

PRO 517

2000 Florida Tomato Institute Proceedings

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Compiled by: C.S. Vavrina



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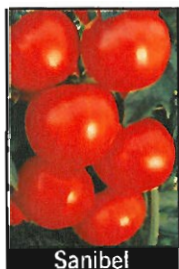
Citrus & Vegetable
MAGAZINE



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Sanibel

Petoseed's lineup of fresh market tomatoes for Florida includes the one-two punch of **Sanibel** and **Sun Chaser**, two uncompromising varieties that offer high yield potential in the main season and the fall slot. Sanibel's extra-firm fruit stands up to even the toughest shipping conditions with very little damage. Sun Chaser can take the heat and keep producing beautiful sets even in the steamiest Southeastern fall. And neither sacrifices flavor or fruit quality.



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Petoseed is committed to focusing our efforts on developing outstanding, highly adaptable varieties for Florida, the capital of fresh market tomato production. Talk to your authorized Petoseed dealer to find out more about how Sanibel and Sun Chaser can help you outscore the competition.

Tomato Institute Program

Ritz Carlton Hotel • Naples, Florida • September 6, 2000

a.m.

8:45 **Introductory Remarks** - Charlie Vavrina

8:55 **The Florida Tomato Program** - Dan Cantliffe

9:15 **Distance Diagnostic and Identification System** - Jim Fletcher, **pg. 2**

9:35 **Postharvest Decay - Recent Outbreaks and Possible Causes** - Steven A. Sargent, Jerry A. Bartz and Stephen M. Olson, **pg. 3**

9:55 **The Role of the Grower/Shipper in Food Safety** - Robert Stovicek, Primus Labs

10:35 **Robotics in Agriculture** – Carnegie Mellon University

10:55 **European Greenhouse Industry: Growing Practices and Competitiveness in U.S. Markets**
Dan Cantliffe and John J. VanSickle, **pg. 6**

11:15 **Marketing Margins and Price Transmission: Recent Evidence on Pricing Behavior in the U.S. Fresh Tomato Industry** - Suzanne Thornsby and John J. VanSickle, **pg. 10**

11:35 - 1 p.m. **LUNCH**

p.m.

1:15 **Industry Update** - Charlie Vavrina

1:35 **Weed Control in the Post Methyl Bromide Era** - J.P. Gilreath and J.W. Noling, **pg. 13**

1:55 **New Tools for Management of Whitefly-Transmitted Geminiviruses** - J.E. Polston and D.J. Schuster, **pg. 17**

2:15 **Tomato Variety Yellow Leaf Curl Virus Resistance Trials** - Phyllis Gilreath, Ken Shuler, Jane Polston, Tracy Sherwood, Gene McAvoy, Phil Stansly and Eric Waldo, **pg. 20**

2:35 **Integrated Effect of Highly UV-Reflective Mulch, Actigard and Reduced-Risk Insecticides on the Incidence of Tomato Spotted Wilt Virus (TSWV) in Tomato** - Tim Momol, Joe Funderburk and Steve Olson, **pg. 25**

2:55 **Reflective Mulches and Their Effect on Tomato Yield and Insect and Disease Management**
- Steve Olson, Julie Stavesky, Tim Momol and Joe Funderburk, **pg. 28**

3:15 **Nematode Control in the Post Methyl Bromide Era** - J.W. Noling and J.P. Gilreath, **pg. 31**

3:35 **UF Tomato Release Possibilities in the Early Twenty-First Century** - J.W. Scott, **pg. 34**

Control Guides

Tomato Varieties for Florida – Donald N. Maynard and Stephen M. Olson, **pg. 36**

Tomato Fertilizer Management – G.J. Hochmuth and E. Simonne, **pg. 40**

Disease Management for Tomato – Tom Kucharek, **pg. 46**

Nematicides Registered for Use on Florida Tomato – J.W. Noling, **pg. 49**

Weed Control in Tomato – William M. Stall and James P. Gilreath, **pg. 50**

Selected Insecticides Approved for Use on Insects Attacking Tomato – Phil Stansly and Susan Webb, **pg. 54**

Distance Diagnostic and Identification System

Jim Fletcher and Larry Halsey

A new method of distance diagnostics is being introduced in Florida. The purpose is to reduce the turn around time associated with diagnostic samples and avoid deterioration of tissue in transit.

This is accomplished by submitting digital images for identification or diagnosis rather than biological samples. As the saying goes, "a picture is worth a thousand words." In this case a digital picture with several million pixels.

Advances in digital cameras and Internet communications provide fast, efficient, effective identification of problems supporting extension agents and their clientele.

Extension agents, specialists, and faculty with the University of Florida Institute of Food and Agricultural Sciences (IFAS) Information Technologies developed the technique. The method involves capturing an image using a digital camera and then sending it via the Internet to a searchable-object database on a central server.

A specialist can retrieve the photo, identify the problem, and send a response, all in a matter of minutes. This system has the advantage of associating the images and their related descriptions in a searchable-object database, which allows agents and specialists to archive samples for future educational use.

The system allows for comprehensive diagnostics, not just pathology sampling. Currently the system is being utilized for insect ID, plant disease ID, nutrition and management problems, plant and weed ID, livestock and aquaculture problems, and any

other mix of images and text.

Twenty-four counties in Florida have been equipped, through Florida First funding, with the new system. These counties were given the Digital Diagnostic and Identification System (DDIS) software, photo enhancing software, dissecting stereoscope, and/or compound microscope, and digital camera, with an MM99 adapter.

The simple and relatively inexpensive adapter is critical as it links the camera directly to the eyepiece of the scopes. This not only decreases the cost of equipment drastically by decreasing hardware and software requirements but also allows the camera to have multiple uses.

In addition, agents were given training in diagnostic techniques and DDIS software. Once the agent takes field pictures and/or scope pictures, images are processed utilizing photo-enhancing software.

The agent then fills out form(s) on DDIS software. In an effort to ensure ease of adoption these forms emulate the traditional paper forms that are currently being used for submission of biologic samples. The agent then attaches up to 5 enhanced images to the form utilizing a browser, enters the email address of the person(s) who he wants to look at the sample.

The agent can send the sample to multiple users if he's unsure what are the causal factors. He can send the sample to a pathologist and a physiologist to have them collaborate on an

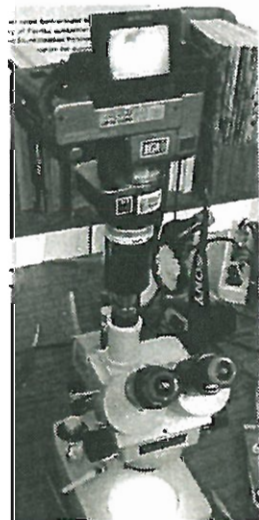
answer. The agent then submits the sample over the Internet. The sample is sent to the searchable-object database and the specialist(s) are notified via email that a sample is waiting for their diagnosis.

The specialist is given several options in responding: 1. Here's the answer, 2. I think this is the answer, 3. Can't make ID from picture please send a biological specimen. Once the specialist answers, the agent is notified via email that there is a response waiting and the agent pulls up the sheet.

An HTML diagnosis report mimics the traditional paper sheets that have been used in the past. The benefit is the agent can type in additional information or cut and paste information from control guides, then either print out a hard copy for the grower or email directly to him.

For more information on this project contact Jim Fletcher at (850) 973-4138 (jhfr@gnv.ifas.ufl.edu) or Larry Halsey and (850) 342-0187 (lah@gnv.ifas.ufl.edu). To visit the DDIS web site and get more information go to <http://ddis.ifas.ufl.edu>. Although users who do not have a University of Florida mail account will not be able to download the DDIS software, users can access help guide and other useful information.

Jim Fletcher, Madison County Extension Director, Madison Fla. and Larry Halsey, Jefferson County Extension Director, Monticello, Fla.



Postharvest Decay - Recent Outbreaks and Possible Causes

Steven A. Sargent, Jerry A. Bartz and
Stephen M. Olson

For the past two fall seasons, we have investigated reports of postharvest decay problems for tomatoes grown in the Palmetto/Ruskin (1998) and Quincy (1999) areas. Any occurrence of postharvest decay is disconcerting and costly to shippers, but these cases were unusual in that decays developed even before the tomatoes were shipped. We report here on three preliminary studies which have aided in developing a better understanding of the possible causes for these outbreaks.

1. Fall 1998: Field and Packing-Line Samples in the Palmetto/Ruskin Area

Situation

In mid-November, 1998, we received reports from Phyllis Gilreath, commercial vegetable extension agent, on significant amounts of postharvest decay in tomatoes grown in Manatee County. The decay developed during ripening and shipping. Two samples picked during the 26-30 October and the 9-13 November were sent to the Postharvest Horticulture Laboratory in Gainesville. These tomatoes had bacterial soft rot which appeared to have been due to inoculation in the field or during handling and packing operations.

On-site Sample Procedures

On Monday, 23 November, we visited one tomato field which had experienced high incidences of postharvest decay and two packinghouses in the Palmetto area. In the field, green and breaker-stage tomatoes ('Florida 91'), still attached to the plant, were carefully swabbed and plated onto nutrient agar for later determination of plate counts. Samples of harvested breaker-stage tomatoes were also collected for ripening in the laboratory to observe any occurrence of soft rot.

At each packinghouse, dump tank water was analyzed for pH and free chlorine concentration. Water was sampled at the inlet and outlet of the dump tanks and from the brush/sponge rolls, and plated on agar. Two tomatoes with soft rot symptoms were located in a ripening room and the leaking juice was swabbed for later analysis.

At the laboratory, organisms which grew out on the media were tested for pathogenicity. Those found to be pathogenic were identified. During this period, we were told that, by the last week of November, no significant decay problems were being encountered by shippers, indicating that some event occurred during late October and early November that favored the development of postharvest bacterial soft rot for roughly a 2-week period.

Results and Analysis

Field Samples. Bacterial soft rot was not generally observed in the field except in a few cases on tomatoes with growth cracks that were still attached to plants. Under typical growing conditions, tomatoes attached to the plant do not develop bacterial soft rot. However, either radial (radiating out from stem) or concentric (roughly parallel cracks around the fruit shoulders) growth cracks provide sites for soft-rot bacteria to infect, particularly during warm and wet situations. Even skin checks can become infected during prolonged wet weather. The presence of decay

in a few tomatoes still attached to plants strongly promotes the dispersal of the decay pathogens during and after harvest.

There were no indications of abnormal populations of decay microorganisms in the field samples. No bacterial soft-rot organisms grew out on the agar media; a few fungi were observed, but were not suspected to be pathogenic and were not identified. The tomatoes sampled in the field ripened normally, with no incidence of decay. This absence of significant surface populations of decay pathogens on healthy, uninjured fruit was considered normal, since the weather had been sunny and dry in the days previous to our sampling.

Packinghouse Samples. Concentrations of free chlorine in the dump tank water were significantly lower (from 0 to 50 ppm) than recommended levels (100 to 150 ppm) at both locations; however pH was adequate, ranging from 6.58 to 7.04. Dump-tank water temperatures were 100° to 104°F. Incoming tomato pulp temperatures ranged from 78° to 82°F.

Regarding the samples taken from the two packing lines, no soft rot bacteria were isolated from dump tank water; some fungi were found, but not identified. However, swab samples from sponge rollers in one packing line contained *Geotrichum* spp., a causal agent for sour rot. Juice from the decaying, packed tomato sample contained *Pseudomonas* spp., suspected to be *P. marginalis*, and *Erwinia* spp., both soft rot pathogens.

Weather Effects. Phyllis Gilreath provided extensive weather information from a site in Myakka City for the months of September, October and November. Average maximum/minimum temperatures were higher than normal during the growing/harvest season. There were significant rain events before the reported problem dates and a rain event on 4, 5 November was apparently followed by several days of cloudy and foggy weather.

The decay events do not appear to have been linked to a single weather event. Our on-site visits occurred after the problem had peaked and no abnormal populations of decay pathogens were encountered in the field or packinghouses. It is likely that higher populations had existed during the time of the problematic harvests and had subsided by the time of our samplings. The observation of decaying fruit in the field was evidence that previous conditions (weather and pathogen numbers) were favorable for various decays. The decay problem reported to us appears likely to have been associated with excessive moisture where the plant canopy remained moist most of the time. The moisture and lush plant growth led to higher microbial populations and an increase in the potential for decay. Periods of abundant rainfall, warm temperatures, and/or heavy morning fogs create ideal conditions for fruit decays. Such conditions are not unusual in Florida in the early Fall or late Spring tomato seasons, and may occur sporadically during any season. At any given time, certain fields may have conditions that favor the development of tomato fruit decays whereas nearby fields do not, often depending on the irregular movement of showers.

2. Fall 1999: Selected Samples from the Quincy Area

Situation

On 20 October, a high incidence of decay was reported for packed tomatoes after gassing. While discussing this incident it was noted that a tropical depression had recently occurred (11 October) and, as a result, about 4 inches of rain had fallen on the Quincy area. Abnormally high army worm infestations were also reported on tomato plants.

Samples Taken From Several Locations

Six cartons of tomatoes ('Florida 91') were received at the Postharvest Horticulture Laboratory on 21 October 21 from two growers. They ranged from green to breaker stages. One sample from grower A had few problems with decay, and five samples from grower B had a severe problem with soft rot. The sample from grower A was taken in the field. Of the five cartons from grower B, one was taken directly from the field, one prior to dumping (from the field bin), one after packing (from the filler), one after overnight gassing, and one from the cull pile. There were from 50 to 66 tomatoes per sample. These samples were stored at 68°F and 85 to 90% relative humidity, and incidence and locations of decay were determined throughout storage until red ripe stage was reached.

Incidence of decay at red-ripe stage was less than 4% for non-cull samples, and no decay developed in the sample from the gas room (Table 1). Decay from the field samples was slightly higher for grower B (4.0%) than for grower A (1.6%). Initial decay was observed at the stem end, whereas later decay occurred at the blossom end. Decay developed rapidly (within one day) in the sample from the cull bin, totaling 24.1% by the end of the storage period. A significant amount of decays (18.0%) were associated with side splits. The low incidence of decay in packed tomatoes was either due to the small sample size or to an overall reduction in the pathogen load in this grower's field by the time the sampling was made.

Samples Stored With and Without Stems Removed

Several growers have reported that the stems of certain cultivars can be difficult to remove at harvest. We wanted to test the idea that, as stems are removed, the tomatoes may be inoculated in the succulent tissue of the freshly created stem scar.

Two cartons of green tomatoes ('Florida 91') were received from Quincy on 10 November. One sample contained tomatoes in which the stem had been removed by workers in the field and the other sample had tomatoes with the stem intact. The tomatoes were stored at 68°F. Following 33 days of storage, no decay was observed in tomatoes from either sample.

Results from these two samples revealed the necessity of designing a broader study in which larger sample sizes could be analyzed throughout the growing season. The question of field inoculation due to weather conditions or by workers during stem detachment could not be adequately answered.

3. Spring 2000: Field and Packing-Line Samples in the Quincy Area

Situation

In preparation for the upcoming Fall 2000 season, we set out to accumulate more preliminary baseline data during Spring 2000 in the Gadsden County tomato production area. The goal was to determine background levels of pathogens from field through packing. Procedures used in the Fall 1998 study were used in this study. Although the spring 2000 weather was unseasonably hot and dry in this area until the beginning of June, it was felt that this data could provide a contrast to fall data which would be collected under typically more rainy, humid conditions.

On 21 June, green/breaker stage tomatoes ('Florida 47') were harvested in one field and sampled again upon arrival in the packinghouse. Another sample ('Florida 47') was harvested at a second field, and a separate sample (probably 'Florida 47') was taken from field bins at an unrelated packinghouse. One of the harvest crew washed his hands in sterile tap water which was later spread over a plate. Tomatoes were also sampled from

packed cartons at each packinghouse. These tomato samples were returned the same day to the laboratory for analysis. In addition, at each packinghouse, water was sampled in the dump tank, and swabs were taken from spray rinse water, the brush/sponge rollers and other points on the packing line. Dump tank water was also analyzed for free chlorine concentration and pH. At the laboratory, the tomato samples were washed in sterile tap water and the water was plated to examine populations of bacteria and fungi.

Results and Analysis

Results from the samples taken in this study supplement data collected in the Fall 1998 study. Except for an occasional ripe tomato, the fruit on the plants did not exhibit symptoms of bacterial soft rot or any other postharvest decay. The decay noted was consistent with sour rot caused by *Geotrichum candidum* or with alternaria rot. Neither organism is considered to be a threat to healthy, mature-green fruit.

Although soft-rot bacteria were not detected from the tomatoes collected in the fields, the total bacterial populations ranged between 3.1×10^6 and 1.5×10^7 colony forming units (cfu) per fruit. Fungal populations were much lower. Many bacteria were also recovered from the washed hands of the field worker, but none were soft-rot bacteria.

In contrast to the previous study in Fall 1998, little to no free chlorine was measured in dump tank water at the particular time these samples were taken. The microbial populations found on fruit were similar for tomatoes sampled in the field, those from field bins prior to packing and those sampled after packing. In both packinghouses, large numbers of bacteria were detected on normally wet areas of the packing line including the brushes and sponge roll bed and from the chutes leading to the waxers. The swab samples (from about 4 cm² area), taken from several other points on the handling equipment of both houses, contained similar numbers of bacteria.

Soft rot bacteria (about 3×10^2 cfu/ml) were detected in the dump tank and flume water of one packing line, which utilized a chlorine dioxide generator. Total numbers of bacteria in this system were high (10^5 to 10^6 cfu/ml). No free chlorine was detected, indicating that either the generator was not working or it could not generate enough chlorine to overcome the demand of accumulated organic material in the water.

The second packing line employed copper-ion technology in the dump tank. Free chlorine was <10 ppm. The total number of bacteria in the dump tank and flume of this operation were <100-fold lower than that from the first packinghouse, however, numerous bacteria (ca. 10^3 cfu/ml) were detected in the water. In contrast, previous samples taken from a packinghouse dump tank, which contained 150 ppm free chlorine, contained only about 10^2 cfu/ml.

4. Current Recommendations to Minimize Postharvest Decay

Postharvest decays occur when microorganisms that attack fruit tissues are deposited in wounds on fruit surfaces or are moved inside fruit. Situations leading to large wounds or where water is forced into fruit increase the chances for decay. Warm, moist conditions speed up decay development and favor large populations of microorganisms on plants and on fruit. Field spray programs are essential in keeping pathogen populations under control.

A key indication that conditions conducive to decay may have occurred or are occurring in a tomato growing area is the

presence of decaying fruit on plants in the field. One or two soft-rotted fruit per field bin or fruit lots that contain large amounts of soil or debris or have other evidence of having been wet at the time of harvest should alert packinghouse personnel to potential decay problems and require the implementation of special precautions. One decayed fruit can contaminate thousands of healthy fruit during handling. Once inoculated, tomatoes cannot be reliably treated for decay control.

Therefore, a routine sanitation program at the packinghouse must be designed and implemented to minimize the postharvest decay potential when conditions favorable to growth of pathogens develop. This program should focus on exclusion of postharvest pathogens during harvest and handling operations, and minimizing the accumulation of those pathogens which are introduced into the system. Targeted points for intervention are sanitation of field bins, dump tanks/flumes, packing line components which remain wet (roller conveyors, brush/sponge roll beds, etc.) and fruit temperature management. For example, field bins must be cleaned and sanitized after each use because fruit can become inoculated when harvested into contaminated bins. Similarly, tomatoes that become inoculated in inadequately sanitized dump tanks and flumes cannot be reliably marketed since many will decay during shipping.

Recirculated water, such as found in dump tanks, should contain 100 to 150 ppm free chlorine at pH 6.8 to 7.2. Total chlorine may not correlate well with free chlorine and, therefore, should not be used to indicate free chlorine concentration. The water temperature should be maintained about 10°F higher than incoming pulp temperatures to reduce infiltration through the stem end. Free chlorine concentration, which is the active, sanitizing agent in chlorinated water, should be measured at least hourly throughout the day for acceptable sanitizing. However, best control of pathogens has been demonstrated in packing lines fitted with automated equipment which monitors and controls free chlorine and pH in the dump tank water.

In work with a laboratory-scale flume, 15 ppm free chlorine at pH 7.0 was sufficient to prevent freshly released soft-rot bacteria from inoculating wounds on fruit floating in water at ambient temperature. However, when spores of the fungal pathogens *Rhizopus stolonifer* (Rhizopus rot) or *Geotrichum candidum* (sour rot) were washed into water, chlorine concentrations of 50 ppm at pH 7.0 failed to completely prevent the infection of wounds on fruit moving through the flume. The efficacy of a sanitizer in water measured over an exposure of one or two minutes does not predict how well that sanitizer will work in a flume. A sanitation system that keeps pathogen levels low in swimming pool or other circulating water environments may not work rapidly enough to protect tomatoes under packinghouse conditions. The large number of microorganisms on tomato surfaces must be killed upon entering the dump tank, otherwise those microbes can be transferred to wounds or other infection courts. This means that kill must occur within seconds of contact with the water.

Brush/sponge roll beds are likely to develop slimes (biofilms) containing postharvest pathogens, because they stay wet during the workday as well as between most workdays. We have found postharvest pathogens in sponge rolls at other packinghouses, particularly when tomatoes coming out of the flume are not rinsed with chlorinated water. Biofilms on rollers will recontaminate the cleaned fruit just before they enter the waxer. Dump tank water should be changed daily and all equipment cleaned and rinsed with a sanitizer or steam to minimize growth of biofilms.

Finally, temperature management is often overlooked as a major decay-control measure. This includes minimizing accumulation of field heat during harvest and handling operations, and

prompt cooling following packing. Studies have shown that inoculated fruit held at >85°F will decay within hours, while the same fruit held at 60° to 65°F will remain sound for days. Forced-air cooling has been shown to be of benefit for tomatoes with pulp temperatures above 80°F by promoting more uniform ripening and reducing decay.

These preliminary studies have clearly demonstrated the importance of proper sanitation in the maintenance and operation of tomato harvest and packing operations. Future studies will focus on providing a greater understanding of the conditions which favor inoculation to reduce the incidence of postharvest decays.

Steven A. Sargent, UF Horticultural Sciences Dept., Gainesville; Jerry A. Bartz, UF Plant Pathology Dept., Gainesville and Stephen M. Olson, UF/IFAS North Florida Research and Education Center, Quincy.

Acknowledgments

We wish to thank Dr. Tom Kucharek, Plant Pathology Department, U.F., Dr. Phyllis Gilreath, Manatee County, and Dr. Tim Momol, North Florida Research & Education Center - Quincy for technical assistance in these studies. We sincerely appreciate the financial support of the Gadsden County Tomato Growers Association for the Spring 2000 study. We also appreciate the assistance of Abbie J. Fox, Horticultural Sciences Department, and Michael Mahovic and Diane Concelmo, Plant Pathology Department, University of Florida, with data collection and laboratory studies.

Additional Information

For additional information about bacterial soft rot and its control, please read the Plant Pathology Fact Sheet PP-12, "Bacterial Soft Rots of Vegetables and Agronomic Crops". The related chapters in SP-170, the Florida Vegetable Production Guide, provide guidelines for proper handling and sanitation of tomatoes.

Storage Day	Grower A		Grower B			
	Field	Field	Bin	Filler	Gas room	Culls
0	1.6 se*	0	1.7 se	0	0	17.2 se (3.4); ss (13.8)
1	0	0	0	0	0	8.3 se (4.2); ss (4.2)
4	0	0	0	0	0	0
6	0	0	0	0	0	2.3 se
8	0	4.0 be	0	3.1 be	0	0
10	0	0	0	0	0	2.3 se
TOTAL	1.6	4.0	1.7	3.1	0	24.1

*Location of decay: se=stem end; be=blossom end; ss=side split.

Decays were identified as sour rot (*Geotrichum* sp.) and soft rot (*Erwinia* sp.). Lactic acid bacteria were also isolated.

European Greenhouse Industry: Growing Practices and Competitiveness in U.S. Markets

Daniel J. Cantliffe and John J. VanSickle

Abstract. Imports of fresh tomatoes into the U.S. declined in 1999 in large part because of declines in imports from Mexico. Imports from other regions of the world increased, however, with imports from European countries almost double what they were in 1996. Most of these tomatoes are produced in greenhouses and increasing returns through the 1997/98 season led to increases in production. Productivity in European greenhouse is nearly 3 fold that in Florida field production. Competitive cost structures in greenhouse production have allowed those producers to increase their presence in U.S. markets.

Introduction

In the past, fresh-market vegetables were supplied to U.S. consumers predominantly from Florida and Mexico. Both areas have, for many years, been in direct competition because of the overlap in production and marketing seasons. Imports of fresh tomatoes have increased significantly over the last decade as imports from Mexico increased from 352,312 metric tons in 1990 to 615,069 metric tons in 1999 (Table 1). Imports from Mexico increased the most after 1994 when the North American Free Trade Agreement (NAFTA) was implemented giving Mexican producers easier access to U.S. markets and a flow of investment capital into the Mexican vegetable production sector.

Increases in imports from Mexico resulted in the filing of an antidumping case with the U.S. International Trade Commission and the U.S. Department of Commerce that was suspended when producers of more than 85 percent of Mexican production agreed in December, 1996 not to sell fresh tomatoes for less than a reference price of \$5.17 per 25 pound carton equivalent. That agreement slowed the increase in imports from Mexico, but there has been a significant increase in imports from other countries.

In recent years, the greater percentage of retail sales of tomatoes showing up in retail markets and supermarkets throughout the U.S. have been produced from greenhouses. Initially, some of this production was from local market areas in proximity to the retail outlet. More recently, and especially in the last two to three years, a greater percentage of tomato sales have come from greenhouse tomatoes, especially cluster-type tomatoes produced in Holland, Israel, Canada, and Spain. Of these four countries, Israel was the first to begin shipment of red ripe tomatoes into U.S. markets during the 1990's. There has been a tremendous conversion of much of the Dutch industry to higher-value crops such as cluster tomatoes during that same period. The Dutch are not so limited by season, and can in fact deliver tomatoes to the U.S. market essentially 12 months of the year.

More recently, greenhouse acreage has increased dramatically in Canada, especially southwest Ontario; much of that area has been devoted to tomato production. Canada increased as a source of imports from 21,774 metric tons in 1996 to 79,554 metric tons in 1999. Spain increased as a source from no imports in 1996 to 5,715 metric tons in 1999. The Netherlands also increased as a source of imports from 23,473 metric tons in 1996 to 34,202 metric tons in 1999. Most of the tomatoes imported from Canada and Europe are greenhouse grown tomatoes competing against field grown tomatoes produced in the United

States and Mexico. Increases in imports of tomatoes, especially greenhouse tomatoes, have had significant impacts on Florida growers of field grown tomatoes. There is growing concern about the impacts of greenhouse grown tomatoes on U.S. growers.

The Israeli production area is limited by both seasonality and cost of transportation, thus reducing its impact on competition with the Florida tomato industry. Canada, on the other hand, has proximity to market, especially the midwest and northeastern markets. Distance seemingly would impinge upon profitability from Dutch-produced tomatoes, especially if they are air-freighted, however, the price and demand at the retail level, especially by the consumer and the grocery store, has retained high returns for Dutch producers.

The Mediterranean region of Europe has one of the largest concentrations of protected crop production in the world with around 247,000 acres (2,471 acres/hectare) of vegetable production grown in greenhouses and 741,000 acres grown with low tunnels and mulching. This 968,000 acres compares with 1.9 billion acres of total fresh vegetable production in the U.S. in 1999 and 193,000 acres of winter fresh vegetable production.

The largest greenhouse producing areas in Europe are Spain (113,667 acres), Italy (61,775 acres), France (23,475 acres) and Greece (9,390 acres). Around 10,000 acres of the greenhouse production in Europe is soilless, mainly using inert substances such as sand, perlite, rockwool, puzolanes and volcanic gravels. The soilless crop area is increasing with Spain and France the largest Mediterranean countries with 3,950 acres and 2,500 acres each in soilless culture in 1996. Production of these crops has increased because of several factors. Changes in diet have contributed to an increase in vegetable consumption in Europe, opening windows of opportunities for vegetable growers. Improvements in transportation also have increased production by improving quality and lowering costs in shipping vegetables. The European Union is considered self-sufficient in vegetable production for most fresh vegetable crops.

Among these four European vegetable producing countries is what some regard as the sleeping giant – Spain. Much of the Spanish greenhouse industry centers around Almeria along the coast of the Mediterranean as well as Murcia to the east. In the Almeria area there are some 80,000-90,000 acres of greenhouse crops grown predominantly in Spanish-style flat-roof greenhouses. In comparison, in 1998 there were approximately 10,000 acres of vegetables grown in greenhouses in the Netherlands. The commodities that dominate in this area are tomatoes, peppers, eggplants, cucumbers, muskmelons, and to some degree, watermelons. The area is known for its extremely arid climate, its available sunshine, and a large influx of new growers to the area. Almeria is potentially the next and possibly the greatest threat to Florida tomato producers for mid-winter competition.

Production Practices in Greenhouse Production

Almeria is located in the region of Andalucia in southeastern Spain. It has an average temperature of 68°F and about 3000 hours of annual sunshine. Besides the crops already mentioned, Almeria produces some 30 different vegetable species. Most of the producers are family-owned operations and have low capital investments, generally producing on the average of about 2.5-3.5 acres. Approximately 90% of the cultivation for tomato production is still being done by sand culture. This culture utilizes sand, gravel, and manure and most growers use drip irrigation. There is, to some degree, a scarcity of water and growers tend to use a lot of pesticide, especially against whiteflies and thrips which spread various viral diseases.

Some producers are switching to more modern greenhouse

types, including Dutch glass as well as plastic houses. Most of the vegetable seed companies in the world have experiment stations (10) somewhere in the vicinity. Production has increased dramatically in the past 25 years, increasing from approximately 600,000 metric tons in 1975 to 2.7 million metric tons in 1997-98. Produce from Almeria is sold via auction or through cooperatives. At present, approximately half of the total production from this area is exported to the European Union, especially Germany, France, and the Netherlands. For these reasons, quality control, food safety, and pesticide residues are major concerns for producers from these regions, and for these reasons quality certification has become a priority for producers in these regions. As such, Almeria has become very competitive because it is relying on selling via high quality and not low prices.

Because of location, climate, and lack of water, Almeria is not being rapidly urbanized, although it is rapidly developing as an agricultural area. Throughout Andalucia the major sources of income are from agriculture, tourism, and white marble. Agriculturally, citrus and greenhouse vegetable production are most important. Previously agricultural production was based solely on grapes and citrus. Originally, table grape production which was developed on wire systems, were covered with plastic to induce earliness for table grapes to be shipped to the European markets. Some growers began growing vegetables, and because of the greater profitability in growing and shipping vegetables, most, if not all of the grape acreage quickly dissipated during the 1970's and 1980's as well as a large amount of new acreage was devoted to vegetable production. By 1997-98, 90% of the total agricultural production of Almeria was in vegetables.

In the Netherlands, similar changes were taking place. Between 1980 and 1998 the value of fruits and vegetables almost doubled, reaching approximately \$2.5 billion. This represents 37% of the total Dutch horticultural production.

In Almeria, Spain vegetables are generally grown as two types of crops which are called winter crops, such as tomato, pepper, cucumber, and certain squashes, and summer crops, such as various muskmelons, watermelons, and green beans. The production peaks are December-January wherein tomato, cucumber, green beans, and pepper are harvested, and then again in May-June where many of melons, especially Galia-type melons are harvested. Tomatoes and sweet pepper represent the highest acreage and are followed by watermelon and muskmelon (Galia melon). Presently, for tomatoes the most important cultivar is long-shelf-life tomato "Daniella" which represents about 80% of the total production.

In the Netherlands, tomato, sweet pepper, and cucumber are the most important vegetable crops. In comparing production per square meter of crops such as tomato, sweet pepper, and cucumber, yields from the Almeria area are still considered quite low when compared to the Netherlands. For example, Almeria in 1998 produced approximately 20,000 acres of tomato or about 770,000 metric tons. In comparing productivity of tomatoes in Almeria, they are producing approximately 22-26 lbs. per square meter, whereas in the Netherlands they are producing approximately 90 lbs. per square meter.

During the 1980's, due to low market prices, many growers in Almeria producing pot plants and cut flowers went bankrupt. For this reason, there is presently very little area devoted to such crops. This is not so in the Netherlands.

Approximately 90% of the greenhouse area in Almeria produces vegetables on an artificial soil called Enarenado. This is a soil mix drawn up by the local growers sits on top of the original soil base wherein they put approximately 10-12 inches of new soil, which is partly clay about an inch of manure and then about

4 inches of special sand, on top which is actually a gravelly bed sand. The remaining 10% of the area is using either perlite or rockwool. Use of coconut fiber has not been widespread as results were not good. The soil mix has been created in order to overcome extremely poor indigenous soils of the region.

Water quality is a prime factor in determining the price of land. Presently, water scarcity does not seem to be a major issue for area growers in Almeria. There are about 200 mm of rain per year, however, there is a requirement of 800-1000 mm for greenhouse production. Water efficiency has improved dramatically, especially with the use of drip irrigation, however, because of high EC water, sometimes drainage may exceed 60% of the irrigation water.

As previously mentioned, production is generally through family companies of small area 2.5-3.5 acres. The family companies generally retain low labor costs and have a strong motivation for work. Since the area is new to this type of agricultural production, second and third generation growers are now coming into the business. Because production becomes seasonal so do the labor requirements. Producers use a lot of temporary labor, especially from African countries. Spain has one of the highest unemployment rates in the European Union, however, it has to bring in most of their labor from foreign countries such as Morocco, various African countries, and even as far as Central and South America. Certain eastern European groups are also migrating to south Spain for work. Recently there have been clashes between growers and especially the Moroccan immigrants, due to poor working and living conditions for the foreign laborer. Several growers have faced strikes, and labor issues appear to be some of the greatest problems facing producers in the area.

Production Costs

Productivity in European greenhouses is more than 3 times the productivity in Florida field production. Data reported by Calatrava-Requena *et al.* (2000) indicate that Spanish greenhouses growing fresh tomatoes in the Almeria region averaged 5,081 and 4,607 cartons (25 pound equivalents), respectively, in the 1996/97 and 1997/98 production seasons (Table 2). These yields compare to yields in the Manatee Ruskin production area of 1,785 cartons in 1996/97 and 1,554 in 1997/98. Preharvest costs for Spanish greenhouse tomatoes totaled \$10,339.85 per acre in 1996/97 and \$9,192.84 in 1997/98. Gross margins for paying for fixed costs and packing and marketing costs totaled \$13,249.91 per acre in 1996/97 and \$20,313.32 per acre in the 1997/98 season. These gross margins compare to \$9,436.41 per acre for field production in the Manatee Ruskin area in Florida in the 1997/98 production season.

Costs of production between Almeria and the Netherlands differ somewhat. Broken into the three areas of production costs, marketing costs, and total costs, it takes approximately \$0.12 per pound to produce tomatoes in Almeria and \$0.25 per pound in the Netherlands. Marketing in Spain costs another \$0.13 per pound, while in Holland it is only \$0.07 per pound, leaving total costs for production and marketing of \$0.26 per pound in Almeria versus \$0.32 per pound in the Netherlands. As previously stated, Almeria exports most of its produce to Germany, France, and the Netherlands. It also exports fair amounts to Poland, Hungary, and Russia. In going overseas, Canada and U.S. are main areas of export, although at present these attribute to very small amounts.

The major difference between Almeria and the Netherlands relates to the fact that in Spain energy costs are low and production costs are low, primarily due to the natural climatic condi-

tions of good temperature and good light. Also, greenhouse production costs in Spain are considerably lower than those of the Netherlands, especially because many of the greenhouses are homemade and all are primarily of plastic. In the Netherlands, energy costs are considerably higher because of the inherently poor conditions of light and temperature in the winter season as well as the greater costs in the Netherlands for labor and the higher costs for the much more sophisticated greenhouse production systems, wherein glass, computerization, as well as soil-less media are the norm. The main issue is that Spain has managed to acquire a large market share in Europe and will now try to improve its export position by improving its market share in other parts of the world, especially the United States. Not only are prices competitive from Spain, but also the quality of Spanish produce is excellent. Presently, the marketing scheme of auctions and cooperatives is not as efficient in Spain as it is in other areas such as the United States or the Netherlands. Also transportation costs have increased dramatically, especially in the last year due to the increase in fuel prices. For Almeria production to continue to grow, it will continually need to be more sophisticated in both production and marketing practices. There are several growers, especially over in the Murcia area, that produce approximately 300 hectares of tomatoes, which equates to over 750 acres of greenhouse tomatoes for a single producer. These growers are well educated, seem to be financially sound, and have new and exciting tomato products that they will be introducing into the U.S. marketplace this year, such as 'Baby Sweetheart' cluster tomatoes which could be a high impact commodity for Spanish producers to break in heavily into the U.S. tomato market.

In the Netherlands, rapid innovations have kept Dutch producers competitive. They are strongly vertically integrated and they look to consumer- and retail-driven types of production. They thrive on producing high-quality products under environmentally-sound production techniques. Unfortunately, the Dutch have the disadvantage of expensive raw materials, labor, and a high demand for fuel in the winter season. Technologically, the Dutch are very quick to adapt and innovate as any needs demand to improve their efficiency and effectiveness of production. The Dutch also have developed what they call an organization in grower groups, which are small groups of growers with the same specific crop and in the same area, wherein they visit each others' greenhouse and discuss matters related to production. These groups along with groups at the national level operate under LTO, an organization of farmers and growers. LTO develops programs for producers and sets priorities for research. There is no effectively run extension service at this time in Spain. There are several public and private research stations in Almeira. The Dutch privatized what they call their governmental advisory (extension) service several years ago, whereas the Spanish have never had an effective extension type of service that cooperated both with research center and university research programs.

Conclusions

Greenhouse production of vegetable crops has increased throughout the world and those increases have resulted in increased imports of vegetables from Canada and Europe. These vegetables enter the U.S. and compete with field grown crops in supermarkets and institutional outlets. Higher productivity and competitive cost structures allow greenhouse vegetables to enter the U.S. and compete with field grown tomatoes. It is critical that Florida growers to develop new technologies to compete with the quality and cost of greenhouse grown tomatoes. Increases in imports from European sources is likely to continue and will force the U.S. industry to adapt to changes in consumer tastes

that are being developed by these greenhouse grown tomatoes.

Daniel J. Cantliffe, chairman, UF Horticultural Sciences Dept., Gainesville, and John J. VanSickle, professor, UF Food and Resource Economics Dept., Gainesville.

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Table 1. Imports (metric tons) of fresh tomatoes from Mexico, Spain, The Netherlands, Canada, and the World. 1990 to 1999.

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Mexico	352312	353576	183115	400494	376032	593064	685681	660609	734053	615069
Spain	15	1	2	0	21	0	0	4440	6498	5715
Netherlands	1194	2410	2532	7044	7547	12401	23473	33718	36804	34202
Canada	3075	2671	5214	4733	7673	11658	21774	37504	61729	79554
World	360995	360829	196028	418394	395974	620933	737157	743205	856852	740656

Table 2. Preharvest costs and marketing margins for fresh tomatoes produced in Spanish greenhouses, 1996-1997 and 1997-1998, compared to fresh tomatoes grown in the Manatee Ruskin producing area in 1997-1998.

	Manatee/Ruskin – 1997-1998	Spain – 1996-1997	Spain – 1997-1998
Yield (25#/acre)	1,5545,0814,607		
Average Price (\$/25#)	\$9.15	\$4.64	\$6.40
Total Revenues	\$14,219.10	\$23,589.77	\$29,506.16
Preharvest costs (\$/acre)			
Fertilizers	\$326.22	\$2,395.50	\$2,124.46
Pesticides	\$1,143.18	993.66	767.20
Seeds	\$224.00	889.81	683.22
Water	653.20	709.89	
Labor	\$462.64	4,778.85	4,319.48
Other	\$1,217.55	628.84	588.59
Total Preharvest Costs	\$3,373.59	\$10,339.85	\$9,192.84
Gross Margin (\$/acre)	\$9,436.41	\$13,249.91	\$20,313.32

Sources: Smith and Taylor, 1999 and Calatrava-Requena *et al.*, 2000.

Marketing Margins and Price Transmission: Recent Evidence on Pricing Behavior in the U.S. Fresh Tomato Industry

Suzanne Thornsberry and John VanSickle

Abstract

The market for U.S. fresh tomatoes has undergone substantial change over the last decade and marketing margins between farm and retail levels have increased. Pricing of fresh tomatoes at retail concerns growers who believe that large fluctuations in farm prices are not reflected in retail prices and that retail prices are more likely to increase when farm prices increase than will decline when farm prices decline. Such a pricing scheme can cause inefficiencies in the market and result in inefficient allocations of resources. An empirical analysis of prices at farm, wholesale and retail levels by Girapunthong (2000) suggests that prices for tomatoes originate at the farm level and pass through to wholesale and retail levels. This result is different than that of previously published work and suggests that market structure may be changing. The results also indicate that pricing is symmetric between farm and retail levels, indicating that price increases and price decreases are passed on equally from farm to retail levels. These results suggest that increases in direct purchasing of produce by retail buyers from grower/shippers may be giving producers more influence in the pricing of fresh tomatoes. Asymmetry in pricing does exist between producer and wholesale markets however, suggesting that producer price decreases are passed on more fully at the wholesale market than are price increases. One strategy suggested by these results is for growers to base pricing relationships on the price they are able to negotiate with retail buyers. Since prices are currently published only for sales in terminal markets, the shift of retail produce buying from these markets to direct purchasing removes much of the transparency in produce marketing. Publishing data on sales of tomatoes to end users will add transparency and help the market to operate more efficiently.

Introduction

The market for U.S. fresh tomatoes has undergone substantial change during the 1990s. Along with consolidation among both buyers and sellers at almost every layer within the supply chain, changes in marketing margins between farm, wholesale, and retail levels have occurred. There has been an increase in the margins between producers and the retail level in the 1990's (Figure 1). In a recent study, Worth (1999) suggested that higher marketing costs might be responsible for increasing margins. Retailers have longer operating hours, employ more staff and provide more services than in the past. Weaver (1998) identifies these as reasons why the retail food sector has been one of the few sectors to experience declining labor productivity in the 1990's. In contrast, however, fewer stages in the market process would indicate downward pressure on marketing costs. McLaughlin and Perisio (1994) concluded that retailers are buying more of their produce directly from producers (Table 1) and more recent evidence from Florida tomato shippers reinforces their result by documenting less product moving through brokers and wholesalers over the last five years.

Two concerns, often raised by agricultural producers regarding retail pricing, were noted by McLaughlin in 1995 and are frequently still heard among produce shippers. The primary focus is

flexibility in retail prices rather than actual producer price level. First, large fluctuations in farm level prices are not reflected at the retail level. Second, retailers do not lower prices to consumers in times of oversupply, thus restricting product movement and further depressing price. In a market economy either practice could lead to a disconnect in market signals between the final consumer and suppliers throughout the system, resulting in an inefficient market. Although such relationships in the U.S. fresh tomato industry were studied by Ward in his seminal 1982 work on vegetable pricing, recent structural adjustments within the tomato industry suggest that the pricing relationships may have changed.

Asymmetry in pricing is defined as the difference in reaction of firms to price increases compared to price decreases. It can be viewed in two forms. The first relates to the speed that prices change throughout the market system. The second relates to the extent of adjustment; i.e., whether price changes at one level are fully reflected at other levels of the marketing system. Ward used economic price models to focus on the pricing relationships for fresh vegetables between farm, wholesale, and retail markets for several produce commodities. The models used by Ward addressed the questions of causality (which price series leads the market), symmetry (whether price changes at one level are fully reflected at other levels of the marketing system), and/or lags (the length of time between price changes among different price series). His work concluded that prices for fresh vegetables were set at the wholesale market level and that changes in market price flowed outward from wholesale markets to retail and producer levels. He also concluded that there was asymmetry in the pricing system with price decreases at wholesale level passed on more fully to producer and retail levels than were price increases.

Worth (1999) recently completed a similar study for six different vegetables, including fresh tomatoes, and found asymmetry in tomato pricing with retailers passing on more cost increases to consumers than cost decreases. He suggested that retailers do not pass on price decreases because they attempt to stabilize prices and that increasing use of storage at the retail level might be decreasing the effects of supply shocks on consumer price.

Our study focuses on the pricing relationships between retail, wholesale and producer levels for fresh tomatoes. The primary objectives of our research were to investigate the price transmission framework for fresh tomatoes in the vertical marketing system and to determine where the price leadership for fresh tomatoes originates. Knowledge about these issues should help the fresh tomato industry develop programs that will benefit producers and consumers alike and assure a more efficient marketing system.

Recent Evidence

To provide a consistent update on fresh market tomato pricing relationships, Ward's (1982) estimation procedures were used by Girapunthong (2000). As an indicator of causality, Granger (1986) causality tests were used to evaluate where the leadership for pricing fresh market tomatoes originates. The Granger causality test determines whether one price series can better predict the outcome of another price series than the reverse relationship.

The results of the Granger causality tests completed by Girapunthong in the fresh tomato market suggest that prices flow from producer to wholesale and retail markets. These results are different from those published in previous work (Ward, 1982) and suggests that the structure of the fresh tomato market has changed. These results are consistent with changes in relationships within the industry. As the industry has moved to more direct marketing from the producer to the end users, it may have given producer/shippers more leadership in pricing their fresh tomatoes.

The procedure developed by Ward to evaluate pricing symmetry separates price increases and price decreases in the estimation of the price model and allows for testing of differences in response. Econometric results derived by Girapunthong indicate that pricing relationships between the producer and retail sectors are symmetric, i.e., increases in producer price are passed on to consumers by retailers as are decreases in producer price. In contrast, the relationship between producer and wholesale prices was asymmetric, with producer price decreases being passed on more fully to wholesale than were price increases. This suggests that wholesalers may be following declining markets to stay competitive, but that they are slower to increase prices in rising markets, possibly to retain customers. In addition, many of the tomatoes sold in wholesale markets are handled by repackers who have facilities for storing fresh tomatoes for short periods of time. Such capability and the extension of the shelf-life for tomatoes permits larger inventories to be held when rising markets are anticipated. Therefore, wholesalers can follow increasing producer prices at a slower rate than they would need to follow declining prices.

Conclusions

These results imply that pricing relationships in the fresh tomato market are more efficient currently than when Ward estimated the same relationships in 1982. Increasing margins suggest that costs and services are increasing in the fresh tomato market and that producers should examine the product they supply to determine whether they can participate in the expanded services being provided to consumers and capture some of the value-added. Integrating forward in the fresh tomato marketing system would require producers to provide a consumer-friendly product that would require fewer services between the shipper and retail markets.

The relationship between producer and wholesale prices is asymmetric, suggesting that repackers are using inventory capabilities to maintain profit margins and a reliable customer base. This would suggest that the prices producers charge for their product could be more efficiently based on prices established by the retail sector. Such a strategy would require more transparency, however, in the pricing of product by end users. There is transparency in the wholesale markets because USDA publishes data on prices at the producer and wholesale market levels. However, very little data is published on pricing at the retail sector level and the cost factors that drive price at retail. Lack of transparency in the retail sector may be contributing to increasing margins. As less product moves through the wholesale markets, and influences from this sector continue to decline, information from the retail sector will become increasingly important. Public policymakers need to examine the pricing transparency issue and publish more data that would help producers in pricing their products.

In response to a request from producer groups throughout the U.S., the Economic Research Service of USDA is examining retail structure, trade practices and pricing strategies within the U.S. as they impact fresh fruit and vegetable markets. Seven products are included in the study: fresh market tomatoes, fresh grapefruit, fresh oranges, table grapes, carrots, lettuce, and bagged salads. The objectives of the study are to 1) characterize the types of marketing fees and services (including non-invoice charges) that may have been included in produce contracts; 2) determine whether such fees and services are related to size of shipper or retailer, connected to product performance or quality standards, occurring for only select categories of produce, or increasing in occurrence; and 3) empirically analyze price mar-

gins including such fees and services to statistically test for the presence of retailer market power

The USDA study is collecting information through a series of written surveys with produce shippers, more extensive personal interviews with selected shippers and retailers, retail pricing data, and regularly published prices. Publication of an ERS report including results from all phases of the research is anticipated in December 2000.

Suzanne Thornsbury, assistant professor, UF's Indian River Research and Education Center, Ft. Pierce, and John J. VanSickle, professor, UF Food and Resource Economics Dept., Gainesville.

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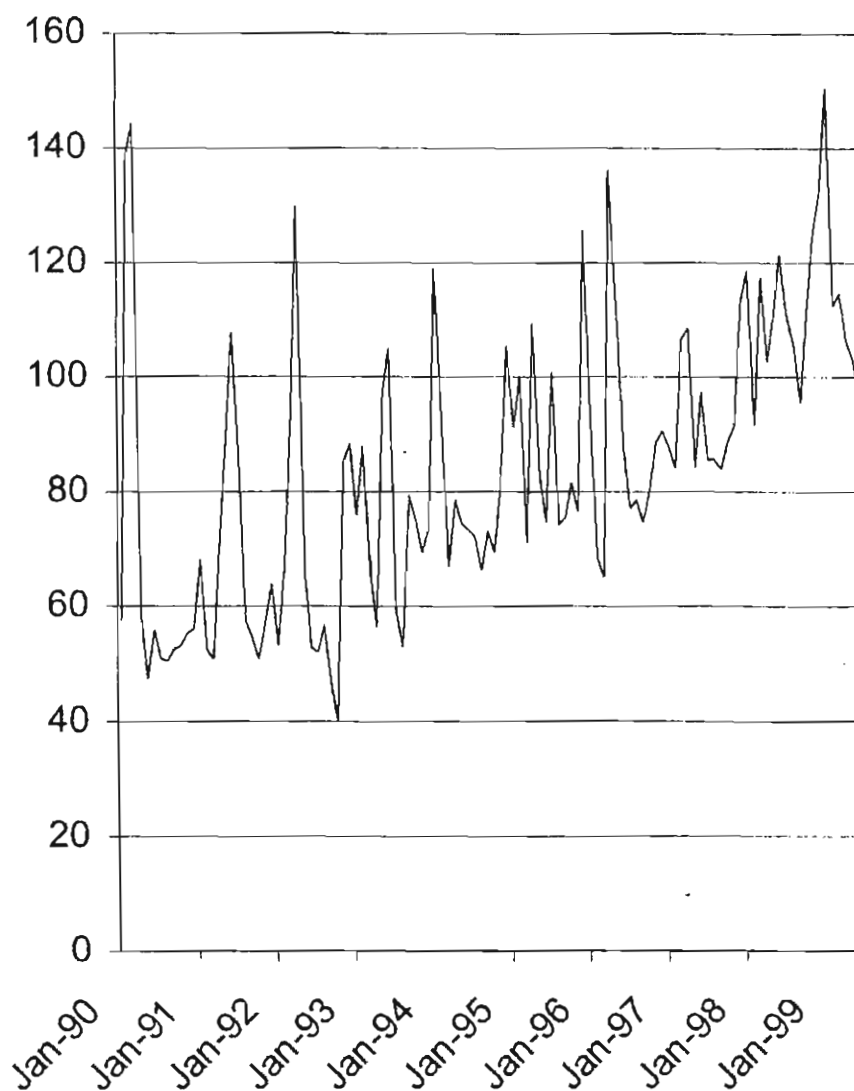
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Table 1. Percent of produce sourced by supermarkets from grower/shippers, brokers and terminal markets, 1973, 1982 and 1993.

Year	Grower/shipper	Broker	Terminal
1973	39	29	33
1982	41	34	27
1993	53	27	20

Source: McLaughlin and Perisio, 1994

Figure 1. Monthly farm retail margins as a percentage of farm price, January, 1990 to June, 1999



Weed Control in the Post Methyl Bromide Era

J. P. Gilreath and J. W. Noling

The loss of methyl bromide in the very near future will represent a time of change for most vegetable growers. Soilborne pest control always has been a challenge for growers, but the loss of methyl bromide may force some growers to make drastic changes in the way they farm. Most of us have forgotten how to apply herbicides, other than in row middles, and which herbicides to select for weed control in the bed. Some of us never knew because we entered farming after methyl bromide became the industry standard. There are few farms with the proper application equipment readily available and gearing up to meet the demands of an age without methyl bromide will be demanding. While growers have several options for control of nematodes and soilborne diseases, there are few options for weed control in the bed. The most significant pest for growers will be weeds. Not only do we have few options for weed control, but weeds are the most visible pests. A grower does not see nematodes and he may not see the manifestation of some soilborne diseases until late in the season, but he generally sees weed problems early in the season. When growers complain of fumigant failure, it is usually due to the appearance of nutsedge or other tough weeds growing through the mulch film or out of the plant holes. As a result, you, as growers, need to start learning how to use the replacements now, while you still have time.

In January 2001, there will be a 50% reduction in the availability of methyl bromide. No one knows what the price will be, nor do they know what concentration will be available. One rumor has it that it will be offered as a 50/50 mixture with chloropicrin. That would represent 175 lbs of methyl bromide per treated acre, if a grower were using the "standard" rate of 350 lbs of 67/33 formulated product. This rate of methyl bromide is probably at or below the minimum quantity necessary for good weed control, especially for nutsedge, under ideal conditions. Few of us ever have ideal conditions, so this means that nutsedge will become more widely distributed and more prevalent with time. Even with methyl bromide, we have seen nutsedge spread and the seriousness of it as a weed increase. Without methyl bromide, there is a chance that nutsedge will become an even greater problem.

For some time University of Florida and USDA scientists have been trying to address the personal protective equipment (PPE) issue with Telone products. For most growers, this is the biggest hurdle to the adoption of Telone (II, C-17, and C-35) as an alternative to methyl bromide, outside of the nutsedge control issue. The approach of most scientists has been to shift from in bed application to broadcast application of Telone products. This eliminates PPE for all but one worker: the tractor driver making the application. Results of this type of application are less than conclusive. Most of the research has been conducted on commercial farms where methyl bromide has been used in the past. Seldom do we encounter populations of rootknot nematodes or high incidences of soilborne disease on commercial farms. We have obtained some results with the control of purple nutsedge; however, these results have been varied. In several trials on tomato, application of Tillam preplant incorporated and broadcast application of Telone C-35 have produced tomato yields equivalent to methyl bromide or Telone C-35 in the bed with Tillam. We even have observed residual weed control in the row middles from our broadcast application of Tillam, but not every time. We also have seen what appears to be improvement in root-

knot nematode control with broadcast application in at least one trial. What we do not feel comfortable with, at this time, is control of soilborne diseases with broadcast applications of Telone combined with chloropicrin (Telone C-17 or C-35). More research is needed on this aspect of soilborne pest control before we can tell you that broadcast application Telone products will control both nematodes and soilborne diseases.

Some of the research conducted over the past two years has focused on identification of the best applicator for broadcast and, based on limited data, it appears that the Yetter coulter rig is doing the best job, in most situations. However, there have been some problems even with this rig. One of the big pluses for coulters is their ability to slice through trash in the field. We do not drag tying twine and scraps of plastic mulch as we do with sweeps, knives, or other equipment. One of the objectives of this applicator is to put the Telone deeper in the soil so more nematodes are killed. If the soil is too wet, this can result in a longer residual life for Telone and an increased incidence of crop damage or a longer waiting period from application to planting.

Regardless of what fumigant we are using, weed control will be the greatest challenge. Each vegetable crop has a short list of herbicides labeled for use in them. Tomato growers are perhaps the luckiest for they have Tillam which does provide some control of nutsedge. However, even Tillam requires a certain amount of attention to detail to achieve any level of success. Most growers will find that they will have to shift their thinking from weed control to weed management. Weed management will dictate that those fields with heavy infestations of nutsedge should be the primary recipients of any available methyl bromide. This is an investment for the future of those fields. Growers also should do more to manage weeds in the off-season. Practices like cover cropping can impact nutsedge populations with the selection of crop often being the most important aspect. For example, nutsedge populations actually have been higher where millet was grown than where no cover crop was planted. Iron clay pea and some other broadleaved cover crops have reduced populations. Remember one thing, though: these changes in populations are only temporary. Thus, my emphasis on management rather than control. Even methyl bromide does not completely eradicate nutsedge. If it did, a grower would not have to retreat fields so often. Double cropping encourages soilborne pest resurgence, even resurgence of nutsedge. Cultural programs combining the application of herbicides, such as Roundup, during the offseason with cultivation can help with nutsedge management, but they will not eliminate it. They reduce it to a manageable level for a short time and if the program is abandoned for any length of time, nutsedge quickly returns.

Along with selection of herbicides based on label for a specific crop, growers will need to know something about their specific weed pests in each field in order to choose the right herbicide. No one herbicide controls all weeds. Growers also will have to consider plant back restrictions of various labeled products (Table 1). If you are going to use Devrinol on tomato and will be following it with double cropped cucumbers, you may have a problem because the plant back restriction on Devrinol is 12 months and cucurbits are not listed on the Devrinol label. I have not seen any injury to double cropped cucumbers from Devrinol residues in my research, but the label does specify a 12 month interval from application to planting a nonregistered crop, like cucumber. Interestingly, if my memory serves me correctly, some cucurbits were on the Devrinol label for a short period of time, until there was some crop damage reported. This is something which you will have to consider BEFORE you begin the tomato crop.

Whatever herbicide you use, you will have to learn how to

apply it. You need a sprayer dedicated to herbicides to minimize the potential for accidental application of residues to other crops and you need to know how to calibrate the sprayer and operate it properly. Most problems with herbicides are due to mistakes made during calibration and application errors, like excessive overlap between nozzles. These may seem like very basic issues, but it is usually the little details that cost you money. While I am sure that all of you know how to calibrate and operate a sprayer properly, I also am sure that most of you will not be the actual applicator. Things always go bump in the night, and spray equipment is one of those things. Some slop in a fungicide or insecticide application typically has minimal impact. If you get a bit too much, you just get better control, unless the tank mix is on the "hot" side. Too little spray material and you don't get the control you should, but then there is always next time. Herbicides are a different critter. Too little herbicide and you get poor weed control with no opportunity for a second application. Too much herbicide and you stand a good chance of crop injury. Streaks in the application pattern usually mean too much herbicide in some part of the field and they often seem to be right where the crop will be planted. Many of these herbicides need to be incorporated into the soil and your choice of implement can influence results. Each herbicide has its advantages and limitations. I could tell ten people how to calibrate, apply and incorporate Tillam, along with all the little tricks I have learned, and I bet at least one person would have either crop damage or poor control. Yet, when quizzed about what the grower did, I bet I would hear that they did everything just the way I instructed. Sometimes you never figure out what went wrong, but most times I hear something weeks later than confirms what I suspected; someone did not follow ALL of the instructions closely. In order to help you get up to speed on the principal herbicides with which you will be working in the near future, I want to spend the rest of my time discussing them and what I think you need to know, as briefly as possible.

Table 2 lists those herbicides registered for use in tomato beds. Please note that I have not listed Sencor or Lexone as one of those herbicides. While I have used Sencor IN the bed of tomatoes in the past, it always has been in nonmulched tomato production. If you put a polyethylene roof over a herbicide, it may cause it to act much differently than it did without that mulch film. Most of you have seen Sencor damage on tomato, so I probably don't need to caution you too much about this. Sencor use in nonmulched tomato is restricted to established plants and, in a nonmulched, nonfumigated bed, you have microorganisms present that can degrade it. In mulched culture, Sencor moves with the soil water and can concentrate around the plant hole, just like fertilizer salts. A higher concentration can spell damage under these conditions.

Tillam: Tillam is an old compound, having been around about 30 years now. It is labeled only for tomato, tobacco, and sugar beets. Last time I checked, Florida did not have a significant sugar beet industry and after the recent jury awards I am not sure about tobacco's future as a crop. Until last fall there was a label restriction against using it in hand transplanted tomatoes. The restriction was based on concerns by the EPA that workers might inhale damaging quantities of Tillam as they leaned forward to set the transplant because it is a volatile product. After much discussion the decision was made to modify the existing label to allow use in Florida in hand transplanted tomatoes, provided the application be made 3 weeks prior to transplanting. That restriction has been lifted for about 3 years to give the manufacturer time to generate the data necessary for a permanent label amendment. Tillam is fairly effective against nutsedge and many other weeds, but its best attribute is the capacity to provide

some control of nutsedge. Tillam is very volatile and must be mechanically incorporated as soon as it is applied. The best way to do this is the mount your spray boom on the front of your incorporation implement. Occasionally I observe a failure with Tillam, but it usually can be explained. The incorporation method for Tillam can be quite important, not only for good weed control, but also for minimization of phytotoxicity or yield effects. Field research has demonstrated that Tillam, if not applied and incorporated properly, can be quite phytotoxic to tomato. If you don't believe me, just ask the guy whose 5 acres I stunted a few years back. That story did have a happy ending though; it happened during one of those odd seasons when the later the better the market. As a result, the grower did not lose money on that particular 5 acres, but he did not bother to tell me that until a few years had passed. Incorporation with a grove disk (a shallow cultivating disk) or a field cultivator (S-tine harrow with crumbler bars) appeared to provide sufficient mixing of Tillam for good weed control and no crop injury. Thorough incorporation with a light disk or a field cultivator is the preferred method and can provide results comparable to methyl bromide when combined with Telone C-17 or Telone C-35.

Tillam must be applied at the full label rate of 2/3 gallon (86 oz.) per treated acre to be effective. Reducing the rate will reduce efficacy greatly. Rates in excess of 2/3 gallon per acre may cause crop injury and reduce tomato fruit production. Small discrepancies in rate generally are not a problem. Typical damage consists of stunting and may include malformed leaves. Foliar chlorosis is not normally observed and would suggest some other causal agent. Good agitation in the tank is important and spray pressure should be maintained below about 40 psi to minimize spray drift and assure that all product is going where you want it - on the soil.

Tillam should be applied uniformly to the entire field from ditch to ditch so there is no chance that nontreated soil can be pulled into the bed. Not only should the sprayer be checked for uniformity and accuracy of application rate, but Tillam also must be incorporated properly. Research has demonstrated that Tillam must be mixed thoroughly into the soil to the depth of the bed to provide good nutsedge control. Since bedders pull soil from about 6 to 8 inches deep, Tillam must be incorporated to at least this depth. Deeper mixing also may be advantageous for broadcast field applications. For example, nutsedge control has been achieved even in the row middles when the broadcast, pre-bed application of Tillam was deeply incorporated and all of the Tillam treated soil was not moved into the finished bed. If nutsedge is not the target weed, Tillam can be applied more shallowly, but movement of too much nontreated soil into the bed can reduce efficacy. A shallow incorporation on the bed surface would provide control of small seeded annual weeds, such as crabgrass, but would not provide good nutsedge control since nutsedge easily can emerge from deeper in the bed.

Method of incorporation for Tillam can be quite important, not only for good weed control, but also for minimizing phytotoxicity or negative plant growth and yield effects. For example, in one experiment plant stunting was observed when Tillam was incorporated with bedding disks. Bedding disks tend to fold soil and layer surface applied materials rather mixing them thoroughly. A concentrated layer of Tillam in the soil can cause delays in plant development, early season phytotoxicity, and restrict root growth until the herbicide degrades to a point where it no longer impedes root development. In the study in question, tomato fruit production was reduced to about 2/3 of what it should have been and maturity was delayed by approximately 2 weeks (remember my story about the late market). Application of Tillam in the throat of a bedder, expecting the bedder to proper-

ly mix it into the soil, is a recipe for disaster similar to the use of bedding disks or disk/hillers. The mixing is not thorough enough with this equipment and poor weed control and crop injury are almost certain to follow. Thorough incorporation with a disk, rototiller, or a field cultivator is the preferred method and can provide results comparable to methyl bromide when combined with Telone C-17 or C-35. Incorporation with a disk may require two passes to thoroughly mix Tillam, whereas under *good* soil conditions a field cultivator (s-tine harrow) usually can achieve the desired extent of mixing in one pass. A rototiller is the best incorporation implement, but they are slower than a disk or cultivator, require more horsepower to operate and are not as readily available as a disk or cultivator.

Speed of incorporation can be important for good mixing. Generally when using a disk or a field cultivator, ground speed should be at least 6 mph in order to throw the soil more and assure complete working of the soil. At slower speeds soil mixing is not as good because of less action. With disks, the amount of set can be a factor in mixing. Maximum set is to be discouraged because it tends to bury the herbicide more than desired and disking at this stage is strictly for herbicide incorporation, not for land preparation where maximum set to the gangs is more commonly practiced. The extent of set should be enough to mix the soil to the desired depth without leaving the soil surface in a less than acceptable condition, such as deep troughs or ridges, and not so much that the ground speed can not be maintained above six mph.

Soil temperature and moisture conditions can be very important in determining the level of weed control achieved with Tillam. For example, soil which is too dry promotes volatilization of Tillam into the atmosphere. A dry sand also tends to be warmer than a moist one and volatilization losses can be rapid. Some of the worst performance observed in research occurred when Tillam was applied to a soil that was on the dry side and the cultivator fluffed the soil, allowing the soil to dry even more.

In addition to volatilization, performance can be lost due to poor mixing. Soil moisture can play a significant role in this. A soil which is very dry does not "flow" as well through a disk or cultivator as does one with optimum moisture content. Good mixing is dependent upon the soil particles having some adhesion to one another so that the soil is more easily turned and blended rather than moving more like a liquid as it does when it is too wet or dry. If the soil is wet, it becomes sticky and will not break apart as it is disturbed, moving around field cultivator sweeps or points, much like butter would. This can result in uneven distribution of Tillam in the bed when the bed is formed which, in turn, can mean areas where weeds germinate and emerge. It is very difficult to mix dry soil; the soil tends to fall out of the disk blades prematurely and does not "turn over" when a field cultivator moves through it. Soil moisture should be adequate for good seed germination so that it mixes well when Tillam is incorporated and so the weed seed and tubers germinate quickly. Since about one-half the Tillam is present in the soil after 2 weeks, it is important that weed seed germinate and tubers sprout soon after application when the maximum amount of Tillam is present.

Nutsedge often becomes a problem on bed shoulders, even with the use of methyl bromide. This is because the shoulder gets hotter than most of the rest of the bed and pesticide loss is greater under higher temperatures. Tillam can exhibit the same behavior, presumably due to volatilization and faster degradation on shoulders.

Soil should be free of weeds and debris should be well decomposed, as it should be when applying methyl bromide.

Some growers allow some weed growth to be disked into the soil at time of fumigation and expect good efficacy. While this often works with methyl bromide, it is a poor practice in which to engage when using any of the other fumigants and herbicides. Tillam will not control weeds once they have emerged from the soil and it is important that it be applied prior to germination and emergence. This is especially important with nutsedge. Fields should be clean cultivated for several weeks prior to Tillam application and all plant debris should have decomposed enough so that it is no longer recognizable.

Lastly, you should not expect Tillam to control ALL weeds. If you do not have nutsedge in your field, you may wish to select another herbicide. Herbicide selection should be based on weeds expected to be a problem. Thus, knowing the field history is important.

Devrinol: This is another old compound which has never found much favor with growers. Frequently it does not work very well and the residual life appears to be rather short; however, there are some things you can do to improve performance. A lot of the problem with Devrinol in the past was due to how it was applied. Devrinol breaks down quickly in sunlight and without overhead irrigation we have no way to move it into the soil surface to protect it from photo destruction. Because it is considered to be completely degraded after 24 hours of exposure to bright sunlight, mechanical incorporation greatly improves its performance. It is effective against a wide range of grass and broadleaf weeds, but it is very weak on nutsedge, especially at the current labeled rates for tomato and pepper. Strawberry allows a 2x increase in use rate over that registered for tomato and it makes a big difference in weed control. If you are going after small seeded annual weeds, then a surface application just prior to laying plastic mulch will probably do. You may want to improve upon that by shallowly incorporating it in the bed surface, but if you are going after nutsedge, you should incorporate to the full depth of the bed because nutsedge will emerge from throughout the bed profile. The equipment used for incorporation is important and is the same as that which was discussed under Tillam. How effective is Devrinol against nutsedge? I have observed a range of control from no control to about 60 to 70%, but lower is more the norm.

Treflan: Many of the same comments made for Tillam apply to Treflan. Just like Tillam, Treflan is a very volatile product and must be incorporated thoroughly, immediately after application. Immediately means within seconds. The use rate must be closely adhered to or you may experience crop injury. Although it does not control nutsedge, Treflan has an advantage in that it is labeled on quite a few vegetable crops. It is especially effective against grass weeds. The plant back restrictions vary by crop, but in general average 5 months for nonlabeled crops. Proper incorporation is a must with Treflan. The same equipment suggested for use with Tillam can be used with Treflan. Refer to the comments under Tillam for more information on this.

Future herbicides: Gowan recently acquired the marketing rights to Permit and will be developing and marketing it under the name Sandea. This product is effective against emerged nutsedge and they hope to register it for use on tomato. This would provide tomato growers with a safe cleanup material which could be used to control nutsedge which has recently emerged through the mulch. There are a few other possible herbicides, but none are as close to registration as Sandea, and I hesitate to mention them for fear that it would only give you false hope. Even as valuable as tomatoes are to the state of Florida, they are still a minor crop for registration purposes. Minor crop spells minor return to investors for pesticide manufacturers and

they are not inclined to spend the money on new registrations which are not going to show a real profit. Combined with that is the sensitivity of tomatoes to many herbicides.

Growers will be facing challenges in the post methyl bromide era. Perhaps their greatest challenge will be effective weed control, especially nutsedges. Attention to details can make a big difference in how effective your herbicide program is. Knowing field histories will become increasingly important in the future because growers will be targeting specific weeds within fields. Greater emphasis will need to be placed on year-round weed management rather than seasonal weed control. Yes, life without methyl bromide will be a challenge, but that is what farming is all about: challenges.

J.W. Noling, UF/IFAS, Citrus Research and Education Center, Lake Alfred, Fla. and Jim Gilreath, UF/IFAS, Gulf Coast Research & Education Center, Bradenton, Fla.

Table 1. Principal herbicides for use in tomato crop beds and use considerations.

Herbicide	Incorporation required	Plant back restriction
Devrinol	no, but aids in nutsedge control	12 months for nonlabeled crops
Tillam	yes, immediately	none listed on label
Treflan/Trilin	yes, immediately	5 months on average

Table 2. Herbicides labeled for use in tomato and their effectiveness against nutsedge.

Crop	Herbicide	Nutsedge control
Tomato	Tillam	yes, but not consistent
	Sencor/Lexone. not in bed	no
	Treflan/Trilin	no
	Devrinol	fair to no control, erratic

New Tools for Management of Whitefly-Transmitted Geminiviruses

J. E. Polston and D. J. Schuster

Summary

Tomato yellow leaf curl virus (TYLCV-Is) is a whitefly-transmitted geminivirus that is a major concern for tomato growers in the southeast U.S. The virus is continuing to expand its geographic range both within and outside of the U.S., presumably through the movement of whiteflies that carry the virus, and virus-infected plant material. Virus-infected transplants are one method for the re-introduction of virus into fields at the beginning of the season. Different approaches were explored this past year to interfere with transmission of TYLCV-Is in order to develop new methods for the protection of tomato transplants in transplant production houses.

Current Status of TYLCV-Is and TYLCV-Is Management in the U.S.

Continued Expansion. Tomato yellow leaf curl virus (TYLCV-Is) is continuing to spread throughout the world at a rapid pace. The virus was first identified in Israel nearly 40 years ago and was confined to the eastern Mediterranean until the late 1980's or early 1990's when it was introduced into the Caribbean. In the early 1990's the virus was reported for the first time from Cuba (1990), the Dominican Republic (1992) and Jamaica (1993). Within a few years the virus was reported from Mexico (1997), Florida (1997), The Bahamas (1998), and Georgia (1999). The virus also spread into the western Mediterranean and was reported for the first time from Portugal (1996), Spain (1999), and Reunion (1999). The mechanism suspected of introducing this virus to the Caribbean is the transatlantic movement of infected plant material.

In the U.S., TYLCV-Is is found in all tomato-producing counties in Florida. Initial spread was rapid and occurred within a year after its discovery. In spite of directed management practices, TYLCV-Is has continued to appear in more and more farms, and once present slowly increases in incidence from season to season. In Georgia, TYLCV-Is is continuing its spread throughout the southern half of the state, appearing in new counties as well as new farms.

Management. The management practices for TYLCV-Is and other whitefly-transmitted geminiviruses are primarily cultural (eliminate the primary sources of virus) and chemical (reduce vector populations through multiple applications of pesticides). Cultural practices that have been shown in various parts of the world to reduce the incidence of geminiviruses in the field are the use of tolerant cultivars, UV-reflective mulches, production in tunnels made of whitefly-proof screening and/or UV absorbent screening, sanitation, and whitefly and geminivirus host-free periods. Repeated applications of a number of foliar and systemic contact insecticides and growth regulators have been used to manage populations of the whitefly vector.

In Florida tomato fields, practices used to manage TYLCV-Is are roguing, use of imidacloprid in transplants and at the time of transplant to the field, rotation of contact and growth regulator insecticides, and sanitation. Currently available insecticides to manage whitefly populations are effective for reducing populations to a level that reduces the physiological damage caused by feeding. However, pesticides alone are not always sufficient to reduce populations to the extent that transmission of geminiviruses is prevented. Geminiviruses can be transmitted rapidly,

often before insecticides can take effect. At this time, the neonicotinoid systemic insecticides imidacloprid (Admire®) and thiamethoxam (Actara®) are the primary means of managing geminiviruses in Florida. Imidacloprid has been shown to reduce rates of geminivirus transmission, has some repellency against whiteflies, and has been shown to interfere with the feeding behavior of whiteflies (Isaacs *et al.*, 1999). While these insecticides can reduce the transmission of geminiviruses, they do not prevent transmission. In addition, imidacloprid may be phytotoxic depending on the plant age and concentration, which limits the amount and plant age at which it can be applied. This is especially relevant when considering the use of this for protection of transplants.

Though there are a number of approaches used to manage TYLCV-Is in the field, transplant producers have fewer options. Imidacloprid can be detrimental to young tomato plants, and its use in the plant house as well as in the field is undesirable since this will facilitate the development of whitefly resistance to the insecticide. Transplants in the plant house are at the mercy of populations of whiteflies that migrate from old tomato fields, some of which may have fed on TYLCV-Is infected plants.

The development of new methods for transplant producers to manage whiteflies and TYLCV-Is would slow even further the spread of TYLCV-Is from season to season and from location to location which would be a benefit to both tomato and transplant producers.

New Approaches That Interfere With the Movement of TYLCV-Is

Fulfill® for Protection of Transplants. Fulfill® (pymetrozine) is a chemical found to repel aphids and interfere with their normal feeding behavior. This insecticide has a unique mode of action and represents a new class of insect control agents. Its ability to interfere with aphid feeding was found to reduce the transmission of persistently transmitted viruses. For these reasons, we evaluated this compound for its usefulness as a protectant for tomato transplants from whitefly transmission of TYLCV-Is.

The compound was found to provide excellent protection against transmission of tomato yellow leaf curl virus by relatively high populations of whiteflies (3 to 5 per plant), reared on TYLCV-Is infected tomato plants, that were added one day after one application of Fulfill. Transmission rates were determined 4 weeks after addition of whiteflies by visual inspection for symptoms. Results with two different rates of Fulfill are shown in **Figure 1**. No phytotoxicity was observed at either rate.

A study was then conducted to determine for how many days a single application of Fulfill would be effective in reducing transmission (residual activity). Two rates of Fulfill were evaluated using 3 to 5 viruliferous whiteflies per plant added at 1, 4, 8 or 11 days after a single application. Results are shown in **Figure 2**. Control plants, not shown in **Figure 2**, for all times and rates were 95 to 100% infected. The higher rate of Fulfill was shown to have activity for 7 days while the lower rate had acceptable activity for 4 days.

Fulfill demonstrated useful protection from transmission of TYLCV-Is presumably through interference with normal whitefly feeding. Fulfill has a very different chemistry than the neonicotinoid insecticides, and might prove useful in the plant house for reduction of whitefly feeding and subsequent transmission of TYLCV-Is and other whitefly-transmitted geminiviruses, without contributing to a build-up of whitefly resistance to either Admire or Actara.

Identification of Whitefly Repellents. This past year we

developed a bioassay for the evaluation of a number of compounds for their ability to repel adult whiteflies and then used this bioassay to test 21 compounds for their ability to repel adult whiteflies. Sunspray Fine Oil has known repellency to whiteflies and therefore we used this as our standard and compared all test compounds to it. Several plant-derived oils as well as SunSpray Fine Oil were shown to repel whiteflies (Table 1). We found several commercial products with reputed repellency to have little to no effect on whiteflies in our bioassay (Table 2). Further work is in progress to develop these findings into new control measures, and to determine if the measured repellencies have an effect on virus transmission.

Others. We tested Actigard® (Novartis) and 12 different strains of plant growth promoting rhizobacteria (PGPR) for their ability to induce tomato transplants to be more resistant to infection by TYLCV-Is. We used an approach similar to that used to test Fulfill. We found that Actigard applied as a soil drench at the highest rates tested, reduced the rate of transmission of TYLCV-Is by about 50%. Actigard in combination with other approaches may prove to be a useful strategy. However further testing at higher rates is required to determine if Actigard will be sufficiently effective for transplant producers. The 12 strains of PGPR's that were tested increased the growth rate of the transplants, did not show any phytotoxicity, but did not have any

effect on the transmission of TYLCV-Is. We are also studying ways to reduce UV light in plant houses. UV light has been shown to be critical for movement of whiteflies and transmission of TYLCV-Is to new plants.

Conclusions

New approaches are needed for the management of TYLCV-Is. Transplant producers require greater control of whiteflies and virus transmission than fruit producers but have few methods appropriate to their needs. Several approaches for plant house management of whiteflies and virus transmission were explored this past year. At least one approach, weekly applications of Fulfill, was found to show some promise. Other approaches, such as the use of Actigard and the use of whitefly repellents, may have potential but require further study. Studies on these and other approaches are in progress.

Jane Polston (jep@mail.ifas.ufl.edu) and D.J. Schuster (djsj@gnv.ifas.ufl.edu), both with UF's Gulf Coast Research and Education Center, Bradenton, Fla.

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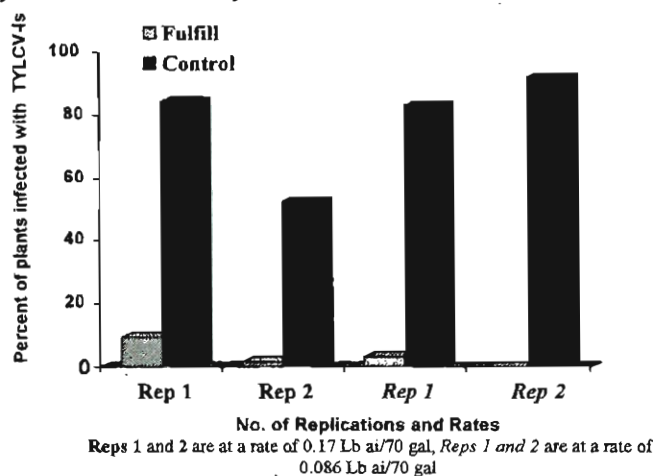


Figure 1. Effect of Two Rates of Fulfill on Transmission of TYLCV-Is. Whiteflies (3-5 per plant) reared on TYLCV-Is infected tomato plants were added one day after application of Fulfill. Transmission rate was determined 4 weeks after addition of whiteflies.

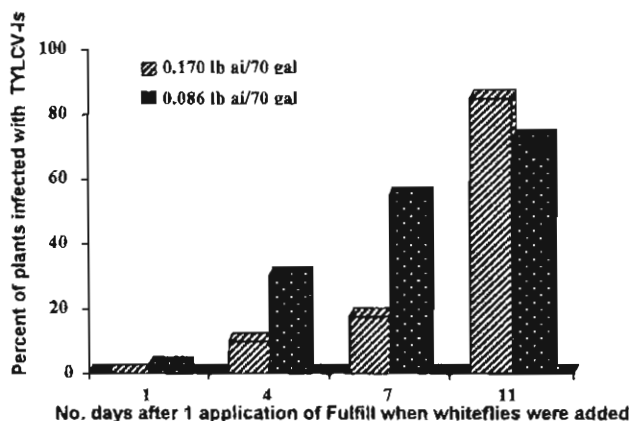


Figure 2. Residual Activity of a single Application of Fulfill at Two Rates. Whiteflies (3-5 per plant) reared on TYLCV-Is infected tomato plants were added 1, 4, 7, or 11 days after one application of Fulfill. Transmission rate was determined 4 weeks after addition of whiteflies. Untreated controls (not shown) were 95-100% infected after the 4 week incubation period.

Table 1. Compounds found to have repellency to silverleaf whitefly adults in a laboratory bioassay.

Material	RC₅₀¹	Relative repellency
Sunspray Ultrafine Oil ®	0.15	high
Capsacin (0.1%)	>0.10 ²	---
Castor Oil	0.48	moderate
Cineole	0.46	moderate
Citronellal	0.09	high
Geranium Oil	0.12	high
Ginger Oil	0.06	high
Hamlin Oil	0.06	high
Limonene	0.22	high
Olive Oil	0.03	high
Winter Green Oil	0.08	high

¹ Estimated concentration (% v/v) required to repel 50% of the whitefly population.

² Higher concentrations were too injurious to handle.

Table 2. Commercial products and compounds found to have no or poor repellency to silverleaf whitefly adults in a laboratory bioassay.

Material	RC₅₀¹	Relative repellency
Sunspray Ultrafine Oil®	0.15	high²
Bio Crack ®	3.67	low
Capsacin (0.1%)	>0.1 ³	---
Envirepel ®	>10.0	very low
Neemix ®	>5.0	very low
Organocide (New) ®	1.60	low
Organocide (Old) ®	1.39	low
Pepper Wax ®	21.13	very low
Trilogy ®	2.17	low
Tryptophan	>5.0	very low
Tween 20 ®	13.45	very low
Yeast + sucrose + water	>5.0	very low

¹ Estimated concentration (% v/v) required to repel 50% of the whitefly population.

² Included as a point of reference.

³ Higher concentrations were too offensive to handle.

Tomato Yellow Leaf Curl Virus Resistant Tomato Variety Trials

Phyllis Gilreath, Ken Shuler, Jane Polston, Tracy Sherwood, Gene McAvoy, Phil Stansly and Eric Waldo

Additional index words. silverleaf whitefly, *Bemisia argentifolii*, *Lycopersicon esculentum*, fruit yield.

Abstract. Six of the most promising tomato yellow leaf curl virus (TYLCV-Is) resistant hybrids currently available were evaluated in trials conducted in the fall, winter and spring of 1999-2000. In the Palmetto/Ruskin production area, two observational trials were planted on commercial farms in Ruskin and Bradenton, and one trial was conducted to evaluate yield at the Gulf Coast Research and Education Center, Bradenton. In Palm Beach County, one trial was conducted for harvest on a commercial farm in Boynton Beach. An additional trial was conducted at the Southwest Florida Research and Education Center, Immokalee. At all locations, six TYLCV-resistant varieties were compared to at least 2 standard varieties. Virus pressure was light at the four sites in Manatee and Palm Beach counties. Silverleaf whitefly numbers and virus pressure were very high in Immokalee. All plants of the standard cultivars which showed symptoms of TYLCV-Is exhibited 100% infection by 8 weeks after transplanting, whereas resistant varieties were only 0 to 3% symptomatic, with the exception of HA3044 that reached 54% during the same period. Total marketable yield ranged from 1881 to 2899 25-lb cartons per acre in Manatee, from 1577 to 2300 cartons per acre in Palm Beach county, and from 343 to 2658 cartons per acre in Immokalee. All top yielding varieties had acceptable horticultural characteristics. Fruit quality parameters, such as catfacing, scars and zippers, were also evaluated.

Introduction

Since its first occurrence in Florida in July 1997, tomato yellow leaf curl virus (TYLCV-Is) has caused major economic damage to Florida's \$420 million tomato crop (Polston *et al.*, 1999). Symptoms occur within two to three weeks after infection and include stunting, reduction in leaf size, chlorosis, mottling and upward curling of leaves, flower abscission and significant yield reduction (Polston, *et al.*, 1994). The virus has a broad host range including crop and weed species (Polston, Reif and Foley, 1999). Control has centered primarily around management of the vector, the silverleaf whitefly (SLWF), by both chemical and cultural methods. Even with widespread use of the soil applied systemic insecticide imidacloprid (Admire 2F, Bayer Corp.) and diligent roguing of symptomatic plants in commercial fields, TYLCV-Is has continued to spread geographically and is still causing significant economic losses for tomato producers in Florida (Polston *et al.*, 1999). There is also concern about potential resistance problems that may develop in the future as a result of widespread use of imidacloprid (Schuster, 1999). The use of resistant varieties is one of the newest of several potential tools growers can use to combat TYLCV-Is in Florida. Five variety trials were conducted during the fall, winter, and spring of 1999/2000 to evaluate 6 tomato cultivars for resistance to TYLCV-Is and horticultural characteristics, including yield. The cultivars evaluated in these trials were selected because they have reported tolerance or resistance to TYLCV-Is and horticultural

characteristics that make production in Florida economically feasible.

Materials and Methods

Observational trials. Two observational trials were conducted on commercial farms in Ruskin and Bradenton in fall 1999. Varieties included 4 lines from Hazara, HA3017A, HA3017B, HA3044 and HA3048, 2 lines from Petoseed, Px150420 and Ps150535, and 2 grower standard cultivars, Sanibel (Petoseed) and FL47 (Asgrow). Both trials were transplanted on September 9, 1999, and the 10 plant plots were replicated 4 times in a randomized complete block design. Seepage irrigation was used in the Ruskin trial and drip was utilized in the Bradenton trial. Standard production practices were followed, including the use of Admire in the transplant house and in the plant hole. Plants were evaluated for virus incidence two times during the season, once approximately 8 weeks after transplanting and again just prior to first harvest.

Bradenton. The trial at the Gulf Coast Research and Education Center in Bradenton was transplanted on September 9, 1999, with 16 plants in each of 4 blocks using a randomized complete block design. Varieties planted were the same as those in the observational trials. Plants were spaced 2 ft apart on raised, fumigated, polyethylene-covered beds on 5 ft centers with seepage irrigation. Plants were treated with imidacloprid in the transplant house and in the field at the time of planting (16 oz/A). They were sprayed once each with Lannate and Thiodan, and twice with Knack. Other production practices were standard. Plots were harvested three times on December 2, December 16, 1999 and January 3, 2000, and separated as to marketable and cull on the basis of size, shape or defects.

Palm Beach County. This trial was transplanted on a commercial farm in Boynton Beach on October 8, 1999, with 8 plants per plot, replicated 3 times in a randomized complete block design. Varieties were similar to the Bradenton trial with the addition of 'Leila' from Rogers Seed. 'Leila' was included because in previous grower field trials some tolerance to TYLCV-Is had been reported. Spacing was 2 ft between plants on raised, fumigated, polyethylene-covered beds on 5.25 ft centers. Standard production practices were followed, including the use of Admire in the transplant house and in the field as a drench at the time of transplanting. Plots were harvested on January 7, January 18, January 28, and February 11, 2000, and separated as to marketable and cull on the basis of size, shape or defects.

Immokalee. In this trial at the Southwest Florida Research and Education Center, nine varieties were transplanted on March 15, 2000, with an average of 17 plants per plot, replicated 4 times in a randomized complete block design. Spacing was 1.5 ft between plants on raised, polyethylene-mulched beds on 6 ft centers. Varieties were the same as in the Palm Beach trial. Drip irrigation was utilized along with standard production practices. Admire was not used in either the transplant house or in the production field. On March 16, one tomato plant of the variety 'Neptune' was transplanted into the center of each plot to serve as an inoculum source of TYLCV-Is. The infected plants had been exposed to viruliferous whiteflies in the greenhouse for 21 days prior to transplanting and all were showing symptoms of TYLCV-Is. Evaluations for symptoms of TYLCV-Is were made twice weekly beginning on March 31. Red fruit were harvested on May 25 and the remainder of the fruit was harvested on May 31/June and graded and sized.

Results and Discussion

Observational trials. Both SLWF and virus pressure were very low in both observational trials conducted on grower farms in Bradenton and Ruskin. Although there were scattered TYLCV-Is infected plants on both farms, there were no TYLCV-infected plants in the Bradenton trial plots. In the Ruskin trial, two FL 47 plants and one Sanibel plant showed TYLCV-Is symptoms at 8 weeks after transplanting. Growers were able to observe these varieties under commercial conditions and larger trials of selected cultivars have since been initiated by several growers.

Bradenton. Low whitefly and virus pressure was also a factor in this trial. Two 'FL 47' plants tested positive for TYLCV-Is and one 'Sanibel' plant was also infected. The only virus that was observed in the resistant cultivars was in one HA 3048 plant that was infected with tomato mottle virus. There were no significant differences in early yield of large, medium or total marketable fruit (Table 1). Production of extra large early fruit was lowest for HA3017A, but was not significantly different from Px150420, 'Sanibel' or 'FL47'. Season total yield of marketable fruit ranged from 1881 to 2899 25-lb cartons per acre for HA3017A and Ps150535, respectively. Total marketable yield was highest with Ps150535, but was not significantly different from HA3044 or Px150420. There were no differences in season total yield of extra large size fruit. Cull fruit were separated by type as indicated in Table 2. The majority of the fruit culled were generally small, scarred or zippered. Catfacing was most notable with 'FL47' and 'Sanibel'.

Palm Beach County. Virus pressure was very low at this site; thus, data are only presented for yield (Table 3). Highest early yield of extra large fruit was produced with Px150535, but was not different from 'Sanibel' or 'FL47'. Total marketable early yield was also highest with Ps150535 at 815 25-lb cartons per acre, but was not significantly different from 'Sanibel', 'FL47' or 'Leila'. Ps150535 also produced the highest yield of season total marketable fruit at 2300 25-lb cartons per acre, although it was not significantly different from 'Sanibel'. Ps150535 and 'Sanibel' also produced the largest total yield of extra large fruit at 283 and 312 25-lb cartons per acre, respectively, but that yield did not differ significantly from 'FL47'.

Immokalee. Highest yielding cultivars of season total extra large fruit were HA3017B, HA3017A, Ps150535, HA3048 and HA3044 (Table 4). Results for total marketable yield were similar. These findings were somewhat unexpected since approximately 60% of the HA3044 plants were showing symptoms of TYLCV-Is by first harvest (Table 5). Lowest yielding cultivars in this trial were the grower standard cultivars 'Sanibel', 'FL47' and 'Leila'. This would be expected since they were showing high incidences of TYLCV-Is symptoms within 4 weeks after transplanting and were almost 100% infected within 8 weeks after transplanting.

Based on these results, additional trials of TYLCV-Is resistant tomato varieties on commercial farms are warranted. Depending on location, one or more resistant varieties performed as well or better than commercially accepted grower standard cultivars with regard to yield in the absence of TYLCV-Is. In the presence of TYLCV-Is all resistant varieties performed much better than the susceptible varieties. With one exception, the resistant varieties also demonstrated excellent resistance to expression of symptoms of TYLCV-Is. Both Hazera and Petoseed have limited quantities of seed available for growers to trial, and some trials have already been initiated. Growers should contact their Hazera or Petoseed representative for availability information.

Phyllis Gilreath, Manatee County Cooperative Extension Service, Palmetto, Fla.; Ken Shuler, Palm Beach County Cooperative Extension Service, West Palm Beach, Fla.; Jane Polston and Tracy Sherwood, Gulf Coast Research & Education Center, Bradenton, Fla.; Gene McAvoy, Hendry County Cooperative Extension Service, LaBelle, Fla.; Phil Stansly, Southwest Florida Research & Education Center, Immokalee, Fla. and Eric Waldo, Hillsborough County Cooperative Extension Service, Seffner, Fla.

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Table 1. Early and season total fruit yield of tomato yellow leaf curl virus resistant tomato varieties at Gulf Coast Research and Education Center, Bradenton in fall 1999.

Variety	Early yield (25 lb cartons/A ^z)				
	Extra Large	Large	Medium	Total Marketable ^y	Culls
HA3017A	552 b ^x	171	26	746	92 d
HA3017B	889 a	153	31	1074	172 cd
HA3044	800 a	205	26	1032	207 cd
HA3048	891 a	173	73	1136	280 abc
Px150420	701 ab	244	47	992	162 cd
Ps150535	825 a	243	96	1162	317 ab
Sanibel	642 ab	140	44	827	423 a
FL47	752 ab	247	45	1042	392 a
		NS	NS	NS	

Cultivar	Season total yield (25 lb cartons/A)				
	Extra Large	Large	Medium	Total Marketable ^y	Culls
HA3017A	994 ^x	644 c	244 c	1881 e	329 c
HA3017B	1328	572 c	249 c	2149 de	322 c
HA3044	1745	962 ab	332 c	2589 abc	465 bc
HA3048	1359	600 c	223 c	2182 cde	461 bc
Px150420	1054	1119 a	666 a	2838 ab	546 b
Ps150535	2292	991 ab	513 b	2899 a	764 a
Sanibel	985	618 c	472 b	2078 de	837 a
FL47	1023	889 b	529 b	2443 bcd	863 a
	NS				

^z Acre = 8712 linear bed ft; 4356 plants.

^y Total marketable fruit includes extra large, large and medium size fruit.

^x Means within columns separated by Duncan's Multiple Range Test, lower case for 5% level; upper case for 1% level; NS = no significance.

Table 2. Classification of cull tomatoes from tomato leaf curl virus resistance trial at the Gulf Coast Research and Education Center, Brandenton in fall, 1999.

Variety	Percent culls by type of damage					
	Small	Scars	Zippers	Misshapen	Worm Holes	Catface
HA3017A	52	23	7	4	9	5
HA3017B	38	24	14	5	9	9
HA3044	26	36	11	5	9	10
HA3048	29	23	22	8	10	9
Px150520	13	10	40	18	11	8
Ps150535	19	17	20	11	24	9
'Sanibel'	11	22	24	12	18	14
'FL47'	13	16	15	9	28	18

Table 3. Early and season totla fruit yield of tomato yellow leaf curl virus resistant tomato varieties at Palm Beach County in fall/winter, 1999-2000.

Variety	Early yield (25 lb cartons/A ^z)				
	Extra Large	Large	Medium	Total Marketable ^y	Culls
HA3017A	61 de ^x	187 d	160	519 cd	50 b
HA3017B	79 cde	306 abc	186	641 bc	43 b
HA3044	120 bcd	248 cd	146	580 bcd	110 a
HA2048	47 e	165 d	152	425 d	46 b
Px150420	107 bcde	290 bc	170	632 bc	36 b
Ps150535	206 a	408 a	155	815 a	54 b
Sanibel	160 ab	369 ab	129	711 ab	67 b
FL47	145 abc	349 abc	186	726 ab	42 b
Leila	129 bcd	325 abc	147	654 ab	32 b
			NS		

Variety	Season total yield (25 lb cartons/A)				
	Extra Large	Large	Medium	Total Marketable ^y	Culls
HA3017A	76 d ^x	432 d	529	1735 bc	110 c
HA3017B	86 d	590 cd	600	1845 bc	151 bc
HA3044	139 cd	546 cd	474	1577 c	286 a
HA3048	68 d	430 d	588	1768 bc	197 b
Px150420	153 bcd	709 bc	558	1893 b	135 bc
Ps150535	283 a	981 a	558	2300 a	136 bc
'Sanibel'	312 a	881 ab	468	2178 a	123 bc
'FL47'	235 ab	693 bc	486	1877 bc	89 c
'Leila'	186 bc	710 bc	472	1817 bc	101 c
			NS		

^z Acre = 8297 linear bed ft; 4149 plants.

^y Total marketable fruit includes extra large, large, medium and small size fruit.

^x Means within columns separated by Duncan's Multiple Range Test, lower case for 5% level; upper case for 1% level; NS = no significance.

Table 4. Season total fruit yield of tomato yellow leaf curl virus resistant tomato varieties at Immokalee in spring 2000.Yield (25 lb cartons/A²)

Variety	Extra Large	Large	Medium	Total Marketable ^y	Insect	Culls Disease	Catfacing
HA3017A	1721 a ^x	347 ab	394 a	2658 a	37	27 bc	35 bcd
HA3017B	1948 a	297 bc	235 b	2580 ab	43	27 bc	70 b
HA3044	1515 a	357 a	264 b	2309 bc	31	45 ab	175 a
HA3048	1531 a	385 a	351 a	2464 abc	50	25 bc	60 bc
Px150420	951 b	182 c	157 c	1337 d	43	70 a	12 cd
Ps150535	1705 a	291 bc	161 c	2231 c	52	12 a	23 bcd
'Sanibel'	274 c	78 d	101 cd	530 e	19	52 ab	27 bcd
'FL47'	289 c	64 d	64 d	458 e	39	29 bc	6 d
'Leila'	208 c	58 d	41 d	343 e	37	39 bc	8 d
					NS		

² Acre = 7,260 linear bed ft; 4840 plants.^y Total marketable fruit includes extra large, large, medium and small size fruit.^x Means within columns separated by Duncan's Multiple Range Test, 5% level, NS = no significance.**Table 5.** Incidence of symptoms of tomato yellow leaf curl virus (TYLCV-Is) in tomato varieties at Immokalee in spring 2000.% Plants with TYLCV-Is symptoms

Variety	4 weeks ^z	8 weeks	First harvest
HA3017A	0	0	0
HA3017B	0	0	0
HA3044	19	54	60
HA3048	2	3	3
Px150420	0	2	2
Ps150535	0	0	0
'Sanibel'	73	99	100
'FL47'	96	100	100
'Leila'	90	100	100

^z weeks after transplanting.

Integrated Effect of Highly UV-Reflective Mulch, Actigard and Reduced-Risk Insecticides on the Incidence of Tomato Spotted Wilt Virus (TSWV) in Tomato

Tim Momol, Joe Funderburk and Steve Olson

Introduction

Tomato spotted wilt virus (TSWV) is the type species of the genus *Tospovirus* in the family *Bunyaviridae*. Over the past two decades, increased outbreaks of TSWV occurred in a vast number of crops. The disease was originally described in Australia (Brittlebank, 1919), with its etiology recognized by Samuel *et al.* (1930). Over the past ten years, eleven additional tospovirus species have been described. These differ in serology, genome sequence, vector specificity, and natural host range. Thrips and TSWV are still considered new, emerging problems on agricultural crops in the southern US, even though growers in Georgia and northern Florida identified thrips and TSWV as their most serious insect and disease problems in a recent survey (Bauske *et al.* 1998). The growers further revealed that they apply on average 12.3 and 16.4 insecticides per season in Georgia and Florida, respectively. The conventional insecticide program for thrips consists of broad-spectrum insecticides (namely methamidophos). No single control measure has been reported as effective in reducing the TSWV incidence.

Tomato spotted wilt symptoms on tomato vary greatly, young leaves usually develop numerous small dark spots. Growing tips may dieback and streaks appear on terminal stems. Early infections cause severe stunting and severe reductions of fruit production. Infected plants after fruit-set produce fruit with chlorotic or necrotic ring spots (Fig.1). Green fruit with such spots will ripen with yellow blotches or spots. The most frequently affected plants in the southeastern United States are tomato, peanut, tobacco and pepper. TSWV is known to infect over 1,000 plant species in 80 botanical families.

Eight species in two genera, *Frankliniella* and *Thrips*, are reported to transmit TSWV (Mound 1996, Webb *et al.* 1998). In Florida, the two main vectors are the western flower thrips (*Frankliniella occidentalis*) and the tobacco thrips (*F. fusca*). TSWV replicates in thrips vectors, thus the insect not only spreads the virus, but serves as a virus host. The virus is acquired by the larvae but not by the adults, and the adults can spread the virus to healthy host plants. The adults that successfully acquire the virus as larvae are responsible for transmission and spread. The adults persistently transmit TSWV and their control with insecticides does not prevent successful transmission due to the short time of feeding necessary for infection to occur (Nagata 1999).

Individual growers in the southern US typically have responded to the threat of TSWV by applying broad-spectrum insecticides on a calendar basis (e.g., Bauske *et al.* 1998). This approach is costly, highly toxic to farm workers, and extremely disruptive to IPM programs, and research consistently has revealed that losses to solanaceous crops in the southern US from TSWV typically is the result of primary infection which can not be prevented by insecticide use (e.g., Puche *et al.* 1995, McPherson *et al.* 1995, 1997). The reason is that the disease is transmitted to the plant before thrips are killed by insecticides. However, control of larval thrips feeding on infected plants can prevent secondary spread that would occur when these thrips

develop to adult. Few insecticides are efficacious against thrips and some of these are carbamate and organophosphate insecticides that may not be available in the near future due to the Food Quality Protection Act.

Because insecticides do not prevent adult thrips that acquire disease from infected plants outside a tomato field from transmitting disease after migrating into the field, we have been investigating other management tactics. Highly UV-reflective aluminum (metallized) mulch is effective in reducing primary infections of TSWV. We showed during five years of research (1996-2000) that using metallized mulch reduces thrips populations and subsequent virus incidence about one half to two thirds in replicated field experiments (J. Funderburk, S. Olson, J. Stavisky and T. Momol, unpublished data). Better results were obtained in commercial tomato fields during the springs of 1999 and 2000.

Plants can activate protective mechanisms upon detection of invading pathogens. Protection expressed locally at the site of primary inoculation and also systemically in tissues remote from the initial treatment is known as systemic acquired resistance (SAR) (Sticher *et al.* 1997). Benzothiadiazole (Actigard, Novartis) has been registered commercially in some countries as an inducer of systemic acquired resistance against a broad range of pathogens (Gorlach *et al.* 1996). A label is expected in tomato in the year 2001 in the US. The SAR inducer benzothiadiazole has been effective in reducing incidence of TSWV on tobacco, especially in combination with insecticide imidacloprid (Csinos, Pappu, and McPherson unpublished). This tactic is effective in reducing both primary and secondary spread of TSWV.

No single management tactic is highly effective in reducing losses from thrips and TSWV. Resistant varieties offer the best promise for reducing losses from TSWV, but an integrated approach will still be necessary to reduce damage from thrips and to prevent development of TSWV strains able to infect resistant cultivars (as happened in Hawaii). The objective of this study was to determine the separate and combined effects of reduced-risk insecticides, a systemic acquired resistance inducer, and metallized mulches on primary and secondary spread of tomato spotted wilt virus in tomato.

Materials and Methods

A randomized complete block experiment with four replications was conducted in the spring of 2000. The tomato crop was produced using typical commercial practices. A split-split-plot treatment arrangement was used to determine the separate and combined effects of each tactic on efficacy to reduce TSWV incidence. Tomato cultivar was 'FL 47'. Six-week-old transplants were spaced every 50 cm in raised beds covered with plastic mulch. Plants were irrigated based on plant needs through a trickle tube placed at the center of each bed. Treatment arrangement was a split-split plot with mulch type the whole plot treatments, Actigard/no Actigard as the split plot treatments (16 replicates) and insecticide treatments (4 replicates) the split-split plot. Mulch type was selected as the whole plot because the mulch type can affect thrips on adjacent rows. Interplot interference was detected in the experiment conducted in 1999, therefore the whole plots in 2000 were separated by a 2 m buffer zone. The standard mulch type was black and the other type was metallized mulch. The Actigard treatment was a regimen of applications: 2 g [AI]/4000 plants washed in 1 week prior to transplanting and 26.25 g [AI]/ha four foliar sprays applied every fifteen days after transplanting. Insecticide treatments for thrips were untreated, spinosad (0.07 kg [AI]/ha), and methamidophos (0.4 kg [AI]/ha) and a combination of spinosad with methamidophos. These were applied weekly for six weeks from late April to early June.

Plot size for each split-split plot was 4 rows by 11 m. The two center rows were used for parameter evaluation. Parameters evaluated included % infected plants (tomato spotted wilt incidence), and fruit yield and quality. Incidence of TSWV in each plot was determined by % plants with visible symptoms weekly or bi-weekly from May 2nd to June 21st. Symptomatic plants were tested for each sampling date by ELISA (Agdia, Elkhart, IN) in order to confirm a diagnosis of TSWV. Thrips were sampled 1, 4, and 7 days after each weekly application of insecticides. On each sample date, ten flowers from each sub-subplot were placed in 70% alcohol and carried to the laboratory for processing under 40x.

Results and Discussion

In the spring of 2000, North Florida experienced a severe epidemic of TSWV on tomatoes. In this experiment infections occurred naturally. Thrips common in the tomato flowers were *F. occidentalis*, *F. tritici* and *F. bispinosa*.

The overall incidence of TSWV was significantly lower in metallized mulch plots than the black mulch plots (Table 1). Applications of Actigard did not decrease disease incidence in metallized mulch treatments. Actigard was effective in reducing disease incidence on black mulch.

Insecticide applications gave little benefit in reducing TSWV incidence. The reason is that most of the disease was the result of primary infections. Controlling thrips larvae with insecticides was effective in reducing the amount of secondary disease incidence that occurred primarily in mid- to late-season. The regimen of metallized mulch, Actigard, and insecticides reduced TSWV compared to incidence on untreated black mulch by up to 76%.

Our research has demonstrated that metallized mulch is an effective tactic to reduce thrips populations and resulting infection by TSWV. This tactic serves to reduce both primary and secondary infection. Secondary infection can occur if thrips larvae are not controlled by insecticides. Methamidophos is efficacious against thrips, and spinosad is a safer, biological insecticide with efficacy against western flower thrips adults and larvae. Actigard needs further evaluation, but shows promise as a management tactic against TSWV.

Tim Momol, Plant Pathologist; Joe Funderburk, Entomologist; and Steve Olson, Horticulturist, UF's North Florida Research and Education Center, Quincy, Fla.

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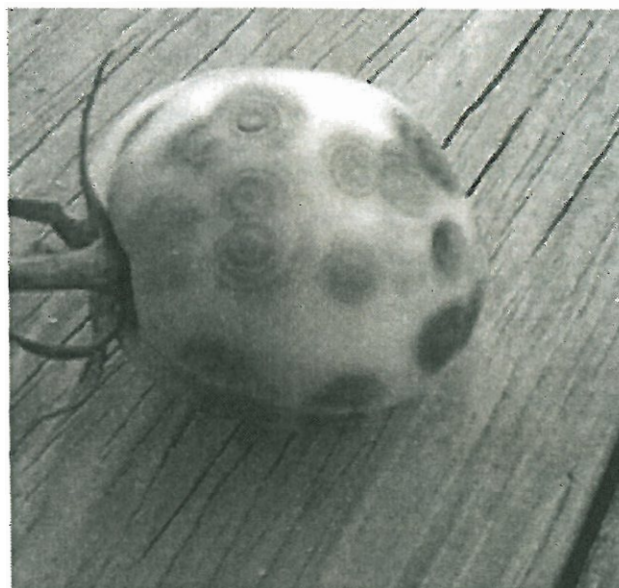


Fig. 1. Necrotic and concentric ring spots due to TSWV infection on young tomato fruit.

Table 1. Effect of mulch type, Actigard and insecticides on the incidence of TSWV in tomato.

		% Incidence of TSWV (Final Disease)			
Mulch Type	Insecticide ^z	Actigard		No Actigard	
Black	UTC	33.3 ^y	28.7 ^x	46.3	38.1
	Mon	28.6		38.2	
	Spin	29.8		34.9	
	Mon+Spin	23.0		33.0	
Highly Reflective (Metallized)	UTC	23.8	17.3	22.5	19.7
	Mon	11.4		16.2	
	Spin	17.1		24.1	
	Mon+Spin	16.9		16.0	

^z Insecticide, UTC = Untreated control, Mon = Monitor (methamidophos), Spin = Spin Tor (Spinosad), Mon+Spin (Monitor and Spin Tor weekly alternated).

^y % Incidence is average of 4 replicates

^x % Incidence is average of 16 replicates

Reflective Mulches and Their Effect on Tomato Yield and Insect and Disease Management

Steve Olson, Julie Stavesky, Tim Momol and Joe Funderburk

Tomato Spotted Wilt Virus (TSWV) was first documented in the north Florida/ south Georgia production area in 1988. In the beginning the virus was at a low level with periodic outbreaks in the fall. In the past few years it has become a serious problem in the spring crop, with incidence ranging from as little as 10 % to almost 100 %. Most losses from TSWV are due to primary infection, which past research has shown that primary infection can not be prevented with insecticide sprays. Secondary infection within a field can however be reduced by insecticide applications. The primary vector in the spring has been the Western Flower Thrips (WFT). At this time the lack of reliable management tactics stands as a major impediment to the implementation of integrated pest management in tomatoes in the southeastern United States.

For the past 5 years experiments have been conducted at the North Florida Research and Education Center (NFREC), Quincy to investigate tactics that can reduce WFT numbers and incidence of TSWV. Potential management strategies would include those which prevent or slow the initial movement of thrips onto plants in the tomato fields, which would reduce the primary spread of TSWV. One such tactic which is showing a great deal of promise is use of highly reflective (metalized) mulches. These metalized mulches have a thin layer of aluminum applied to a polyethylene mulch and usually have reflectance levels of 75 % or higher.

Insect and Disease Control

In replicated spring trials from 1996 through 2000, metalized mulches have consistently reduced WFT numbers by up to 50 % in tomato flowers. A representative example of the effect of mulch reflectance on WFT populations is shown in **Figure 1**. When the number of thrips is reduced, the primary spread of TSWV is also reduced. For example, in 1997, nearly 40 % of plants grown on black mulch were infected, while only about 20 to 25 % of plants grown on metalized mulch plots were infected with TSWV at harvest time (**Figure 2**).

Large scale grower trials have also been evaluated. In early April of 1998 approximately 1 acre of a 15 acre tomato field had metalized mulch applied. Early growth was slower than the black mulch due the cooling effect of the metalized mulch. As temperatures increased the growers remarked that the plants on the metalized beds caught up with the plants on the black mulch and by the end of the season the plants on the metalized beds were larger than those on the black mulch. The 1 acre block was scouted separately from the rest of the field. By harvest time the incidence of TSWV was only 10 % in the metalized area compared to 19 % in the black mulch area. In the spring of 2000 these same growers had a field of 30 acres where they used the metalized mulch for tomato production. At final scouting date (6/18/00), the metalized field had an incidence of 11 % compared to 45 % in the black mulched area, a 75 % reduction in virus.

Yields

The metalized mulch was also evaluated for its effect on tomato yield and fruit size. In the spring of 1998, with 'FL 47' tomatoes, the black mulch produced significantly higher yield on

a per plant basis than those on the metalized mulch beds (**Table 1**). However, on a per acre basis there were no differences in yields between the two mulch systems. One reason for this is that the metalized mulches are much cooler than the black mulch due to the reflection of sunlight back up away from the beds. Early season growth on the metalized mulch is much slower, thus the reduction in yield on a per plant basis. However, the overall yields with the metalized mulch were equal to those produced on the black mulch due to the reduction of TSWV with the metalized mulch. Fruit size was not affected by mulch type. Because of this cooling effect on soils we do not recommend use of metalized mulches for late February or early March planting in the north Florida/ south Georgia production area.

In the fall of 1998, production on metalized mulch was compared to production on white on black mulch which is standard for fall (mid July to mid August) planting. From earlier trials the metalized films were found to have even greater cooling effects on beds than the white on black. Neither yields or fruit size of 'Equinox' tomatoes were affected by mulch type (**Table 2**).

In the spring of 1999, from a late March planting, neither yields or fruit size were affected by mulch type (**Table 3**). Early production season of 1999 was warmer than 1998 negating early growth differences. Also incidence of TSWV was not affected by mulch type, probably due to plot to plot interference of mulch type. In our experiments we have found the presence of the metalized mulch can have an affect on plots as far away as 18 feet and can confound small plot trials.

Summary

The use of metalized mulches in tomato production for suppression of WFT numbers and incidence of TSWV has shown great promise. Our research has shown that use of the metalized mulch can result in a reduction in TSWV even greater than currently labeled insecticides when compared to unsprayed controls. Costs of the metalized mulch are about 25 % higher than that of other mulches currently used in tomato production, but large scale field trials have shown that the extra costs are justified due to the suppression of TSWV. At this time we do not recommend their use for early spring plantings due to their cooling effect on the beds. In some grower trials, we have looked at using metalized strips in the drive rows during early plantings and have shown reduction in TSWV in the rows next to the metalized strip. We also plan to evaluate painting a narrow black strip down the middle of the metalized beds to look at the effect on early plantings for yields and thrips and TSWV control. The metalized mulches are hard for the field crews to work around due to their blinding effect and growers have had to provide sunglasses to their field help.

Steve Olson, Julie Stavesky, Tim Momol and Joe Funderburk, North Florida Research and Education Center, Quincy, Fla.

Table 1. Effect of mulch type on yield and fruit size of FL 47 tomatoes. NFREC, Quincy, FL. Spring, 1998.

Mulch	Lbs/plant	Boxes/acre	Fruit wt. (oz)
Metalized	10.67	1311	7.4
Black	12.06	1277	7.3
P level	0.05	ns	ns

Table 2. Effect of mulch type on yield and fruit size of Equinox tomatoes. NFREC, Quincy, FL. Fall 1998.

Mulch	Boxes/acre	Fruit wt. (oz)
White on black	1468	5.9
Metalized	1488	5.9
P level	ns	ns

Table 3. Effect of mulch type on yield and fruit size of FL 47 tomatoes. NFREC, Quincy, FL. Spring, 1999.

Mulch	Boxes/a	Fruit wt. (oz)
Metalized	2257	8.0
Black	2189	7.9
P level	ns	ns

Figure 1. Effect of UV-reflective mulch on western flower thrips populations in the spring of 1996.

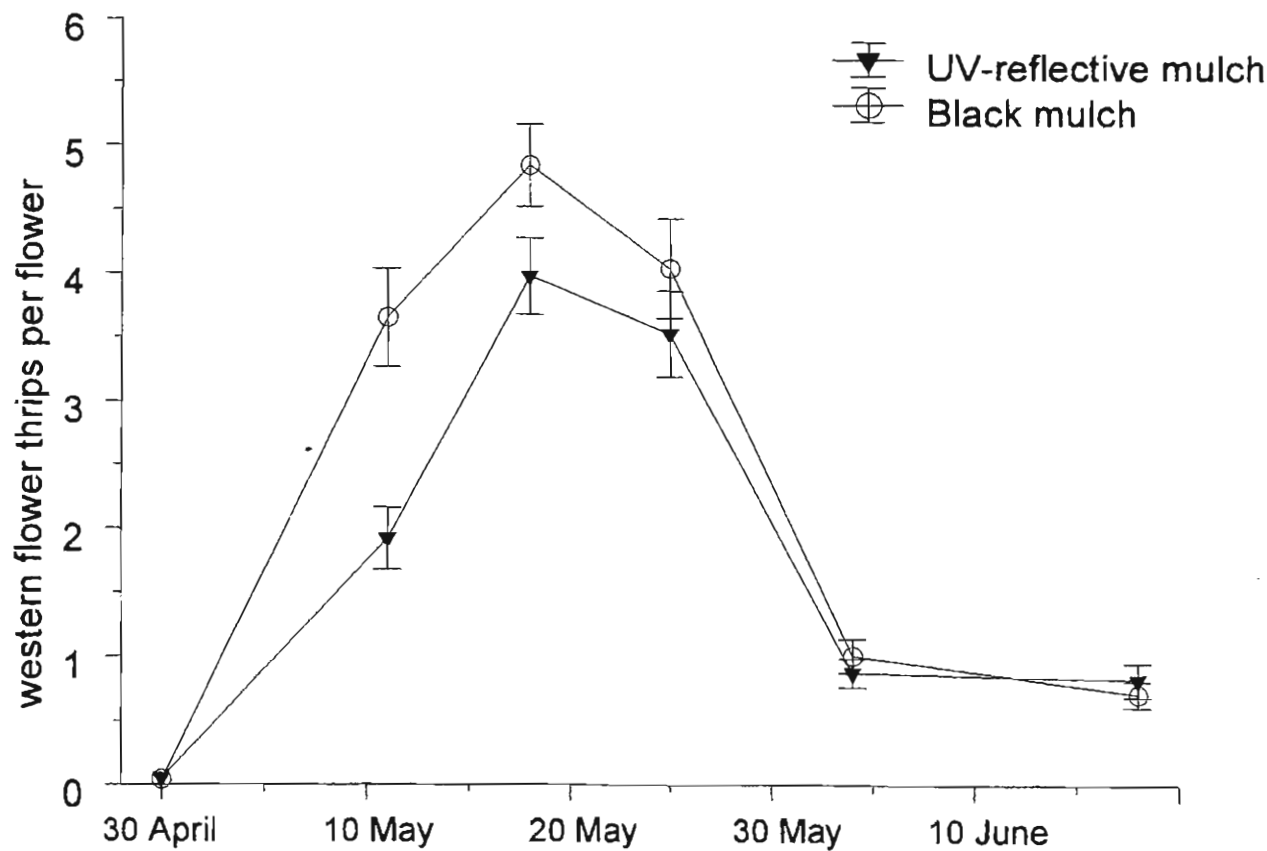
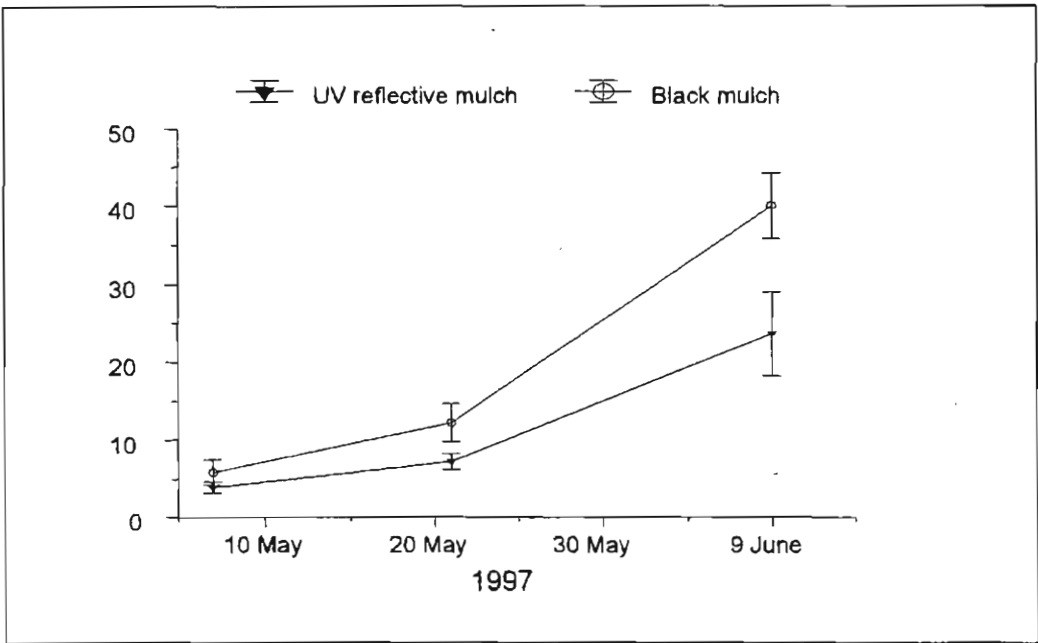


Figure 2. Incidence of TSWV in tomato in the spring of 1997.



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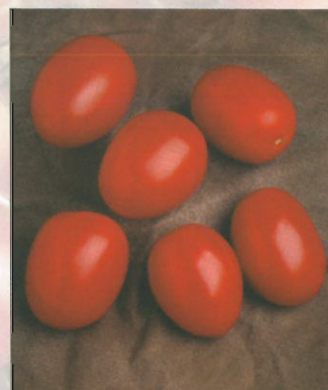
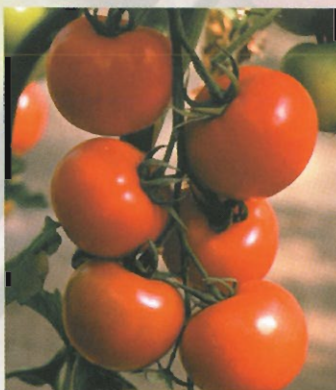
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Nematode Control in the Post Methyl Bromide Era

J.W. Noling and J.P. Gilreath

Root-knot nematode (*Meloidogyne* spp.) has long been recognized as the most economically important nematode pest of tomato in Florida. Fortunately, it has not constituted a major soil-borne pest problem in crops where methyl bromide is currently used for soil fumigation. Problems, when they occur, usually develop at the row ends where fumigant flow is prematurely discontinued or within fields where gas cylinders were exchanged. In other instances, problems have occurred when soil and environmental conditions were not conducive for optimal diffusion of methyl bromide gas through soil. Problems associated with nematodes is expected to intensify as the methyl bromide phase-out incrementally proceeds toward January 1, 2005.

As in 1999, methyl bromide production and importation will again be reduced from 1991 baseline levels another 25% after January 1, 2001. The additional 25% reduction mandated for 2001 means that now manufacturers can only produce 50% of the levels produced in 1991, and then must efficiently distribute this reduced amount to current agricultural uses within the United States. The natural forces of the market place will redefine allocations to various methyl bromide users. Once again, methyl bromide prices are expected to increase as supply is further reduced and demand remains high, as are problems with nematodes. In this paper we will try to address current research on alternative management tactics which can have an impact on nematode control in the post methyl bromide era. Readers are also encouraged to review previous Tomato Institute Proceedings as well as the June 2000 issue of *Citrus & Vegetable Magazine* for a more comprehensive distillation of progress and problems identifying alternatives to methyl bromide.

Methyl Bromide Formulations and Application Rate

Previous research has demonstrated that methyl bromide (Mbr) is the component with principal nematicidal activity and chloropicrin (Pic) is only weakly nematicidal. With a formulation change from 98% Mbr / 2% Pic to 67/33 following the last interim reduction in 1999, the incidence and severity of nematode problems was observed to increase in strawberry fields around Plant City, Florida. The degree to which this increase is actually related to a change in formulation is not known. In addition to a formulation change, some growers have also tended towards reduced application rates from previous standards. With increased cost and possibly reduced availability, growers will likely want to reduce rates, and once again, the expectation of increased pest incidence, severity, and of reduced yields should also be expected.

Plastic Mulches

Plastic mulches are used not only for horticultural reasons, but are also used to allow more effective use of methyl bromide (or other fumigants) by reducing the rates in which fumigants volatilize from soil. Emissions of methyl bromide from soil is influenced by a number of factors including soil type, moisture content, temperature, organic matter content, wind speed, fumigant injection depth, as well as the time in which the plastic mulch is installed after soil injection. The permeability of the mulch is directly related to the thickness and chemical composition of the mulch, ambient temperature, tarp integrity, and the dosage and formulation of the fumigant applied. The most commonly used mulches in Florida are low-density polyethylene

mulches (LDPE). Over the years, improvements in LDPE production technologies have resulted in the availability of films of reduced thickness while maintaining good tensile strength. A variety of thicknesses are available, generally ranging from 0.6 to 1.25 mil. In general, thicker mulches have lower permeability for most fumigant gases.

Because permeability decreases as density increases, high-density polyethylene (HDPE) mulches are less permeable than LDPE tarps. Virtually impermeable films (VIF), allows very little methyl bromide (or other gases) to pass through them. Compared to LDPE tarps, certain VIF films are over 20,000 times less permeable to methyl bromide. Historically however, VIF films have had problems with tensile strength, i.e., they tear easily and do not stretch well. Research continues here in Florida on the use of higher barrier mulches to reduce effective dosages and emissions of methyl bromide and other fumigants such as 1,3-D (Telone). Much of this research, some of which was conducted in Florida, showed that methyl bromide application rates can be reduced by 50 percent without serious compromise to pest control or crop yield if an appropriate, less permeable plastic mulch is used. There is no question that these new mulches will be more expensive (2x), but use of HDPE and VIF tarps are likely to become more cost effective as methyl bromide availability decreases and pricing increases in future years. In some cases, it may also be possible to mitigate future regulatory concerns regarding the use of some soil fumigants with use of a higher barrier plastic mulch.

Telone C-17 and Telone C-35

Over 20 large scale field demonstration trials have been performed since 1996 comparing Telone C-17 or Telone C-35 applied in-row or broadcast, in combination with the herbicide Tillam to methyl bromide for weed, disease, and nematode control and for crop yield response. Although with some variability, average yield of the Telone C-17 or C-35 + Tillam in-row treatments is expected to be within 1 to 5% of methyl bromide yield. The requirement for a full spray suit, rubber gloves, boots, and a full face respirator by all personnel in the field at the time of planting has prompted a new research focus towards evaluation of broadcast, rather than in-row, treatments applied prior to bedding to minimize personnel protective equipment requirements. Based on the results of only a few large scale demonstration trials, tomato yields averaged from broadcast Telone treatments are expected to be about 10% less than that of methyl bromide. It is reasonable to believe at this time that yield losses currently estimated for use of Telone broadcast treatments can be reduced in the future with additional research and refinements in application technology. It is not clear at this time however, whether any U.S. EPA regulatory change in requirement for personal protective equipment (boots, gloves, respirators, etc.) or whether any reduction in buffer zones, which currently restrict application of Telone within 300 feet of any occupied dwelling, is achievable in the near term. Nor is there any certainty whether certain herbicides (i.e., Tillam / Pebulate), which serves as an integral component of the current methyl bromide alternative for tomato, will be available in the future if certain regulatory issues are not resolved between the U.S. EPA and chemical manufacturer.

New Product Evaluations

Propargyl Bromide. During spring and fall of 1999, and spring 2000, the use of propargyl bromide was evaluated for control of the southern root-knot nematode, *Meloidogyne incognita*, *Fusarium oxysporum*, and yellow nutsedge and resultant impacts on tomato plant growth, development, and yield (cv FL 47). For the three experiments, application rates from 40 to 300 lb/a have

been evaluated and compared with other fumigants such as Vapam (75 gal/a), Basamid (400 lb/a), Telone II (18 gal/a), Telone C-17 (35 gal/a), Telone C-35 (26 gal/a), and an untreated control. In all three experiments, propargyl bromide demonstrated excellent nematicidal, herbicidal, and fungicidal (spring 2000) activity, and produced tomato yields equal to that of methyl bromide and of other fumigants such as Telone II, Telone C17, or Telone C35. It would appear that application rates in the range of 40- 80 lb/a will be required to achieve adequate nematode, weed, and disease control. Field research with propargyl bromide is continuing at research sites in Florida and California, however, it is not clear at this time when, or if, federal product registration will occur in a time frame to make it available for use in Florida agriculture before 2005.

Methyl Iodide. Field research on the use of methyl iodide (TomenAgro Inc.) has continued in Florida and California, with replicated studies conducted in both tomato and strawberry during the past year. The principal research focus has centered on co-application of methyl iodide with chloropicrin to enhance disease control efficacy, and due to the high cost of methyl iodide, on reduced application rates. In general the results from studies coordinated through the USDA IR-4 alternatives to methyl bromide program, all have demonstrated encouraging results with regard to satisfactory nematode control and near equivalent crop yields compared to that of methyl bromide. Field research is expected to continue in the near term. It is not clear at this time however, when, or if, federal product registration will occur in a time frame to make it available for use in Florida agriculture before 2005.

PlantPro 45. A complex form of iodine (Ajay North America), continues to be evaluated as a alternative to methyl bromide for control of root-knot nematode on tomato and strawberry in Florida. The results from recently performed USDA greenhouse and field experiments have in general been encouraging for nematode and disease control. Field applications of PlantPro 45 have been made via multiple applications (120 ppm preplant and 80 ppm postplant; 90 gal/a) through two drip lines per bed, 17 and 35 days after transplanting. The results from a Sanford, FL chemigation study on tomato showed that PlantPro 45 provided levels of nematode control equivalent to that of soil fumigation with methyl bromide (400 lb/a). However, some inconsistencies in nematode control, crop performance, and of crop phytotoxicity to tomato were observed in IR-4 trials performed this past spring in Live Oak and Lake Gem, FL. It would appear that efficacious use of PLANTPRO 45 is contingent upon uniform distribution of the compound within the mulched bed, and of proximity and placement of the drip tubes in relation to plants within rows.

Messenger. (Eden Bioscience, Bothell, WA) is a compound containing a protein called Harpin, which according to the manufacturers technical bulletin, reputedly activates natural defense systems in the host plant, referred to as systemic acquired resistance (SAR). According to the U.S. EPA, use of the Harpin protein has the potential to substantially reduce use of methyl bromide for protection against soilborne pathogens and pests, such as certain nematodes and fungal diseases. At this time, the authors are not aware of any Florida field studies substantiating the degree to which Messenger improves plant vigor, growth, stress tolerance, or tomato yield increase by activating plants to suppress or repel nematodes.

Other Compounds. Other compounds are being investigated by the USDA include transplant applications of biological inoculants (Gustafson Inc., Plano, TX) which colonize the plants

root system, and induce plant growth promoting effects. These plant growth promoting rhizobacteria are designed to improve seedling and transplant survival and growth in spite of the presence of soilborne pests and disease organisms. The mode of action responsible for their plant growth effects are fairly complex and in some cases, not well understood. Further research characterizing the utility of these compounds under different environmental conditions, and the ways and means in which to increase their effectiveness is necessary.

Nonchemical Strategies

Over the years many alternative soilborne pest and disease control practices have been evaluated on a statewide, national, and international scale. There has been a considerable amount of research on alternative nonchemical practices in Florida. In some trials, practices that improve soil health and crop productivity have included the following: soil solarization, soil organic matter management using a variety of organic residues, better rotations, and more intensive use of cover crops. For example, much of Florida research has demonstrated the potential for significant increases in tomato yield with increasing soil amendment application rates. In a number of studies, soil pest density (nematodes or fungi) were not reduced by the amendment, but actually increased in response to increased plant growth. In this regard, use of amendments may actually increase pest management problems and as such should not be considered a stand alone methyl bromide replacement. In other Florida trials, use of a composted organic amendment was evaluated alone and in combination with a chemical pest control strategy. In this trial, tomato plants grown in fumigated non-composted soil had fewer root galls than plants from fumigated composted soil. Gall indices from roots in fumigated composted soil were not different from the untreated control. The higher gall numbers in the fumigated composted soil was likely the result of higher soil water content which restricted fumigant movement, particularly within deeper soil profiles.

Plant Resistance

Field research has continued in Florida with regard to the evaluation of nematode resistant crop varieties in both tomato and pepper. This past spring, temperature controlled growth room studies confirmed: 1) the heat sensitivity of the Mi gene in the root-knot nematode resistant tomato variety Sanibel; 2) the loss of nematode resistance to this gene at soil temperatures above 90 F; and 3) the development of a resistance breaking biotype of the root-knot nematode after repeated plantings of resistant Sanibel. Many nematode infested vegetable growing fields in Florida likely contain populations of *Melodogyne* which similarly possess the ability to overcome resistance conferred by the Mi gene in tomato, particularly at soil temperatures above 90 F. Given the almost daily occurrence of high soil temperature in the fall, and the temperature sensitivity of the resistance gene in tomato, use of the resistant cultivar Sanibel is probably better suited for spring plantings when cooler temperatures initially prevail. Some consideration should also be given to alternating use susceptible and resistant varieties to further minimize selection pressures towards resistance breaking biotypes. Growers should realize that once resistance breaking capability develops in a nematode population it is not currently possible to revert the nematode population back to a previous state where the resistant gene functions properly. Even with resistant Sanibel, some management consideration of initial soil population density of the nematode to avoid significant yield loss.

Cover Crops

Cover crops are another nonchemical tactic that reduces nematode population densities and has been a focus of research efforts within the state. In general, exclusion of weeds that host nematodes and problems encountered with poor germination or stand establishment of some cover crops have been the principal problems. The importance of weed suppression cannot be underestimated as a desirable characteristic of any particular cover cropping system. For example, in studies performed in central Florida, highest soil population densities of the northern root-knot nematode were observed in cover crops which supported highest weed population densities. Discounting iron clay pea and cowpea for their impacts to sting nematode, only sesame and sunnhemp were the only summer cover crops which suppressed both weeds and nematodes in two years of study. In addition to suppressing weeds and nematodes, providing excellent ground cover, both sunnhemp and sesame produced the highest plant biomass of any cover crop in both experiments during 1998 and 1999. Seed germination and plant establishment was excellent, and from all appearances is well adapted for production in west central Florida. Unlike iron clay pea, cowpea, or velvetbean, the incidence of foliar disease or insect defoliation was also minimal. As a legume, sunnhemp has the advantage of contributing more nitrogen to subsequently grown crops than sesame. Given the high levels of plant biomass produced, woody nature of stalks produced, additional time and possible disking operations will be required to get the field debris to decay before plastic laying / bedding operations can be initiated in the fall. At present, sunnhemp seed is in very scarce supply. The United States Department of Agriculture and soil conservation service agencies are currently examining environmental conditions and requirements for improving seed production capabilities in Florida.

Conclusion

After the methyl bromide phaseout, growers will have to rely on other chemical and nonchemical pest and crop management strategies. During the methyl bromide phaseout, growers will have to learn how to use these alternative systems. The change from methyl bromide to another system will not occur without flaw or problem. In all reality, some combination of alternative treatments will have to be grower developed and evaluated to achieve similar broad spectrum pest control and yield as that of methyl bromide. Given the limited time remaining before the next interim reduction of 25% on January 1, 2001 and another 20% effective January 1, 2003, it is imperative that Florida growers actively continue field testing of methyl bromide alternatives.

With the transition from methyl bromide to other alternative strategies, new problems are expected to 'surface' because they were unnecessary considerations with something as flexible as methyl bromide. For example, in every grower field which has been surveyed, a compacted zone (traffic layer) occurs at a soil depth of 6-8 inches. The presence of the zone may ultimately influence the overall success of an alternative fumigant treatment and dictate the time and degree to which various soilborne pests and pathogens recolonize the plant root system. Failure to adequately manage weeds within the field will not only affect crop yields in itself but serve as alternative hosts to nematodes, causing additional crop production problems. It has also been shown that various herbicides persist, and have the ability to cause crop phytotoxic responses for a much longer time in fumigated, microbially inactive soils. Uniform management of the soil water table will also be more critical in the post methyl bromide era, since deep injection of some fumigants into saturated soil horizons has been observed to remain virtually undegraded in soil,

causing planting delays and potentially other problems. What should be evident, is that not everything can be predicted or foreseen, and large scale problems coupled with low prices can be particularly unforgiving. In short, the sooner on-farm research is initiated, the better off growers will be in the post methyl bromide era of Florida crop production.

J.W. Noling, UF/IFAS, Citrus Research and Education Center, Lake Alfred, Fla. and Jim Gilreath, UF/IFAS, Gulf Coast Research & Education Center, Bradenton, Fla.

University of Florida Tomato Release Possibilities in the Early Twenty-First Century

J. W. Scott

In my last Tomato Institute paper (Scott, 1998) I reported that the trend of the University of Florida tomato (*Lycopersicon esculentum* Mill.) breeding program was to release breeding lines to the seed industry rather than finished hybrid cultivars. The breeding lines Fla. 7771, Fla. 7775, and Fla. 7781 mentioned in that paper have now been released. However, the trend to release breeding lines does not preclude the release of finished cultivars. In developing inbreds, test cross hybrids are made to assess the utility of the inbreds as parents. Those with better performance in the test crosses are then released. However, some of the crosses that have been tested appear to be worthy of release and in this report I will discuss some possible hybrid releases. These will be released because it is felt that they can be of benefit to Florida tomato growers.

Fla. 7816. Yield trial results and observations of grower and other trials have shown this hybrid to have consistently good marketable yields during all growing seasons and regions in Florida. It is a cross between Fla. 7777 and Fla. 7722. Fla. 7777 has very large globe shaped fruit, late season maturity, and a large vine. Fla. 7722 is a medium sized, heat-tolerant, flat-round tomato with early maturity and a moderate sized vine. The hybrid has a large vine that sets fruit suitable for three even harvests which allows growers flexibility in a fluctuating market. Maturity is mid-season and fruit have fruit size comparable to presently grown cultivars and generally include more fruit in the 6x6 and 6x7 sizes than 'Florida 47'. Fruit shape is a deep, flat-round type that is consistent under a range of growing conditions. There have been occasional fasciated fruit but this has been of minor importance. The fruit have smooth blossom scars that result from combining a different nipple gene from each parent, a concept put forth in our earlier work on blossom scar smoothness (Barten, *et al.*, 1994). Fla. 7777 has the *n-2* gene and Fla. 7722 has the *n-4* gene. This combination in Fla. 7816 results in smooth fruit without the possibility of mature fruit with nipples that can occur under some conditions in cultivars with the *n-4* gene in both parents. Fruit are firm, have good crack resistance, and good flavor. Shoulders are light green and the pedicel is jointed.

Fla. 7885. This hybrid represents a new generation of heat-tolerant cultivars in that it has two heat-tolerant parents. Other heat-tolerant hybrids have one heat-tolerant parent crossed with a heat sensitive parent. The heat-sensitive parents have very large fruit that provide adequate fruit size to the hybrids as was described by Scott *et al.* (1986). That report also presented data indicating the best level of heat-tolerant fruit setting would be obtained from hybrids with two heat-tolerant parents. Until now such hybrids have not been available due to the inadequate fruit size of the heat-tolerant inbreds. The larger fruited parent of Fla. 7885 is Fla. 7776 a globe shaped tomato that has a fair level of heat-tolerance. The size and heat-tolerance are not apparent from the data in Table 1, but it is common for globe-shaped tomato genotypes not to perform well in summer yield trials. Fla. 7776 does have moderate heat-tolerance and large fruit based on numerous observations. The other parent is Fla. 7906, an inbred with good heat-tolerance and medium to large fruit. Fla. 7885 has a medium sized vine, but has excellent fruit cover even in the top

of the vine. The improved heat-tolerance results in early maturity in both spring and fall crops, especially the latter (Table 1). One defect of Fla. 7885 is zippering, a disorder that is more prevalent under cooler growing conditions. Thus, even though Fla. 7885 has done well in both spring and fall trials it will probably prove to be more advantageous in the fall than in the spring. The Fla. 7776 parent had graywall in a Homestead trial and thus more trials are needed before a release decision will be made. So far graywall has not been seen in Fla. 7885 and trial results have been consistently good. Fla. 7885 fruit have light green shoulders, a consistent flat-round shape, good firmness, and smooth blossom scars. Fla. 7776 has the *n-2* nipple gene and Fla. 7906 is still segregating the *n-4* gene. This needs to be fixed before release.

NC 99405. Seed of the jointless pedicel, heat-tolerant breeding line release Fla. 7771 was sent to Dr. Randy Gardner at North Carolina State University. He crossed Fla. 7771 with a very large fruited, jointless inbred to make this hybrid. It has looked good in trials in North Carolina and in Florida in fall 1999 (Table 1) and spring 2000. NC 99405 is the first jointless pedicel hybrid that can compete with jointed pedicel, heat-tolerant hybrids under high temperature conditions. Fruit size and shape have been consistently good. More trials are needed before a release can be made and such a release will require an agreement between both Universities. However, it is mentioned here because it represents another type of tomato cultivar that may soon be available to Florida tomato growers.

Spotted wilt resistant hybrids. Recently, spotted wilt virus has caused serious losses to North Florida tomato growers. Resistance is conferred by a single dominant gene (*Sw-5*) that is in the cultivar Stevens. Work has been underway to move this gene into parent lines adapted to Florida conditions. We are using a molecular marker linked to *Sw-5* (Stevens *et al.*, 1996) to select resistant plants. In spring 2000 resistant hybrids were tested in trials at the Gulf Coast and North Florida Research and Education Centers. Four hybrids- Fla. 7964, Fla. 7965, Fla. 7966, and Fla. 7967, were considered worthy of further testing for possible release. These will be tested this fall at both research centers and more seed of the four will be made in anticipation of expanded testing in 2001. Two parents involved in three of the four hybrids are Fla. 7776 and Fla. 7777 that have been mentioned above. Since this disease has been posing such a serious threat to the North Florida tomato industry, the plan is to move as quickly as possible on a release if one of the hybrids performs consistently. So far this disease has not caused serious losses on the Florida peninsula, but the disease is present in the southern production regions and poses a potential threat to these growers as well.

High lycopene hybrids. These hybrids are of interest because they have an attractive, deep red interior color due to the increased lycopene the red pigment in tomato. More importantly, recent medical literature has indicated lycopene is a potent antioxidant that is associated with reduced incidence of several cancers (for literature see Scott, 1996). Four hybrids have undergone extensive testing in university trials and grower fields in Florida and several other states. The most consistent performer has been Fla. 7862. Yields have been very good but the fruit size is not quite as large as cultivars presently being grown in Florida. The 5x6 yield has not always been as high while 6x6 and 6x7 yields were often higher. The parents of this hybrid are Fla. 7781, a Fusarium crown rot resistant breeding line released last year and Fla. 7804 a Fusarium wilt resistant inbred. Thus, as well as high lycopene resulting from the crimson (*ogc*) gene, Fla. 7862 is resistant to Fusarium crown rot and Fusarium wilt race 3.

Fla. 7945 is a crimson hybrid that has looked good in limited testing in fall 1999 and spring 2000 at the Gulf Coast Research and Education Center. Seed was increased in spring 2000 so expanded testing can be done this fall in University of Florida trials at four Research and Education Centers and on grower farms. Parents are Fla. 7907, a new large fruited heat-tolerant inbred and Fla. 7946, an inbred closely related to Fla. 7804 mentioned above. Thus, in addition to high lycopene, Fla. 7945 has heat-tolerance and resistance to Fusarium wilt race 3. Although more testing is needed, the flavor of this hybrid may be superior to that of most of the cultivars presently grown in Florida or Mexico. Fla. 7862 and Fla. 7945 are cultivars that can be termed functional foods since they have added health benefits over normal cultivars of the same crop. They may fit a vine ripe harvest system where fruit could favorably compete with cluster and hydroponic tomatoes that often are sold for higher prices in the market.

Summary. Several hybrids have been described that represent many years of breeding activity. Fla. 7816 is the result of projects to improve blossom-end smoothness and vine size (over previous releases from the author). Fla. 7885 represents years of selection for heat-tolerant inbreds with greater fruit size. NC99405 resulted from work spanning 18 years to develop an inbred with heat-tolerance, large fruit, jointless pedicels, and with a lack of defects. It also represents cooperation between the two large public fresh market tomato breeding programs left in the United States. Previous cooperation between these two programs resulted in the cultivar Floralina, a Fusarium wilt race 3 resistant hybrid presently available from PetoSeed. The spotted wilt virus resistant hybrids come from a project that began in 1990 but was stalled for a few years due to problems in developing a good disease screening procedure. Work on high lycopene tomatoes using the *ogc* gene has been ongoing since 1981 with a renewed emphasis in the 1990's. A project not mentioned is the development of bacterial spot resistant cultivars. There is considerable work being done in this area and there may in fact be a release made in the next couple of years. However, more observations are needed and this topic has been saved for a future date.

Whereas it appears that the program is moving back to release of finished hybrids, this is not really the case. The type of releases made are dictated by the situation, and the present situ-

ation favors finished hybrids as the best way to get this particular material out to Florida growers. Seed companies interested in marketing seed of these hybrids will get the parents right away and other companies will get them later. Thus, this release procedure is not totally different than that of breeding line releases. It also should be mentioned that it is not known how much of the above material will in fact be released. This depends on performance in ongoing trials and on general interest of the seed industry and Florida growers. I do think the work described shows an increased versatility in the types of cultivars now becoming available over what has been available in the past. This would not be possible without the continued support of the Florida Tomato Committee, the help of numerous cooperators at the University of Florida, and the excellent work performed by my research staff.

J. W. Scott, Plant Breeder, UF/IFAS, Gulf Coast Research and Education Center, Bradenton, Fla.

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Table 1. Yield, fruit size, and cull percentage for tomato cultigens grown in summer 1999 at Bradenton, Florida. Plants grown in a completely randomized block design with three blocks and 10 plants plots. There were 18 inches between plants and 36 inches between plots.

Entry	Early season ²			Total season ⁴		
	Yield (lb./plant)	Fruit size (oz)	Cull (% by wt.)	Yield (lb./plant)	Fruit size (oz)	Cull (% by wt.)
Fla. 7885	2.74 a ³	5.1 ab	31 c	5.13 a	4.7 a-c	36 b
NC 99405	1.45 b	6.0 ab	34 bc	4.72 ab	5.2 a	32 c
Fla. 7906	0.95 bc	5.0 ab	41 a-c	3.48 a-c	4.6 a-c	46 a-c
Fla. 7324	0.69 bc	4.7 b	44 a-c	3.13 bc	4.1 c	44 a-c
Equinox	0.95 bc	5.5 ab	53 a-c	3.08 bc	5.0 a-c	41 a-c
Fla. 7771	0.88 bc	5.4 ab	53 a-c	3.07 bc	4.6 a-c	49 a-c
Fla. 7776	1.14 bc	5.2 ab	50 a-c	2.36 c	4.6 a-c	57 a
Fla. 7907	0.37 c	5.7 ab	58 ab	2.12 c	4.9 a-c	45 a-c
Florida 47	0.36 c	6.1 a	61 a	1.51 c	5.1 ab	52 ab

²Early season = first two harvests, Total season = four harvests. Fruit harvested one time per week at breaker maturity or beyond.

³Mean separation in columns by Duncan's Multiple Range test at $P \leq 0.05$.

Tomato Varieties for Florida

Donald N. Maynard and Stephen M. Olson

Variety selection, often made several months before planting, is 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 and race 2; Verticillium wilt (race 1); gray leaf spot; and some tolerance to bacterial soft rot. Available resistance to other diseases such as Fusarium wilt, race 3 may be important in certain situations

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.

'Florida 47' was grown on about 36% of the acreage in Florida in the 1999-2000 season - a notable increase from the approximately 23% of the acreage the previous season. 'Florida 47' was grown on about 47% of the acreage in southwest Florida and 32% of the east coast acreage.

'Sanibel' had about 14% of the state's acreage. It was the predominant variety in Miami- Dade County with almost 60% of the acreage.

All BHN varieties are lumped together and comprise about 13% of the state's acreage, mostly in southwest Florida and north Florida.

'Solar Set' acreage increased to over 12% of the state total mostly in west-central Florida.

'Florida 91' acreage increased to about 7% from a fraction the previous year. The Palmetto- Ruskin area was the principal production site.

Other varieties with some acreage in the 1999-2000 season were the long-time popular 'Agriset 761' (5%), 'Solimar' (5%), and 'Sun Chaser' (2%). Many other varieties and advanced experimental hybrids were grown on less than 1% of the state's acreage.

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; Indian River Research and Education Center, Fort Pierce and North Florida Research and Education Center, Quincy for the Spring 1999 season are shown in **Table 1**. High total yields and large fruit were produced by 'BHN 399' at Bradenton, 'Agriset 761', 'Solimar' and 'Floralina' at Fort Pierce, and 'Florida 7851' at Quincy. 'Florida 7815' produced high yields at two of the three locations. 'Sanibel' produced large fruit at all three locations and 'Solimar' at two locations. Not all entries were grown at each location.

Table 1. Summary of University of Florida tomato variety trials. Spring 1999.

Location	Variety	Total Yield (ctn/acre)	Variety	Large Fruit Size (oz)
Bradenton	Sunpak	2878	BHN 399	7.0
	PS 647095	2665	Solimar	6.9
	Florida 7815	2647	Florida 7851	6.8
	BHN 399	2642	Sanibel	6.8
	ASX 9110	2635 ¹	ASX 202	6.8 ²
Fort Pierce	Agriset 761	3620	Sunbeam	6.9
	Florida 7815	3584	Florida 47	6.8
	Florida 7862	3449	Solimar	6.2
	Solimar	3185	Floralina	6.2
	Floralina	3116 ³	Agriset 761	6.1
			Sanibel	6.1 ⁴
Quincy	BHN 444	3379	Sunbeam	8.2
	Florida 7862	3161	Florida 7851	8.1
	BHN 248	2934	RFT 6131B	8.0
	NC 96365	2891	Sanibel	7.9
	Florida 7851	2795 ⁵	PS 69696	7.9 ⁶

¹19 other entries had yields similar to ASX 9110.

²13 other entries had fruit weight similar to ASX 202.

³6 other entries had yields similar to Floralina.

⁴2 other entries had fruit weight similar to Sanibel.

⁵18 other entries had yields similar to Florida 7851.

⁶11 other entries had fruit weight similar to PS 69696.

Seed Sources:

Agrisales: Agriset 761, ASX 202, ASX 9110.

Asgrow: Florida 47, Sunbeam, Sunpak, Solimar.

BHN: BHN 248, BHN 399, BHN 444.

North Carolina State University: NC 96365.

Novartis: RFT 6131B.

Petoseed: Floralina, Sanibel, PS 647095, PS 69696.

University of Florida: Florida 7815, Florida 7851, Florida 7862.

Summary results listing the five highest yielding and five largest fruited entries from trials at the University of Florida's Gulf Coast Research and Education Center, Bradenton; the Indian River Research and Education Center, Ft. Pierce; and the North Florida Research and Education Center, Quincy for the fall 1999 season are shown in **Table 2**. High total yields and large fruit size were produced by "Florida 7816" at Bradenton; 'Equinox', 'Florida 7816', and 'Florida 7921' at Fort Pierce; and 'BHN 120A' and PX 647095 at Quincy. 'Florida 7885' and 'Florida 7921' produced high yields at all three locations. 'Florida 7816' produced large fruit at all locations. Again, not all entries were included at all locations.

Overall, results of these trials indicate that no single variety dominates the industry as during the periods when 'Sunny' and 'Agriset 761' were preeminent. Furthermore, varieties appear to be more location and seasonal specific than in the past.

Table 2. Summary of University of Florida tomato variety trial results. Fall 1999.

Location	Variety	Total Yield (ctn/acre)	Variety	Large Fruit Size (oz)
Bradenton	Florida 7885	2648	Florida 7816	6.9
	Florida 7921	2445	BHN 190	6.8
	BHN 273	2422	Solar Set	6.6
	Florida 7816	2419	Florida 91	6.5
	HA-3017B	2390 ¹	Sunbeam	6.5 ²
Fort Pierce	Florida 7921	950	Sunbeam	5.0
	Florida 7816	867	Florida 7816	4.9
	Florida 7885	856	Solar Set	4.9
	Agriset 761	821	Florida 7921	4.8
	Equinox	8213	Equinox	4.8 ³
			Florida 47	4.8 ⁴
Quincy	Florida 7885	2288	Florida 7816	6.3
	Solar Set	2265	Florida 91	6.2
	Florida 7921	2237	BHN 120A	6.1
	PX 647095	2229	Captiva	6.1
	BHN 120A	2197 ⁵	PX 647095	6.0
			Equinox	6.0 ⁶

¹13 other entries had yields similar to HA-3017B.

²11 other entries had fruit weight similar to Sunbeam.

³5 other entries had yields similar to Equinox.

⁴4 other entries had fruit weight similar to Florida 47.

⁵12 other entries had yields similar to BHN 120A.

⁶12 other entries had fruit weight similar to Equinox.

Seed Sources:

Agrisales: Agriset 761, Equinox.

Asgrow: Florida 47, Florida 91, Solar Set, Sunbeam.

BHN: BHN 120A, BHN 190, BHN 273.

Hazera: HA 3017B.

Petoseed: Captiva, PX 647095

University of Florida: Florida 7816, Florida 7885, Florida 7921.

Tomato Varieties for Commercial Production

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

Large Fruited Varieties

Agriset 761. Midseason, determinate, jointed hybrid. Fruit are deep globe and green shouldered. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), Alternaria stem canker, gray leaf spot. (Agrisales).

BHN-444. 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 and 2), and Tomato Spotted Wilt Virus. **For Trial.** (BHN).

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. (Asgrow).

Floralina. A midseason, determinate, jointed hybrid. Uniform, green shoulder, flattened globe-shaped fruit. Recommended for production on land infested with Fusarium wilt, Race 3. Resistant: Fusarium wilt (race 1, 2, and 3), Verticillium wilt (race 1), gray leaf spot. (Petoseed).

HA 3057. Early-midseason maturity. Uniform green shoulder, flattened globe-shaped fruit. Heat tolerant. Resistant: Fusarium wilt (race 2), Verticillium wilt (race 1), TMV, and TYLCV. **For Trial.** (Hazera).

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. (Asgrow).

Sanibel. A late-midseason, jointless, determinate hybrid. Deep oblate shape fruit with a green shoulder. Tolerant/resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), Alternaria stem canker, root-knot nematode, and gray leaf spot. (Petoseed).

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. (Asgrow).

Sunbeam. Early midseason, deep-globe shaped uniform green fruit are produced on determinate vines. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and race 2), gray leaf spot, Alternaria stem canker. (Asgrow).

Plum Type Varieties

Marina. Medium to large vined 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, 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 (race 0), Alternaria stem canker, and gray leaf spot. (Petoseed).

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

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 1), Verticillium wilt (race 1). **For Trial.** (Novartis).

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. (Petoseed).

Reference

Maynard, D. N. (ed.). 2000. Vegetable variety trial results in Florida for 1999. Fla. Agr. Expt. Sta. Circ. S-396.

Tomato variety evaluations were conducted in 1999 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
J. W. Scott Gulf Coast Research & Education Center - Bradenton
P. J. Stoffella Indian River Research & Education Center - Fort Pierce

Tomato Fertilizer Management

G. J. Hochmuth and E. Simonne

Prior to each cropping season, soil tests should be conducted to determine fertilizer needs. Obtain an IFAS soil sample kit from the local agricultural Extension agent for this purpose. Commercial soil testing laboratories also are available, however, be sure the commercial lab uses methodologies calibrated for Florida soils. Routine soil testing will help reduce overfertilization which reduces farming efficiency and increases the risk of groundwater pollution.

The crop nutrient requirements of nitrogen, phosphorus, and potassium (designated in fertilizers as $N-P_2O_5-K_2O$), **Table 1**, represent the optimum amounts of these nutrients needed for maximum production.

A portion of this required nutrition will be supplied by the native soil and by previous crop residue. The remainder of the nutrient requirements will be supplied by fertilizer, and this amount must be determined by soil testing. Fertilizers are applied only to soils testing very low in the specific plant nutrients. Automatic use of fertilizer without a soil test may result in wasted fertilizer, crop damage from salt injury, reduced yields and quality, and a risk to the environment if fertilizer runs off or leaches into the groundwater.

Liming

The optimum pH range for tomatoes is between 6.0 and 6.5. Fusarium wilt problems are reduced by liming within this range, but it is not advisable to raise the pH higher than 6.5 because of reduced micronutrient availability.

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.

Blossom-End Rot

At certain times, growers have problems with blossom-end-rot, especially on the first one or two 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 is with the water stream. Anything that impairs the ability of the plant to obtain water will increase the risk of BER. These factors include damaged roots from flooding or mechanical damage, clogged drip emitters, inadequate water applications, and alternating dry-wet periods. Other causes include high fertilizer rates, especially potassium and nitrogen. High fertilizer increases the salt content and osmotic potential in the soil reducing the ability of roots to obtain water. Excessive N encourages excessive vegetative growth. Calcium moves preferentially to the transpiring leaves thus reducing the proportion of Ca that is deposited in the fruit.

There should be adequate Ca in the soil if the double-acid 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. Foliar-applied Ca stays on the leaf from where it more likely will wash during a rain.

BER is most effectively controlled by attention to irrigation and fertilization. Maintaining adequate and uniform amounts of moisture in the soil are keys to reducing BER potential. Growers who keep N and K rates at soil-test-predicted levels are at least risk from BER.

Micronutrients

For virgin, sandy soils, or sandy soils where a proven need exists, a general guide for fertilization is the addition of micronutrients (in pounds per acre) manganese -3, copper -2, iron -5, zinc -2, boron -2, and molybdenum -0.02. Micronutrients may be supplied from oxides or sulfates. Growers using micronutrient-containing fungicides need to consider these sources when calculating fertilizer micronutrient needs. More information on micronutrient use is available. *See 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. For more information on foliar micronutrient fertilization of tomatoes, consult the Commercial Vegetable Fertilization Guide, Circular 225E.

Table 1. Fertility recommendations for mulched tomatoes on irrigated soils testing very low in phosphorus and potassium.

Soil	Number of expected harvests	Nutrient requirements	Supplemental Applications ¹	
		lbs/A ² N-P ₂ O ₅ -K ₂ O	lbs/A N-P ₂ O ₅ -K ₂ O	Number of Applications
Mineral	2-3	200-150-225	30-0-20	0-2

¹Sidedressing to replenish nitrogen and potassium can be accomplished by the use of a liquid fertilizer injection wheel.

²Approximately 7200 linear bed feet of crop per acre (43,560 square feet).

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 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 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.
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.

There is equipment that will do most of the operations in steps 4 and 5 above in one pass over the field. More information on fertilization of mulched crops is available.

Water management with the seep irrigation system is critical to successful crops. Use water-table monitoring devices and tensiometers in the root zone to help provide an adequate water table but no higher than required for optimum moisture. Do not fluctuate the water table since this can lead to increased leaching losses of plant nutrients.

Mulched Culture with Overhead Irrigation

For the sandy soils, maximum production has been attained by broadcasting 100 percent of the fertilizer in a swath 3 to 4 feet wide and incorporating prior to bedding and mulching. Be sure fertilizer is placed deep enough to be in moist soil. Where soluble salt injury has been a problem, a combination of broadcast and banding should be used. Incorporate 30 percent to 40 percent of the nitrogen and potassium and 100 percent of the phosphorus and micronutrients into the bed by rototilling. The remaining nitrogen and potassium is applied in bands 6 to 8 inches to the sides of the transplant and 2 to 4 inches deep to place it in contact with moist soil. Perforation of the plastic is needed on coarse sands where lateral movement of water through the soil is negligible.

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 the crop. Where drip irrigation is used, apply all phosphorus and micronutrients, and 20 percent to 40 percent of total nitrogen and potassium prior to mulching. Use the lower percentage (20 percent) on tomatoes which will be seep-irrigated for the first 2 weeks of the season. 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 K₂O 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 K₂O to ensure young transplants are established quickly. In most situations, some preplant N and K fertilizers are needed.

Suggested schedules for nutrient injections are presented in **Table 2**. These schedules have been successful in both research and commercial situations, but might need slight modifications based on potassium soil-test indices and grower experience.

Additional nutrients can be supplied through drip irrigation if deficiencies occur during the growing season. Be careful not to apply excessive amounts of water with the fertilizer because severe leaching can occur. Tensiometers can be used to help monitor soil moisture and guide the application of water. More detail on drip-irrigation management for fertilization is available.

Sources of N-P₂O₅-K₂O

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.

Slow-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 fertilizers incorporated in the bed. Nitrogen from natural organics and most slow-release materials should be considered ammoniacal nitrogen when calculating the amount of ammoniacal nitrogen.

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

Recent research has shown that 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 K₂O are applied, then there should be no concern for the K source or its associated salt index.

Tissue Analyses

Analysis of tomato leaves for mineral nutrient content can help guide a fertilizer management program or assist in diagnosis of a suspected nutrient deficiency. Tissue nutrient norms are presented in **Table 3**.

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 4**. More information is available on plant analysis.

George Hochmuth, UF/IFAS, North Florida Research and Education Center, Quincy, Fla. and E. Simonne, UF/IFAS Horticultural Sciences Dept., Gainesville, Fla.

Suggested Literature

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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>

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

Table 2. Schedules for N and K₂O injection for mulched tomato on soils testing low in K.

Crop development		Injection (lb/A/day) ²	
stage	weeks	N	K ₂ O
1	2	1.5	1.5
2	2	2.0	2.0
3	7	2.5	3.0
4	1	2.0	2.0
5	1	1.5	1.5

Total nutrients applied are 200 lb N and 225 lb K₂O per acre (7260 linear bed feet). These injection programs assume no N or K preplant. If 20% of N and K are applied preplant in the bed, then first two week's of injection can be reduced or omitted.

Table 3. Deficient, adequate, and excessive nutrient concentrations for tomatoes [most-recently-matured (MRM) leaf (blade plus petiole)].

Tomato	MRM ² leaf	5-leaf stage	%-----											----- ppm				
			N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo				
		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	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	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						
	MRM leaf	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				

Table 4. Suggested nitrate-N and K concentrations in fresh petiole sap for tomatoes.

Stage of growth	Sap concentration (ppm)	
	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

Disease Management for Tomato

Tom Kucharek

University of Florida, Plant Pathology Dept.

Chemical	Maximum Rate/Acre/		Minimum Days to Harvest	Pertinent Diseases	Select Remarks
	Application	Crop			
**For best possible chemical control of bacterial spot, a <u>copper</u> fungicide must be <u>tank-mixed</u> with a maneb or mancozeb fungicide.					
Ridomil Gold EC	2 pts/trtd acre	12 pts/trtd acre		Pythium diseases	See label for use at and after planting.
Ridomil WSP	2 lbs/trtd acre	6 lbs/trtd acre			
Kocide 101, Blue Shield or Champion WP's	4 lbs		1	Bacterial spot	
Kocide LF, Cuproxat or Champion FL's	5½ pts		1	Bacterial spot	
Champ	2¾ pts		1	Bacterial spot	
Basicop or Basic Copper 53	4 lbs		2	Bacterial spot	
Oxycop WP	6 lbs		2	Bacterial spot	
Microspense C.O.C. 53WP	4 lbs		2	Bacterial spot	
Manex 4F	2.4 qts	16.8 qts	5	Early and late blight, Gray leaf spot, Bacterial spot ¹	Field and Greenhouse use
Kocide or Blueshield DF's	4 lbs		2	Bacterial spot	
Maneb 80 WP	3 lbs	21 lbs	5	Same as Manex FL	Field and Greenhouse use
Manex II or Dithane F45 FL's	2.4 pts	16.8 qts	5	Same as Manex FL	
Dithane, Penncozeb or Manzate 75 DF's	3 lbs	21 lbs	5	Same as Manex 4 FL	
Bravo 720, Terranil 6L or Echo 720	3 pts		2	Early and late blight, Gray leaf spot, Target spot	Use higher rates at fruit set and lower rates before fruit set.
Maneb 75DF	3 lbs	22.4 lbs	5	Same as Manex FL	
Terranil 90DF or Echo 90 DF	2.3 lbs		2	Early and late blight, Gray leaf spot, Target spot	Use higher rates at fruit set and lower rates before fruit set.

Table. Disease Management for Tomato continued

Chemical	Maximum Rate/Acre/		Minimum Days to Harvest	Pertinent Diseases	Select Remarks
	Application	Crop			
Bravo W75	3 lbs		1	Early and late blight, Gray leaf spot, Target spot	
Bravo 500, Echo 500, or Agronil FL's	4 pts		2	Early and late blight, Gray leaf spot, Target spot	Use higher rates at fruit set and lower rates before fruit set.
Ridomil Gold Bravo 81W	3 lbs		2	Early and late blight, Gray leaf spot, Target spot	Limit is 4 appl/crop
Ridomil Gold MZWP ²	2.5 lbs	7.5 lbs	5	Late blight	Limit is 3 appl/crop
Benlate 50WP	1 lb		1	Leaf mold, Botrytis, Sclerotinia	
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 70W	2.5 lbs ³		14	Late blight	Limit is 3 appl/crop.
Sulfur			1	Powdery mildew	
Kocide 2000	3 lbs		1	Bacterial spot	
Kocide 4.5 LF	2 ⅔ pts		1	Bacterial spot	
Dithane M45 or Manzate 80 WP's	1 ½ lbs	21 lbs	5	Same as Manex 4F	
Aliette 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.

Table. Disease Management for Tomato continued

Chemical	Maximum Rate/Acre/		Minimum Days to Harvest	Pertinent Diseases	Select Remarks
	Application	Crop			
Bravo Ultrex 82.5 WDG	2.75 lbs		2	Early and Late blights, Gray leafspot, Target spot, Botrytis, Rhizoctonia fruit rot	Use higher rates at fruit set.
Bravo Weather Stik	3 pts		2	Same as Bravo Ultrex	Use higher rates at fruit set
Quadris 2.08 FL	6.2 fl oz	37.2 fl oz	0	Early blight, late blight, sclerotinia	Alternate with other types of fungicide. Limit is 6 appl.
Botran 75W	1 lb	4 lbs	10	Botrytis	Greenhouse tomato only. Limit is 4 applications. Seedlings or newly set transplants may be injured.
Exotherm Termil	1 can/1000 sq. ft.		2	Botrytis, Leaf mold, Late & Early blights, Gray leafspot	Greenhouse use only. Allow can to remain overnight and then ventilate. Do not use when greenhouse temperature is above 75F.
¹ When tank mixed with a copper fungicide. ² Do not exceed limits of mancozeb active ingredient as indicated for Dithane, Penncozeb, Manex or Manzate 200. ³ Maximum crop is 3.0 lbs a i. of metalaxyl from Ridomil/copper, Ridomil MZ 58 and Ridomil Bravo 81W					

NEMATOCIDES REGISTERED FOR USE ON FLORIDA TOMATO

Row Application (6' row spacing - 36" bed) ⁴					
Product	Broadcast (Rate)	Recommended Chisel Spacing	Chisels (per Row)	Rate/Acre	Rate/1000 Ft/Chisel
FUMIGANT NEMATOCIDES					
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	9-18 gal	12"	3	4.5-9.0 gal	26 - 53 fl oz
Telone C17	10.8-17.1 gal	12"	3	5.4-8.5 gal	31.8-50.2 fl oz
Vapam	50-75 gal	5"	6	25 - 37.5 gal	56 - 111 fl oz
NON-FUMIGANT NEMATOCIDES					
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 and Telone C-17 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. Consult manufacturers label for other use restrictions which might apply.

³. Use of methyl bromide for agricultural soil fumigation is scheduled for phaseout Jan 1, 2005.

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 1, 2000 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.

Prepared by: J. W. Noling, Extension Nematology, CREC, Lake Alfred, FL



Weed Control in Tomato¹

William M. Stall and James P. Gilreath²

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

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

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

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

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2. William M. Stall, professor, Horticultural Sciences Department, and James P. Gilreath, professor, Gulf Coast Research and Education Center-Bradenton, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

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plants, for all practical purposes, growers probably would be wise to use Diquat only. On canals where drift onto the crop is not a problem and weeds are more woody, Rodeo, a systemic herbicide, could be used. Other herbicide possibilities exist, as listed in Table 1. Growers are cautioned against using Arsenal on tomato farms as tomatoes are very sensitive to this herbicide. Particular caution should be exercised if Arsenal is used on seepage irrigated farms as it has been observed to move in some situations.

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

The greatest row middle weed control problem confronting the tomato industry today is control of nightshade. Nightshade has developed varying levels of resistance to some post-emergent herbicides in different areas of the state. Best control with post-emergence (directed) contact herbicides are obtained when the nightshade is 4 to 6 inches tall, rapidly growing and not stressed. Two applications in about 50 gallons per acre using a good surfactant 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 than others and herbicide labels may specify a minimum active ingredient rate for the adjuvant in the spray mix. Before selecting an adjuvant, refer to the herbicide label to determine the adjuvant specifications.

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.

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

Table 1. Chemical weed controls: tomatoes.

Herbicide	Labelled Crops	Time of Application to Crop	Rate (lbs. AI./Acre)	
			Mineral	Muck
Clathodem (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.				
Diquat (Diquat H/A)	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 labelled. Add 16 to 32 ozs. of Valent X-77 spreader per 100 gals. of spray mix. Thorough coverage of vines is required to insure maximum burndown.				
Diquat dibromide (Diquat)	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.				
MCDS (Enquik)	Tomatoes	Postemergence directed/shielded in row middle	5 - 8 gals.	—
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.				
Metribuzin (Sencor DF) (Sencor 4) (Lexone DF)	Tomatoes	Postemergence Posttransplanting after establishment	0.25 - 0.5	—
Remarks: Controls small emerged weeds after transplants are established direct-seeded plants reach 5 to 6 true leaf stage. Apply in single or multiple applications with a minimum of 14 days between treatments and a maximum of 1.0 lb ai/acre within a crop season. Avoid applications for 3 days following cool, wet or cloudy weather to reduce possible crop injury.				
Metribuzin (Sencor DF) (Sencor 4) (Lexone DF)	Tomatoes	Directed spray in row middles	0.25 - 1.0	—
Remarks: Apply in single or multiple applications with a minimum of 14 days between treatments and maximum of 1.0 lb ai/acre within crop season. Avoid applications for 3 days following cool, wet or cloudy weather to reduce possible crop injury. Label states control of many annual grasses and broadleaf weeds including, lambsquarter, fall panicum, <i>amaranthus</i> sp., Florida pusley, common ragweed, sicklepod, and spotted spurge.				
Napropamid (Devrinol 50DF)	Tomatoes	Preplant incorporated	1.0 - 2.0	—
Remarks: Apply to well worked soil that is dry enough to permit thorough incorporation to a depth of 1 to 2 inches. Incorporate same day as applied. For direct-seeded or transplanted tomatoes.				
Napropamid (Devrinol 50DF)	Tomatoes	Surface treatment	2.0	—
Remarks: Controls germinating annuals. Apply to bed tops after bedding but before plastic application. Rainfall or overhead-irrigate sufficient to wet soil 1 inch in depth should follow treatment within 24 hours. May be applied to row middles between mulched beds. A special Local Needs 24(c) Label for Florida. Label states control of weeds including Texas panicum, pigweed, purslane, Florida pusley, and signalgrass.				
Paraquat (Gramoxone Extra)	Tomatoes	Premergence, Pretransplant	0.62 - 0.94	—
Remarks: Controls emerged weeds. Use a non-ionic spreader and thoroughly wet weed foliage.				

Table 1. Chemical weed controls: tomatoes.

Herbicide	Labelled Crops	Time of Application to Crop	Rate (lbs. AI./Acre)	
			Mineral	Muck
Paraquat (Gramoxone Extra)	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.				
Pebulate (Tillam 6E)	Tomato	Pretransplant	4	—
		Incorporated		
		Directed	6	—
Remarks: Do not use on seeded tomatoes. Has supplemental labeling for use in transplanted tomatoes grown under polyethylene mulch and in combination with Telone C-17 or C-35. Transplants may be set by hand if chemical resistant gloves are worn. Consult label for incorporation methods recommended. May be applied post transplanting as a directed spray to clean cultivated soil. There is a 8 day PHI. Product is volatile and not persistent in soil. Susceptible weeds germinating late in the season may not be controlled.				
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.				
Sethoxydim (Poast)	Tomatoes	Postemergence	0.188 - 0.28	—
Remarks: Controls actively growing grass weeds. A total of 4½ 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 (1½ pts.) to perennial grasses emerging from rhizomes etc. Consult label for grass species and growth stage for best control.				
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.				

Selected Insecticides Approved for Use on Insects Attacking Tomato

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Phil Stansly, SW Florida Research and Education Center, Immokalee;
Susan Webb, Entomology and Nematology Dept. Gainesville

Selected insecticides approved for use on insects attacking tomato. Phil Stansly, Southwest Florida Research and Education Center, Susan Webb, Entomology and Nematology Dept., Gainesville			
Chemical Name	Rate Per Acre	Days to Harvest	Insects
Admire 2E	16 - 24 fl oz(soil use)	21	aphids, flea beetles, Colorado potato beetle, thrips, whiteflies
Agrimek 15EC (abamectin)	8 - 16 fl oz	7	leafminers, tomato pinworms, mites, Colorado potato beetle
Ambush 2EC (permethrin)	3.2 - 12.8 oz	up to day of harvest	beet armyworms, cabbage loopers, Colorado potato beetles, cutworms, hornworms, leafminers, southern armyworms, tomato fruitworms, tomato pinworms, whiteflies
Pounce 3.2EC (permethrin)	2 - 8 oz	0	Same above
Applaud 70P	0.35 lb/acre	7	Whiteflies
Asana XL .66EC (esfenvalerate)	2.9 - 9.6 fl oz	1	aphids, armyworms, beet armyworms, flea beetles, grasshoppers, hornworms, souther armyworms, cabbage loopers, Colorado potato beetle, cutworms, leafminers, tomato fruitworms, whiteflies, yellow-striped armyworms
Baythroid 2 F (cyfluthrin)	1.6 - 2.8 oz	0	aphids, beet armyworms, European corn borer, horn worms, southern armyworms, stinkbugs, cabbage loopers, Colorado potato beetle, cutworms, leafminers, thrips, tomato fruitworms, tomato pinworms
BT (Bacillus Thuringiensis)	See label		armyworms, hornworms, salt marsh caterpillars, cabbage loopers, corn earworms, cutworms, loopers, tomato fruit worms

Confirm 2F	6 – 8 oz	7	armyworms, loopers, hornworm
Cygon 4EC Dimethoate 4EC (dimethoate)	0.5 - 1 pt	7	aphids, leafhoppers, leaf-miners
Cythion 5EC Malathion (malathion)	1 - 3 pts	1	aphids, armyworms, cabbage loopers, cutworms, leafhoppers, leafminers, mealy bugs, thrips, whiteflies, drosophilias, flea hoppers, mites
Di-Syston 8EC (disulfotam)	1 - 3 pt 38" row spacing	30	aphids, Colorado potato beetle, leafhoppers, mites
Danitol 2.4EC (fenpropathrin)	10.67 fl oz	3	aphids, thrips, tomato fruit worms, tomato pinworms, whiteflies, yellow-striped armyworms, stink bugs
D.z.n.; AG-500 4EC (diazinon)	0.5 – 1.5 pt (foliar) 2 – 4 qt (preplant)	1	mole crickets, wireworms, aphids, armyworms, banded cucumber beetles, fall armyworms, drosophilias, symphylans, southern armyworms, cutworms, leafminers
Guthion 2L (EC)	0.5 – 6 pt	up to 4 days of harvest if 3 pts or less; 14 for >3 pts	aphids, banded cucumber beetles, flea beetles, grasshoppers, hornworms, stinkbugs, Colorado potato beetle, corn earworm, cucumber beetles, leafhoppers, leafminers, thrips, tomato fruitworm, tomato pinworm, tubeworms, whiteflies, drosophilias, European corn borer, yellow-striped armyworms
Kelthane MF (dicofol)	0.75-1 .5 pt	2	mites
Knack (pyriproxyfen)	8 –10 fl oz.	7	immature whiteflies
Kryocide 96WP (cryolite)	8 -16 lbs	14	blister beetles, flea beetles, hornworms, cabbage loopers, tomato fruitworms, tomato pinworms

Lannate 2.4 L (methomyl)	1.5 - 3 pts	1	aphids, armyworms, beetles, armyworms, variegated cutworms, fall armyworms, hornworms, southern armyworms, tomato fruitworms, tomato pinworms, loopers
Monitor 4EC (methamidophos)	1.5 - 2 pts fresh fruit only	7	aphids, leafminers, tomato fruitworms, tomato pinworms, whiteflies
Neemix .25EC (azadirachtin)	0.5 -2.0 gal/acre		armyworms, hornworms, psyllids, saltmarsh caterpillars, cabbage loopers, Colorado potato beetle, cutworms, leafminers, loopers, tomato fruitworm (corn earworm), tomato pinworm, whiteflies
NoMate MEC (Pheromone)	1.34-2.68 oz/acre		tomato pinworms
Provado 1.6E (imidacloprid)	3.75 fl oz	0 - foliar	aphids, whiteflies, Colorado potato beetle
Pyrellin EC (pyrethrin + rotenone)	1 - 2 pts	0	vegetable weevil, ants, aphids, Colorado potato beetles, cucumber beetles, European corn borer, flea beetles, flea hoppers, leafhoppers, leafminers, loopers, mites, plant bugs, stink bugs, thrips, whiteflies
Pyrenone 4EC (pyrethrin + piperonyl butoxide)	2 - 12 oz	0	crickets, aphids, armyworms, cabbage loopers, Colorado potato beetles, corn ear worms, cucumber beetles, drosophilias, flea beetles, leafhoppers, psyllids, thrips, whiteflies
Sevin 80S(WP) (carbaryl)	0.63 – 2.5 lbs	3	fall armyworms, flea beetles, grasshoppers, hornworms, plant bugs, stinkbugs, Colorado potato beetle, cutworms, leafhoppers, tomato fruitworms, tomato pinworms, lace bugs European corn borer

Soap , insecticidal (M-Pede) 49% EC	see label	0	aphids, leafhoppers, plant bugs, thrips, whiteflies, mites
SpinTor 2SC (spinosad)	1.5 – 8 oz	1	Colorado potato beetle larvae, hornworms, loopers, tomato fruitworm, armyworms, thrips, leafminers, European corn borer
Sulfur	See label	–	mites
Sunspray Ultrafine (Horticultural spray oil)	See label 1 - 2 gal/100 gal water	0	aphids, leafhoppers, leafminers, thrips, whiteflies, mites
Telone II; C-17 (dichloropropene)	See label	preplant	wireworms
Thiodan 3EC, Phaser (endosulfan)	2/3 – 4/3 qt	2	aphids, blister beetles, flea beetles, hornworms, stinkbugs, cabbage loopers, Colorado potato beetles, tomato fruitworms, whiteflies, mites, yellow-striped army worms
Vydate L 2EC (oxamyl)	2 - 4 pts	3	aphids, Colorado potato beetles, leafminers
Warrior T (lambda-cyhalothrin)	1.92 - 3.84 fl oz	5 - caution, see label	aphids, beet armyworms, European corn borer, fall army worms, flea beetles, grasshoppers, hornworms, plant bugs, stinkbugs, cabbage loopers, Colorado potato beetles, cutworms tomato fruitworms, tomato pinworms, whiteflies, European corn borer, yellow-striped armyworms

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