation Management for Tomatoes** - Eric Simonne, UF, Horticultural Sciences Department, Gainesville, **pg. 6**

10:35 **Tomato Soilborne Diseases and Florida Plant Diagnostic Network (FPDN)** - Tim Momol, UF, NFREC, Quincy, **pg. 12**

10:55 **TYLCV Resistant Varieties Available Now and Future Outlook from the IFAS Breeding Program** - Jay Scott, UF, GCREC, Bradenton, **pg. 15**

1:15 **SWF Resistance Management Update,** Dave Schuster, UF, GCREC, Bradenton, **pg. 19**

11:35 **Lunch and Visit Sponsor Information Tables**

Afternoon Moderator: *Darrin Parmenter, Palm Beach County Extension Service, West Palm Beach*

1:00 **Status of Vegetable and Agronomic Crop Best Management Practices Manual** - Rich Budell, FDACS, Tallahassee, **pg. 5**

1:20 **Use of "Soft" Pesticides in a Pest Management Program for Tomatoes and Peppers** - Phil Stansly, UF, SWFREC, Immokalee, **pg. 26**

1:40 **Emerging Viral Diseases of Tomato -** Jane Polston, UF, Plant Pathology Department, Gainesville, **pg. 43**

2:00 **New Product Updates** - Industry representatives

3:00 **Adjourn**

Control Guides

Four (4) CEUs for pesticide applicators have been approved. CCA CEUs have been applied for.

Outlook for Florida Tomatoes Under FTAA and Future Marketing Issues

John J. VanSickle
UF/IFAS, International Agricultural Trade & Policy Center, Gainesville

The U.S. tomato industry is one of the largest global suppliers of tomatoes in the world. U.S. producers grew 12.275 million metric tons of all types of tomatoes in calendar year 2003 on 166,100 hectares (410,433 acres) with a yield of 592,309 hectograms per hectare (2,113 cartons/acre). The U.S. is the second leading producer of tomatoes, trailing only China who produced 27.151 million metric tons on 1,205,153 hectares (2.97 million acres) with a yield of 239,398 hectograms per hectare (843 cartons/acre). Global production of tomatoes increased 45 percent from 1993 to 2003 **(Table 1)** as consumers increased demand for produce in general, and tomatoes specifically, in response to diet and health concerns and the evolution of more efficient production and marketing practices that are giving consumers greater access to higher quality produce year-round.

Competition in the U.S. market has been strong with domestic and foreign suppliers competing to serve this important market. Consumption of fresh tomatoes reached 2.46 million metric tons in 2003. Imports accounted for 939,257 metric tons of this consumption with U.S. producers exporting only 142,461 metric tons of fresh tomatoes. Mexico supplies 80 percent of these imports with Canada supplying almost 14 percent. U.S. exports go mainly to Canada (78 percent) and Mexico (13.6 percent).

The U.S. has been a leader in opening markets to international trade. The North American Free Trade Agreement (NAFTA) created a free trade zone between the U.S., Canada and Mexico. NAFTA has seen the phasing out of tariffs on trade between these countries and trade has increased as a result. Since NAFTA was implemented, several new free trade agreements (FTAs) have been negotiated with the Bush Administration finalizing agreements with 12 countries: Chile, Jordan, Singapore, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Australia, Morocco, the Dominican Republic and Bahrain. The Bush Administration is currently negotiating with 10 other countries to develop FTAs: Panama, Colombia, Ecuador, Peru, Thailand, and with five nations of the Southern African Customs Union (SACU) – Botswana, South Africa, Lesotho, Swaziland and Namibia. The U.S. is also aggressively pressing for global free markets through the World Trade Organization and for hemispheric openness through the Free Trade Area of the Americas.

The agricultural negotiations in these agreements focus on the three pillars of opening markets: 1) eliminating export subsidies; 2) phasing out tariffs and; 3) cutting domestic support. Agriculture has been a focus in all of the previous agreements negotiated. The growth in domestic support to agriculture in the U.S. as a result of the 2002 Farm Bill has caused several nations to call on greater discipline in providing support to agriculture in future free trade zones. Developing countries object to domestic support programs like those in the U.S. because they believe it leads to unfair competitive advantage in global markets. They organized their objections to domestic support during the Cancun Ministerial for the WTO, causing U.S. Trade Representative Robert Zoellick to declare "the breakdown in Cancun was not a success, but rather a missed opportunity."[1] The Miami Ministerial for the Free Trade Area of the Americas also saw repeated calls for more discipline on domestic support.

The fresh produce industry receives very little domestic support for its programs. The largest threat to the produce industry and the fresh tomato industry comes from elimination of tariffs and the increase in Foreign Direct Investment that will increase productivity in competing countries relative to U.S. producers. **Table 2** shows the tariff structure on imports of fresh tomatoes in the U.S. and the import values for the tomatoes imported during the 4 different tariff periods. The largest tariffs are collected during the late spring/early summer period (March 1 to July 14) and in the late fall market period (September 1 to November 14). Tariff rates during these periods are 3.9 cents/kg and the volume of trade during these periods in 2003 totaled $561 million with $536 million of this entering duty free from Canada and Mexico. The tariff rates for the other periods (July 15 to August 31 and November 15 to February end) equal 2.8 cents/kg. Trade during these periods in 2003 was $107.2 million and $46.8 million, respectively. Again, Canada and Mexico accounted for most of this trade during these periods in 2003, with $99.7 million in the July 15 to November 15 period and $24.3 million in the November 15 to February end period. Total tariffs collected on all imports declined from $19.1 million in 1993 to $3.5 million in 2003 as all tariffs on imports from Canada and Mexico were eliminated in the NAFTA.

As we look to future agreements, the WTO and FTAA are the two agreements under negotiation that are likely to have the largest impacts on U.S. producers of fresh tomatoes. VanSickle[2] estimated the probable economic effects of the reduction or elimination of U.S. tariffs on selected fresh vegetables and concluded that elimination of tariffs will have a small impact because the larger countries exporting to the U.S. already enjoy duty free entry. The larger impacts are more likely to be felt from increases in Foreign Direct Investment that could increase the productivity of tomato producing countries and make them more competitive in U.S. markets.

Table 3 details the area harvested, yield and total production in different regions of the world. Asia is the leading producing region in the world, producing more than half the global production of tomatoes at 58 million metric tons. Western Europe follows with 15.1 million metric tons followed by North American producers at 11 million metric tons. There are a couple of points that stand out in **Table 3**. First, the U.S. is able to compete in global markets because of its higher productivity with yields of 635,031 hectograms per hectare (2,266 cartons/acre). These yields are second only to Israel where almost all production comes from greenhouses. Western Europe is also increasing its production of fresh tomatoes because of the rising productivity they have experienced over the years, realizing 580,212 Hg/Ha (2,070 cartons/acre) yields in 2003. The region that appears to pose the largest threat to U.S. producers is Asia. The large area planted to tomatoes in Asia, at 2.5 million hectares, is nearly 60 percent of the global area devoted to tomato production. Yields in Asia are low however, at 231,318 Hg/Ha (825 cartons/acre), or just slightly more than a third the yields realized by U.S. producers. Investments in Asian markets that increase their producers' productivity could have large impacts on U.S. and other global producers. Another potential threat to U.S. producers is South America where producers in that region are in the upper half of all producers in productivity, with yields in 2003 averaging 440,344 Hg/Ha (1,571 cartons/acre). In South America, the larger threat to U.S. producers comes by way of what the FTAA might do to increase productivity and increase trade in tomatoes in U.S. markets from their suppliers.

Table 4 shows the area harvested, yields and total production in 2003 for countries in South America, the countries most likely to benefit from provisions of the FTAA. Most other countries of Central America and the Caribbean already benefit from duty free entry from previous agreements, so it is useful to examine South

American countries for the potential to increase their presence in U.S. markets from implementation of a FTAA. Under current conditions, there are two countries in South America that appear poised to take advantage of any benefits provided by an FTAA or WTO. Brazil and Chile already experience higher yields that could compete with other North American producers. While land may be a constraint in Chile, Brazil has demonstrated an ability to expand production on a number of commodities that were once the domain of U.S. producers (e.g., citrus and soybeans). Technologies that improve qualities and shelf life of tomatoes in Chile and Brazil could lead to greater competition in U.S. markets. Lower tariffs are not likely to drive the innovations that will be necessary to increase their competitiveness in U.S. markets, but increases in Foreign Direct Investment could be the driving force to this increased productivity.

Conclusions

U.S. negotiators are determined to open international markets to American products. They also recognize the benefits to our trading partners in globalizing markets. An op-ed piece published by USTR Zoellick following his development of an FTA with Morocco seems to capture the belief of our current leaders.

> "America's strategic interest in the outcome of this struggle (in the Arab world) is immense, but our ability to influence it is limited. From the Middle East to Southeast Asia, only fellow Muslims can lead their brothers and sisters to a better Islamic future. But the United States is not without influence. Through free-trade agreements, for example, we can embrace reforming states, encouraging their transformation and bolstering their chances for success even as we open new markets for American goods and services."[3]

The recent agreement by European negotiators to eliminate export subsidies in the next WTO signifies a major development in negotiations. While there is not likely to be an agreement prior to the November elections in either the WTO or FTAA negotiations, we are likely to see progress. There is little doubt that trade will be an issue in the campaign, and in the next term of the President, regardless of who wins the election.

[1]Robert Zoellick. "Remarks of U.S. Trade Representative Robert Zoellick At the Opening of the G-90 Trade Ministers Meeting Mauritius. July 12, 2004. http://www.ustr.gov/releases/2004/07/2004-07-12-transcript-mauritius.pdf

[2]John VanSickle. "Probable Economic Effects of the Reduction or Elimination of U.S. Tariffs on Selected U.S. Fresh Vegetables." IATPC PBTC 02-2. May 2002. http://www.fred.ifas.ufl.edu/iatpc/archive/PBTC_02-02.pdf

[3]Robert Zoellick. "When Trade Leads to Tolerance." The New York Times. June 12, 2004. http://www.ustr.gov/speech-test/zoellick/2004-06-12.htm.

Table 1. Area harvested, yield and total production of tomatoes in the world, 1993 to 2003.

Year	Area Harvested (1,000 Ha.)	Yield (Hg/Ha)	Production (1,000 MT)
1993	3,003.9	260,299	78,192.1
1994	3,134.2	266,026	83,380.1
1995	3,267.2	268,136	87,606.6
1996	3,397.9	275,938	93,761.7
1997	3,401.5	264,972	90,132.6
1998	3,639.6	262,805	95,650.5
1999	3,927.6	276,759	108,701.4
2000	3,981.7	272,670	108,569.1
2001	3,993.3	265,867	106,170.8
2002	4,122.2	274,110	112,995.1
2003	4,310.6	262,855	113,308.2

Source: FAOSTAT data, 2004. http://apps.fao.org/faostat/ **last updated February 2004.**

Table 2. U.S. tariff schedules and import values for fresh tomatoes in 2003.

Tariff Period	Tariff Rate (cents/kg)	2003 Import Value ($1,000)
11/15 – 2/end	2.8	$561,417
3/1 – 7/15 9/1 – 11/14	3.9	$46,881
7/15 – 8/31	2.8	$107,273

Source: USITC data, 2004. http://dataweb.usitc.gov/ **last updated February 2004.**

Table 3. Regional area, yield and production of tomatoes, 2003.

Region	Area Harvested (1,000 Ha.)	Yield (Hg/Ha)	Production (1,000 MT)
North America	174.7	635,031	11,094.0
Central America	81.8	303,811	2,486.6
Caribbean	56.1	149,938	842.2
South America	150.6	440,344	6,634.4
Eastern Europe	148.1	157,878	2,339.2
Western Europe	261.1	580,212	15,151.4
Israel	3.0	1,200,000	360.0
Asia	2,509.1	231,318	58,041.6

Source: FAOSTAT data, 2004. http://apps.fao.org/faostat/ **last updated February 2004.**

Table 4. Area, yield and production of tomatoes in selected countries of South America, 2003.

Country	Area Harvested (1,000 Ha.)	Yield (Hg/Ha)	Production (1,000 MT)
Argentina	17.5	382,857	670.0
Bolivia	10.1	133,130	135.1
Brazil	61.4	592,309	3,641.4
Chile	20.0	650,000	1,300.0
Colombia	16.8	235,119	395.0
Ecuador	6.4	112,767	72.8
French Guiana	0.1	290,000	3.7
Guyana	0.5	54,000	2.7
Paraguay	1.7	341,176	58.0
Peru	6.0	250,000	150.0
Suriname	0.1	136,250	1.0
Uruguay	2.0	180,000	36.0
Venezuela	7.8	214,274	168.4

Source: FAOSTAT data, 2004. http://apps.fao.org/faostat/ **last updated February 2004.**

Status of Vegetable and Agronomic Crop Best Management Practices Manual

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Introduction

The row crop agricultural sector comprises approximately 15% of the agricultural acreage and 35% of the farm gate sales in Florida, and includes many of the more intensive agricultural operations statewide. Given the conventional cultural practices (i.e., double cropping, plasticulture, higher vegetable synthetic fertilizer inputs), the row crop industry, which includes vegetable and field crops, is under increasing scrutiny to control nonpoint source discharges. Efforts are now underway statewide to promulgate Total Maximum Daily Loads (TMDL), as authorized under the federal Clean Water Act and the state's Florida Watershed Restoration Act. TMDLs are by definition the maximum amount of a given pollutant that a water body can absorb or assimilate and still maintain its designated use.

Best Management Practices or BMPs are generally defined to mean practices based on research, field-testing and expert review to be the most effective and practicable means to improve water quality in agricultural discharges. Under state law, the Florida Department of Agriculture and Consumer Services (FDACS), is the lead agency charged with the development of BMPs for nonpoint source agriculture. Working with other state and federal partners, the FDACS has developed a draft manual for this industry and is ready to workshop the manual during the fall of 2004 to get needed grower feedback to facilitate the implementation of BMPs.

Materials and Methods

In order to formulate the BMP manual, a number of reference manuals were consulted, as well as other generally recognized technical guidance documents. These documents consisted of USDA-Natural Resources Conservation Service, Field Office Technical Guide (standards), Conservation Technology Information Center's "Core 4" Program, other states' BMP manuals, and state water management district agricultural exemption criteria. Following three years of Steering Committee and Work Group meetings, the manual is comprised of approximately 150 pages and is organized as follows:

- **Introduction**
- **BMP Evaluation and Implementation**
- **Pesticide Management**
- **Conservation Practices and Buffers**
- **Erosion Control and Sediment Management**
- **Nutrient and Irrigation Management**
- **Water Resources Management**
- **Seasonal or Temporary Farming Operations**
- **Appendix**

Results and Discussion

The general text for this BMP manual is now in final draft format, and efforts are currently underway that focus on developing the implementation mechanics for this manual. Conceptually speaking, implementation is proposed using a progressive process that employs three distinct yet harmonious approaches. The first approach requires that row crop growers implement a universal set of BMPs that are germane to most operations. This then establishes a baseline set of BMPs. The second approach utilizes a decision-tree flowchart to ascribe BMP performance standards with decision-tree endpoints. Growers farming in the North Florida region, South Dade, the Everglades Agricultural Area, using plasticulture, within springs recharge basins, and/or qualify as seasonal or temporary farmers are captured using the flowchart. The last approach incorporates the use of a risk assessment tool for vegetable growers that double crop and do not strictly use published fertilizer rate recommendations. This tool – which is presented in the form of a checklist – will provide additional assurances to protect the water resources. Ultimately, BMP implementation and positive water quality effects for the row crop industry will rest with the successful adoption of practices, widespread implementation in TMDL impaired watersheds, cost-share assistance, and re-infusion of current scientific research into BMP manuals over time.

Following the grower workshops, the BMP manual is scheduled to be adopted by reference under Florida Administrative Code, and the rule will include a reference to a Notice of Intent to Implement form which will enable growers to enroll in a voluntary BMP program to gain presumption of compliance with state water quality standards.

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Conservation Technology Information Center. 1999. Core 4 Program.

United States Department of Agriculture-Natural Resources Conservation Service. 2000. Field Office Technical Guide.

Drip Irrigation Management for Tomato

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Seepage and drip irrigation are the two main irrigation systems used in tomato production in Florida. Seepage irrigation consists of managing a shallow water table perched on an impermeable layer. In this system, water moves through the field horizontally by gravity and vertically upward by capillarity. With drip irrigation, the water is delivered to each plant through tubes and emitters and moves by gravity downward until it reaches an impermeable layer. The main advantages of drip irrigation are high uniformity of water application (90% and above), reduced irrigation water needs, full automation, and possibility to inject fertilizer (fertigation). Hence, educational efforts have aimed, where technically possible and economically feasible, to replace seepage irrigation by drip irrigation. However, drip irrigation is more expensive to install, requires a higher level of maintenance, and only wets a small portion of the field. Hence, the full benefits of drip irrigation require (1) proper design, (2) regular maintenance, and (3) adequate irrigation management (or scheduling).

Scheduling irrigation for tomato consists of knowing when and how much water to apply in a way that satisfies crop water needs, maintains soil water tension between field capacity and 15 cb at the 12-inch depth, and prevents nutrient leaching. Because of the low water holding capacity of sandy soils (approximately 10%, v:v), proper irrigation management requires (1) an estimate of tomato water use, (2) a tool to monitor soil moisture status, (3) a guideline for splitting irrigation, and (4) a method to account for rain contribution to soil moisture (Simonne et al., 2003a). The objective of this article is to present guidelines for splitting irrigation for drip irrigated tomato.

A direct knowledge of how much water can be stored in the root zone can be gained by visualizing water movement in the soil using soluble dye (Clark and Smajstrla, 1993; German-Heins and Flury, 2000). Precise knowledge of where irrigation water goes has direct implications not only on irrigation management, but also on fumigant application (Hochmuth *et al*., 2002; Santos *et al*., 2003) and fertilizer leaching (Simonne *et al*., 2002). A blue dye and controlled irrigation conditions were used to visualize the wetting pattern of drip irrigation using different drip tapes on different soil types used for tomato production in Florida. The main objectives of this project were to (1) describe the shape of the wetting zone for several water volumes applied by drip irrigation, (2) determine if pulsing increases the size of the wetted zone and (3) determine if soluble fertilizer and the water front represented by the dye move together in the soil.

Effect of Irrigation Length on the Size of the Wetted Zone

Method: Several dye tests were conducted in several tomato producing areas of Florida in Gadsden (on an Orangeburg fine sandy loam), Suwannee (on a Lakeland fine sand), St. Lucie (on an Ankona fine sand), Hendry (on a Boca fine sand) and Miami-Dade (on a Krome very gravelly loam) counties. Before the day of the test, the fields were rototilled, raised beds were formed, and drip tape and polyethylene mulch were laid. Dye tests consisted of injecting a soluble blue dye (Terramark SPI High Concentrate, ProSource One, Memphis, TN), irrigating according to treatments, digging longitudinal and transverse sections of the raised beds, and taking measurements. Treatments were drip tape type **(Table 1)** and length of irrigation (1 to 8 hours). Drip irrigation systems consisted of a well, a pump, a back-flow prevention device, a fertilizer injector (model DI16-11, Dosatron, Clearwater, FL), a 150-mesh screen filter, a 70-kPa pressure regulator, and drip tape. After pressurizing the irrigation system, the dye was injected at the 1:49 (v:v) dye: water dilution rate for approximately 30 min. After dye injection, clear water was injected according to treatments.

For each test, a 6-foot-long longitudinal and two transverse sections were dug immediately after completion of each irrigation treatment. Based on emitter spacings, measurements encompassed approximately 6 to 20, and 2 emitters, on the longitudinal and transverse sections, respectively. Vertical depth (D), width (W) and length (L, emitter-to-emitter coverage) of the wetted zone under each emitter were measured as the longest vertical distance from the drip tape to the bottom of the blue ring, the horizontal length perpendicular to the bed axis at the widest point of the wetted zone, and the horizontal length parallel to the bed axis at the widest point of the wetted zone, respectively. Responses of D, W and L to V to irrigation rates were analyzed using regression analysis.

Results: Because dye was injected first followed by clear water, dye patterns appeared as blue rings surrounding uncolored soil. Dye adsorption by soil particles was minimal, and dye position was a good representation of water movement at time of digging. As expected, the absence (or presence) of an impermeable layer in the soil profile affected dye pattern and water movement. For tests performed on the deep sandy soils of Suwannee County, increasing irrigation volume linearly increased the depth of the water front **(Fig. 1)**. The average rate of movement was 0.1 inch/gal/100ft. In other words, the operation of a drip tape with a 24 gal/hr/100ft flow rate resulted in a vertical movement of the water front of 2.4 inches. The presence of a marl layer in Hendry and St. Lucie counties or an impermeable layer in Gadsden county resulted in water redistribution for irrigation times greater than 6 to 8 hours (Simonne *et al.*, 2003b).

For small irrigation volumes, water moved vertically by gravity until it reached the impermeable layer, then moved laterally on top of the impermeable layer. When the water fronts from two adjacent emitters meet, water may move vertically. The practical effect of water redistribution was different based on soil texture. The relatively clayey soil of Gadsden County drains slowly; the soil became muddy and sticky when irrigation was greater than 4 hours. After 6 hours, dye was visible in the row middles. In the coarse textured soils of St. Lucie and Hendry counties, no dye was observed in the row middle. Water redistribution may allow the creation of a 'micro' perched water table which may prevent the field from drying too fast and may provide traction to vehicles in and around the field. The width, depth and length of the wetted zone showed little response to irrigation volume on a rocky soil of Miami-Dade County (**Fig. 2**; Simonne *et al.*, 2004).

These results suggest that single irrigation events should not exceed 2 to 3 hours of irrigation (based on flow rate) or 60 to 75 gal/100ft in fine textured soils. The observations support the rule-of-thumb of 1,000 gal/acre/day/string for tomato irrigation. When tomato plants are large (5 strings), this rule corresponds to approximately 70 gal/100ft/day (calculated as 5,000/72.6).

Similar tests with multiple dye injections are being conducted in commercial fields to visualize the cumulative effect of irrigation rates on vertical water movement in presence of actively growing crops.

Effect of 'Splitting' on the Size of the Wetted Zone

Methods: A dye test was conducted at the North Florida Research and Education Center (NFREC) - Suwannee Valley, near Live Oak, on a 15-foot deep Lakeland fine sand on 3 Dec. 2003. All treatments received a total of 4 hours of irrigation using Roberts Ro-Drip drip tape (24 gal/100ft/hr flow rate; 12-inch emitter spacing) applied in different 'splits': 1 hour on, 1 hour off, repeated four times; 2 hours on, 2 hours off, repeated 2 times; 3 hours on, 1 hour off; and, 4 hours on continuously.

Results: In this test, all treatments received the same total amount of water (96 gal/100ft), but initial amounts were different. The initial amount of water applied was 24, 48, 72 or 96 gal/100ft. The width, depth, and length of the wetted zone were not affected by the split treatments **(Fig. 3)**. These results do not support the practice of splitting irrigation as an attempt to increase the size of the wetted zone. Splitting irrigation should be done as an attempt to keep the irrigation water (and soluble nutrients) within the root zone. In addition, splitting irrigation during crop production (in fields with actively growing vegetable crops) allows a partial depletion of soil water between splits, thereby further reducing the risk of water movement below the root zone.

Relative Movement Between the Dye and a Soluble Fertilizer

Method: On 3 Dec. 2003, potassium nitrate was injected with the dye at a rate of 4 lbs/A of N, which is twice the highest recommended weekly injection rate of N for most vegetables grown in Florida (Olson and Simonne, 2003). After injection, soil samples were taken exactly under four emitters of each treatment and divided into section 'below the dye', 'the dye ring', and 'above the dye'. Soil samples were sent promptly to the Analytical Research Laboratory in Gainesville, FL for NO_3-N extraction and analysis using method 353.2 (US EPA, 1983). The effect of soil sample position on NO_3-N concentration in the soil was determined with ANOVA and Duncan's multiple range test.

Results: When KNO_3 was injected with the dye, NO_3-N concentration was significantly higher in the wetted zone above and in the ring (18 ppm) than below it (3 ppm) for V ranging between 298 and 892 L/100 m (24 to 72 gal/100ft) **(Fig. 4)**. Differences in NO_3-N concentrations between the zone above the ring and in the ring were not significant. With greater V, no significant difference was observed in NO_3-N concentration above, in and below the ring (all 3 mg/kg). As expected, NO_3-N concentration decreased as depth increased. These results support the hypothesis that NO_3 moves with the water front and with the dye in a Lakeland fine sand. Hence, the position of the dye not only represents the movement of water, but also that of NO_3.

Conclusions: Together with proper design and maintenance, good drip irrigation management is essential to ensure high uniformity and achieve tomato full yield potential. As water movement and fertilizer movement are linked, improvement in irrigation management will result in comparable improvements in fertilizer management. Some drip irrigation management recommendations include using 1,000 gal/acre/day/string as a target volume, fine tuning this rate with soil moisture measurements (from a tensiometer, TDR, or EC probe), and splitting irrigation when water volumes are greater than 70 gal/100ft. Splitting irrigation into 2 or 3 daily events may allow a more steady moisture regime in the soil (thereby reducing the risk of blossom-end rot and fruit cracking) and reduce vertical water movement, but will have limited impact on lateral water movement.

In practice, splitting irrigation has to be a compromise between two constraints. On one side, the more frequent the irrigation, the less likely soluble nutrients are to be leached below the root zone. On the other side, frequent and short irrigations may waste water and reduce irrigation uniformity due to a large portion of the irrigation cycle used for system charge and flush. In addition, each irrigation cycle has to deliver enough water to ensure complete wetting between two adjacent emitters to maintain crop uniformity, especially when tomato plants are small.

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Table 1. Characteristics of drip tapes used in dye tests.

Location	Drip tape		
	Manufacturer	Flow rate[z] (gal/100ft)	Emitter spacing (inch)
Gadsen County	Chapin	30	12
	Queen Gil	33	4
Suwannee County	Chapin	30	12
	Eurodrip	18, 26, 40	12, 12, 12
	Netafim	24, 37	12, 12
	Queen Gil	16, 33	4, 4
	Roberts	40, 20, 40, 24	4, 8 ,8 ,12
St. Lucie County	Eurodrip	40	12
	Queen Gil	16, 33	4, 4
	Roberts	40, 40, 24	4, 8, 12
Hendry County	Netafim	24	18
Miami-Dade County	Aquatraxx	22	12
	Eurodrip	27, 35	12 ,12
	Netafim	24	12
	Queen Gil	16, 33	4,4
	T-Tape	21	8

[z] At manufacturer-specified operating pressure

Fig 1. Effect of irrigation volume (Vol., gal/100ft) on depth (inch) of the wetted zone on a Lakeland fine sand using selected drip tapes differing in emitter spacing and flow rate. (Regression equation may be described as: Depth = 4 + 0.10 Vol, R^2 = 0.89)

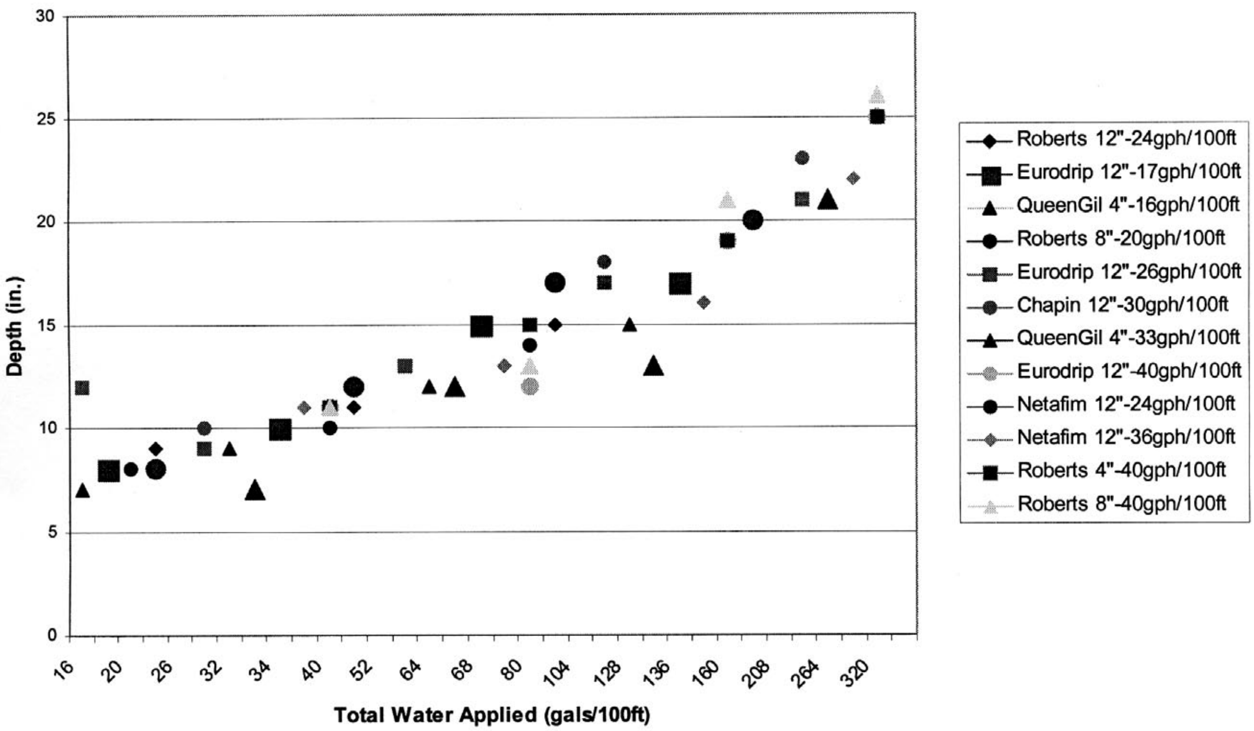


Fig. 2. Response of depth (a), width (b) and emitter-to-emitter irrigation volume (V) for selected drip tapes on a Krome very gravelly loan of Miami-Dade County, Florida.

a.

b.

c.

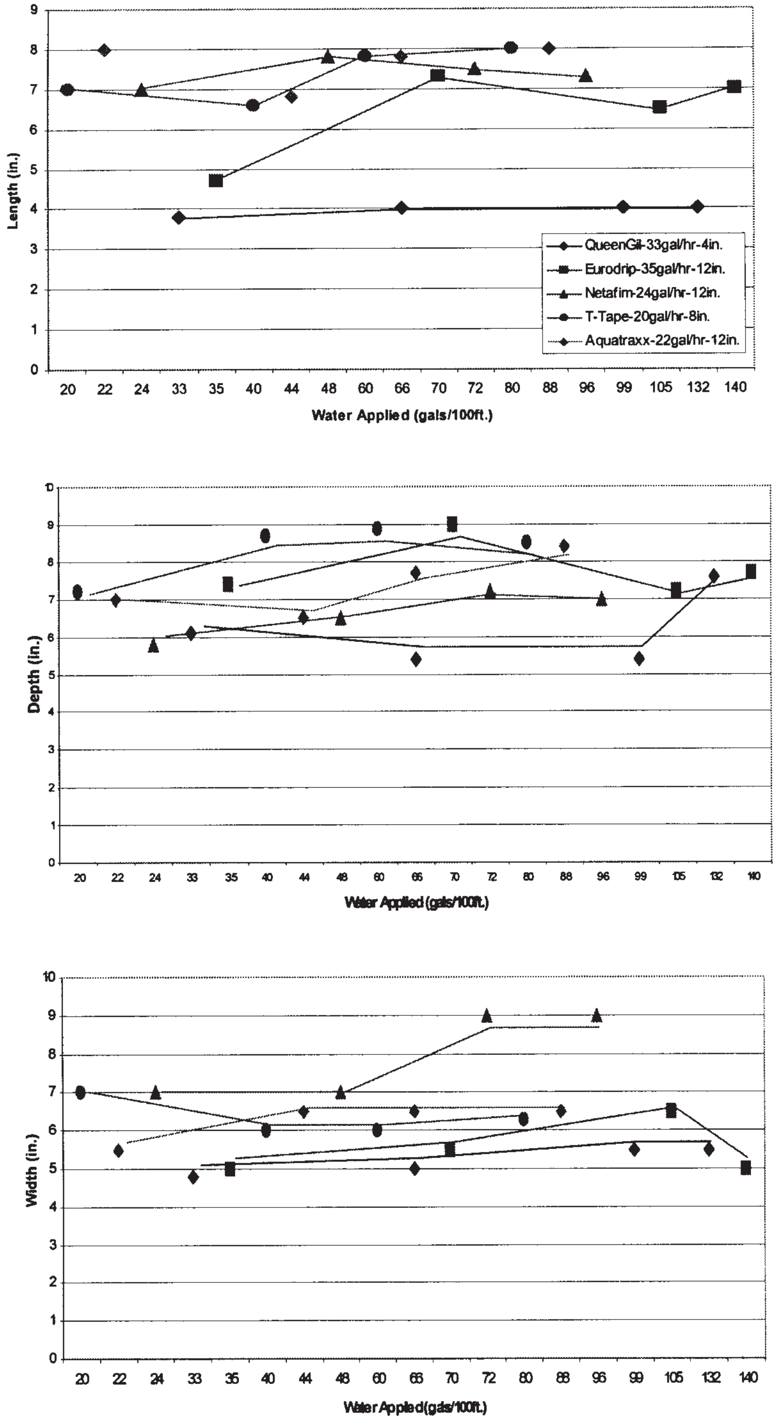
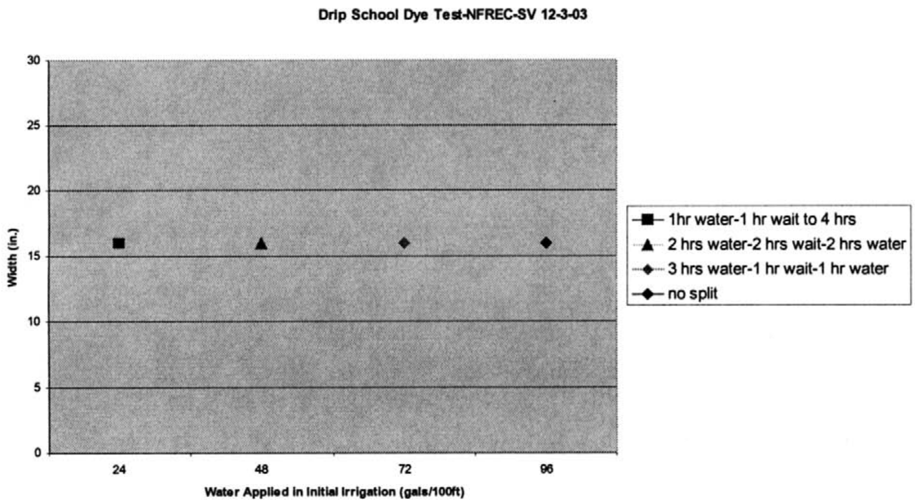
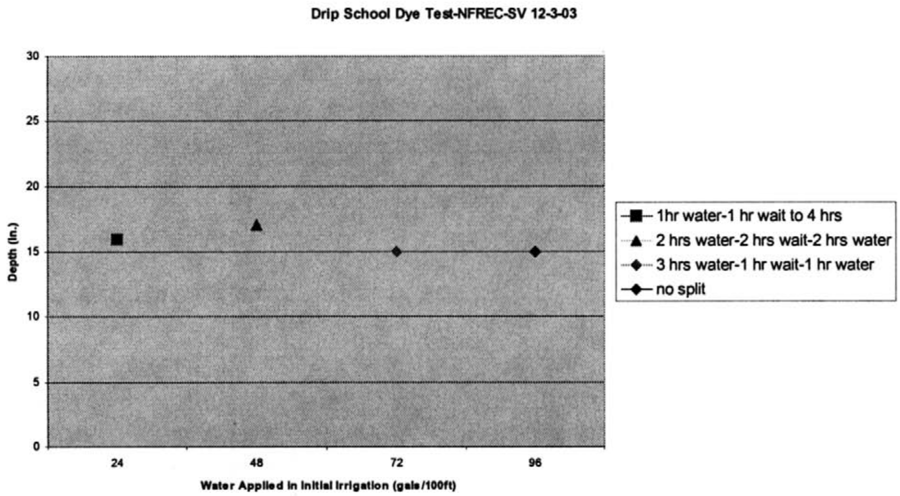


Fig 3. Response of width (A), depth (B), and emitter-to-emitter (length, C) of the wetted zone to 'split' irrigation on a Lakeland fine sand.





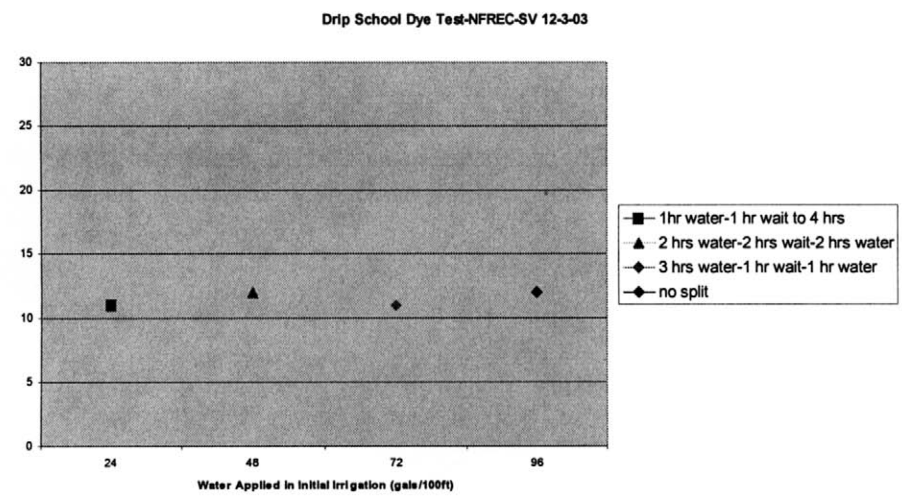
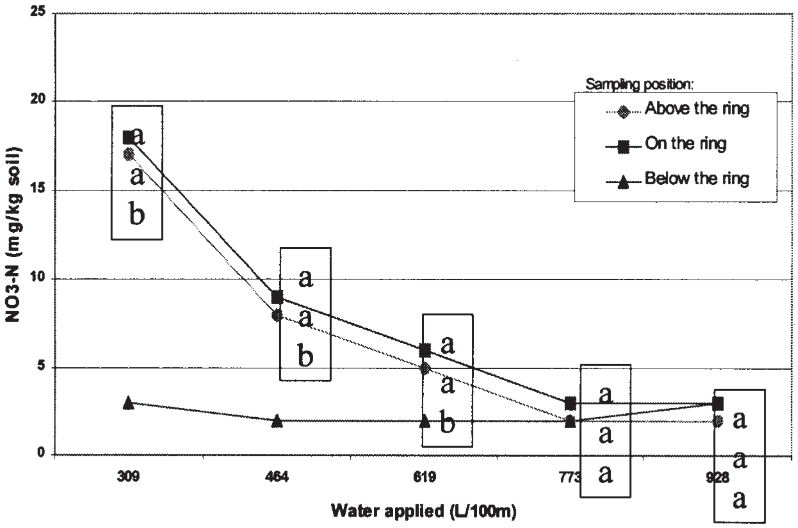


Fig. 4. Effect of irrigation water applied (L/100m) on nitrate content (ppm) in the soil above, on, and below the wetted zone.



Tomato Soilborne Diseases and Florida Plant Diagnostic Network (FPDN)

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Introduction and FPDN

The University of Florida, Institute of Food and Agricultural Sciences (IFAS) Extension is helping to provide plant protection educational programs through partnerships across the continuum from farmers to households, including researchers, extension agents, agricultural producers, private consultants, agricultural industry personnel, and Master Gardeners. Plant health management is particularly challenging in Florida because of the climate and global agricultural markets that cause the state to be susceptible to the accidental or intentional introduction of new pests. Available pest management options are diverse but virtually all of them rely on timely and accurate pest identification and diagnosis.

To assure that pest management recommendation action is rapid and appropriate, the University of Florida, IFAS has established plant pest diagnostic clinics and networks, such as Florida Plant Diagnostic Network (FPDN) and the Distance Diagnostic and Identification Information System (DDIS) that collaborate with Southern Plant Diagnostic Network (SPDN), National Plant Diagnostic Network (NPDN), the Florida Department of Agriculture and Consumer Services (FDACS) and the USDA. The Florida Plant Diagnostic Network (FPDN) is designed to provide plant disease, insect, nematode, and weed diagnostic services for any Florida resident interested in plant pest identification and diagnosis. As part of the UF/IFAS plant diagnostic services, there are four Plant Disease Clinics, one insect identification laboratory and one nematode assay laboratory. Clinics and other related laboratories maintain strong connection with the leading extension specialists, researchers in the field of Plant Pathology, Entomology, Nematology, Horticultural Sciences, Agronomy and FDACS
More information is available at
http://plantdoctor.ifas.ufl.edu/plantpath.html and
http://ipm.ifas.ufl.edu/

Among many different diseases that cause reduction in tomato yield, we focused on three soilborne tomato diseases and their field diagnostics evaluation and current management recommendations in this review.

Bacterial Wilt

Bacterial wilt caused by *Ralstonia solanacearum* is a serious soilborne disease of many economically important crops, such as tomato, potato, tobacco, banana, eggplant, and some ornamental plants. Although diseased plants can be found scattered in the field, bacterial wilt usually occurs in discrete areas (foci) associated with water accumulation in lower areas. The initial symptom in mature plants under natural conditions is wilting of upper leaves during hottest part of the day followed by recovery during the evening and early hours of the morning. The wilted leaves maintain the green color and do not fall-off as disease progresses. Under favorable conditions complete wilt will occur. The vascular tissues in the lower stem of wilted plants show a dark brown discoloration. These symptoms are similar to those of some fungal diseases. A cross section of the stem of a plant with bacterial wilt produces a white, milky strand of bacterial cells in clear water **(Fig. 1)**. This feature distinguishes the wilt caused by the bacterium from that caused by fungal pathogens.

In Florida, bacterial wilt of tomato is caused predominantly by race 1 biovar 1 of *R. solanacearum*. This race has a wide host range that guarantees a long-term survival of the pathogen in soil in the absence of the main susceptible crop. The pathogen can survive in the rhizosphere (root surface) of nonhost plants, including weeds. Soil factors also influence the survival of the bacterium. For example, bacterial wilt is an important disease of tomato in north Florida but it rarely occurs in calcareous soils with a high pH, which is the dominant soil type in Homestead.

Infested soil and surface water, including irrigation water, are the main sources of inoculum. Disease-free areas can be infested through infected planting material, contaminated water or machinery and laborers that get surface contamination from infested fields or other sources. *R. solanacearum* can infect undisturbed roots of susceptible hosts through microscopic wounds caused by the emergence of lateral roots. Transplanting, nematodes, insects and agricultural equipment are other common causes of root wounding, which allow bacteria to enter the plant. The bacterium then colonizes the cortex and makes its way towards the xylem vessel, from where it rapidly spreads in the plant. Bacterial masses prevent water flow from the roots to the leaves, resulting in plant wilting. Severity of the disease depends on soil temperature, soil moisture, soil type (which influences soil moisture and microbial populations), host susceptibility and virulence of strains. High temperature (86°F-95°F) and high soil moisture are the main factors associated with high bacterial wilt incidence and severity. Under these conditions, high populations of bacteria are released into the soil from the roots as the plant wilts.

Because it is caused by a soilborne pathogen with a wide host range, bacterial wilt is very difficult to control after it is established in the field. No single measure prevents losses caused by the disease. Cultural practices, if judiciously used, may reduce disease incidence. Seedlings must be free from infection by *R. solanacearum*. It is mandatory that commercial producers use treated or pathogen free irrigation water. Fields should not be over-irrigated because excess soil moisture favors disease development. Crop rotation and cover crops with non-susceptible plants reduce soilborne populations of the bacterium. Shifting planting dates to cooler periods of the year can be effective to escape disease development. Thymol, a plant derived reduced-risk chemical used as a soil fumigant reduced the incidence of bacterial wilt and increased tomato yield significantly in field experiments. Application method for commercial use of thymol in the field is under development. Some resistant cultivars are available commercially. Through our research program at the UF/IFAS, NFREC, Quincy we found that the use of acibenzolar-S-methyl (Actigard® 50WG, Syngenta Crop Protection) on moderately resistant cultivars such as FL 7514 and BHN 466 enhances disease resistance to a higher level. Acibenzolar-S-methyl treated FL 7514 and BHN 466 produced significantly higher tomato yields than the non-treated controls.

Fusarium Wilt

In the past, Fusarium wilt caused by *Fusarium oxysporum* f. sp. *lycopersici* was one of the most destructive plant diseases in Florida. The development of resistant cultivars has reduced this concern.

Infected transplants are stunted, the older leaves droop and curve downward, and the plants frequently wilt and die. Symptoms on older plants generally become apparent during the interval from blossoming to fruit maturation. The earliest symptom is the bright yellowing of the older, lower leaves. These yellow leaves often develop on only one side of the plant, and the leaflets on one side of the petiole frequently turn yellow before those on the other side. The yellowing process gradually includes more and more of the foliage and is accompanied by wilting of the plant during the hottest part of the day. The wilting becomes more extensive from day to day until the plant collapses and dries up. The vascular tissue of a diseased plant is dark brown in color. This browning often extends far up the stem and is especially noticeable in a petiole scar. This browning of the vascular tissue is characteristic of the disease and generally can be used for its tentative identification. Fruit infection occasionally occurs and can be detected by the vascular tissue discoloration within the fruit.

This pathogen prefers warmer weather (82°F-86°F), and is prevalent in acid and sandy soils. It is soilborne and remains in infested soils for several years. Long crop rotation (5-7 years) does not eliminate the pathogen but greatly reduces yield losses. Ammoniacal nitrogen enhances virulence of the pathogen, but nitrate nitrogen reduces it.

Three physiological races (1, 2, and 3) of this pathogen exist in Florida. Using resistant varieties where available for Race 1 and 2 is recommended. There are some Race 3 resistant cultivars available commercially. For cultivar selection, refer to the section entitled "Tomato Varieties in Florida" by Olson and Maynard in this proceeding. Movement of infected plants and/or infested soil clinging to machinery, hand tools, vehicles, trellising and staking implements, and field crates into areas free of this pathogen should be prevented. Since flooding will spread fungus, it is not recommended that land be flooded. Do not irrigate with surface water that may be contaminated with the fungus. It is recommended that Fusarium-free transplants be used; if transplant trays are reused these should be steam-treated beforehand. Using pre-plant soil fumigants may reduce disease incidence.

Fusarium Crown and Root Rot (FCRR)

Crown and root rot caused by *Fusarium oxysporum* f.sp. *radicis-lycopersici* is most frequently observed in the state's East and West Central and Southwest tomato production areas. The fungus can attack both tomato seedlings in the transplant house and mature plants in the field. Early symptoms of the disease in seedlings include stunting, yellowing, and premature loss of cotyledons and lower true leaves. A pronounced brown lesion that girdles the root/shoot junction (hypocotyl), root rot, wilting and death are advanced symptoms.

External symptoms of FCRR in mature plants include brown discoloration and rot at the soil level in the crown and roots. Infected plants in the field may be stunted, and as they begin to heavily bear fruit, their lower leaves turn yellow and wilt. Wilting first occurs during the warmest part of the day, and plants appear to recover at night. Infected plants may either wilt and die, or persist in a weakened state, producing reduced numbers of inferior fruit. The tap root of infected plants often rots entirely. When diseased plants are sectioned lengthwise, extensive brown discoloration and rot are evident in the cortex and water conducting tissue (xylem) of the crown and roots. Unlike Fusarium wilt, the browning observed in the xylem of the stem does not generally extend more than 8 to 12 inches above the soil line.

The disease is favored by low soil pH and soil temperatures (50°F to 68°F), ammoniacal nitrogen, and waterlogged soil. Integrated management of Fusarium crown and root rot includes: use of disease-free transplants (reused transplant trays should be steam-treated), preplant fumigation, avoidance of ammoniacal nitrogen and reused tomato stakes, maintenance of the soil pH at 6 to 7, rotation with nonsusceptible hosts including monocots, and use of biological control and resistant cultivars. Several cultivars with resistance are now available. For cultivar selection, refer to the section entitled "Tomato Varieties in Florida" by Olson and Maynard in this proceeding.

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Southern Plant Diagnostic Network - http://spdn.ifas.ufl.edu/

Table 1. Summary of field diagnostic features and favorable conditions of three soilborne diseases on tomatoes in Florida.

	Bacterial Wilt	**Fusarium Wilt**	**Fusarium Crown and Root Rot**
Pathogen	*Ralstonia solanacearum*	*Fusarium oxysporum* f.sp. *lycopersici*	*Fusarium oxysporum* f.sp. *radicis-lycopersici*
Symptoms	Under favorable conditions quick and complete wilt, vascular tissue becomes brown, ooze from cross-wise cut stem.	Yellowing of older leaves, usually starts on only one side of the plant, gradual wilting as disease progresses, vascular tissue becomes dark brown which often extends far up the stem.	Symptoms usually first appear during cool season around the time of first harvest as lower leaf yellowing, symptoms progress upwards, some plants may be stunted and wilt quickly, stem cankers develop at and slightly above the soil line, and stem vascular discoloration extends less than 12 in. above the soil line.
Favorable Conditions	High temperature (85-95 °F) and high soil moisture are the main factors associated with high bacterial wilt incidence and severity.	The disease is favored by soil and air temperature at 82-86F.	The disease is favored by cool soil temperature (50-68F).

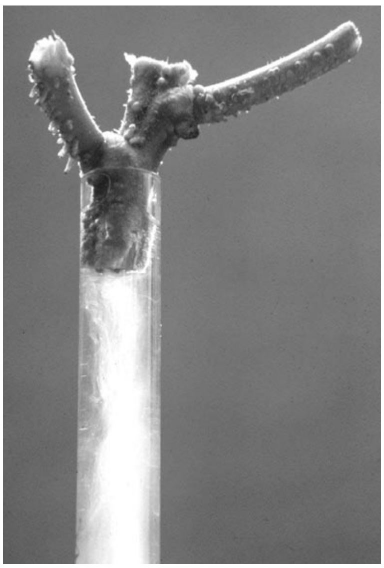

Fig. 1 A cross section of the stem of a plant with bacterial wilt produces a white, milky ooze of bacterial cells in clear water.
Photo courtesy: University of Georgia, Extension Plant Pathology.

Tomato Yellow Leaf Curl Resistant Varieties Available Now and Future Outlook from the IFAS Breeding Program

J.W. Scott

UF/IFAS, Gulf Coast Research and Education Center, Bradenton

Tomato yellow leaf curl virus (TYLCV) was first discovered in Florida in 1997 (Polston *et al.*, 1999). Although it has caused some serious losses on isolated farms, losses have been minimized because of the use of imidocloprid (Admire) insecticide drenches and judicious management by Florida tomato growers. However, more widespread losses were encountered in West Florida in Spring 2004. This resulted from the ability of the whitefly to over-winter because the winter was mild and some tomato crops were grown through the winter period. One of the most attractive strategies to prevent TYLCV is for growers to plant resistant varieties. Up to now resistant varieties have not been widely grown. However, there are several varieties now available and it is suggested that growers try these on adequate acreages in various cropping seasons to determine their acceptability. This is important should the TYLCV problem worsen and threaten the crop production of susceptible varieties altogether in the future.

Resistant Varieties Presently Available

Two seed companies presently have resistant varieties available. Seminis recently released Tygress which was tested as EX 1432427. Tygress is also resistant to Fusarium Wilt Races 1 and 2, Verticillium Wilt Race 1, Gray Leafspot, and Tomato Mosaic Virus. Hazera has released HA-3073 which is resistant to the same diseases as Tygress. Hazera is also in advanced testing of HA-3074 which is resistant to the above diseases plus nematodes, spotted wilt virus and bacterial speck. We had a severe outbreak of TYLCV at GCREC during the Summer 2003 and the Fall tomato trial was heavily infected. There were eight TYLCV resistant varieties from Hazera in the trial and they performed very well **(Table 1)**. They had no TYLCV and yielded well with very large fruit. Growers should contact seed company representatives for availability of these and other new varieties for testing. Hazera also has a plum type, HA-3371, that has resistance to both TYLCV and spotted wilt for growers interested in plum production. Other seed companies may soon have TYLCV resistant varieties available, but I am not aware of them at present.

From a disease management standpoint growers need to understand that resistant varieties can harbor the TYLCV virus, although at a much lower level than that of a susceptible variety. Thus, resistant varieties can be a source of inoculum for nearby susceptible varieties if whiteflies are not controlled. Research by Lapidot *et al.*, (2001) has shown that severely infected susceptible plants do not transmit the virus too well since whiteflies are not attracted to them as much as they are to a healthy plant. However, plants of a susceptible variety that get infected late in the season are attractive to the whitefly, have high virus titers, and thus are the most dangerous source of inoculum. Regardless, the bottom line is that even if resistant varieties are grown it is important that growers maintain good virus management practices. Besides the possible spread to susceptible varieties, whitefly management will prevent irregular ripening caused by the whitefly itself and reduce the chances that a virulent strain of the virus will emerge.

TYLCV Resistance from the IFAS Breeding Program

At IFAS Dave Schuster, Ph.D. and I have been working on geminivirus resistance since 1990 with the help of several Post-Doctoral scientists and a Ph.D. student. The resistance we are working with has primarily been derived from three accessions of *Lycopersicon chilense,* a wild tomato species (Scott and Schuster, 1991; Scott *et al.*, 1995). From this work we have discovered four resistance genes where any two are required for resistance in a given breeding line or variety (Griffiths 1998; Griffiths and Scott, 2001; Scott unpublished). Each year approximately 16,000 plants are screened for geminivirus resistance. Much progress has been made but no varieties have been released. The genes are additive which means a hybrid between a resistant and a susceptible parent (heterozygous resistance) has intermediate resistance **(Table 2)**. Whereas this would be an improvement over a susceptible variety, it would be inadequate compared to the seed company resistant varieties mentioned above. Thus, testing of experimental hybrids with resistance from both parents began in 2004. Last spring the resistance of such hybrids was good (**Table 2** and data not shown) but generally the fruit size or other horticultural traits was not quite at commercial standards. A few of the better hybrids will be tested again in the fall as will new hybrids that were made in the spring. Improved inbreds are being developed and used in the new hybrids. Still more new hybrids will be made in Fall 2004. It is hoped that a resistant variety will be ready for release sometime in 2005 or 2006. Some of the largest fruited inbreds have partial resistance which, when combined with a high level of resistance from the other parent, may provide hybrids with good resistance.

Because two genes are needed for resistance, only one cross has been made every two years to insure that no resistance genes are lost. To speed up this process we have conducted research to find molecular markers tightly linked to the resistance genes (Griffiths, 1998; Griffiths and Scott, 2001). Recently my Post-Doctoral Associate, Yuanfu Ji, has been making good progress in identifying the best markers. By the end of 2004 we may have usable markers for at least three of the genes. Once these markers are available, breeding progress should increase fourfold in that we will be able to make four crosses every two years rather than one. Furthermore, little disease screening would be necessary as the resistance genes can be selected in the laboratory. The markers will be a great asset to our program and to other breeders as they will be made available to them too.

Introgressing multiple genes from a distantly related species like *L. chilense* to tomato is a long, arduous process and, as mentioned, there are no varieties available at present from the IFAS program. However, good progress has been made and with the incorporation of molecular markers to speed up the selection process, the future outlook is promising. For instance, our ability to integrate TYLCV resistance with other desirable traits such as heat-tolerance and bacterial spot resistance (two other projects that have received considerable emphasis) should move rather quickly. Thus, I am confident that the IFAS TYLCV breeding project will make a significant impact on Florida tomato production in the future. In the meantime, it is fortunate that seed company varieties are available to our industry as well as other valuable control measures.

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Table 1. Total marketable yields, average marketable fruit weight, cull percentages, and TYLCV incidence for fresh market tomato entries in Fall 2003. (Harvested: 11 Nov 01 and 11 Dec 03).

Entry	Source	Total Harvest Total	X-Large (cartons/A)[1]	Large	Medium	Culls (%)[2]	Fruit Wt (oz)	TYLCV (%)
TY02-1276	Hazera	2124 a[3]	1596 a	404 a-d	124 e-j	15 de	6.5 ab	0 c
HA-3073	Hazera	1989 ab	1499 ab	355 a-d	136 e-j	21 c-e	6.7 a	0 c
TY02-1314	Hazera	1979 ab	1295 a-d	475 ab	208 b-e	20 c-e	5.9 a-j	0 c
TY02-1298	Hazera	1932 a-c	1304 a-c	460 a-c	169 c-i	10 e	6.1 a-j	0 c
HA-3068	Hazera	1888 a-c	1108 a-f	480 ab	300 a	25 c-e	5.8 b-j	0 c
TY02-1184	Hazera	1693 a-d	1195 a-e	368 a-d	130 e-j	34 a-c	6.0 a-j	0 c
TY02-1155	Hazera	1644 a-d	1296 a-d	285 b-d	64 j	25 c-e	6.4 a-e	0 c
Fla. 8093	GCREC-UF	1601 a-d	738 c-g	582 a	281 ab	16 c-e	5.3 h-j	55 ab
TY02-1220	Hazera	1452 a-d	953 b-g	415 a-d	85 ij	25 c-e	6.0 a-j	0 c
Florida 91	Seminis	1397 a-d	1101 a-f	234 cd	62 j	15 de	6.5 a-c	63 ab
Solar Fire	GCREC-UF	1368 a-d	741 c-g	417 a-d	210 b-e	18 c-e	5.5 f-j	65 ab
Fla. 8135	GCREC-UF	1320 b-d	637 e-g	440 a-d	243 a-d	18 c-e	5.3 h-j	74 ab
Fla. 8092	GCREC-UF	1320 b-d	822 c-g	366 a-d	132 e-j	21 c-e	6.4 a-d	70 ab
STM0231	Sakata	1286 b-d	918 c-g	271 b-d	97 g-j	19 c-e	6.2 a-g	78 ab
SVR01408152	Seminis	1279 b-d	874 c-g	286 b-d	119 e-j	27 b-e	6.1 a-j	48 ab
Fla. 7964	GCREC-UF	1274 b-d	696 c-g	378 a-d	200 b-f	28 a-e	5.5 e-j	63 ab
Soraya	Syngenta	1239 b-d	850 c-g	294 b-d	95 g-j	19 c-e	5.9 a-j	73 ab
Florida 47R	Seminis	1239 b-d	862 c-g	302 b-d	76 ij	20 c-e	6.1 a-i	74 ab
Solar Set	Seminis	1239 b-d	728 c-g	366 a-d	145 e-j	29 a-d	5.6 d-j	70 ab
Fla. 8059	GCREC-UF	1231 b-d	743 c-g	336 b-d	152 d-j	25 c-e	5.6 d-j	81 ab
Sebring	Syngenta	1230 b-d	858 c-g	317 b-d	55 j	19 c-e	6.2 a-h	78 ab
XTM0233	Sakata	1207 b-d	648 e-g	390 a-d	169 c-i	18 c-e	5.4 g-j	70 ab
SVR01408233	Seminis	1203 b-d	853 c-g	260 b-d	90 h-j	23 c-e	6.3 a-f	70 ab
RFT 2102	Syngenta	1180 b-d	781 c-g	298 b-d	102 g-j	30 a-d	6.0 a-j	68 ab
ACR 242 XLT	Abbott & Cobb	1147 cd	516 fg	378 a-d	253 a-c	30 a-d	5.3 j	55 ab
ACR 252 XLT	Abbott & Cobb	1124 cd	515 fg	421 a-d	188 c-g	23 c-e	5.3 j	79 ab
XTM2203	Sakata	1069 d	593 e-g	331 b-d	145 e-j	26 c-e	5.7 c-j	43 b
STM0227	Sakata	1022 d	690 d-g	224 d	108 f-j	24 c-e	6.0 a-j	88 a
ACR 42 XLT	Abbott & Cobb	973 d	544 fg	304 b-d	126 e-j	45 a	5.6 c-j	68 ab
ACR 2012	Abbott & Cobb	954 d	451 g	316 b-d	187 c-h	44 ab	5.3 ij	60 ab

[1]Carton = 25 lbs. Acre = 8712 lbf.
[2]By weight.
[3]Mean separation in columns by Duncan's multiple range test, 5% level.

Table 2. Tomato Yellow Leaf Curl disease severity for selected tomato genotypes at Bradenton, Florida in Spring 2004.

Genotype	TYLCV Rating[z]	Comment
Horizon	3.3 a[y]	Susceptible
7776 x 8262	2.6 b	Heterozygous resistant
8255 x 8257	1.1 c	Homozygous resistant
8258 x 8254	1.0 c	Homozygous resistant
8262	0.9 cd	Resistant inbred
TY02-1298	0.8 cd	Hazera hybrid
8257 x 8254	0.5 d	Homozygous resistant

[z]Rated 56 days after inoculation began on a scale from 0 to 4 where 0 = no symptoms, 1 = slight symptoms, 2 is intermediate, 3 is all infected tissue, and 4 is all infected tissue and stunted.

[y]Mean separation in columns by Duncan's Multiple range test a $P \leq 0.05$ based on a larger number of genotypes.

Silverleaf Whitefly Resistance Management Update

David J. Schuster and Sandra Thompson
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Introduction

An early and more severe outbreak of *Tomato yellow leaf curl virus* (TYLCV) in West-Central Florida in the spring of 2004 emphasizes that the vector of the virus, the silverleaf whitefly (SLWF), *Bemisia argentifolii* Bellows & Perring [also known as biotype B of the sweetpotato whitefly, *B. tabaci* (Gennadius)], remains the key pest of tomatoes in Southern Florida. The virus outbreak occurred despite applications of the nicotinoid Admire 2F® (imidacloprid; Bayer CropScience, Kansas City, MO) to seedlings in plant production houses and despite additional soil applications of either Admire or another nicotinoid Platinum® (thiamethoxam; Syngenta Crop Protection, Inc., Greensboro, NC). Weekly or even more frequent foliar applications of additional insecticides also were made, even though the soil applications of Admire or Platinum were still providing control of whitefly nymphs.

Foliarly applied insecticides included Fulfill® (pymetrozene; Syngenta Crop Protection, Inc., Greensboro, NC), Monitor® (methamidophos; Valent U.S.A. Corporation, Walnut Creek, CA), Malathion® (malathion; numerous suppliers), several different pyrethroids, Endosulfan® (endosulfan; Micro Flo Co., Memphis, TN; Drexel Chemical Co., Memphis, TN), Phaser® (endosulfan; Bayer CropScience, Research Triangle Park, NC), Thiodan® (endosulfan, Universal Crop Protection Alliance, LLC, Eagan, MN), Knack® (pyriproxyfen; Valent U.S.A. Corporation, Walnut Creek, CA), Courier® (buprofezin; Nichino American, Inc., Wilmington, DE) soap and oil. Results were mixed and residual control was short. Most growers refrained from making foliar applications of nicotinoids including Provado® (imidacloprid; Bayer CropScience, Kansas City, MO) and Assail® (acetamiprid; Cerexagri, Inc., King of Prussia, PA), because this practice could encourage the development of resistance to the nicotinoid insecticides (Elbert and Nauen 2000).

There are a number of possible causes of the TYLCV outbreak this past spring. Recent simulation studies have suggested that a very low rate of migrating whitefly adults carrying the virus can saturate a field, resulting in near 100% infection (Holt *et al.* 1999). In addition, nethouse studies have shown that it took 80 min for whitefly adults to die on plants treated 3 and 11 days previously with Admire and 150 min 18 days after treatment (Rubenstein *et al.* 1999). The insecticide lost its potency 25 days after treatment. This is contrasted with control of whitefly nymphs, where either Admire or Platinum can maintain nymphal densities below the threshold of 5 /10 leaflets (Schuster 2002) for at least 8 weeks following a soil application on Florida's sandy soils (Schuster and Morris 2002). Rubenstein *et al.* (1999) also showed that 70% of the plants became infected with TYLCV when caged with viruliferous whiteflies three days after treatment with Admire, 80% became infected 11 days after treatment, and 100% became infected 18 days after treatment. Thus, Admire is much less effective in managing whitefly adults and the resulting transmission of TYLCV than in managing whitefly nymphs. Efficient and intensive whitefly adult management is, therefore, required to reduce TYLCV incidence (Holt *et al.* 1999).

Cultural practices probably contributed to the TYLCV outbreak as well. In some instances, "burn down" of fall fields with contact herbicides was incomplete, with up to 80% of the plants experiencing regrowth. As much as 50% of the plants with regrowth had symptoms of TYLCV. Grape tomatoes planted in the early fall also were still in production when the spring planting commenced and in at least some cases were not destroyed until after the spring planting was completed. Indeterminant grape tomato plants that are infected with TYLCV also exhibit less severe symptoms than determinant, large-fruited tomato plants and can still be harvested. Thus, the "burned down" fields destined for double cropping with a cucurbit crop and the grape tomato fields were potential sources of viruliferous whitefly adults.

Declining susceptibility of whitefly adults to the nicotinoids, as was shown for Admire from 2001 to 2003 (Schuster *et al.*. 2003), could also contribute to an increase in TYLCV incidence. Therefore, continued monitoring for susceptibility of SLWF adults to the nicotinoids is an essential element of whitefly and virus management.

Nicotinoid Resistance Monitoring

A program to monitor the susceptibility of field populations of the SLWF to Admire using a cut leaf petiole method was initiated in 2000 (Schuster and Thompson 2001; Schuster *et al.* 2002, 2003) and was continued in 2004. Monitoring for susceptibility to Platinum was initiated in 2004. The cut leaf petiole method was used to evaluate the relative susceptibility of SLWF populations to Admire from 9 nicotinoid-treated tomato fields in 2001, 14 fields in 2002, 10 fields in the spring of 2003 and 11 fields in the spring of 2004. At least two of the fields in 2003 and one of the fields in 2004 were treated at transplanting with a soil application of Platinum rather than Admire. Susceptibility to Platinum was evaluated in eight nicotinoid-treated tomato fields in 2003 and three fields in 2004. At least five of the fields in 2003 were treated with Admire rather than Platinum.

Bioassays were conducted using adults reared from foliage infested with nymphs that had been collected from each tomato 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 in continuous culture since the late 1980s 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 eight 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.

Over 2001 and 2002, nearly 80% of the RS_{50} values of whiteflies collected from the Admire-treated fields were eight or less, while in 2003, only about 20% of the fields had values of eight or less **(Tables 1 & 2)**. RS_{50} values of 10 or greater were observed in three whitefly populations in 2001, four populations in 2002 and eight populations in 2003. This represented about 20% of the populations in 2001, 30% in 2002 and 80% in 2003 **(Table 2)**. Certainly, the higher proportion of high values observed in 2003 would suggest a decrease in susceptibility of the SLWF in 2003 relative to previous years. However, in the spring of 2004, only one population, or 9% of the populations, had an RS_{50} value of 10 or greater **(Tables 1 & 2)**, thus indicating an increase in susceptibility over 2003. This may be due to the response of growers to an intensive extension education program begun in 2001, but may also represent periodic fluctuations in whitefly susceptibility. Only long term monitoring can determine which is the case. In Arizona, Admire has been available for use since 1993 and the same scenario was observed, i.e. susceptibility declined from 1995-1998 but increased to 1997 levels in 1999 and 2000 (as summarized by Palumbo et al. 2001). A resistance management program was initiated in Arizona in 1995 based upon cultural practices and upon selection, timing and rotation of insecticides in different chemical classes (Dennehy *et al.* 1995).

Susceptibility to Platinum was evaluated only in 2003 and 2004 and for only eight and three populations, all of which had RS_{50} values of three or less **(Table 3)**. Platinum has only been available for use on Florida tomatoes since 2001 while Admire has been available since 1994. Thus, the lower RS_{50} values for Platinum may be due to the shorter period of exposure.

The progeny of adults that survived the Admire bioassay from the Duette site in 2001, the SWFREC site in 2002 and the Parrish, Ruskin 1 and Waterbury sites in 2003 were reared on tomato in the laboratory without exposure to Admire and then were bioassayed again. With the exception of the Parrish site, the RS_{50} values of the progeny of the bioassay survivors from each of the sites declined to acceptable levels within 1 to 4 generations **(Table 4)**. Even the RS_{50} value of the population from the Parrish site declined by about 50% in just one generation. Therefore, reduced susceptibility appears to be unstable and reverts to susceptibility rather quickly. In addition, the progeny of these populations survived poorly and it was difficult to obtain enough whitefly adults to bioassay.

The population from the Lorraine2 site was different and survived very well. An acceptable level of susceptibility did not return until the population had been reared without exposure to Admire for four generations **(Table 5)**. When the population was exposed to potted tomato plants drenched with the LC_{50} of Admire, reduced susceptibility was observed after only one generation. When the population was exposed to potted tomato plants drenched with the field rate of Admire, all adults were killed and no nymphs were produced. Thus, there is the potential, at least with some whitefly populations, of quickly selecting for reduced susceptibility when the whiteflies are exposed to a low dose of Admire.

When the Lorraine2 population that had reverted to susceptibility was exposed to one generation with the LC_{50} of Admire, the RS_{50} for Admire increased to 20.6 **(Table 6)**. When this population with reduced susceptibility to Admire was bioassayed with Platinum, the RS_{50} for Platinum was still within the expected range for susceptibility. Therefore, there did not appear to be cross-resistance between Admire and Platinum, at least within the levels of reduced susceptibility manifested in this population. On the other hand, when the population with an RS_{50} value of 20.6 for Admire was exposed for one generation to the LC_{50} of Platinum and then bioassayed with Platinum, the resulting RS_{50} was about 10, which is high enough to be of concern. When the population that had reverted to susceptibility to Admire (RS_{50} value of 6.2) was exposed to Platinum-treated plants, it took five generations to reach an RS_{50} value approaching concern (9.3). Therefore, it appears that populations with reduced susceptibility to Admire may be predisposed to selection for reduced susceptibility to Platinum, which could lead to reduced susceptibility to both products.

Although susceptibility to Admire appears to have increased in 2004, there still is the potential for the development of tolerance in the SLWF to both Admire and Platinum. Therefore, growers are encouraged to stringently adhere to resistance management recommendations. A Resistance Management Working Group was formed last year to promote resistance management on a regional basis. The group modified previous resistance management recommendations (Schuster and Thompson 2001; Schuster *et al.* 2002, 2003) and met with growers to encourage their adoption. The Working Group consisted of University of Florida/IFAS research and extension personnel, representatives of the chemical companies marketing nicotinoid insecticides, and other interested persons including representatives of Glades Crop Care. Because the recommendations include cultural practices to reduce overall whitefly populations as well as recommendations for insecticide programs, strict adherence to the recommendations by growers will help improve management of TYLCV and will help growers avoid another outbreak of the virus.

Recommendations for Management of Nicotinoid Resistance for Florida Tomato Production

1. **Observe a minimum two-month crop free period from mid-June to mid-August.**

2. **Use a correct crop destruction technique which includes destruction of existing whitefly populations in addition to the physical destruction of the crop.**
   - **a.** Prompt and efficient <u>crop destruction</u> between fall and spring crops to maximally decrease whitefly numbers and sources of TYLCV.
   - **b.** Use a burn down herbicide such as paraquat or diquat in conjunction with a heavy application of oil (2-4% solution) to quickly kill whiteflies.
   - **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.

3. **Reduce overall whitefly populations by strictly adhering to cultural practices including:**
   - **a.** Plant whitefly-free transplants.
   - **b.** Delay planting new crops as long as possible and destroy old crops immediately after harvest to create or lengthen a tomato-free period.
   - **c.** Control whitefly infested weeds, abandoned crops and volunteer plants.
   - **d.** Control weeds on field edges and ditch banks if scouting indicates whiteflies are present and natural enemies are absent.
   - **e.** Manage weeds within crops to minimize interference with spraying.
   - **f.** Avoid u-pick or post harvest pin-hooking operations unless effective control measures are continued.

4. **Use a proper whitefly insecticide program. Follow the label!**
   - **a.** Do not use a nicotinoid on transplants or apply only once 7 days before shipping; use other products in other chemical classes, including Fulfill, before this time.
   - **b.** Apply a nicotinoid like Admire (16 ozs/acre) or Platinum (8ozs/acre) at transplanting and use products of other chemical classes (such as the insect growth regulators Knack or Courier) as the control with the nicotinoid diminishes.
   - **c.** Do not use Admire at less than 16ozs/acre or Platinum at less than 8ozs/acre.
   - **d.** Do not use split applications of either Admire or Platinum (i.e. do not apply at transplanting and then again later).
   - **e.** Never follow a soil or foliar application of a nicotinoid

with another soil or foliar application of the same or different nicotinoid on the same crop or in the same field within the same season (i.e. do not treat a double crop with a nicotinoid if the main crop had been treated previously, unless the double crop is planted at least 60 days after the main crop).

5. **Do unto your neighbor as you would have him do unto you.**
   a. Looking out for your neighbor's welfare 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 the nicotinoids, 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.
   b. Knowing what is going on in the neighbor's fields is important. Growers should try to keep abreast of operations in upwind fields, especially during harvesting and crop destruction, which both disturb the foliage and cause whitefly adults to fly. Peppers have been added recently to the list of TYLCV hosts and whitefly numbers have increased on pepper; thus, 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 can be found in an article by Jane Polston, Ph.D. in the Sept. 2003 Proceedings of the Tomato Institute, available online at the SWFREC website:
http://www.imok.ufl.edu/veghort/docs/tom_inst_2002_091202.pdf

Acknowledgements

The authors wish to express their appreciation to Phyllis Gilreath, Gene McAvoy, Roy Morris, Phil Stansly, Jim Conner and personnel of Glades Crop Care for identifying fields for sampling and/or collecting whitefly samples for bioassaying, and to Bayer CropScience for providing partial funding for the research.

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Table 1. Relative susceptibility (RS_{50}) of silverleaf whitefly adults to Admire in the laboratory using a cut leaf petiole method. Adults were reared from nymph-infested foliage collected from tomato fields.

County/Site	Date	RS_{50}[1]
	2001	
Hendry/Devil's Garden	April	3.1
Collier/Immokalee1, Field 2	May	14.6
Collier/Immokalee2	May	5.1
Manatee/Duette	June	8.0
Hillsborough/Ruskin	June	4.6
Manatee/Ft. Hamer	June	13.1
Manatee/GCREC, Field	June	2.6
Hillsborough/Riverview	July	4.5
Manatee/Myakka City	Dec	4.7
	2002	
Collier/Immokalee1, Field 1	April	7.3
Palm Beach/Boynton Beach	April	2.6
Collier/Immokalee3	April	5.6
Collier/Immokalee4	April	2.9
Collier/Immokalee1, Field 2	May	3.9
Dade/Homestead	May	7.3
Collier/SWFREC	May	21.9
Manatee/Duette	June	35.2
Manatee/Ft. Hamer	June	5.7
Hillsborough/Ruskin	June	3.4
Manatee/GCREC, Field 1	June	14.8
Manatee/GCREC, Field 2	June	5.9
Manatee/Lorraine1	June	1.2
Manatee/Parrish	Nov	21.0
	2003	
Collier/Immokalee2	May	12.1
Hillsborough/Ruskin1	June	19.2
Hillsborough/Ruskin2	June	7.0
Manatee/Duette	June	14.8
Manatee/Ft. Hamer	June	17.8
Manatee/Lorraine2	June	12.8
Manatee/Lorraine3	June	20.6
Manatee/Myakka City	June	3.6
Manatee/Parrish	June	21.2
Manatee/Waterbury	June	14.7
	2004	
Dade/Homestead1	March	5.1
Dade/Homestead2	March	6.9
Collier/Immokalee5	May	6.0
Collier/Immokalee6, Field1	May	5.9
Collier/Immokalee6, Field2	May	6.1
Hendry/Labelle	May	11.4
Hillsborough/Ruskin2	May	5.5
Hillsborough/Ruskin2	June	2.9
Manatee/Parrish	June	7.6
Collier/SWFREC	June	5.8
Manatee/GCREC	June	3.6

[1]Ratio of the LC_{50} of the indicated population to the LC_{50} of the laboratory colony. Increasing values greater than one indicate decreasing susceptibility to Admire relative to the laboratory colony.

Table 2. Four years of monitoring the relative susceptibility (RS_{50}) of whitefly adults to Admire using a laboratory bioassay.

	Year			
	2001	2002	2003	2004
No. sites	9	14	10	11
% sites ≥10	22%	29%	80%	9%
Avg. RS_{50}[1]	6.7	9.9	14.7	6.1

[1]Ratio of the LC_{50} of the field population to the LC_{50} of the lab colony. Increasing values greater than one indicate decreasing susceptibility to Admire relative to the laboratory colony.

Table 3. Relative susceptibility (RS_{50}) of silverleaf whitefly adults to Platinum in the laboratory using a cut leaf petiole method. Adults were reared from nymph-infested foliage collected from tomato fields.

County/Site	Date	RS_{50}[1]
	2003	
Hillsborough/Ruskin1	June	1.8
Hillsborough/Ruskin2	June	1.0
Manatee/Duette	June	3.0
Manatee/Lorraine2	June	2.5
Manatee/Lorraine3	June	0.2
Manatee/Myakka City	June	1.7
Manatee/Parrish	June	1.6
Manatee/Waterbury	June	2.4
	2004	
Collier/SWFREC	June	1.7
Hillsborough/Ruskin2	June	1.4
Manatee/Parrish	June	3.0

[1]Ratio of the LC_{50} of the indicated population to the LC_{50} of the laboratory colony. Increasing values greater than one indicate decreasing susceptibility to Platinum relative to the laboratory colony.

Table 4. Changes in relative Admire susceptibility (RS_{50}) of silverleaf whitefly adults evaluated two to four generations following collection in the field.

Site	Date Collected	Date Evaluated[1]	Estimated no. generations in lab[2]	RS_{50}[3]
		2001		
Duette	13 June	21 June	1	8.0
Duette	13 June	16 Aug	4	1.5
		2002		
SWFREC	21 May	31 May	1	21.7
SWFREC	21 May	10 July	2-3	5.8
		2003		
Parrish	4 June	11 June	1	21.2
Parrish	4 June	17 July	2	11.0
Ruskin1	4 June	11 June	1	19.2
Ruskin1	4 June	17 July	2	4.2
Waterbury	4 June	19 June	1	14.7
Waterbury	4 June	31 July	3	6.4

[1]Survivors of the original bioassay were reared on tomato without selection in the lab.

[2]One generation in the lab requires about 2 wk.

[3]Ratio of the LC_{50} of the field population to the LC_{50} of the lab colony. Increasing values greater than one indicate decreasing susceptibility to Admire relative to the laboratory colony.

Table 5. Changes in relative susceptibility (RS_{50}) of whitefly adults to Admire in the laboratory, 2003.

Site	Date Collected	Date Evaluated	Generations in lab	RS_{50}[1]
Lorraine2	4 June	14 June[2]	1	12.8
Lorraine2	4 June	17 July[2]	2	25.3
Lorraine2	4 June	31 July[2]	3	14.4
Lorraine2	4 June	18 Aug[2]	4	6.2
Lorraine2 $LC_{50}F_1$	4 June	20 Oct[3]	1	28.1

[1]Ratio of the LC_{50} of the field population to the LC_{50} of the lab colony. Increasing values greater than one indicate decreasing susceptibility to Admire relative to the laboratory colony.
[2]Survivors of the original bioassay were reared on tomato without selection in the lab.
[3]Fourth generation survivors were exposed for one generation to the LC_{50} of the susceptible laboratory colony.

Table 6. Changes in relative susceptibility (RS_{50}) of whitefly adults from the Lorraine2 population to Admire and Platinum in the laboratory.

Colony Exposure (LC_{50})[1]		RS_{50}[2]	
Admire	Platinum	Admire	Platinum
No	No	6.2	-------
Yes	No	20.6	4.1
Yes	Yes(F_1)	-------	10.5
No	Yes(F_1)	-------	5.9
No	Yes(F_5)	-------	9.3

[1]The colony was exposed to either the LC_{50} of Admire or Platinum applied to potted tomato plants in the laboratory.

[2]Ratio of the LC_{50} of the field population to the LC_{50} of the lab colony. Increasing values greater than one indicate decreasing susceptibility to Admire or Platinum relative to the laboratory colony.

Use of "Soft" Pesticides in a Pest Management Program for Tomatoes and Peppers

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What Is a "Soft" Pesticide?

The use of "soft" in reference to pesticides is meant to imply selectivity: death to pests while leaving unscathed all beneficial insects, mites, and other non-targets including people. A better term might be "reduced risk" or "smart" in analogy to "smart" weaponry intended to limit collateral damage. The term "soft" might also imply that the price for selectivity may be reduced efficacy compared to the older "hard" or broad-spectrum pesticides that kill everything. Another assumption sometimes made is that being "soft" on humans necessarily means soft on beneficials. Not surprisingly, there are exceptions to all these generalizations.

The history of modern insecticides begins with the first use of DDT during the WW2 years, followed quickly by additional chlorinated hydrocarbons (dieldron, toxaphene, chlordane), organophosphates (parathion, malathion), carbamates (carbaryl, methomyl) and eventually pyrethroids. These constitute the principal groups of broad-spectrum insecticides compared to which all pesticides are selective = "soft". These latter include the insect growth regulators (IGRs): juvenile hormone mimics such as pyriproxyfen (Knack®), chitinase inhibitors such as buprofezin and diflubenzuron (Courier, Dimilin) and ecdysone agonists like tebufenozide and methoxyfenozide (Confirm and Intrepid). There are also the neonicotinoids such as imidacloprid, thiamethoxam and acetamiprid (Admire, Platinum) that are most selective when taken up by the roots thereby avoiding contact exposure of insects on the foliage. There remains a large group of insecticides that defies easy classification and includes bacterial products (B.t. abamectin, spinosad), indoxacarb (Avaunt), pymetrozine (Fulfill), oils and surfactants (soaps and detergents). In addition, there are a number of miticides that all tend to be relatively selective.

Soaps and Oils

True soaps are anionic surfactants consisting of sodium or potassium salts of fatty acids. Commercially available insecticidal soaps are potassium salts of fatty acids, particularly oelic acid that has an 18-carbon chain backbone with one (unsaturated) double bond and was supposedly chosen to optimize the balance between insecticidal activity and phytotoxicity. However, any true soap has the disadvantage of precipitating out in hard water due to the insolubility of its calcium or magnesium salts. Detergents have largely replaced soaps for most cleaning tasks because they precipitate less or not at all in hard water.

Phytotoxicity of both soaps and oils is a function of concentration, plant type, environmental conditions and chemical characteristics of the material. We lab-tested in Immokalee one household liquid detergent widely used on tomato in Florida and composed principally of the anionic surfactants sodium laureth sulfate and sodium dodecyl benzene sulfonate. We found it to be about 4 times more active against whitefly than insecticidal soap. However, it was also more phytotoxic, causing measurable reductions in yield at first pick at rates as low as 0.5% v/v sprayed twice a week, although the effect on yield at this concentration was not significant at once a week intervals **(Fig. 1).**

Horticultural mineral oils (HMOs) are the mainstay of pest management in Florida citrus but are still regarded with suspicion by vegetable growers for fear of phytotoxicity. However, the purity and therefore safety of the best HMOs continues to improve. The optimal oil for killing bugs has 21 carbons in a straight (paraffinic) chain and would boil at about 435°F. However, commercial oils are mixtures of hydrocarbons of different sizes and shapes with different boiling points, so a sort of average or mid-boiling point is used, the temperature at which half the oil boils off. Lighter oils are less volatile and thus shorter acting, whereas heavier oils hang around longer and so are more phytotoxic. The narrower the temperature range between which 10% to 90% of the oil boils off the better, preferably not more than 70F. Another factor affecting phytotoxicity is unsufonated residues (UR), that inert fraction of the oil that <u>will not react</u> with concentrated sulfuric acid. The reactive fraction of unsaturated and aromatic hydrocarbons can cause plant injury and should not constitute more than 8% (UR > 92%). Medicinal paraffinic oil has greater than 99% UR.

Sunspray Ultrafine ® (mid boiling point 415 °F, BP range 65 °F, UR > 92%, 1.2% emulsifier) has always been considered a safe oil for vegetables. We found it could be sprayed twice a week on pepper with or without copper and Manzate® at up to 2% v/v without damage or loss of yield, although we saw problems at 4% **(Fig. 2)**.

Advantages and Selectivity of "Soft" Pesticides

Under advantages of selective insecticides we could include conservation of natural enemies and consequently reduced pesticide use resulting in lower production costs and less rapid selection for insecticide resistance. Another advantage for many "soft" pesticides would be reduced preharvest intervals (PHIs) and re-entry intervals (REIs). Most are not restricted use, reducing paperwork and aggravation. Some, such as soaps, oils and Bt, are relatively inexpensive. On the negative side, selective pesticides may not control all pests present, may be slower acting and may be more expensive that older chemistries.

How selective are the "soft" insecticides? Not surprisingly, this depends on the non-target being considered. EPA regulations require evaluation of pesticide toxicity against a number of non-target organisms including mammals, birds, fish, freshwater crustacia and honeybees. The toxic effects of ingestion are expressed in terms of the LD-50, the amount of material per unit weight of the test organism (milligrams/kilogram) lethal to 50% of the test population. It is understandably difficult to find human volunteers for such testing, so rats are used instead. As a point of reference, the LD-50 for common table salt, NaCl, is considered to be about 3000 mg/kg, or about ½ lb for a 150 lb person. Many active ingredients such as tebufenozide, pyriproxyfen, cyromazine, pymetrozine and of course the Bts have higher LD-50s and are thus less toxic than salt **(Table 1)**. Most broad-spectrum insecticides are considerably more toxic to rats, humans.

Toxicity of pesticides to insects and mites is usually expressed in a similar but distinct unit, the LC-50 (LC-90) or lethal *concentration* necessary to kill 50% (90%) of the population. This is because we usually know what the insect was exposed to but not how much it actually ingested. LC-50s usually vary with the age of the insect and the means by which it was exposed, so it is not always evident from laboratory results the impact of a field application.

One convenient guide to non-target effects on biological control agents is the Koppert "Side Effects Guide" (<u>www.koppert.com</u>) that summarizes published and unpublished laboratory results and field experience with augmentative biological control. While by no means complete, the Guide lists effects of most insecticides, acaricides and fungicides on 22 beneficial arthropods sold by the company for biological control. Three numbers are given for many of these arthropod/pesticide combinations: ratings of effects on mature stages, on immature stages, and weeks of residual effect. Summing these three numbers gives an overall rating given for some pesticides used in Florida tomatoes on the predaceous lacewing *Crysoperla carnea* and the whitefly parasitic wasp *Encarsia formosa* in **Table 1**. We can see that soap is actually less compatible with these beneficial insects than some other pesticides such as pymetrozine (Fulfill®), although much more so than the broad-spectrum insecticides bifenthrin or methomyl.

Effectiveness of Surfactants and Oils for Whitefly Control

Surfactants (including true soaps and detergents) and oils are among the least expensive of insecticides, so can be applied frequently at relatively low cost. It is widely believed that surfactants act by dissolving cell membranes, but there is evidence that they kill by reducing surface tension and allowing water to invade the tracheae, drowning the insect. Oils probably act by sealing the integument, including the spiracles, preventing gas exchange and causing asphyxiation. While many types of surfactants might be used to control insects, petroleum oils appropriate for application to vegetables are restricted to a narrow set of specifications as explained above.

When applied to whitefly nymphs as a leaf dip in the laboratory at field rates or below, the efficacy of soaps or oils is comparable to a pyrethroid **(Fig. 3)**. However, the effectiveness of soaps and especially oils drops off rapidly with decreasing coverage **(Fig. 4)**. In Immokalee, we obtained better coverage and thus better control in the field using a low volume, air assisted sprayer compared to a hydraulic sprayer **(Fig. 5)**. In another trial on eggplant, control of whitefly using air-assisted, motorized back-pack sprayers was better with oil than with endosulfan **(Fig. 6)**.

Last season in Immokalee we began testing a new oil product from Petro-Canada, BioCover LS, a 435°F oil with very high (99%) unsulfonated residue in a 98% emulsifiable concentrate. The plan was to see if an extra measure of pest protection could be provided by adding the oil to the weekly spray of whatever. We intentionally tested a sufficient rate (2%) to cause phytoxicity when applied to 2-week-old seedlings in September that also increased incidence of bacterial spot, although we also saw good whitefly control **(Fig. 6)**. At the 0.5% rate we still had whitefly control without the plant injury and no measurable decrease in yield **(Figs. 7, 8)**.

We repeated the experiment in a late spring trial planted March 31 with rates from 0.25% to 1% sprayed weekly on plants treated with 16 oz of Admire. These were compared to Admire alone and 2 oil treatments at 1% without Admire, BioCover and Sunspray Ultrafine. Whitefly and virus pressure was intense, and by mid May all plants were showing symptoms of TYLCV. However, symptoms were delayed in plants sprayed with BioCover though less so with Ultrafine **(Fig. 9)**. Differences in yield were not significant except between the best and worst treatments **(Fig. 10)**.

We also tested rates up to 2% in Jalapeño pepper without Admire, applied as a tankmix with Actara ® (two applications) or Vydate ® in rotation. We saw significant suppression of whitefly adults **(Fig. 11)** and nymphs **(Fig. 12)** with the BioCover tankmix that increased with rate, though less with Ultrafine. There was no evidence of phytotoxicity at even the highest rate. The big surprise was evidence of enhanced pepper weevil control with the addition of oil. Less fruit infestation was seen on plants sprayed with tank mixes of Actara or Vydate with oil compared to Actara or Vydate alone, and most marketable fruit harvested from plants receiving the 0.5% rate of BioCover **(Fig.13)**.

In a trial conducted on tomato in Spring 2002 in Bradenton, the whitefly population was low early in the season but increased to a moderate level by about 9 weeks after transplanting. The standard in this trial was Admire 2F (16 oz; a registered nicotinoid insecticide) applied as a soil drench one day after transplanting followed by foliar sprays of Courier 70W (0.5 lb; a registered insect growth regulator) and then Knack 0.86EC (8.9 oz; a different registered insect growth regulator) when a threshold of 5 nymphs/10 leaflets was reached (one application each). Experimental insecticides Diamond 0.86EC (8 oz; a new insect growth regulator) and Oberon 240SC (8.5 oz; new insecticidal chemical class) were each applied twice foliarly based upon the above threshold following a soil application of Admire 2F @ 16 oz **(Table 2)**. Fewer whiteflies were seen on plants sprayed with either the Courier/Knack rotation, Diamond or Oberon compared to unsprayed plants, and were below the threshold about 10 days after the first application (Table 3). Plants sprayed eight times weekly with Endosulfan 3EC (21.4 oz; a registered organochlorine insecticide) or a combination of Ecozin 3%EC (8 oz; a registered neem product), Ultrafine Oil (0.5% v/v; a registered paraffinic oil), and Endosulfan 3EC (21.4 oz) had fewer nymphs than the check 9 weeks after transplanting and thereafter, although the numbers generally were not below the threshold. Counts of nymphs on plots sprayed with a Ecozin/Ultrafine Oil combination, PF-2000 (1% v/v; a detergent) or PREV-AM (0.8% v/v; an orange oil-based product) were statistically lower than those of non-treated plots on at least some dates, 8 weeks after transplanting, although counts were not below the threshold. Counts tended to be lower on PREV-AM treated plots, especially 11 and 12 weeks after transplanting.

In conclusion, we have seen that pesticides considered as “soft” actually vary greatly in selectivity to different groups of pest and beneficial insects and mites. Surfactants (primarily soaps and detergents) and high quality horticultural oils are effective against whitefly and other pests, although their efficacy depends greatly on coverage. However, they are inexpensive and so can be sprayed frequently. However, phytotoxicity could be a problem with frequent applications at rates of 1% or above, especially when temperatures are high (oil). Weekly applications at 0.5% have not caused significant phytotoxicity and have provided significant whitefly control, delayed onset of TYLCV in tomato, and reduced damage from pepper weevil in Jalapeño pepper.

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Table 1. LD-50 for rats and toxicity rating (0 to 16) of pesticides used in Florida tomato production to the lacewing *Crysopa carnea* and parasitic wasp *Encarsia formosa* (www.koppert.com).

Broad-Spectrum	LD-50 (mg/kg)	Crysopa	Encarsia
Capture (bifenthrin)	54	16	16
Lannate (methomyl)	17	16	14
IGRs			
Confirm (tebufenozide)	5,000	0	*
Courier (buprofezin)	2,198	*	1.5
Knack (pyriproxyfen)	3,773	0	4
Neem (azadirachtin)	5,000	1	2
Trigard (cyromazine)	3,387	6	0
Neonicotinoids			
Actara, Provado, Assail	1563,424,126	10	8
Platinum, Admire	1563,424	0	0
Miscellaneous			
B.t.	5,000	0	0
Oil (BioCover)	15,000	0	0
Soap (M-Pede)	16,900	6	4
Acramite (bifenazate)	5,000	0	0
Agri-Mek (abamectin)	10	3	6
Fulfill (pymetrozine)	5,820	0	0
SpinTor (spinosad)	3,783	5	*
Salt (NaCl)	3,000	*	*

*information not available

Table 2. Application schedule for insecticides applied to control the silverleaf whitefly on tomato, Fall 2003, GCREC-Bradenton.

	Rate	Soil	Date of application							
Treatment/	Amount/	application	60 gpa		90 gpa			120 gpa		
formulation*	acre	11 Sep	8 Oct	14 Oct	21 Oct	29 Oct	6 Nov	12 Nov	20 Nov	3 Dec
Admire 2F	16.0 oz	X								
then Courier 70W	0.5 lb								X	
then Knack 0.86EC	8.9 oz									X
Admire 2F	16.0 oz	X								
then Diamond 0.86EC	8.0 oz								X	X
Admire 2F	16.0 oz	X								
then Oberon 240SC	8.5 oz								X	X
Ecozin 3% EC	8.0 oz									
+ Ultrafine Oil	0.5% v/v		X	X	X	X	X	X	X	X
Ecozin 3% EC	8.0 oz									
+ Ultrafine Oil	0.5% v/v									
+ Endosulfan 3EC	21.4 oz		X	X	X	X	X	X	X	X
Endosulfan 3EC	21.4 oz		X	X	X	X	X	X	X	X
PF-2000	1.0% v/v		X	X	X	X	X	X	X	X
PREV-AM	0.8% v/v		X	X	X	X	X	X	X	X
Check	----									

* A "+" indicates that the products were combined.

Table 3. Control of the silverleaf whitely on tomato following soil and foliar applications of insecticides, Fall 2003, GCREC-Bradentor

Treatment/ formulation*	Amount/ acre	No. silverleaf whitefly nymphs/10 leaflets									
		13 Oct	20 Oct	27 Oct	3 Nov	11 Nov	17 Nov	24 Nov	1 Dec	8 Dec	Avg
Admire 2F then Courier 70W then Knack 0.86EC	16.0 oz 0.5 lb		2	<1	1	3	5	4	3	1	2
Admire 2F then Diamond 0.86EC	16.0 oz 8.0 oz	0	<1	<1	<1	1	6	6	4	4	2
Admire 2F then Oberon 240SC	16.0 oz 8.5 oz	0	2	2	<1	8	9	8	2	3	4
Ecozin 3% EC + Ultrafine Oil	8.0 oz 0.5% v/v	3	4	1	4	6	20	13	13	20	9
Ecozin 3% EC + Ultrafine Oil + Endosulfan 3EC	8.0 oz 0.5% v/v 21.4 oz	3	3	2	<1	3	7	7	6	12	5
Endosulfan 3EC	21.4 oz	2	1	1	1	4	5	9	3	11	4
PF-2000	1.0% v/v	8	5	2	9	11	23	16	14	14	10
PREV-AM	0.8% v/v	3	4	1	<1	5	28	13	6	9	7
Check	----	1	6	5	4	8	40	19	31	33	15
LSD $P = 0.05$	----	5	5	3	4	6	14	8	9	14	4

*A "+" indicates that products were combined.

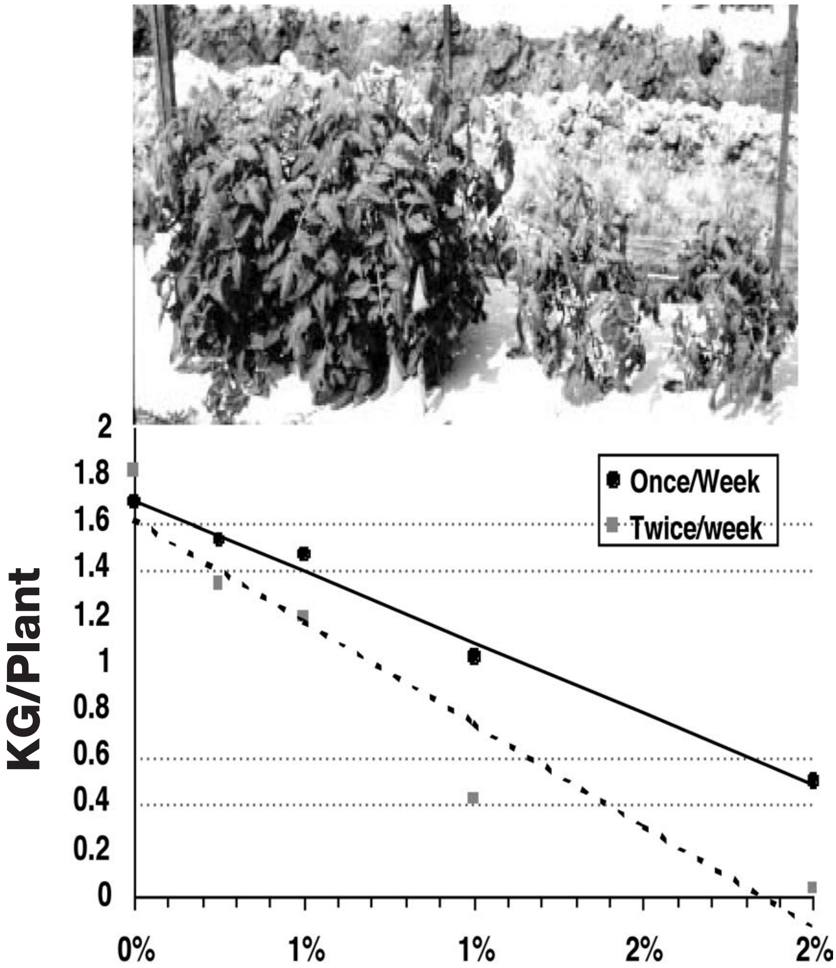


Fig.1. Effect of detergent sprays on tomato. A. Plants sprayed with water (left) or 2% v/v New Day Dish Detergent (right). B. Regression of yield at first harvest against rate of New Day.

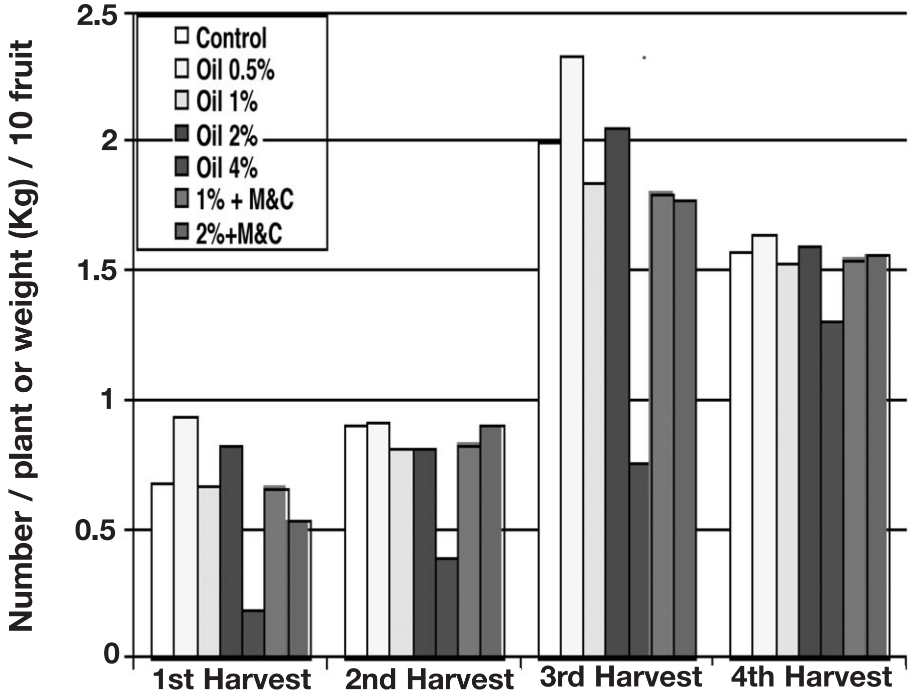
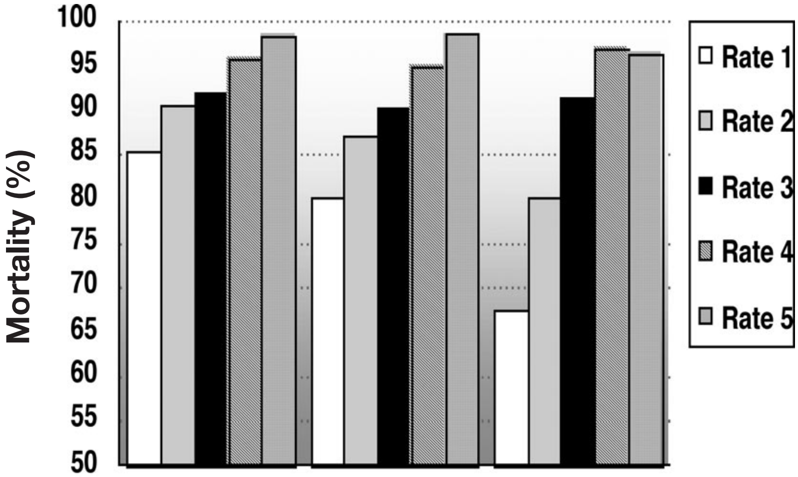


Fig. 2. Effect of Sunspray UltraFine Spray Oil alone or with Manzate and copper on yield of Bell pepper, (Vavrina, 1994)



Bifenthrin	Sunspray	M-Pede
0.15 ppm	0.2%	0.2%
0.3	0.5	0.5
0.6	1.0	1.0
1.2	2.0	2.0
2.4	3.0	3.0

Fig. 3. Contact toxicity of insecticides applied as a leaf dip to young nymphs of *B. tabaci*

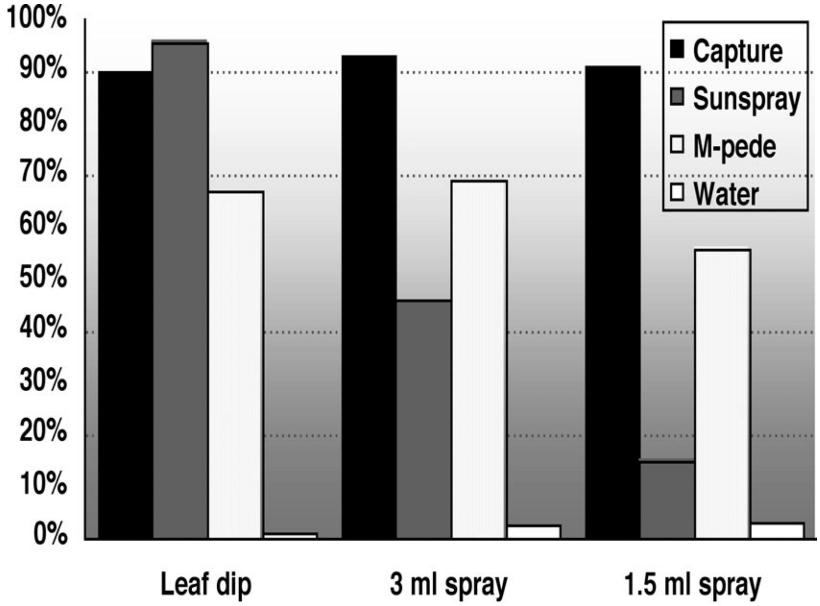


Fig. 4. Mortality to 1st Instar SLWF nymphs from pesticides applied by leaf-dip and Potter Tower spray in 3 ml or 1.5 ml volume, Capture @ 32 oz./100 gal, Sunspray and M-Pede @ 0.5%

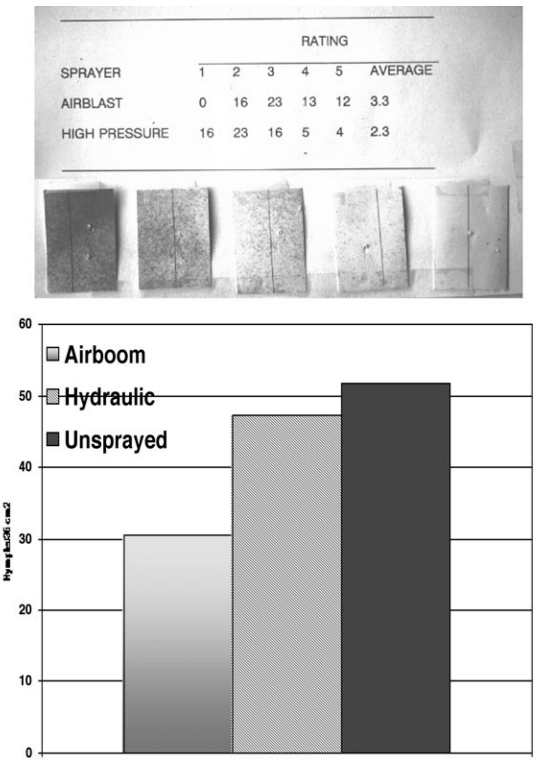


Fig. 5. Effect of sprayer type on coverage of water sensitive paper pinned to tomato leaf underside and whitefly control

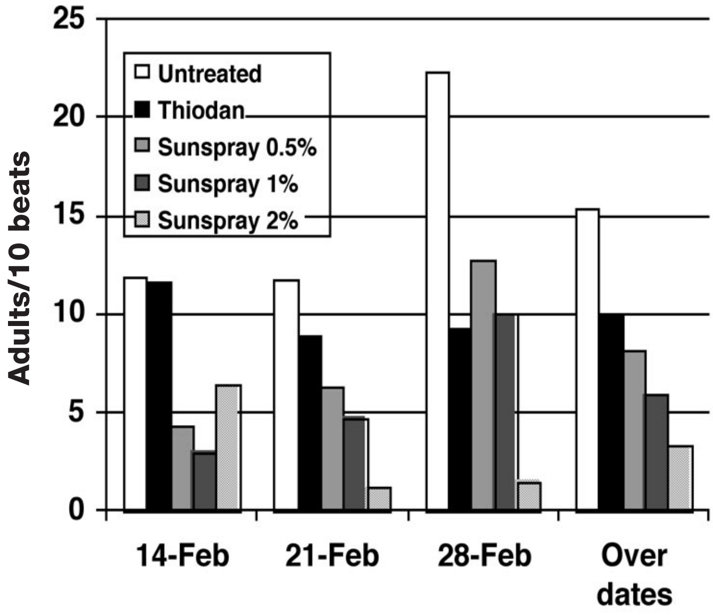


Fig. 6. Control of SLWF on commercial eggplant, Sinaloa, Mexico, 1997. Applications made with motorized air assisted backpack sprayers.

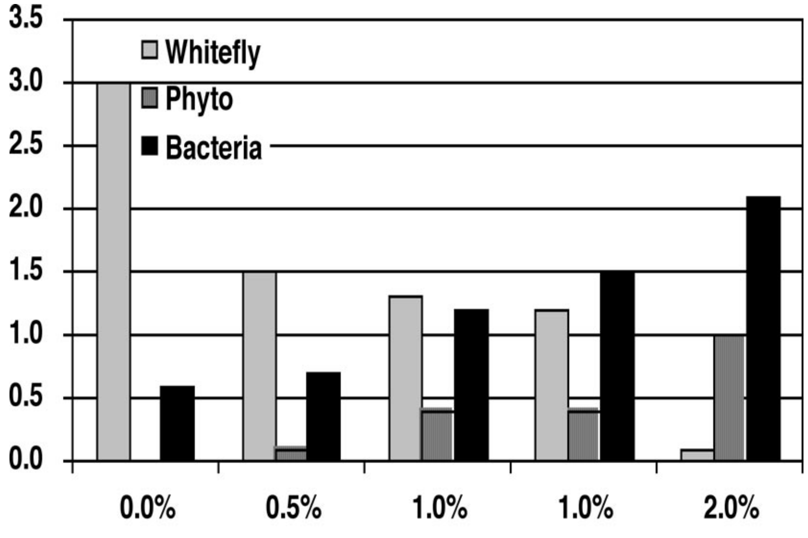


Fig. 7. Effect of BioCover oil concentration applied weekly alone or in combinationwith standard pesticides on incidence of SLWF, phytotoxicity rating and bacterial spot, Fall 2003. All treatments included Admire except for 2nd 1% oil.

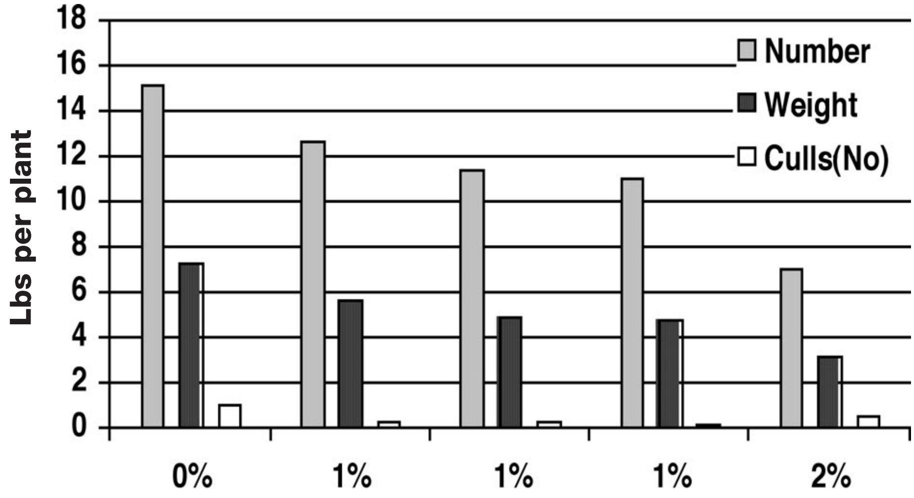


Fig. 8. Effect of concentration of BioCover Oil applied weekly alone or in combination with other pesticides on tomato yield, fall 2000.

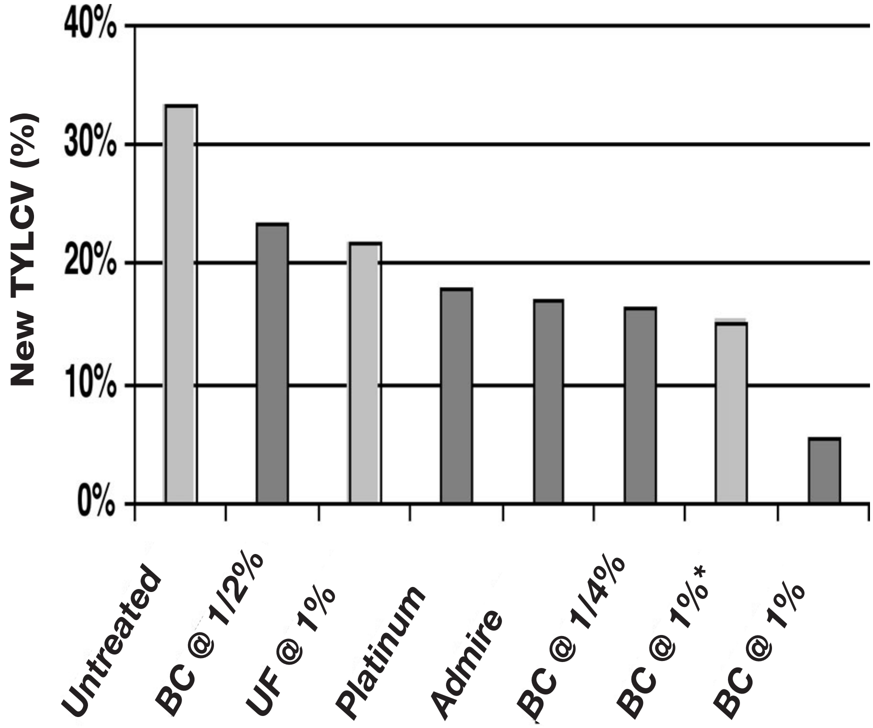


Fig. 9. Appearance of TYLCV symptomatic plants 26 Apr - 5 May, 5 weeks after transplanting. Solid bars indicate plants were drenched with neonicotinoid 1 day after planting. Plants sprayed weekly with BioCover or Sunspray Ultrafine as indicated.

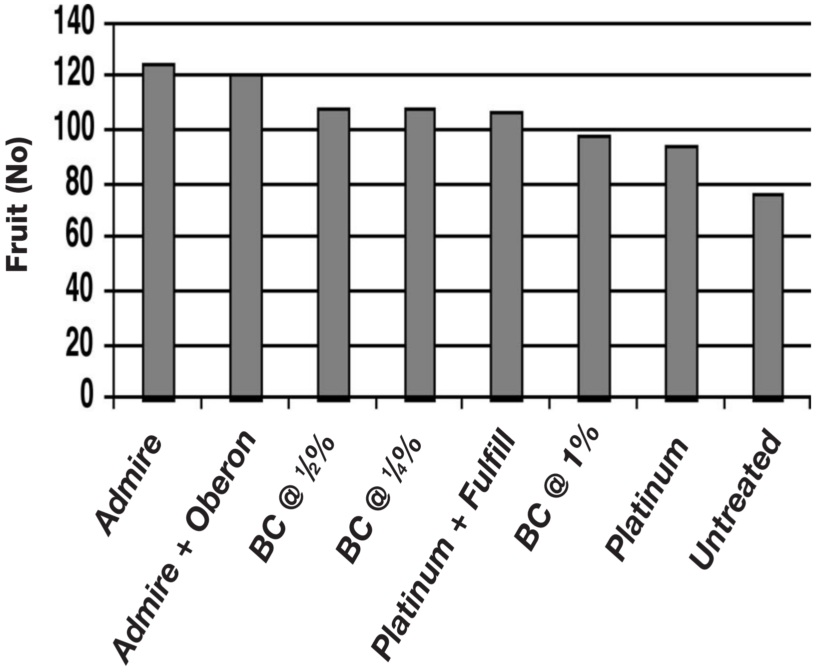


Fig. 10. Yield (fruit number per 20 tomato plants), spring 2004. All plants but control drenched with neonicotinoid 1 day after planting. Plants sprayed weekly with BioCover or Sunspray Ultrafine as indicated.

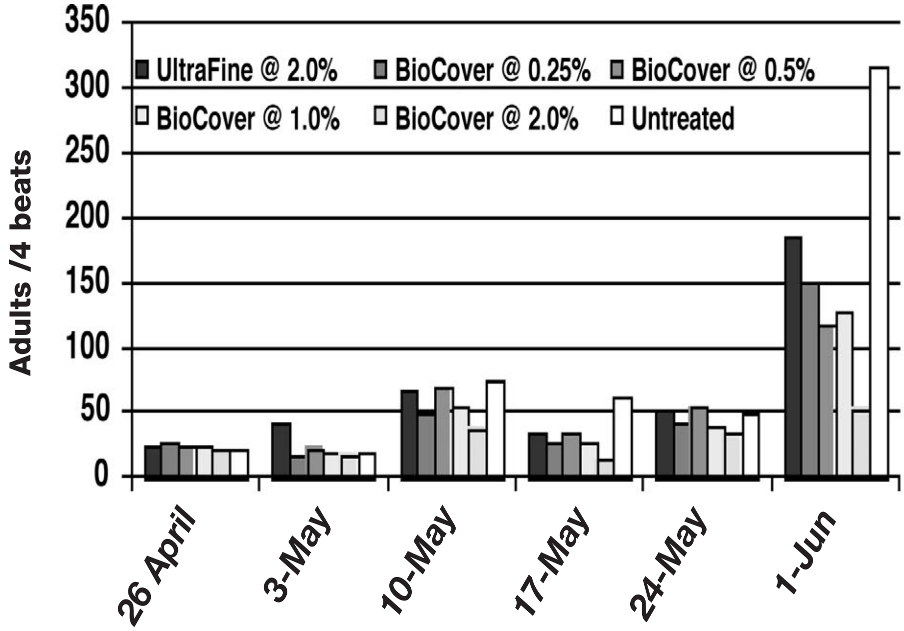


Fig. 11. Effect of weekly sprays of BioCover or UltraFine Oil tankmixed with a standard rotation of Actara (2 sprays) and Vydate (4 sprays) on adult SLWF. Jalapeño Pepper - spring 2004.

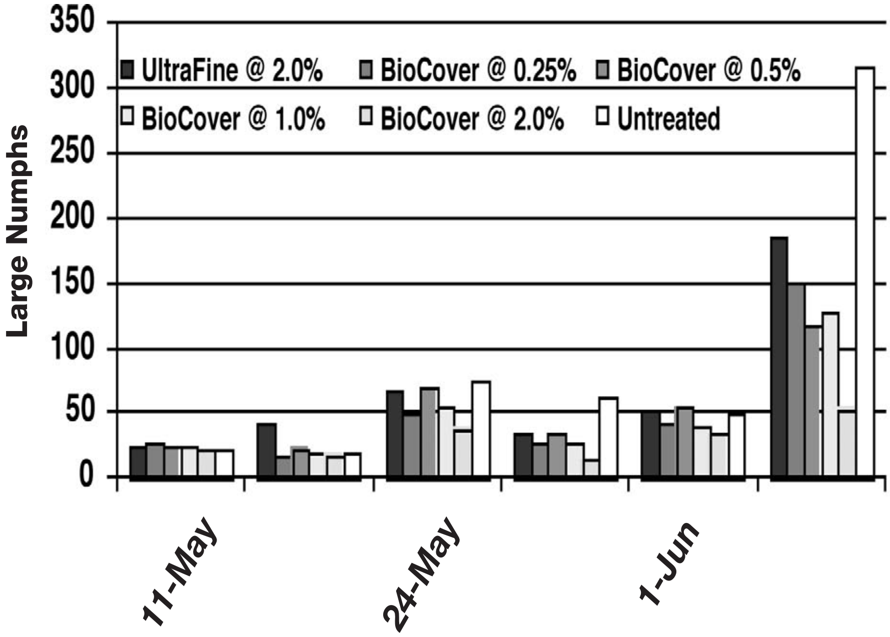


Fig. 12. Effect of weekly sprays of BioCover or UltraFine Oil on large nymph SLWF, Jalapeño Pepper - spring 2004.

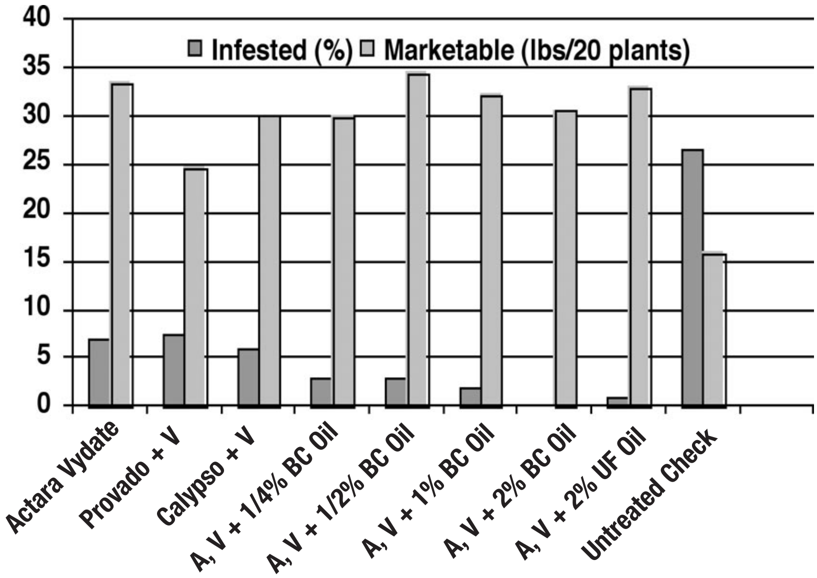


Fig. 13. Effect of weekly sprays of BioCover or UltraFine Oil on weevil infestation and yield in Jalapeño Pepper - spring 2004.

Emerging Viral Diseases of Tomato

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Tomato production losses due to viral diseases have been on the increase in tomato throughout the tropics and subtropics over the last 10 years. These new diseases have several causes. Some of them are new viruses ("New"), never recognized previously. Some are due to viruses whose incidence has increased over the last 10 to 15 years ("Emerging"). Some are due to viruses which have been present in a given area but whose importance has increased ("Re-emerging") due to changes in crop production practices or natural changes in the vector or virus. Some viral diseases are caused by viruses which have been known for a long time, but are still causing outbreaks ("Chronic/spreading"). **Table 1** lists several means by which viruses can change in their importance.

Although researchers can agree on the differences between what is a new virus and what is a re-emerging virus, there is sometimes very little agreement on which category to place a given virus. A survey of the four websites that list viruses of concern in tomato and the description of these viruses as to category is shown in **Table 2**. Begomoviruses are considered New and Emerging, and are the most frequent group of entries in the AgNIC/ProMED site concerned begomoviruses (55 reports), of which Tomato yellow leaf curl virus (TYLCV) was the most prominent single begomovirus mentioned. (The AgNIC/ProMED site is a collection of reports of outbreaks submitted by researchers and regulatory personnel. It is a good site to use for determining which viruses are spreading and sometimes is useful for estimating how big a concern a virus might be.) The next most frequently appearing virus is Pepino mosaic virus (PepMV) although it does not appear on any other website. PepMV could be considered an Emerging virus. Tomato spotted wilt virus (TSWV) is the third most frequent virus in the AgNIC/ProMED site and is listed as Emerging, Re-emerging, and Chronic. This probably reflects the difficulty in managing TSWV as well as its sporadic impact from year to year in any given location. The next most frequently appearing entries in the AgNIC/ProMED site are the Criniviruses – Tomato chlorosis virus and Tomato infectious chlorosis virus. These are considered New and Emerging viruses. Other viruses that appear on the sites are Cucumber mosaic virus (CMV) which is described as New and Re-emerging, and Potato spindle tuber viroid, which appears at low incidence and sporadically, and Tomato apical stunt viroid, which is a new viroid pathogen of tomato.

Begomoviruses, PepMV and the two Criniviruses are considered the most relevant for Florida growers and as such, are described below in more detail.

Selected Viruses of Concern

Begomoviruses. More than 50 begomoviruses are now known to naturally infect tomato. This is a tremendous increase from 1985 when only four were known. This represents a genuine increase in the number of epidemics caused by begomoviruses and the number of begomoviruses. In addition, there has been a movement of known begomoviruses from one location to another. For this reason begomoviruses are considered both New and Emerging viruses.

This increase in begomoviruses is due to several factors. One is the movement of a whitefly vector (*Bemisia tabaci* biotype B) that feeds and reproduces on tomato. The movement of this vector has two major implications. One, it allows the movement of viruses from weeds to tomatoes that did not previously have a whitefly vector that would feed on both the weed in question and tomatoes. And secondly this vector, since it feeds on so many different plants, can put different viruses in the same plant and the viruses can then have the opportunity to exchange genetic material and thereby create new viruses and new virus strains. This has been shown to have occurred in the case of cassava geminiviruses, and several tomato begomoviruses appear to be recombinants of at least two other begomoviruses. The movement of infected fruit, which can serve as sources of virus for whiteflies to infect healthy plants, presents further means of virus spread. Another possible reason is the movement of infected transplants. And a final reason is the possible movement of symptomless hosts (not tomato) or the movement of viruliferous whiteflies on non-host plants.

It is becoming clear that begomoviruses can occur in mixed populations. In Spain, three viruses and several strains are known to occur in tomato **(Table 3)**. In Florida, there are now three begomoviruses known to infect tomato, Tomato mottle virus, which appeared in the late 1980's, Tomato yellow leaf curl virus, which appeared in 1997, and Sida golden mosaic virus, which was first found in tomato in 2002. There is circumstantial evidence to suggest that Tomato mottle virus came from a weed, and there is strong evidence that Sida golden mosaic virus came from the weed Sida acuta. Tomato yellow leaf curl virus was moved from the eastern Mediterranean in infected but symptomless tomato transplants. Based on these and other examples, it is expected that more begomoviruses will appear in tomato and other Florida crops in the future.

Pepino mosaic virus PepMV (Potexvirus). PepMV is a highly contagious virus. It is seed-transmitted, and very easily mechanically transmitted on tools, shoes, clothing, hands, pinching, grafting, and by plant-to-plant contact. While a high density of bumblebees has been associated with the spread of PepMV in greenhouses, the risk of spreading the virus via hand pollination is probably much greater. PepMV is spread over long distances by the transportation of infected tomato fruit and contaminated seed.

PepMV causes symptoms in both tomato fruit and foliage. Fruit from infected plants show irregular ripening in streaks and patches. Foliage can show a variety of symptoms from a few small irregular spots, to chlorosis between the veins, to chlorotic leaf margins, to bunchy tops. This virus has also been implicated in a die-back disease of tomato in southeastern Spain. Estimates of yield losses range from less than 10% to 40%.

PepMV was first reported in 1974 from infected pepino plants (*Solanum muricatum*) in Peru. Then in 1999 the virus was found on greenhouse tomato crops in the Netherlands. From 2000 to the present the virus has appeared sporadically in Germany, the United Kingdom, France and Italy, and annually in Spain. In the Western Hemisphere the virus was reported in Canada (Ontario) in 2000 and in British Columbia in 2002. The virus is probably present in the U.S. since in 2000 the virus was detected in fruit shipped to Canada which were produced in Arizona, Colorado, and Texas. It has not been reported from Florida, yet.

The virus is managed in Europe through eradication using very strict phytosanitary procedures and quarantines. In the field PepMV virus would be managed very much like TMV with great care being taken to stop plant to plant spread and to purchase virus-free transplants. To produce PepMV-free transplants, transplant producers would have to follow guidelines similar to those used to prevent the introduction of Tomato mosaic virus.

Tomato Chlorosis Virus (ToCV) and Tomato Infectious Chlorosis Virus (TICV). ToCV and TICV are whitefly-transmitted Criniviruses. They are considered New and Emerging viruses since they were not discovered until the 1990's and since their discovery has been reported to occur in several locations around the world.

ToCV and TICV cause identical symptoms on tomato which are interveinal yellowing of middle and older leaves, and an increase in the stiffness of older leaves. Symptomatic leaves may also show bronzing along with the chlorosis. Neither of these viruses is known to cause any symptoms in tomato fruit. It is not clear what effects ToCV has on tomato yields, but TICV has caused significant yield losses ($2 million in 1993, Orange Co. California).

There are differences in the ability of whiteflies to vector these two viruses. **Table 4** shows that both viruses are transmitted by the greenhouse whitefly (*Trialeurodes vaporariorum)*, but only ToCV is transmitted by *Bemisia tabaci* and the banded-wing whitefly (*Trialeurodes abutilonea*). Both viruses are transmitted in a semi-persistent manner which means the whitefly can acquire the virus within a few minutes and can only transmit the virus for 2 to 3 days before the transmissibility is lost.

Epidemics of ToCV and TICV are always associated with high populations of whiteflies, however not always the same whitefly. So epidemics of TICV are always associated with high populations of the greenhouse whitefly, whereas epidemics of ToCV have been associated with high populations of the greenhouse whitefly, the silverleaf whitefly, and/or the banded-wing whitefly.

Both viruses have become widespread over the last 10 years and are continuing to appear in new areas in the tropics and subtropics. ToCV was found in Florida in the early 1990's and is seen each year in tomato fields. TICV has never been found in Florida.

The reasons for this increase are the movement of an efficient vector (the silverleaf whitefly), the movement of infected tomato transplants, and the movement of symptomless but infected plant hosts or the movement of host plants that are infested with whiteflies carrying the viruses.

Summary

It is likely that Florida, like many of the other tomato production regions in the subtropics and tropics, will continue to be affected by new viruses as well as by established ones. For many of these viruses, resistant cultivars will be a solution, but there will be a lag time between the appearance of a new virus and the development of resistant cultivars. In the interim, fast response to new introductions by regulatory personnel and university researchers, and the rapid development of cultural and chemical management practices will allow growers to produce crops in this threatening and dynamic environment.

Table 1. Conditions that Can Give Rise to the Emergence of New Viral Diseases:

No.	CONDITION	EXAMPLES OF TOMATO VIRUSES
1	Ecological or social changes bring plant species into contact with unknown vector or viruses.	Begomoviruses, ToCV, TICV
2	New habitats are created which permit a rare or remote virus to become abundant and in contact with plants.	Begomoviruses, ToCV, TICV
3	The virus is introduced into previously unexposed populations.	Begomoviruses, ToCV, TICV
4	Population movements bring non-resistant plant populations in contact with populations that harbor viruses without severe morbidity.	Begomoviruses, CMV
5	Plant populations become more vulnerable to virus infection through malnutrition or environmental stresses.	
6	Viruses can spill over from other species.	PepMV, TSWV
7	Viruses can 'evolve' towards greater virulence.	TSWV
8	Mixed virus communities allow for recombination creating new strains or new viruses.	Begomoviruses
9	Bio-engineered organisms escape or are released into the environment and evolve.	None known

Table 2. Viruses of Concern for Tomato Production in the U.S.

VIRUS	AgNIC/ ProMED[1]	NCSU[2]	PLANT DISEASE 1999 Feature Article[3]	APHIS-PPQ[4]
Begomoviruses	~ 55	E, N	E	-
Pepino mosaic virus (PepMV)	~ 15	-	-	-
Tomato spotted wilt virus (TSWV)	~10	E, C	R	-
Tomato chlorosis virus	~8	-	N, E	-
Tomato infectious chlorosis virus	~5	N	N, E	-
Potato spindle tuber viroid (PSTVd)	~3	-	-	-
Tomato apical stunt viroid (TASVd)	1	-	-	-
Cucumber mosaic virus (CMV)	0	N/R	-	-

N = New, E = Emerging, C = Chronic, spreading, R = Re-emerging.

[1] Agriculture Network Information Center (AgNIC) in collaboration with ProMED (http://laurel.nal.usda.gov:8080/agnic/pmp/alpha.html)
[2] North Carolina State University, *New and Emerging Plant Diseases Project* (http://www.ces.ncsu.edu/depts/ent/clinic/Emerging/vhost.htm)
[3] APS Feature Article PLANT DIS 1999 (http://www.apsnet.org/online/feature/NewViruses/Top.html)
[4] APHIS-PPQ Pest Det. & Mgmt. Prog., Emerg. Pest Issues (http://laurel.nal.usda.gov:8080/agnic/pmp/alpha.html)

Table 3. Diversity of Begomoviruses in a single tomato production region in Spain.

Virus	Strains
Tomato yellow leaf curl virus (TYLCV)	TYLCV
	TYLCV-Mld
Tomato yellow leaf curl Malaga virus (TYLCMalV)	None known
Tomato yellow leaf curl Sardinia virus (TYLCSV)	TYLCSV-Spain [1]
	TYLCSV-Spain [2]
	TYLCSV-Sic

Table 4. Ability of *Tomato chlorosis virus* and *Tomato infectious chlorosis virus* to be transmitted by three different whiteflies.

Whitefly	Virus Transmitted	
	ToCV	TICV
Greenhouse whitefly	yes	yes
Banded-wing whitefly	yes	no
Silverleaf whitefly	yes	no

CONTROL GUIDES

Tomato Varieties for Florida

Stephen M. Olson[1], Donald N. Maynard[2]

[1]UF/IFAS, North Florida Research & Education Center, Quincy; [2]UF/IFAS, Gulf Coast Research and Education Center, Bradenton

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 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

Summary results listing the five highest yielding and the five largest fruited varieties from trials conducted at the University of Florida's Gulf Coast Research and Education Center, Bradenton; and North Florida Research and Education Center, Quincy for the Spring 2003 season are shown in **Table 1**. High total yields and large fruit size were produced by Fla. 8092, Solar Fire and FL 91 at Bradenton. There was very little overlap between locations. The same entries were not included at both locations.

Table 2 shows a summary of results listing the five highest yielding and five largest fruited entries from trials at the University of Florida's Indian River Research and Education Center, Ft. Pierce and the North Florida Research and Education Center, Quincy for the fall 2003 season. High total yields and large fruit size were produced by Fla. 8092, Solar Fire, and FL 91 at Fort Pierce. Solar Fire produced high yields at both locations and Fla. 8092 produced large fruit at both locations. Not all entries were included at all locations.

Tomato Varieties For Commercial Production

The varieties listed have performed well in University of Florida trials conducted in various locations in recent years.

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 and 3), root-knot nematode, gray leaf spot and Tomato Spotted Wilt. For Trial. (Harris Moran).

BHN 640. Early-midseason maturity. Fruit are globe shape but tend to slightly elongate, and green shouldered. Not for fall planting. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1, 2 and 3), gray leaf spot, and Tomato Spotted Wilt. For Trial. (BHN).

HA 3073. A midseason, determinate, jointed hybrid. Fruit are large, firm, slightly oblate and are uniformly green. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), gray leaf spot, Tomato Yellow Leaf Curl Virus and Tomato Mosaic Virus. For Trial. (Hazera)

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

Sebring. A late midseason determinate, jointed hybrid with a smooth, deep oblate, firm, thick walled fruit. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1, 2 and 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. For Trial. (University of Florida)

Solar Set. An early, green-shouldered, jointed hybrid. Determinate. Fruit set under high temperatures (92°F day/72°night) is superior to most other commercial varieties. Resistant: Fusarium wilt (race 1 and 2), Verticillium wilt (race 1), Alternaria stem canker, and gray leaf spot. (Seminis).

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).

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 Virus and Tomato Yellow Leaf Curl Virus. For Trial. (Seminis).

Plum Type Varieties

Marina. Medium to large vine determinate hybrid. Rectangular, blocky, fruit may be harvested mature green or red. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), Alternaria stem canker, root-knot nematodes, gray leaf spot, and bacterial speck. (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).

Spectrum 882. Blocky, uniform-green shoulder fruit are produced on medium-large determinate plants. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), root-knot nematode, bacterial speck, Alternaria stem canker, and gray leaf spot. (Seminis).

Supra. Determinate hybrid rectangular, blocky, shaped fruit with uniform green shoulder. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), root-knot nematodes, and bacterial speck. (Syngenta).

Veronica. Tall, determinate hybrid. Smooth plum type fruit are uniform ripening. Good performance in all production seasons. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), Alternaria stem canker, nematodes, gray leaf spot and bacterial speck. (Sakata).

Cherry Type Varieties

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). For trial. (Syngenta).

Cherry Grande. Large, globe-shaped, cherry-type fruit are produced on medium-size determinate plants. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1), Alternaria stem blight, and gray leaf spot. (Seminis).

Grape Tomatoes

Grape tomatoes are elongated cherry type tomatoes with very sweet fruit and fruit length about twice that of the diameter. The fruit usually range in weigh from 0.2 to 0.5 grams/ft. The plant habit and fruit flavor are very similar to Sweet 100 and Sweet Million, two old indeterminate cherry varieties. These varieties had limited commercial use due to plant growth habit and severe fruit cracking. The original ‘grape’ tomato variety was Santa, a high quality indeterminate variety. Santa is a proprietary variety and has limited availability. St. Nick is another indeterminate variety that is available. There are also available several new indeterminate varieties available but information is limited. Also on the market are several determinate varieties such as Sweet Olive and Jolly Elf, but flavor is not as good as the older indeterminates. There are also new yellow and pink varieties available. Most of the grape varieties are fairly resistant to fruit cracking.

Reference

This information was gathered from results of tomato variety trials conducted during 2003 at locations specified in each table.

Tomato variety evaluations were conducted in 2003 by the following University of Florida faculty:

D. N. Maynard, Gulf Coast Research & Education Center–Bradenton.

S. M. Olson, North Florida Research & Education Center – Quincy

P. J. Stoffella, Indian River Research & Education Center–Fort Pierce.

Table 1. Summary of University of Florida tomato variety trial results. Spring 2003.

Location	Variety	Total yield (ctn/acre)	Variety	Average fruit wt. (oz)
Bradenton	Fla. 8135	3223	HA-3072	8.2
	TY02-1276	3036	TY02-1276	8.0
	XTM 0233	3035	HA-3603	7.9
	Fla. 8093	3023	HA-3073	7.8
	ACR 2012	2807[1]	EX 2427	7.7[2]
Quincy	Fla. 8135	2724	Fla. 8092	7.5
	SVR 8383	2665	Biltmore	7.3
	SVR 7421	2505	SVR 8383	7.2
	NC 0227	2426	XTM 0231	7.2
	NC 0236	2400[3]	Amelia	7.1[4]

[1] 21 other entries had yields similar to ACR 2012.
[2] 10 other entries had fruit weight similar to EX 2427.
[3] 23 other entries had yields similar to NC 0236.
[4] 7 other entries had fruit weight similar to Amelia.

Seed Sources:

Abbott & Cobb: ACR 2012.
Hazera: TY02-1276, HA-3072, HA-3073, HA-3603.
Harris Moran: Amelia.
North Carolina State: NC 0227, NC 0236.
Seminis: Biltmore, EX 2427, SVR 7421, SVR 8383.
Sakata: XTM 0231, XTM 0233.
University of Florida: Fla. 8092, Fla. 8093, Fla. 8135..

Table 2. Summary of University of Florida tomato variety trial results. Fall 2003.

Location	Variety	Total yield (ctn/acre)	Variety	Average fruit wt. (oz)
Fort Pierce	Fla. 8135	1699	FL 91	7.5
	Fla. 8092	1548	Fla. 7973	6.8
	Solar Fire	1496	FL 47	6.7
	Fla. 8093	1486	Fla. 8092	6.5
	FL 91	1481[1]	Solar Fire	6.1[2]
Quincy	Fla. 8093	3147	Amelia	6.8
	Fla. 7964	2700	Soraya	6.5
	Solar Fire	2632	Sebring	6.4
	RFT 2103	2604	Fla. 8092	6.2
	SVR 8383	2581[3]	SVR 8152	6.2[4]

[1] 5 other entries had yields similar to FL 91.
[2] 5 other entries had fruit weight similar to Solar Fire.
[3] 21 other entries had yields similar to SVR 8383.
[4] 11 other entries had fruit weight similar to SVR 8152.

Seed Sources:

Harris Moran: Amelia, Solar Fire.
Seminis: FL 47, FL 91, SVR 8152, SVR 8383.
Syngenta: Sebring, Soraya, RFT 2103.
University of Florida: Fla. 7964, Fla. 7973, Fla. 8092, Fla. 8093, Fla. 8135.

Water Management For Tomato

Eric Simonne

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Approximately 45,000 acres of tomatoes were harvested in Florida during the 2002-2003 growing season. The value of the fresh-market tomato crop that year was estimated at slightly above $508 million (USDA, National Agricultural Statistics Service, Vegetable Summary: http://jan.mannlib.cornell.edu/reports/nassr/fruit/pvg-bban/vgan0103.txt). The main areas of production are Gadsden County (Quincy), Manatee County (Palmetto-Ruskin), Hendry County (southeast coast), Palm Beach County (southwest coast), and Dade County (Homestead). Production started in Suwannee county (Live Oak) in 2001 and has increased since then. Most of the tomato acreage today uses plasticulture (raised beds, polyethylene mulch and drip irrigation) Some tomatoes are still grown with polyethylene mulch and seepage irrigation.

Water and nutrient management are two important aspects of tomato production in all these 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 in Florida. Recommendations in this article should be considered together with those presented in the 'Fertilizer and nutrient management for tomato', also included in this publication.

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

A wide range of irrigation scheduling methods is used in Florida, with corresponding levels of water management **(Table 1)**. The recommended method to schedule irrigation for tomato is to use 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**). 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 called 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 2)** 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 3)**. 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 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 or wind drift of spray droplets, leaks in the pipe system, surface runoff, subsurface runoff, or deep percolation within the irrigated area. Tomato irrigation requirement is determined by dividing the desired amount of water to provide to the plant (ETc), by Ea as a decimal fraction (Eq. [2]).

Eq. [2] Irrigation requirement =
Crop water requirement / Application efficiency IR = ETc/Ea

In areas where real-time weather information is not available, growers use the '1,000 gal/acre/day/string' rule for drip-irrigated, winter 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/100 lbf/ day and 60 gal/100 lbf/day for 1 and 4 strings, respectively.

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). 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 depths is useful to understand the dynamics of soil moisture. When both SWT are within the 4-8 cb range (close to field capacity), this means that moisture is plentiful in the rooting zone. This may happen after a large rain, or when tomato water use is less than irrigation applied. When the 6-in SWT increases (from 4-8 cb to 10-15cb) while SWT at 12-in remains within 4-8, the upper part of the soil is drying, and it is time to irrigate. If the 6-in SWT continues to raise (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 within 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

Time 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 ($500 to $700/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 gravely soils of Miami-Dade County.

The advantage of TDR is that probes need not be buried permanently, and readings are available instantaneously. This means that, unlike the tensiometer, TDR can be used as a hand-held, portable tool. As the potential use of TDR as an on-farm tool for scheduling irrigation for vegetables is still under evaluation, it should be used cautiously.

TDR actually determines percent soil moisture (volume of water : volume of soil). In theory, a soil water release curve has to be used to convert soil moisture into SWT. However, because TDR provides an average soil moisture reading over the entire length of the rod (as opposed to the specific depth used for tensiometers), it is not practical to simply convert SWT into soil moisture to compare readings from both methods. 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 4). 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 volume of an irrigation exceeds the values in table 4, then irrigation should be split. Splitting will not only reduce nutrient leaching, 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 45,560/6). 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 ½ hours to apply 75 gallons. The total volume applied will be 8,168 gallons/2-acre (75 x 108.9).

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 procedures
5	Recommended	Using together a water use estimate based on tomato plant stage of growth, a measurement of soil water moisture, and a guideline for splitting irrigation

Table 2. Crop coefficient estimates (Kc) for tomato[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)

Table 3. Historical Penman-method reference ET (ETo) for four Florida locations (in gallons per acre per day) .

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

[z] Assuming water application over the entire area, i.e., sprinkler or seepage irrigation with 100% efficiency.

Table 4. 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

Fertilizer and Nutrient Management For Tomato

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

Calibrated Soil Test: Taking the Guesswork Out of Fertilization

Prior to each cropping season, soil tests should be conducted to determine fertilizer needs and eventual pH adjustments. Obtain a UF/IFAS soil sample kit from the local agricultural Extension agent 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-K_2O) 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 produced on 6-ft centers. Under these conditions, there are 7,260 linear feet of tomato row in an acre. When different row spacings are used or when a significant number of drive rows are left unplanted, it is necessary to adjust fertilizer application accordingly.

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 1-acre tomato field planted on 7-ft centers with one drive row every six rows, there are only 5,333 lbf (6/7 x 43,560 / 7). If the recommendation is to inject 10 lbs of N per acre (standard spacing), this becomes 10 lbs of N/7,260 lbf or 0.14lbs N/100 lbf. Since there are 5,333 lbf/acre in this example, then the adjusted rate for this situation is 7.46 lbs N/acre (0.14 x 53.33). In other words, an injection of 10 lbs of N to 7,260 lbf is accomplished by injecting 7.46 lbs of N to 5,333 lbf.

Liming

The optimum pH range for tomatoes is 6.0 and 6.5. This is the range for 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 corrected according to the soil test. If both elements are "low", and lime is needed, then broadcast and incorporate dolomitic limestone. Where calcium alone is deficient, lime with "hi-cal" limestone. 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 with the fertilizer.

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 lime are more expensive than the traditional liming materials, and therefore are not routinely used.

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

Fertilizer-Related Physiological Disorders

Blossom-End Rot. At certain times, growers have problems with blossom-end-rot, especially on the first or second fruit clusters. Blossom-end rot (BER) is basically 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 in the plant occurs with the water (transpiration) stream. 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. High total fertilizer increases the salt content and osmotic potential in the soil reducing the ability of roots to obtain water, and high N increases leaf and shoot growth to which Ca preferentially moves, by-passing fruits.

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 formally 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 virgin, acidic sandy soils, 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. More information on micronutrient use is available from the suggested literature list.

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

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

1.) Land preparation, including development of irrigation and drainage systems, and liming of the soil, if needed;

2.) Application of "starter" fertilizer or "in-bed" mix. This should comprise only 10 to 20 percent of the total nitrogen and potassium seasonal requirements and all of the needed phosphorus and micronutrients. Starter fertilizer 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 "modified broadcast" technique for systems with wide bed spacings. Use of modified broadcast or banding techniques can increase phosphorus and micronutrient efficiencies, especially on alkaline (basic) soils;

3.) Formation of beds, incorporation of herbicide, and application of mole cricket bait;

4.) Application of remaining fertilizer. The remaining 80 to 90 percent of the nitrogen and potassium is placed in narrow bands 9 to 10 inches to each side of the plant row in furrows. The 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; and,

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/or tensiometers 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.

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, prior to mulching. 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 percent 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 should be considered ammoniacal nitrogen when calculating the total amount of ammoniacal nitrogen applied.

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 tomatoes. 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.

Analysis of tomato leaves for mineral nutrient content can help guide a fertilizer management program during the growing season or assist in diagnosis of a suspected nutrient deficiency. Tissue nutrient norms are presented in **Table 2**. Growers with drip irrigation can obtain faster analyses for N or K by using a plant sap quick test. Several kits have been calibrated for Florida tomatoes. Interpretation of these kits is provided in **Table 3**.

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

Supplemental Fertilizer Applications

In practice, supplemental fertilizer applications allow vegetable growers to numerically apply fertilizer rates higher than the standard UF/IFAS recommended rates when growing conditions require to do so. The two main growing conditions that may require supplemental fertilizer applications are leaching rains and extended harvest periods. Applying additional fertilizer under the three circumstances described in **Table 1** is part of the current UF/IFAS fertilizer recommendations and proposed fertilizer 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 requires management levels of 3 or above **(Table 4)**.

Suggested Literature

Florida Department of Agriculture and Consumer Services. 2003. Florida Vegetable and Agronomic Crop Water Quality and Quantity BMP Manual.
http://www.floridaagwaterpolicy.com/PDFs/BMPs/vegetable&agronomicCrops.pdf

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.

Hochmuth, G. J. and E. A. Hanlon. 2000. IFAS standardized fertilization recommendations for vegetable crops. Univ. Fla. Coop. Ext. Circ. 1152, http://edis.ifas.ufl.edu/cv002

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

Production system	Nutrient	Recommended base fertilization[z]							Recommended supplemental fertilization[z]		
		Total (lbs/A)	Preplant[y] (lbs/A)	Injected[x] (lbs/A/day) Weeks after transplanting[w]					Leaching rain[r,s]	Measured 'low' plant nutrient content[u,s]	Extended harvest season[s]
				1-2	3-4	5-11	12	13			
Drip irrigation, raised beds, and polyethylene mulch	N	200	0-70	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	0-70	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 (K_2O).
[y] applied using the modified broadcast method (fertilizer is broadcast where the beds will be formed only, and not over the entire field). Preplant fertilizer cannot be applied to double/triple crops because of the plastic mulch; hence, in these cases, all the fertilizer has to be injected.
[x] This fertigation schedule is applicable when no N and K_2O are applied preplant. Reduce schedule proportionally to the amount of N and K_2O applied preplant. Fertilizer injections may be done daily or weekly. Inject fertilizer at the end of the irrigation event and allow enough time for proper flushing afterwards.
[w] For a standard 13 week-long, transplanted tomato crop.
[v] Some of the fertilizer may be applied with a fertilizer wheel though the plastic mulch during the tomato crop when only part of the recommended base rate is applied preplant. Rate may be reduced when a controlled-release fertilizer source is used.
[u] Plant nutritional status may be determined with tissue analysis or fresh petiole-sap testing, or any other calibrated method. The 'low' diagnosis needs to be based on UF/IFAS interpretative thresholds.
[t] Plant nutritional status must be diagnosed every week to repeat supplemental application.
[s] Supplemental fertilizer applications are allowed when irrigation is scheduled following a recommended method. Supplemental fertilization is to be applied in addition to base fertilization when appropriate. Supplemental fertilization is not to be applied 'in advance' with the preplant fertilizer.
[r] A leaching rain is defined as a rainfall amount of 3 inches in 3 days or 4 inches in 7 days.
[q] Supplemental amount for each leaching rain
[p] Plant nutritional status must be diagnosed after each harvest before repeating supplemental fertilizer application.

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

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

[z]MRM=Most recently matured leaf.

Table 3. Recommended nitrate-N and K concenrations 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

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

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

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

Weed Control in Tomato

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

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

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

Certainly fence rows and areas around buildings and pumps should be kept weed-free, if for no other reason than safety. Herbicides can be applied in these situations, provided care is exercised to keep 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 build up on the rye, contact herbicide can be applied to kill it and eliminate it as a host, yet the remaining stubble could continue serving as a windbreak.

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

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

Chemical weed control: Tomatoes.

Herbicide	Labeled Crops	Time of Application to Crop	Rate (lbs. AI./Acre) Mineral	Muck
Clethodem (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.				
Diquat (Reglone)	Tomato Vine Burndown	After final harvest	0.375	---
Remarks: Special Local Needs (24c) label for use for burndown of tomato vines after final harvest. Applications of 1.5 pts. material per acre in 60 to 120 gals. of water is labeled. Add 16 to 32 oz. of Valent X-77 spreader per 100 gals. of spray mix. Thorough coverage of vines is required to insure maximum burndown.				
Diquat dibromide (Reglone)	Tomato	Pretransplant Postemergence directed-shielded in row middles	0.5	---
Remarks: Diquat can be applied as a post-directed application to row middles either prior to transplanting or as a post-directed hooded spray application to row middles when transplants are well established. Apply 1 qt of Diquat in 20-50 gallons of water per treated acre when weeds are 2-4 inches in height. Do not exceed 25 psi spray pressure. A maximum of 2 applications can be made during the growing season. Add 2 pts non-ionic surfactant per 100 gals spray mix. Diquat will be inactivated if muddy or dirty water is used in spray mix. A 30 day PHI is in effect. Label is a special local needs label for Florida only.				
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.				

Chemical weed control: Tomatoes.

<table>
<tr><th rowspan="2">Herbicide</th><th rowspan="2">Labeled Crops</th><th rowspan="2">Time of Application to Crop</th><th colspan="2">Rate (lbs. AI./Acre)</th></tr>
<tr><th>Mineral</th><th>Muck</th></tr>
<tr><td>MCDS (Enquik)</td><td>Tomatoes</td><td>Postemergence directed/shielded in row middle</td><td>5 - 8 gals.</td><td>---</td></tr>
<tr><td colspan="5">Remarks: Controls many emerged broadleaf weeds. Weak on grasses. Apply 5 to 8 gallons of Enquik in 20 to 50 gallons of total spray volume per treated acre. A non-ionic surfactant should be added at 1 to 2 pints per 100 gallons. Enquik is severely corrosive to nylon. Non-nylon plastic and 316-L stainless steel are recommended for application equipment. Read the precautionary statements before use. Follow all restrictions on the label.</td></tr>
<tr><td>S-Metolachlor (Dual Magnum)</td><td>Tomatoes</td><td>Pretransplant Row middles</td><td>1.0 - 1.3</td><td>---</td></tr>
<tr><td colspan="5">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.</td></tr>
<tr><td>Metribuzin (Sencor DF) (Sencor 4)</td><td>Tomatoes</td><td>Postemergence Posttransplanting after establishment</td><td>0.25 - 0.5</td><td>---</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>Metribuzin (Sencor DF) (Sencor 4)</td><td>Tomatoes</td><td>Directed spray in row middles</td><td>0.25 - 1.0</td><td>---</td></tr>
<tr><td colspan="5">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.</td></tr>
<tr><td>Napropamid (Devrinol 50DF)</td><td>Tomatoes</td><td>Preplant incorporated</td><td>1.0 - 2.0</td><td>---</td></tr>
<tr><td colspan="5">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.</td></tr>
</table>

Chemical weed control: Tomatoes.

Herbicide	Labeled Crops	Time of Application to Crop	Rate (lbs. AI./Acre) Mineral	Muck
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)	Tomatoes	Fallow bed	0.25 - 0.5	
Remarks: Must have a 30 day treatment-planting interval. Apply as a preemergence broadcast or banded treatment at 1-2 pt/A to preformed beds. Mulch may be applied any time during the 30-day interval.				
Paraquat (Gramoxone Extra) (Gramoxone Max)	Tomatoes	Premergence; Pretransplant	0.62 - 0.94	---
Remarks: Controls emerged weeds. Use a non-ionic spreader and thoroughly wet weed foliage.				
Paraquat (Gramoxone Extra) (Gramoxone Max)	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 Extra) (Gramoxone Extra)	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.				

Chemical weed control: Tomatoes.

Herbicide	Labeled Crops	Time of Application to Crop	Rate (lbs. AI./Acre) Mineral	Muck
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) (Trilin) (Trilin 10G) (Trifluralin 480) (Trifluralin 4EC) (Trifluralin HF)	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.				
Trifluralin (Treflan HFP) (Treflan TR-10) (Trilin) (Trilin 10G) (Trifluralin 480) (Trifluralin 4EC) (Trifluralin HF)	Direct-Seeded tomatoes (except Dade County)	Post directed	0.5	---
Remarks: For direct-seeded tomatoes, apply at blocking or thinning as a directed spray to the soil between the rows and incorporate.				

Chemical Disease Management for Tomatoes

Tom Kucharek, *UF/IFAS, Plant Pathology Department, Gainesville*

Chemical	Maximum Rate / Acre / Application	Maximum Rate / Acre / Season	Min. Days To Harvest	Pertinent Diseases	Remarks
****For best possible chemical control of bacterial spot with copper fungicides, maneb or mancozeb must be added to the tank mix.**					
Ridomil Gold 4 EC	2 pts./trtd. acre	3 pts./trtd./ acre		Pythium diseases	See label for use at & after planting.
Kocide 101 or Champion 77 WPs	4 lbs.		2	Bacterial spot &speck	3 lbs. maximum for Nu-Cop
Kocide 4.5 LF	2 2/3 pts		1	Bacterial spot & speck	
Kocide 2000 53.8 DF	3 lbs.		1	Bacterial spot & speck	
Champ 57.6 DP	1 1/3 lbs		1	Bacterial spot & speck	
Basicop 53 WP	4 lbs.		1	Bacterial spot & speck	
Kocide 61.4 DF	4 lbs			Bacterial spot & speck	
Manex 4 F	2.4 qts.	16.8 qts.	5	Early & late blight, Gray leaf spot, Bacterial spot[1]	
Dithane, Manzate or Penncozeb 75 DFs	3 lbs.	22.4 lbs.	5	Same as Manex 4 F	
Maneb 80 WP	3 lbs	21 lbs.	5	Same as Manex 4 F	
Dithane F 45 or Manex II 4 FLs	2.4 pts.	16.8 qts.	5	Same as Manex 4 F	
Dithane M-45, Penncozeb 80, or Manzate 80 WPs	3 lbs.	21 lbs.	5	Same as Manex 4 F	
Equus 720[4], Echo 720, or Chloro Gold 720 6 Fls	3 pts. or 2.88 pts.	20.1 pts.	. 2	Early & late blight, Gray leaf spot, Target spot	Use higher rates at fruit set & lower rates before fruit set.
Amistar 80 DF	2 ozs	12 ozs	0	Early Blight, late blight, Sclerotinia, powdery mildew, target spot, buckeye rot	Limit is 2 seqential appl. or 6 appl.. total. Alternate with broad spectrum fungicides.
Maneb 75 DF	3 lbs.	22.4 lbs.	5	Same as Manex 4 F	Field & Greenhouse Use.

[1]When tank mixed with a copper fungicide

[2]Do not exceed limits of mancozeb active ingredient as indicated for Dithane, Penncozeb, ManexII or Manzate products

[3]Maximum crop is 3.0 lbs. a.i. of mefenoxam from Ridomil-containging products

[4]Do not tank mix with Copper Count N

[5]Label indicates 1/3, 1/2, and 3/4 oz. for 30-50, 60-70, and 70-100 gpa of water

Chemical	Maximum Rate /Acre/ Application	Season	Min. Days To Harvest	Pertinent Diseases	Remarks
Quadris 2.08 FL	6.2 fl.ozs.	37.2 fl.ozs.	0	Early Blight Late Blight Sclerotinia Powdery mildew Target spot Buckeye rot	Do not make more than 2 sequential applications with Quadris. Do not make more than 6 appl. or alternate or tank mix with fungicides for which resistance to a pathogen exists. For soilborne diseases see onions section.
Echo 90 DF or Equus 82.5DF	2.3 lbs.		2	Early & late blight, Gray leaf spot, Target spot	Use higher rates at fruit set & lower rates before fruit set.
Ridomil Gold Bravo 76.4 W	3 lbs.	12 lbs	14	Early & late blight, Gray leaf spot, Target spot	Limit is 4 appl./crop
Ridomil MZ 68 WP[2]	2.5 lbs.	7.5 lbs.	5	Late blight	Limit is 3 appl./crop
JMS Stylet Oil	3 qts.		NTL	Potato Virus Y Tobacco Etch Virus	See label for specific info on appl. technique (e.g. use of 400 psi spray pressure)
Ridomil Gold Copper 64.8 W	2 lbs.[3]	6 lbs.	14	Late blight	Limit is 3 appl./crop. Tank mix with a maneb or mancozeb fungicide
Sulfur (many brands)			1	Powdery mildew	
Aliette 80 WDG	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.
Bravo Ultrex 82.5 WDG	2.6 lbs.	18.3 lbs	2	Early & Late blights, Gray leafspot, Target spot, Botrytis, Rhizoctonia fruit rot	Use higher rates at fruit set.
Bravo Weather Stik 6 FL	2 ¾ pts.	20 pts	2	Same as Bravo Ultrex	Use higher rates at fruit set.
Botran 75 W	1 lb.	4 lbs.	10	Botrytis	Greenhouse tomato only. Limit is 4 applications. Seedlings or newly set transplants may be injured.
Nova 40 W	4 ozs.	1.25 lbs.	0	Powdery mildew	Note that a 30 day plant back restriction exists.

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[3]Maximum crop is 3.0 lbs. a.i. of mefenoxam from Ridomil-containging products
[4]Do not tank mix with Copper Count N
[5]Label indicates 1/3, 1/2, and 3/4 oz. for 30-50, 60-70, and 70-100 gpa of water

Chemical	Maximum Rate /Acre/ Application	Season	Min. Days To Harvest	Pertinent Diseases	Remarks
Actigard 50 WG	1/3-3/4 oz[5]	4 ozs.	14	Bacterial spot Bacterial speck	Do not use highest labeled rate in early sprays to avoid a delayed onset of harvest. Begin with 1/3 oz. rate and progressively increase the rate as instructed on the label. Limit is 6 appl./crop/ season. Do not exceed a concentration of 3/4 oz.100 gal. of spray mix. Begin spray program before occurrence of disease.
ManKocide 61.1 DF	5.3 lbs.	112 lbs.	5	Bacterial spot Bacterial speck Late blight Early blight Gray leaf spot	
Cuprofix Disperss 36.9 DF	6 lbs			Bacterial speck Bacterial spot	
Gavel 75DF	1.5 to 2.0 lbs	16 lbs	5	Buckeye rot, early blight, gray leaf spot, late blight, leaf mold	
Cabrio 2.09 F	16 fl oz	96 fl oz	0	Same as Quadris	6 appl maximum. Do not use more than 2 sequential applications
Tanos 50 DF	8 0 ozs	72 ozs	3	Target spot Bacterial spot (suppression)	
Tanos 50 DF	8 0 ozs	72 ozs	3	Target spot Bacterial spot (suppression)	
Acrobat 50 WP	6.4 ozs	32 ozs			
Allpro Exothern Termil, 20%	1 can/1000 sq. ft.		7	Botrytis, leaf mold, late & early blight, grey leaf spot	Greenhouse use only. Allow can to remain overnight & then ventilate. Do not use when greenhouse temperature is above 75 F

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[3]Maximum crop is 3.0 lbs. a.i. of mefenoxam from Ridomil-containging products
[4]Do not tank mix with Copper Count N
[5]Label indicates 1/3, 1/2, and 3/4 oz. for 30-50, 60-70, and 70-100 gpa of water

Selected Insecticides Approved for Use on Insects Attacking Tomatoes

Susan E. Webb, *Entomology and Nematology Department, UF/IFAS, Gainesville*

Chemical Name	REI (hours)	Days to Harvest	Insects	Notes
Acramite-50WS (bifenazate)	12	3	twospotted spider mite	One application per season.
Admire 2F (imidacloprid)	12	21	aphids, Colorado potato beetle, flea beetles, leafhoppers, thrips (foliar feeding thrips only), whiteflies	Most effective if applied to soil at transplanting.
Agree WG (*Bacillus thuringiensis* subspecies *aizawai*)	4	0	lepidopteran larvae (caterpillar pests)	Apply when larvae are small for best control. Can be used in greenhouse. OMRI-listed.
***Agri-Mek 0.15EC** (abamectin)	12	7	Colorado potato beetle, *Liriomyza* leafminers, spider mite, tomato pinworms, tomato russet mite	Do not make more than 2 sequential applications. Do not apply more than 0.056 lb ai per acre per season.
***Ambush 25W** (permethrin)	12	up to day of harvest	beet armyworm, cabbage looper, Colorado potato beetle, granulate cutworms, hornworms, southern armyworm, tomato fruitworm, tomato pinworm, vegetable leafminer	**Do not use on cherry tomatoes.** Do not apply more than 1.2 lb active ingredient per acre per season. Not recommended for control of vegetable leafminer in Florida.
***Asana XL 0.66EC** (esfenvalerate)	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	Not recommended for control of vegetable leafminer in Florida. Do not apply more than 0.5 lb ai per acre per season.
Assail 70WP (acetamiprid)	12	7	aphids, Colorado potato beetle, whiteflies	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)	12	3	beet armyworm, hornworms, loopers, southern armyworm, tomato fruitworm, tomato pinworm, suppression of leafminers	Do not apply more than 14 ounces of product per acre per crop. Minimum spray interval is 5 days.
Aza-Direct (azadirachtin)	4	0	aphids, beetles, caterpillars, leafhoppers, leafminers, mites, stink bugs, thrips, weevils, whiteflies	Antifeedant, repellant, insect growth regulator. OMRI-listed.
***Baythroid 2** (cyfluthrin)	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)	(1) lst and 2nd instars only (2) suppression Do not apply more than 0.26 lb ai per acre per season. Maximum number of applications: 6.
Biobit HP (*Bacillus thuringiensis* subspecies *kurstaki*)	4	0	caterpillars (will not control large armyworms)	Treat when larvae are young. Good coverage is essential. Can be used in the greenhouse. OMRI-listed.
BotaniGard 22 WP, ES (*Beauveria bassiana*)	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)	12	1	aphids, armyworms, corn earworm, cutworms, flea beetles, grasshoppers, mites, stink bug spp., tarnished plant bug, thrips, whiteflies	Make no more than 4 applications per season. Do not make applications less than 10 days apart.
CheckMate TPW, TPW-F (pheromone)	0	0	tomato pinworm	For mating disruption - See label. TPW formulation is OMRI-listed.
Condor (*Bacillus thuringiensis* subspecies *kurstaki*)	4	0	caterpillars	Do not use in combination with any chlorothalonil-based fungicides. Use caution when mixing with other oil-based products or surfactants. Treat when larvae are young. Good coverage is essential.
Confirm 2F (tebufenozide)	4	7	armyworms, black cutworm, hornworms, loopers	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 70WP (buprofezin)	12	7	whitefly nymphs	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*)	4	0	caterpillars	Use high rate for armyworms. Treat when larvae are young.
***Danitol 2.4 EC** (fenpropathrin)	24	3 days, or 7 if mixed with Monitor 4	beet armyworm, cabbage looper, fruitworms, potato aphid, silverleaf whitefly, stink bugs, thrips, tomato pinworm, twospotted spider mites, yellowstriped armyworm	Use alone for control of fruitworms, stink bugs, 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*)	4	0	caterpillars	Use higher rates for armyworms. OMRI-listed.
Dimethoate 4 EC, 2.67 EC (dimethoate)	48	7	aphids, leafhoppers, leafminers	Will not control organophosphate-resistant leafminers.
***Diazinon 4 E; *50 W** (diazinon)	24	1	**foliar application:** aphids, beet armyworm, banded cucumber beetle, *Drosophila*, fall armyworm, dipterous leafminers, southern armyworm **soil application at planting:** cutworms, mole crickets, wireworms	Will not control organophosphate-resistant leafminers. Do not apply more than five times per season.
DiPel DF (*Bacillus thuringiensis* subspecies *kurstaki*)	4	0	caterpillars	Treat when larvae are young. Good coverage is essential. OMRI-listed.
Entrust (spinosad)	4	1	armyworms, Colorado potato beetle, flower thrips, hornworms, *Liriomyza* leafminers, loopers, other caterpillars, tomato	Do not apply more than 9 oz per acre per crop. OMRI-listed.

			fruitworm, tomato pinworm	
Extinguish ((S)-methoprene)	4	0	fire ants	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. This is the only fire ant bait labeled for use on cropland. May be applied by ground equipment or aerially.
Fulfill (pymetrozine)	12	0	green peach aphid, potato aphid, suppression of whiteflies	Do not make more than two applications. 24(c) label for growing transplants also.
***Fury** ***Mustang Max** (zeta-cypermethrin)	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. Aides in control of aphids, thrips and whiteflies.	Not recommended for vegetable leafminer in Florida. Do not make applications less than 7 days apart. Do not apply more than 0.3 lb ai per acre per season.
Intrepid (methoxyfenozide)	4	1	beet armyworm, cabbage looper, fall armyworm, hornworms, southern armyworm, tomato fruitworm, true armyworm, yellowstriped armyworm	Do not apply more than 1.0 lb ai/acre per season. Product is a slow-acting IGR that will not kill larvae immediately.

Javelin WG (*Bacillus thuringiensis* subspecies *kurstaki*)	4	0	most caterpillars, but not *Spodoptera* species (armyworms)	Treat when larvae are young. Thorough coverage is essential. OMRI-listed.
Kelthane MF 4 (dicofol)	12	2	tomato russet mites, twospotted and other spider mites	Do not apply more than twice a season or more than 1.6 pt per year.
Knack IGR (pyriproxyfen)	12	14	immature whiteflies	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.
Kryocide; Prokil Cryolite 96 (cryolite)	12	14	blister beetle, cabbage looper, Colorado potato beetle larvae, flea beetles, hornworms, tomato fruitworm, tomato pinworm	Minimum of 7 days between applications. Do not apply more than 64 lb per acre per season.
***Lannate LV, *SP** (methomyl)	48	1	aphids, armyworms, beet armyworm, fall armyworm, hornworms, loopers, southern armyworm, tomato fruitworm, tomato pinworm, variegated cutworm	Do not make more than 16 applications per crop.
Lepinox WDG (*Bacillus thuringiensis* subspecies *kurstaki*)	12	0	for most caterpillars, including beet armyworm (see label)	Treat when larvae are small. Thorough coverage is essential.
Malathion 5 EC, 8 F (malathion)	12	1	aphids, *Drosophila*, mites	Can be used in greenhouse.
***Monitor 4EC**	48	7	thrips (North Florida	(1) Use as tank mix

(methamidophos) [24(c) labels]			only), whiteflies[1]	with a pyrethroid for whitefly control. Do not apply more than 10 pt per acre, or 18 pt per acre in North Florida per season.
M-Pede 49% EC (Soap, insecticidal)	12	0	aphids, leafhoppers, mites, plant bugs, thrips, whiteflies	OMRI-listed.
Neemix 4.5 (azadirachtin)	12	0	aphids, armyworms, hornworms, psyllids, Colorado potato beetle, cutworms, leafminers, loopers, tomato fruitworm (corn earworm), tomato pinworm, whiteflies	IGR, feeding repellant. OMRI-listed.
NoMate MEC TPW (pheromone)	0	0	tomato pinworm	For mating disruption - See label.
Phaser 3EC (endosulfan)	24	2	aphids, blister beetle, cabbage looper, Colorado potato beetle, flea beetles, hornworms, stink bugs, tomato fruitworm, tomato russet mite, whiteflies, yellowstriped armyworm	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.
Platinum (thiamethoxam)	12	30	aphids, Colorado potato beetles, flea beetles, whiteflies	Soil application. See label for rotational restrictions.
***Pounce 3.2 EC** (permethrin)	12	0	beet armyworm, cabbage looper, Colorado potato beetle, dipterous leafminers, granulate cutworm, hornworms, southern armyworm, tomato fruitworm, tomato pinworm	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.
***Proclaim** (emamectin benzoate)	48	7	beet armyworm, cabbage looper, fall armyworm, hornworms, southern armyworm, tobacco budworm, tomato fruitworm, tomato pinworm, yellowstriped	No more than 28.8 oz/acre per season.

			armyworm	
Provado 1.6F (imidacloprid)	12	0 - foliar	aphids, Colorado potato beetle, leafhoppers, whiteflies	Do not apply to crop that has been already treated with imidacloprid or thiamethoxam at planting. Do not apply more than 18.75 oz per acre as foliar spray.
Pyrellin EC (pyrethrin + rotenone)	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	
Sevin 80S; XLR; 4F (carbaryl)	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	(1) suppression Do not apply more than seven times.
Sevin 5 Bait (carbaryl)	12	3	ants, crickets, cutworms, grasshoppers, mole crickets, sowbugs	
SpinTor 2SC (spinosad)	4	1	armyworms, Colorado potato beetle, flower thrips, hornworms, *Liriomyza* leafminers, loopers, *Thrips palmi*, tomato fruitworm, tomato pinworm	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.
Spod-X LC (beet armyworm	4	0	beet armyworm	Treat when larvae are small (1st and

nuclear polyhedrosis virus)				2nd instar). Follow label instructions for mixing. Use only non-chlorinated water at a pH near 7 for mixing. OMRI-listed.
Sulfur (many brands)	24	see label	tomato russet mite	
***Telone C-35** (dichloropropene + chloropicrin)	5 days (See label)	preplant	garden centipedes (symphylans), wireworms	See supplemental label for restrictions in certain Florida counties.
Trigard (cyromazine)	12	0	Colorado potato beetle (suppression of), leafminers	No more than 6 applications per crop.
Ultra Fine Oil, JMS Stylet-Oil, and others (oil, insecticidal)	4	0	aphids, beetle larvae, leafhoppers, leafminers, mites, thrips, whiteflies	Do not exceed four applications per season. Organic Stylet-Oil is OMRI-listed.
***Vydate L 2EC** (oxamyl)	48	3	aphids, Colorado potato beetle, leafminers (except *Liriomyza trifolii*), whiteflies (suppression only)	Do not apply more than 32 pt per acre per season.
Trilogy (extract of neem oil)	4	0	aphids, mites, suppression of thrips and whiteflies	Apply morning or evening to reduce potential for leaf burn. Toxic to bees exposed to direct treatment. OMRI-listed.
***Warrior** (lambda-cyhalothrin)	24	5	aphids[2], beet armyworm[1], cabbage looper, Colorado potato beetle, cutworms, fall armyworm[1], flea beetles, grasshoppers, hornworms, leafhoppers, leafminers[2], plant bugs, southern armyworm[1], stink bugs, thrips[3], tomato fruitworm, tomato pinworm, whiteflies[2], yellowstriped armyworm[1]	[1] for control of 1st and 2nd instars only. [2] suppression 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*)	4	0	caterpillars	Treat when larvae are young. Thorough coverage is essential. May be used in the greenhouse. Can be used in organic production. OMRI-listed.
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.				
OMRI listed: Listed by the Organic Materials Review Institute for use in organic production.				
*** Restricted Use Only**				

Insecticides Currently Used on Vegetables

S.E. Webb[1] and P.A. Stansly[2]

[1]Entomology and Nematology Department, UF/IFAS, Gainesville,[2]Entomology and Nematology Dept. SWFREC, UF/IFAS, Immokalee

The following table lists many of the common insecticides currently labeled for use on vegetables in Florida. A number of new materials have been registered in the past few years or have had additional crops added to their labels. Some older organophosphate insecticides (methyl parathion, in particular) are now restricted to just a few crops, a result of recent ruling related to the Food Quality Protection Act. Changes continue, thus this listing many not be totally accurate at the time of printing.

No attempt has been made to list all available formulations. Some are listed under "Signal Word," when different formulations differ in toxicity. Many of the listened insecticides are limited to specific vegetables. Specific crop recommendations and pesticide labels should be consulted for more detailed information.

Insects can become resistant to any insecticide if it is used repeatedly. This also applies to alternating insecticides with similar modes of action, for example following a soil application of Admire with foliar applications of Actara or Assail (all neonicotinoids). To complicate matters, some insecticides in the same class have different modes of action and some unrelated chemicals have the same mode of action. In general, pesticides with the same mode of action should be used no more than twice in any crop cycle if residual activity is long. To aid in developing a spray program we have included a column with a code number for the mode of action of each insecticide. A footnote lists the mode of action associated with the code. In addition to alternating insecticides with different modes of action, integrating other non-chemical control measures in a pest management program should help to delay resistance.

Table begins on page 80

Insecticides Currently Used on Vegetables

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Table 1. Insecticides For Use On Vegetables

Insecticide	General Characteristics	Signal Word	MOA	Typical Target Pests
Organophosphates				
*Counter (terbufos)	systemic action	Danger-Poison	1B	soil pests
*Diazinon		Caution	1B	aphids, beetles, caterpillars, soil pests, thrips
Dibrom (naled)	some short residual fumigant action	Danger	1B	caterpillars
Dimethoate	local systemic	Warning	1B	aphids, leafhoppers, mites
*Di-Syston (disulfoton)	systemic action	Danger-Poison	1B	aphids
*Guthion (azinphosmethyl)		Danger-Poison	1B	beetles, caterpillars, maggots
Imidan (phosmet)		Warning	1B	caterpillars, sweetpotato weevil
Lorsban (chlorpyrifos)	long residual	Caution (15G) Warning (50W, *4E)	1B	caterpillars, soil pests
Malathion	short residual	Warning	1B	broad spectrum
*Metasystox-R (oxydemetonmethyl)	systemic; contact & stomach action	Warning	1B	aphids, thrips & other sucking insects
*Mocap (ethoprop)	contact action	Warning (10G, *15G)	1B	aphids, caterpillars
*Monitor (methamidophos)	long residual	Danger-Poison	1B	aphids, caterpillars & other pests
Orthene (acephate)	contact action & local systemic action	Caution	1B	aphids, caterpillars
*Penncap-M (methyl parathion)	contact & fumigant action; slow release formulation	Warning (Penncap-M only)	1B	caterpillars, thrips
*Thimet (phorate)	systemic action	Danger-Poison	1B	soil pests
Carbamates				
*Furadan (carbofuran)	systemic action	Danger-Poison	1A	beetles, some caterpillars
*Lannate (methomyl)	very short residual	Danger-Poison	1A	caterpillars, leafhoppers
Larvin (thiodicarb)	larvicide & ovicide	Warning	1A	caterpillars
Sevin (carbaryl)	use can result in aphid and mite outbreaks	Caution (4F, XLR, Bait) Warning (80S)	1A	beetles, leafhoppers, caterpillars
*Temik (aldicarb)	systemic action	Danger-Poison	1A	aphids, mites, some beetles
*Vydate (oxamyl)	contact action, systemic if applied to soil	Danger-Poison	1A	aphids, thrips, some beetles
Organochlorines				
Kelthane (dicofol)		Caution (MF) Warning (35)	20	spider mites, broad mites
Phaser (endosulfan)	fairly long residual	Danger-Poison	2	aphids, beetles, caterpillars, whiteflies

Continued...

Table 1. Insecticides For Use On Vegetables

Insecticide	General Characteristics	Signal Word	MOA	Typical Target Pests
Pyrethroids	long residual; work best in cool weather (<75°F)			broad spectrum
*Ambush (permethrin)		Warning	3	caterpillars, beetles, leafhoppers, thrips
*Ammo (cypermethrin)		Caution	3	caterpillars, beetles, leafhoppers, thrips
*Asana (esfenvalerate)		Warning	3	caterpillars, beetles, leafhoppers
*Baythroid (cyfluthrin)		Danger	3	caterpillars, beetles, leafhoppers, thrips
*Capture, Brigade (bifenthrin)		Warning	3	caterpillars, beetles, leafhoppers, thrips, whiteflies
*Danitol (fenpropathrin)		Danger	3	caterpillars, leafhoppers, whiteflies
*Force (tefluthrin)		Caution	3	soil pests
*Mustang Max (zeta-cypermethrin)		Warning	3	caterpillars, beetles, leafhoppers, thrips
*Pounce (permethrin)		Caution (3.2EC, 1.5G) Warning (25WP, WSP)	3	caterpillars, beetles, leafhoppers, thrips
Pyronyl (Pyrethrins)	contact, stomach, & fumigant action; extract from chyrsanthemums	Caution	3	broad spectrum
*Warrior (lambda-cyhalothrin)		Warning	3	caterpillars, beetles, leafhoppers, thrips
Other insect nerve poisons				
Acramite-50WS (bifenazate)	contact action, not systemic	Caution	2	mites
*Agri-Mek (abamectin)	active once ingested; some contact action; mostly stomach poison	Warning	6	mites, leafminers, some beetles, tomato pinworm
Avaunt (indoxacarb)	ingestion plus contact, slightly to moderately translaminar	Caution	22	caterpillars
Fulfill (pymetrozine)	feeding inhibitor	Caution	9B	aphids, whiteflies
*Proclaim (emamectin benzoate)	ingestion & topical; translaminar, not systemic	Caution	6	caterpillars
SpinTor (spinosad)	ingestion & contact; enters leaf but does not translocate	Caution	5	caterpillars, some beetles and thrips

Continued...

Table 1. Insecticides For Use On Vegetables

Insecticide	General Characteristics	Signal Word	MOA	Typical Target Pests
Insect Growth Regulators				
Confirm (tebufenozide)	slow acting	Caution	18	caterpillars
Courier (buprofezin)	disrupts egg hatch and molting; use in rotation with other insecticides	Caution	16	whiteflies
*Dimilin (diflubenzuron)	slow acting, disrupts molting process, reduces egg hatch of pepper weevil	Caution	15	caterpillars, pepper weevil
Extinguish [(S)-methoprene]	slow acting	Caution	7A	fire ants
Intrepid (methoxyfenozide)	slow acting	Caution	18	caterpillars
Knack (pyriproxyfen)	use in combination or rotation with other insecticides	Caution	7C	whiteflies
Neem (azadirachtin; Azatin, Neemix)	slow acting, also acts as feeding repellent	Caution (Azatin XL Plus) Warning (Neemix 4.5)	18A	broad spectrum
Trigard (cyromazine)	most effective against small leafminer larvae	Caution	17	dipterous leafminers, some beetles, maggots
Neonicotinyls				
Actara (thiamethoxam)	local systemic	Caution	4	aphids, some beetles, potato leafhopper, stinkbugs, whiteflies
Admire (imidacloprid)	systemic, long residual	Caution	4	aphids, some beetles, leafhoppers, whiteflies
Assail (acetamiprid)	local systemic, ovicidal effects	Caution	4	aphids, Colorado potato beetle, whiteflies
Platinum (thiamethoxam)	systemic, long residual	Caution	4	aphids, some beetles, potato leafhopper, stinkbugs, whiteflies
Provado (imidacloprid)	local systemic	Caution	4	aphids, some beetles, leafhoppers, whiteflies
Miscellaneous				
Bacillus thuringiensis (B.t.)	pest must ingest; slow acting but feeding stops long before death	Caution	11	caterpillars or beetles, depending on strain
Cryolite (Kryocide)	pest must ingest; not rainfast; an inorganic fluorine compound	Caution	9A	beetles, caterpillars
Mycotrol (*Beauveria*)	contact; slow acting		23	whiteflies, aphids, leafhoppers
Oil (SunSpray Ultra Fine Spray Oil)	contact activity	Caution	23	mites, aphids, whiteflies

Continued...

Table 1. Insecticides For Use On Vegetables

Insecticide	General Characteristics	Signal Word	MOA	Typical Target Pests
Soap (M-Pede)	contact activity; phytotoxic at high temperatures	Warning	23	aphids and other soft-bodied arthropods
*Vendex (fenbutatin-oxide)		Danger-Poison	12	mites

*Restricted Use Pesticide

Adapted from: Welty, Celeste. Insecticides for use on vegetables in Ohio. pp. 46-48, 2002 Ohio Vegetable production Guide, Ohio State University.

Mode of Action Code (Adapted from Insecticide Resistance Action Committee) (http://plantprotection.org/irac/general_resources/IRACMOAJan02.pdf) **:**

1. Acetyl choline esterase inhibitors
    A. carbamates
    B. organophosphates
2. GABA-gated chloride channel antagonists
3. Sodium channel modulators
4. Acetyl choline receptor agonists/antagonists
5. Acetyl choline receptor modulators
6. Chloride channel activators
7. Juvenile hormone mimics
    A. methoprene, hydroprene
    B. fenoxycarb
    C. pyriproxifen
8. Compounds of unknown or non-specific mode of action (fumigants)
9. Compounds of unknown or non specific mode of action (selective feeding blockers)
10. Compounds of unknown or non specific mode of action (mite growth inhibitors)
11. Microbial disrupters of insect midgut membranes (includes Transgenic B.t. crops)
12. Inhibition of oxidative phosphorylation, disrupters of ATP formation
13. Uncoupler of oxidative phosphorylation via disruption of H proton gradient
14. Inhibition of magnesium stimulated ATPase
15. Inhibit chitin biosynthesis
16. Inhibit chitin biosynthesis type 1-Homopteran
17. Inhibit chitin biosynthesis type 2-Dipteran
18. Ecdysone agonist/disruptor
    A. blocks secretion of Prothoracicotropic Hormone
19. Octopaminergic agonist
20. Site II electron transport inhibitors
21. Site I electron transport inhibitors
22. Voltage dependant sodium channel blocker
23. Physical or biological mode of action probably not subject to selection for resistance.

Nematicides Registered for Use on Florida Tomatoes

J.W. Noling, *Entomology & Nematology Department, UF/IFAS, CREC, Lake Alfred*

	Row Application (6' row spacing - 36" bed)[4]				
Product	Broadcast (Rate)	Recommended Chisel Spacing	Chisels (per Row)	Rate/Acre	Rate/1000 Ft/Chisel
FUMIGANT NEMATICIDES					
Methyl Bromide[3] 67-33	225-375 lb	12"	3	112-187 lbs	5.1 - 8.6 lb
Chloropicrin[1]	300-500 lb	12"	3	150-250 lbs	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. 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. Use of methyl bromide for agricultural soil fumigation is scheduled for phase-out Jan 1, 2005. Continued use on a limited may occur after Jan 1, 2005 via international approval of specific Florida requests for Critical Use Exemptions (CUE).
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.

Rates are believed to be correct for products listed when applied to mineral soils. Higher rates may be required for muck (organic) soils. Growers have the final responsibility to guarantee that each product is used in a manner consistent with the label. The information was compiled by the author as of July 19, 2004 as a reference for the commercial Florida tomato grower. The mentioning of a chemical or proprietary product in this publication does not constitute a written recommendation or an endorsement for its use by the University of Florida, Institute of Food and Agricultural Sciences, and does not imply its approval to the exclusion of other products that may be suitable. Products mentioned in this publication are subject to changing Environmental Protection Agency (EPA) rules, regulations, and restrictions. Additional products may become available or approved for use.