2003 Tomato Institute Program

Ritz Carlton • Naples, Florida • September 3, 2003

Moderator: *Mary Lamberts, Miami/Dade County Extension Service, Homestead*

9:00 **Welcome & Opening Remarks -** Larry Arrington, Associate Dean for Extension, UF/IFAS, Gainesville

9:15 **The "State of the Florida Tomato" Address -** Reggie Brown, Florida Tomato Committee, Orlando

9:30 **Mexican Competition: Now from the Greenhouse -** Dan Cantliffe, Horticultural Sciences Department, Gainesville, pg. 2

9:50 **Methyl Bromide CUE: Where Do We Stand? -** Mike Aerts, Florida Fruit & Vegetable Association, Orlando

10:10 **"Solar Fire" and Other Hot Tomato Variety Topics -** Jay Scott, GCREC, Bradenton, pg. 4

10:30 **Tomato Yellow Leaf Curl Virus Revisited -** Jane Polston, Plant Pathology Department, Gainesville, pg. 9

10:50 **What's Up With All These Whiteflies? -** Dave Schuster, GCREC, Bradenton, pg. 12

11:20 **Lunch**

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

1:00 **New Product Updates -** Industry Representatives

2:15 **Tomato Disease Update -** Pam Roberts, SWFREC, Immokalee, pg. 20

2:35 **Tomato Herbicides: What We Have Gained, What We Have Lost and Possible Future Labels -** Bill Stall, Horticultural Sciences Department, Gainesville, pg. 22

2:55 **Weed Hosts, Field Distributions and Sampling Strategies for Root Knot Nematode -** Joe Noling, CREC, Lake Alfred, pg. 23

3:15 **Innovative Approaches for Soil Fumigation -** Dan Chellemi, USDA-ARS, Ft. Pierce, pg. 34

3:35 **VIF Research and Role in Methyl Bromide Phaseout: Update on Long Term Methyl Bromide Alternatives Study -** Jim Gilreath, GCREC, Bradenton, pg. 38

4:00 **Adjourn**

Control Guides:

Tomato Varieties for Florida - Stephen M. Olson, UF, NFREC, Quincy; and Donald N. Maynard, UF, GCREC, Bradenton, pg. 42
Water Management for Tomato - Eric H. Simonne, Horticultural Sciences Department, UF, Gainesville, pg. 45
Fertilizer and Nutrient Management for Tomato - Eric H. Simonne, Horticultural Sciences Department, UF, Gainesville, pg. 49
Weed Control in Tomato - William H. Stall, Horticultural Sciences Department, UF, Gainesville; James P. Gilreath, UF, GCREC, Bradenton, pg. 56
Chemical Disease Management for Tomato - Tom Kucharek, Plant Pathology Department, UF, Gainesville, pg. 59
Selected Insecticides Approved for Use on Insects Attacking Tomatoes - S. E. Webb, Entomology & Nematology Department, UF, Gainesville, pg. 62
Nematicides Registered for Use in Florida Tomatoes - J. W. Noling, UF, CREC, Lake Alfred, pg. 68

Mexican Competition: Now from the Greenhouse

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Commercial greenhouse production of horticultural crops in Mexico started in the 1950s. Initially local growers produced flowers in wood-type structures covered with plastic. It was not until the 1980s, however, that greenhouse-type structures were used in vegetable production. By today's standards, these structures were semi-rustic. In the 1990s, larger, more modern greenhouse structures began to appear in various places in Mexico. More vegetables started to be produced, primarily destined to export market, and thus at that time investment capital became available as well as interests from various groups from countries including Israel, Holland, and Spain began to both sell and operate greenhouses for vegetable production in Mexico.

Presently there is in excess of 5000 acres of greenhouse production in Mexico. Estimates place about half of this production in vegetables and the other half in floral production.

Growers in Mexico have turned to greenhouse production of vegetables in order to provide a controlled environment to improve product quality. Mexican greenhouse producers have been attempting to develop vegetable brands that are accepted in the marketplace by wholesalers and other buyers. They hope to improve their image on product quality and food safety as well as maintain stricter control of water quality.

It is estimated that there are approximately 12 major providers of vegetable greenhouse products to the United States from Mexico (Lopez and Shwedel, 2001). These producers are primarily targeting the winter market when the prices are highest. The use of greenhouse production helps the Mexican producers offset certain problems with production as it relates to weather, both rain and cold temperatures, and thus they are able to better adjust the timing for market delivery.

Presently there are various reasons for Mexican producers to develop a greenhouse industry for vegetables. These include 1) the need to reduce the impacts from variations in climatic conditions on produce quality. 2) The opening of the Mexican economy, bringing with it access to different types of technology, i.e. people are willing to invest in Mexico. 3) The search for solutions to different problems that affect open field production, for instance, various diseases, insects, weeds, etc. 4) An increase in demand by consumers for better and safer products, especially for export markets where food safety issues, including the border quality, have the potential to become major trade issues.

Mexican vegetable greenhouse production has been highly developed in five states including Baja California which is 9.5% of the production, Baja California Sur 13.5%, Sonora 6.9%, Sinaloa 26.3%, and Jalisco 27.4% (Lopez and Shwedel, 2001). It is estimated that total value for vegetable production from Mexican greenhouses is in excess of $300 million today. The major vegetable crops produced are tomatoes (60% of the total greenhouse area), cucumbers (20%), and peppers (10%). Of the tomatoes, the main varieties are vine-ripe large rounds, cherry tomatoes, Roma tomatoes, and also a group called greenhouse tomatoes.

Twelve years ago, in 1991, there were only 125 acres of vegetables being produced in greenhouses in Mexico. Because of NAFTA and the enhanced access to the U.S. market, interest in greenhouse production has grown dramatically over this period. Further, as the Mexican economy improves and the peso strengthens, the greenhouse industry has expanded greatly in the last two or three years. Presently there is in excess of 2500 to 3000 acres of greenhouses being dedicated to vegetable production. Although much of the production is in the five Mexican states previously mentioned, there are 15 states in Mexico with greenhouse vegetable production. About 84% of the total production, however, is in those five states.

The U.S. is by far the most important market for Mexican greenhouse vegetable producers. Over 92% of the greenhouse production for export goes to the U.S. The rest goes to Canada and as far away as to Europe and the E.U. (Lopez and Shwedel, 2001).

In 2000, total imported tomato value into the U.S. was approximately $147 million, or 95,000 tons of fresh market tomatoes. Of those values, $78 million of tomatoes produced in the greenhouse were being imported from Canada, while $36 million worth of tomatoes were being imported from Mexico. In contrast to only one year previous, 1999, the value had risen over $100 million because of import of greenhouse tomatoes into the U.S. which in 1999 was somewhat under $44 million at 28,000 tons. Mexican producers had only $4.2 million of that market share. Thus, in the one-year period, importation of tomatoes from Mexican greenhouses increased in value from $4.2 to $36.1 million. Subsequent to that, importation of tomatoes from Mexican greenhouses has increased. Several large field producers of Mexican tomatoes have converted to partial or total production coming from greenhouses over the past 4-5 years. Dutch and Canadian greenhouse tomato prices are still higher than those tomatoes coming from Mexico. The lower prices are somehow reflected in transportation cost differential to major markets, cheaper labor costs and newness of the Mexican greenhouse industry in the marketplace. As the greenhouse industry matures, it is bound to expand and product prices are bound to improve.

With regard to structures, plastic greenhouses cover about 95% of the total area of the greenhouse production and only 5% or less of the area is covered with glass. The primary reason is the price differential and the fact that in many regions in Mexico, glass is not needed. The plastic film used is PVC (polyvinilic chloride) and most of the greenhouses are high-roofed generally 4-5 meters from floor to the top beam. A large number of the greenhouses are locally produced in Mexico. However, there are also a large number of greenhouses from Israel, Canada, the Netherlands, Spain, France, and the U.S. Mexican greenhouses are of somewhat less quality, but also cost less than imported houses. Israeli greenhouse manufacturers will sometimes help with funding of greenhouse construction, while greenhouse manufacturers from Spain will setup greenhouses for certain growers free of cost for a certain percentage of return on the crop that will be produced from the greenhouse. It is estimated that the basic structure for 2.5 acres is $165,000 USD for construction (Lopez and Shwedel, 2001). This price includes all the metal and plastic, but does not include any mechanical features, or the irrigation. Many times local labor is used for construction, and whenever lesser materials are used construction prices can be somewhat lowered as much as 50% from that cost.

In Mexico local banks will loan capital for investments for periods of only up to five years. The credit market has relatively high borrowing costs in local currency, thus most producers are forced to go with less expensive plastic style greenhouses. In many areas of Mexico, especially in Sinaloa, which is the second largest vegetable producing state, temperatures in the winter time can fall either near or below freezing. Most greenhouses were constructed without heating systems, however new greenhouses are being constructed with either hot water tubing or gas generated space heaters. The heaters are generally manually operated, and thus producers can be assured that if temperatures go to or below freezing, they will have produce to sell in the winter time in the U.S. market.

In summary, most areas of Mexico provide a perfect environment for greenhouse vegetable production. Good day length and strong light intensity during the winter months are prime factors in developing a greenhouse industry in this region of the world. Technology has been available from outside sources and especially cost effective in construction are the Israeli type high-roof passive ventilated greenhouses, and more recently into Spanish new-style greenhouses. Production of crops from the greenhouse gives production advantages, such as improved scale of efficiencies from a variety of different systems and the ability to market a premium product. Some of the constraints are the fact that in much of the production areas there is a long distance to the market place, especially in places in Baja or Sinaloa or Jalisco, in many cases a 36-hour ride or longer to southern California or southern Arizona. Further, material costs are similar to the U.S. or higher, but labor in general is considerably lower. Another concern, especially in the Baja, is water, both quantity and quality.

Greenhouse production is in fact becoming more common and more popular in Mexico. Medium and large producers are beginning to develop strong greenhouse production systems and take advantage of existing marketing outlets. With access to North America, especially the U.S., through NAFTA, foreign investment has been greatly stimulated. Tomatoes are still the most important crop produced in Mexican greenhouses, although cucumbers and peppers have continued to increase in quantity of production. Continuation of constraint on the entire industry relates to the volatility of the market for greenhouse products. Generally with field produced vegetables, many of the Mexican companies have established contractual agreements both within the local markets within Mexico, as well as with markets in the U.S. This has allowed them to better adjust to price fluctuations. Finally, although Mexico has inexpensive labor, it is not an absolute low-cost producer because capital and energy tend to be higher than in North America and in fact, than in the E.U. Essentially, if premium prices are not continued to be paid for Mexican produce from the greenhouse, it is potentially possible that these producers are in danger of going out of business.

It should be recognized that tomato production from greenhouses in Mexico is still only a small percentage of the total production of tomatoes being produced and exported from that country. The most significant factor to concentrate a threat from Mexican greenhouse tomato production to the Florida market would be the broadening of the greenhouse production area. As already experienced, 5-6 other states outside of Sinaloa that normally would not produce tomatoes in winter now do. Continuation of high price returns in a high quality market could have a profound influence on the future for Florida tomato producers.

As to the future of greenhouse tomato production, presently there are approximately 850 acres of greenhouse tomatoes being produced in the U.S., or about 6% of the total tomatoes produced in this country. The major states producing greenhouse tomatoes are Arizona, Texas, Colorado, and Pennsylvania. On a global scale, Canada is producing approximately 1600 acres of greenhouse tomatoes, Belgium 1700 acres, Mexico 1800 acres, and Holland produced 2200 acres. Again, this does not seem like a lot coming from greenhouses on a world basis, but if one would look at the statistics of where most of these tomatoes wind up, this production is in many cases in direct competition with Florida tomato producers. A last thought to leave however, and one that has been related by these authors in a previous paper and a previous talk to the Florida Tomato Institute, is the fact that the world leader, Spain, presently has well over 50,000 acres of greenhouse space devoted to the production of tomatoes. Further, as the Spanish greenhouse industry matures and improves on their marketing abilities, they too will be not only another competitor, but may be the major competitor for Florida production tomato market space in the U.S.

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‘Solar Fire’ and Other Hot Tomato Breeding Topics

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The Fall 2002 Florida tomato season was more stressful than most as high temperatures and rainfall persisted through October essentially extending the summer season by a month. This caused severe losses to growers because the heat depressed fruit set and many of the fruit that did set were unmarketable due to cracking and rain check from the rains. There were also serious outbreaks of bacterial spot caused by *Xanthomonas campestris* pv. *vesicatoria* that further reduced yields while increasing production costs due to increased spraying in attempt to control the disease. These problems are always present in Florida Fall crops to some degree. Presently, growers do not have many choices in heat-tolerant varieties that will provide desired levels of marketable production in the fall. Varieties with resistance to bacterial spot and good horticultural characteristics are not available. Today I am going to report on the release of ‘Solar Fire’, tested as Fla. 7943B. It is a heat-tolerant tomato variety that performed well under the very stressful Fall 2002 conditions and it is anticipated that it will be of benefit to Florida tomato growers in future years. Secondly, I will briefly report on some new experimental heat-tolerant varieties that are presently being tested in University and grower trials. Lastly, I will give an update on development of bacterial spot tolerant, heat-tolerant varieties.

‘Solar Fire’

‘Solar Fire’ hybrid was released on July 1, 2003. As of this writing a seed company is being sought for exclusive seed production and distribution rights. A fair amount of seed was produced at GCREC last spring and testing on a number of grower farms is taking place this fall.

‘Solar Fire’ has a medium sized, slightly open, vine with good fruit cover. Pruning is not necessary and heavy pruning would likely be detrimental. However, growers might want to experiment with light pruning to see if there is any benefit under their conditions. The fruit are large (Tables 1,2), flat-round, smooth, firm (Table 3), have light-green shoulders, and ripen to a good red color (Table 3). The fruit maintain a regular symmetrical shape and blossom scars are smooth. One of the parents, Fla. 7776, has the nipple type blossom scar (*n-2* gene) so the hybrid is heterozygous for this gene. The other parent, Fla. 7946, has smooth blossom scars under a range of growing conditions. The fruit crack less than most tomato cultivars presently grown in Florida. For instance, there was much rainfall in the 2002 Fall seasons in Florida and the yield of ‘Solar Fire’ was relatively good in part because of the lack of cracking (Table 1). Maturity is early especially under high temperature conditions (see Bradenton data in Table 1). The heat-tolerant fruit setting ability of ‘Solar Fire’ was illustrated by the marketable yield at Quincy and the early marketable yield at Bradenton where it was significantly greater than the varieties in Table 1 and all other varieties except for Fla. 7885B (data not shown).

‘Solar Fire’ is resistant to races 1, 2, and 3 of Fusarium wilt [*Fusarium oxysporum* Schlechtend. F. sp. *lycopersici* (Sacc.) Snyder and Hansen] (*I, I-2, I-3*genes), Verticillium wilt race 1 (*Verticillium dahliae* Kleb.) (*Ve* gene), and gray leafspot caused by *Stemphyllium solani* Weber (*Sm* gene). It has moderate resistance to fruit soft rot (*Erwinia carotovora* subsp. *carotovora*) as indicated by its intermediate water uptake (Table 4). ‘Solar Fire’ is tolerant of common fruit disorders. There has been some zippering, blotchy ripening, blossom-end rot, and graywall under some conditions, but expression of these has not been more than cultivars presently grown in Florida.

Experimental Heat-tolerant Varieties; Fla. 8092, Fla. 8093, and Fla. 8135

Several new hybrids are being tested and at least one could be released in the near future if warranted. Last year I reported some merits of heat-tolerant inbred Fla. 8044 (Scott, 2002). This inbred has a high level of heat-tolerant fruit setting ability with good firmness and blossom scar smoothness. Its vine is not particularly strong. It is a parent in several hybrids in my program and crossing in some seed company programs has taken place. The three hybrids of most interest at present with Fla. 8044 as a parent are Fla. 8092, Fla. 8093, and Fla. 8135. All yielded well in the Spring trial at GCREC (Maynard et al., 2003). Seed has been limited up to now but crosses made in Spring 2003 now allows for more testing in Fall 2003. In a very stressful Summer 2002 trial where all marketable yields were depressed from heat, rain, and bacterial spot incidence, Fla. 8093 had significantly more marketable yield than all other hybrids tested (Table 5). Fla. 8094 also has Fla. 8044 as a parent, thus three of the four highest yielding hybrids had Fla. 8044 as a parent. Of the Fla. 8044 hybrids, Fla. 8092 has the strongest vine. It had more zippering than desired in Spring 2003, but will be tested more in the future. Zippering is generally more severe under cool conditions. Other hybrids in advanced testing are Fla. 7973 and Fla. 7964. They might be released soon and were described last year (Scott, 2002). Additional hybrids including some heat-tolerant, spotted wilt resistant types have shown some potential, but it is premature to discuss them here as testing has been limited.

Bacterial Spot Tolerance

One of the problems in developing bacterial spot tolerant varieties for Florida growers is that there are several races of the pathogen. There are presently four races that infect tomato and three of these have been identified in Florida. The original race was T1 and breeding that started in 1983 focused on incorporation of resistance from the small-fruited accession Hawaii 7998. In 1991, before commercially acceptable T1 resistant varieties were developed, race T3 emerged in Florida and it has now largely replaced T1. Studies have shown that T3 is antagonistic to T1, which helps explain its prevalence (Jones et al., 1998). Breeding for race T3 is based on incorporation of resistance from Hawaii 7981, another small-fruited accession. Hybrids with heterozygous T3 resistance (one of the two parents is resistant, the hybrid resistance level is intermediate between the parents) are presently being evaluated for possible release. Heterozygous resistant hybrids had very good resistance under heavy bacterial spot infection in North Florida in Fall 2002. One of the hybrids, Fla. 8217, had good horticultural type in a Homestead trial in Winter 2003. In Homestead it looked better than Fla. 8224 (Table 5) which is closely related. Several hybrids have been tested at GCREC during the last year and a few show some promise and will be tested in the future. Meanwhile, T4 has recently been identified in Dade and Manatee counties and it may be present elsewhere (Astua-Monge et al., 2000). It is not known how widespread and prevalent this race will become. It was severe in 2002 summer breeding plots at GCREC. Whereas it rendered most T3 resistant breeding lines susceptible, we did discover that PI 114490 had resistance. This resistance was confirmed in Spring 2003 when T4 was again present in breeding plots. PI 114490 had earlier been shown to have resistance to race T2 in Ohio experiments (Scott et al., 1997). Race T2 has not been found in Florida. PI 114490 also has resistance to race T1 (conferred by the same two genes as race T2) and partial resistance to race T3 (Scott et al., 2003). In Summer 2002 and Spring 2003 we also found breeding line Fla. 8233, with PI 114490 and the Hawaiian accessions in its pedigree, to be resistant to race T4. Growth chamber experiments indicated that this line has hypersensitive resistant reactions to races T1 and T3. This line and some others will be field tested for resistance to races T1 and T2 in Ohio in Summer 2003. Possibly Fla. 8233 has resistance to all four races. This is important because it may have a durable resistance that will be effective against any future races that may emerge. Furthermore, Fla. 8233 has heat-tolerance, medium fruit size, and other desirable characteristics. Thus, development of commercially acceptable varieties may not take as long as previous breeding efforts using Hawaiian accessions for resistance to races T1 and T3. Numerous crosses were made with Fla. 8233 in Fall 2002 and F_1's are being advanced to the F_2 generation in spring 2003. Selections of the F_2's will take place in late summer 2003. Two of the hybrids even appeared to be near commercial acceptability in Spring 2003. It is not realistic to assume that the two will actually be acceptable for release, but it does illustrate that Fla. 8233 is a good horticultural source to begin this breeding effort. Over 20 years of a concerted breeding effort has not resulted in a bacterial spot resistant release. Perhaps the tide is turning.

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Table 1. Marketable yield and fruit size for tomato genotypes under high temperature conditions in North (Quincy) and West Central (Bradenton) Florida in Fall, 2002.

	Quincy, Florida			Bradenton, Florida				
	Marketable yield (25 lb cartons/A)			Early marketable yield (25 lb cartons/A)		Total season marketable yield (25 lb cartons/a)		
Genotype	Total	Extra Large	Fruit size (g)	Total	Extra large	Total	Extra large	Fruit size (g)
'Solar Fire'	1641 a[z]	1156 a	183 a	1083 a	954 a	1480 a	1235 a	187 ab
'Solar Set'	1398 b	799 b	159 b	740 b	609 b	1461 a	1085 ab	176 b
'Florida 47'	1221 bc	732 b	163 b	430 c	354 c	908 b	729 b	176 b
'Florida 91'	1126 c	751 b	173 ab	780 b	707 b	1307 ab	1136 a	196 a

[z]Mean separation within columns by Duncan's multiple range test at $P \leq 0.05$ based on a larger number of genotypes.

Table 2. Marketable yield, fruit size, and culls for selected tomato genotypes in Spring 2002 at Bradenton, Florida.

Genotype	Marketable Yield (25lb. Boxes/A)	Fruit size (g)	Culls (% by wt.)
'Solar Fire'	3610 a[z]	189.7	10.4 c
'Floralina'	2637 ab	169.0	23.7 b
'Sanibel'	2602 ab	190.5	37.7 ab
'Florida 47'	2587 ab	185.4	39.0 ab
'Solar Set'	2412 b	176.3	43.3 a
		ns	

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

Table 3. Firmness and fruit color for selected tomato genotypes in Fall 2002 at Bradenton, Florida.

Genotype	Firmness[z] (mm deformation)	External Fruit Color[y]		Internal Fruit Color	
		L	Hue Angle	L	Hue Angle
'Solar Set'	4.1 a[x]	45.5 d	48.2 c	48.1	52.5 b
'Florida 91'	3.1 b	47.3 b	50.8 b	49.8	53.1 ab
'Solar Fire'	3.0 b	46.4 c	49.8 b	48.6	52.2 b
'Florida 47'	2.7 b	48.2 a	52.4 a	49.6	54.5 a
				ns	

[z]Determined with a pressure tester using a 1 kg. weight for 5 seconds with a fruit contact plate 1.5 cm in diameter. Pressure applied over a locule in equatorial plane.

[y]Data taken with a Minolta CR-300 chromameter; higher L values indicate lighter color (value), lower hue angles indicate more red color (hue).

[x] Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

Table 4. Water uptake for fruit of tomato genotypes immersed in water for three minutes[z].

Cultivar	Fruit wt. (g)	Water uptake[y]
'Solar Fire'	210 b[x]	1.09 b
Fla. 7964	186 c	1.13 b
'Florida 47'	205 b	2.02 a
'Florida 91'	234 a	1.68 a
'Solar Set'	199 b	0.76 c

[z]For all columns, values equal the average of 10 fruit selected from harvest of four field plots.

[y]Data were adjusted for fruit size and relate to soft rot susceptibility where less uptake means more tolerance to soft rot (Bartz, 1991).

[x]Mean separation in columns by Least Square Means test at $P \leq 0.05$.

Table 5. Marketable yield, fruit size, and culls for tomato genotypes at Bradenton, Florida, Summer 2002.

Genotype	Marketable Yield (25 lb cartons/A)	Fruit Size (oz.)	Culls (% by wt.)
Fla. 8093	1052 a[z]	5.6 a	43.7 c
HMX 1803	711 b	6.0 ab	59.2 a-c
Fla. 8094	681 b	5.7 a-c	49.0 c
Fla. 8092	539 bc	6.1 a	57.8 b-c
Fla. 7885B	510 bc	5.4 a-c	57.8 b-c
Fla. 7964	428 b-d	5.1 a-c	61.9 a-c
Fla. 8224	372 b-d	5.6 a-c	71.1 a-c
'Sun Chaser'	297 cd	4.5 c	75.5 ab
'Solar Set'	205 d	4.8 bc	80.0 a
'Florida 91'	198 d	6.4 a	73.9 ab
'Florida 47'	157 d	5.4 a-c	80.8 a

[z]Mean separation in columns by Duncan's multiple range test at $p \leq 0.05$.

Tomato Yellow Leaf Curl Virus Revisited

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Tomato yellow leaf curl virus (TYLCV) is one of the most economically significant and damaging viruses to tomato. Unfortunately it is also one of the most difficult viruses of tomato to manage. A solid understanding of the annual disease cycle of TYLCV is very helpful in the successful management of TYLCV. However, the disease cycle of TYLCV varies among the different tomato production regions in Florida (see Proceedings of the Tomato Institute 2002 for diagrams of these cycles. [http://www.imok.ufl.edu/veghort/index.htm])

It is expected that recommendations for successful management of TYLCV will be adjusted as production practices change and as new information regarding the pathogen/pest is obtained. With that in mind, there are 3 items that must now be considered in the management of TYLCV, and they are:

- **The gradual expansion of the tomato production period and the decrease in size of the tomato-free periods**
- **The increase in production of grape tomatoes**
- **A new crop host of TYLCV**

Expansion of the tomato production period and the decrease in size of the tomato-free periods. Tomato production seasons have been increasing in length over the last few years. This has resulted in the reduction in size or in some locations in the elimination of tomato-free periods in the summer and winter. Tomato-free periods of about 2 months in the summer and 1 month in the winter are very important tools for management of TYLCV and for management of insecticide resistance in whiteflies. The reduction and/or elimination of these tomato-free periods is having an undesirable impact on incidences of TYLCV-infected plants and on the susceptibility of whiteflies to insecticides including imidacloprid and thiamethoxam.

The increase in production of grape tomatoes. A problem related to the increase in tomato production seasons is the long crop cycle employed in grape tomato production. Grape tomatoes are in the ground for up to 9 months or even more in some cases. Because of their long time in the field, grape tomatoes are acting as a good reservoir of whiteflies and TYLCV.

Incidences of TYLCV-infected plants can become quite high in grape tomato fields. This is due to several reasons. Fruit is being harvested for a large percent of the time that the plants are in the field, so only a limited number of pesticides, representing a limited number of classes of pesticides, can be applied for whitefly and TYLCV management. In addition, other virus management practices such as rouging and reflective mulches are less effective due to the long duration of the crop.

In addition, tomato plants in the field this long are good places for the development of pesticide resistance in whiteflies. Many generations of whiteflies can be produced in these fields. Since these fields are sprayed many times with insecticides there is a good opportunity to select for whiteflies which are more tolerant to the insecticides being applied. Whiteflies with greater tolerance to insecticides mean higher incidences of TYLCV-infected plants in successive plantings.

Right now there are no obvious recommendations that can be followed to minimize the impact of long season grape tomatoes (maintained for more than 5 months) on tomato production in the region. There is substantial circumstantial data that shows that whiteflies and TYLCV can move many miles from a source of virus. The greatest impact is within 6 miles downwind although impacts have been felt within 10 miles or more. It is difficult to control whiteflies in mature tomato plants due to the dense foliage. Tomatoes that are being harvested can be sprayed with very few insecticides so optimal whitefly management is not possible. In terms of TYLCV management, roguing would remove too many of the plants, and reflective mulches lose their ability to reflect light after a few months in the field.

A new crop host of TYLCV. Earlier this year we determined that pepper (*Capsicum annuum*) can be infected by TYLCV. We are in the process of screening pepper cultivars that are grown in Florida for resistance to infection by TYLCV. The information we have to date is shown in Tables 1, 2 and 3. A few cultivars that we tested were immune to infection with TYLCV (Table 1) but most cultivars could be infected (Table 2). No foliar symptoms were seen on any of the infected plants and fruit on infected plants appeared unaffected. Although many cultivars could be infected (Table 2), the rates of transmission to pepper were lower than those to tomato. In many cases we were only able to infect a few pepper plants out of 10 when we used 40 to 100 viruliferous whiteflies. These lower rates of transmission are most likely due to the whiteflies' feeding preferences; Florida whitefly populations feed more readily on tomato than pepper. Similar conditions using tomato plants would result in 100% infection of the tomato plants being tested. We also found that whiteflies which fed on TYLCV-infected pepper plants could acquire virus and infect healthy tomato plants. To summarize, pepper is a host of TYLCV, most cultivars are susceptible, whiteflies can acquire TYLCV from infected pepper plants, but pepper is a more difficult host to inoculate than tomato.

These data imply that, in the field, pepper could serve as a reservoir of TYLCV but it is not clear yet how important a role pepper is or will play. It is clear that right now tomato plants are a much better source of TYLCV than pepper. However, the ability of pepper to serve as a source of TYLCV will depend upon the populations of whiteflies present in the pepper fields, the proximity of the pepper field to an old (and TYLCV-infected) tomato field, and proximity to a young and vulnerable tomato field. Further studies will be conducted to determine how frequently TYLCV-infected pepper plants occur in the field and the significance of pepper in epidemics of TYLCV in tomato. Until then, if growers suspect that peppers are playing a role in their area, they can select pepper cultivars which are immune to TYLCV (Table 1).

Conclusion

Although the timing of field production and harvest is usually based primarily on market prices, the consequences of such timings on disease and insect management should be taken into consideration, since these consequences will be felt in costs of production. Field production that creates small or absent tomato-free periods will cause increases in incidences of TYLCV-infected plants, and increases in the resistance of whiteflies to insecticides. Production of grape tomatoes for more than 4 to 5 months eliminates the tomato-free period, provides a good reservoir of TYLCV, and is an excellent location for the development of whiteflies with resistance to insecticides. Tomatoes are still the best reservoir of TYLCV. Peppers are probably not a significant source of TYLCV yet, although as whitefly populations increase in peppers it is likely to become a more important reservoir in the future.

Management Tactics for TYLCV – A Review

Following is a list of the methods used to manage TYLCV. Many of these should be used at the same time. However, even all these methods combined have been shown to be inadequate when a source of TYLCV-infected plants that have moderate to high populations of viruliferous whiteflies is within a few miles of a field of young susceptible crop plants.

Chemical Control of Whiteflies. As with other plant viruses which can be transmitted for long periods of time by their insect vector, suppression of the vector can provide an effective means of reducing virus spread within a field, and from field to field. Management of begomoviruses ("whitefly transmitted" geminiviruses) through applications of insecticides is expensive but is effective in many situations. Several systemic and foliar-applied insecticides are available for killing whitefly adults and immatures.

At the beginning of the season, imidacloprid (Admire™) or thiamethoxam (Platinum™) should be applied as a soil drench in the transplant house one week before transplant to the field. This is designed to interfere with whitefly feeding and TYLCV transmission, and can protect the transplants in the field for up to 2 weeks. Imidacloprid (Admire™) or thiamethoxam (Platinum™) should be added to the setting water at the time of transplant at a rate that will protect the plants for approximately 8 weeks (Admire™ at 16 oz./A, or Platinum™ at 8 oz./A). The insecticide application in the greenhouse protects the transplants during the few days that it takes for these chemicals to be taken up by the plants in the field.

These initial drenches should be followed by a rotation of foliar-applied insecticides once whitefly reproduction is observed in the field. Several foliar insecticides are available and should be applied when immature densities exceed a population density of 5 per 10 leaflets (the terminal leaflet of the 7th-8th leaf from the top of 10 plants/2 acres). The most effective rotation is the use of the insect growth regulators - Knack™ (10 oz./A) and Applaud™ (0.5 lb/A). If applied at the population threshold previously described, whitefly populations can be managed with a minimal number of applications. If adults are seen in the field, a mixture of Thiodan™ plus a pyrethroid is effective. It is very important not to follow the use of Admire™ or Platinum™ with Provado™. Imidacloprid and thiamethoxam are the same class of insecticides (neonicotinoid). Using these in rotation will only increase the chances of whiteflies developing resistance to this class of insecticides. When applying foliar insecticides, it is essential to maintain good coverage on the underside of the leaves where whiteflies reside. Good whitefly control during the last few weeks of the crop will reduce the carry over of whiteflies and virus to the next planting. It is important to use all these insecticides at the label rates and to pay attention to re-entry and pre-harvest intervals.

Biological controls, which often work well in the absence of broad-spectrum pesticides to reduce the impact of the whitefly as a pest, at this time do not offer sufficient control of the vector to reduce the incidence of TYLCV-infected plants.

Cultural Practices

Cultural practices should be used in combination with the chemical practices mentioned previously. Several cultural practices have been shown to be beneficial in reducing incidences of TYLCV-infected tomato plants.

Sanitation. Since yield losses from TYLCV are more severe the earlier in the season the infections begin, nearby tomato plantings that have TYLCV-infected tomato plants are very important sources of whiteflies and virus. New plantings, especially those downwind of the older fields, are extremely vulnerable to infection by TYLCV. Removal of tomato plants promptly after harvest is an important component of an effective management program.

Virus-free Transplants. When possible, tomato transplants should be purchased from production sites that are not located near tomato fields. This reduces early infections and reduces the amount of TYLCV introduced into the field. Transplants should be treated with imidacloprid one week prior to transplanting.

The use of pymetrozine (Fulfill™) has been shown to protect tomato transplants in the planthouse from infection with TYLCV. Pymetrozine is a feeding inhibitor, and acts very quickly. Once whiteflies probe treated plants, feeding stops (ie transmission of TYLCV is not possible) and whiteflies die within 24 hours due to dehydration. Current label instructions dictate that pymetrozine can be applied twice in a production cycle at one-week intervals. Foliar sprays of other insecticides can be used to kill adults that alight on transplants but these usually have little effect on virus transmission since they do not act fast enough to interrupt feeding behavior. Imidacloprid is not registered for use in transplant production except for an application in the last week of production for protection in the first two weeks in the field.

Roguing. During the first few weeks of the crop, fields should be inspected for TYLCV-infected plants. All symptomatic plants that are found should be rogued from the field. This will eliminate these plants are sources of virus for nearby plants later in the season when whitefly control is less effective.

Reflective Mulches. Studies in Florida have shown that reflective mulches, which cause whiteflies to become disoriented, are more effective in reducing the incidence of *Tomato mottle virus* (ToMoV) than yellow plastic mulches. These mulches would be expected to reduce incidences of TYLCV-infected plants. Reflective mulches have the added advantage of disorienting aphids and reducing the incidences of aphid-borne viruses like *Potato virus Y* and *Tobacco etch virus*.

Weed Control. The importance of weeds in TYLCV epidemics in Florida is not clear. Many times high incidences are easily correlated with proximity to older tomato fields that have TYLCV-infected plants and high whitefly populations. Although in Cyprus, eradication of over-wintering weed hosts significantly reduced the incidence of TYLCV, the same approach was not effective in Israel. The importance of weeds in TYLCV epidemics has not been established. The identities of the weed species that play a role, however minor, in the spread of TYLCV have also not yet been determined. It is likely that the weed species that do play a role will vary among the different production regions in the state.

Trap Crops. The use of trap crops of squash, a highly preferred whitefly host, delayed TYLCV spread when planted 30 days before in alternate rows with tomatoes. Studies indicate that the larger the land allocated to the trap crop, the more effective it will be. Trap crops are more effective for small plots of tomatoes. The optimal ratio of trap crop to tomato has not yet been established.

Resistant Cultivars. Fresh market tomato hybrids with resistance to TYLCV have been evaluated in Florida. Several cultivars produced significantly greater yields compared to the common commercial cultivars when grown in the presence of high TYLCV and whiteflies. These cultivars also produced acceptable yields and fruit quality in the absence of TYLCV. Hazera Genetics, Inc. and Seminis Inc. (Petoseed) are two seed companies with TYLCV-resistant cultivars. In addition, Gemstar is a tolerant processing or saladette-type tomato from Petoseed that has resistance to TYLCV. At this time, all the hybrids being released have tolerance but not immunity to TYLCV. Early infections of these cultivars with TYLCV and high populations of whiteflies carrying TYLCV will overcome the resistance present in all commercially available cultivars.

For optimal results, these resistant cultivars should be used in combination with the other management practices. Resistant cultivars can be used with the greatest effect by selecting these cultivars for production when incidences of TYLCV-infected plants are expected to be at their highest. This would be in the first two plantings in the fall in West Central Florida, the last planting or two in Southwest Florida, and any planting where a large source of TYLCV is expected or known to be within a few miles. Resistant plants will be infected but good yields can still be obtained. It is important to remember to use good whitefly control practices since these resistant cultivars can serve as sources of TYLCV for later planted or near-by susceptible cultivars. At times of the year when virus pressure is expected to be lower, other desired cultivars can be used.

Table 1. Pepper cultivars with immunity to TYLCV.

Cultivar	Fruit Type	Seed Source
'Double Up'	Bell, green-red	Sakata
'Red Rooster' (spur pepper)	Ornamental	Unknown
'SPP0615'	Jalapeno	Sakata
'Sweet Banana'	Banana	Ferry Morse
'Tiburon'	Poblano	Sakata

Table 2. Pepper cultivars with susceptibility to TYLCV.

Cultivar	Fruit Type	Seed Source
'Brigadier'	Bell, green	Rogers
'California Wonder'	Bell, green	American Seed
'California Wonder 300TMR'	Bell, green	Ferry Morse
'Camelot X3R'	Bell, green	Seminis - Petoseed
'Cascabella'	Hot, cone	Ferry Morse
'Crusader'	Bell, green	Rogers
'El Rey'	Jalapeno	Sakata
'Long Hot'	Cayenne	Seminis - Asgrow
'Olympus'	Bell, green-red	Enza Zaden
'Orion'	Bell, green	Enza Zaden
'Pepper Grande – Jalapeno'	Jalapeno	Seminis – Asgrow
'SCM334'	Wild serrano	Sakata
'Senorita'	Red "cheese"	Sakata
'Sentry"	Bell, green-red	Rogers
'SPP0132'	Bell,green-orange	Sakata
'Stilleto'	Bell, red	Rogers
'Twist Sweet'	???	YuAnFarms (Korea)
'Wizard X3R'	Bell, green	Seminis - Asgrow
'XPP0701'	Anaheim	Sakata

Table 3. Cultivars still under study.

Cultivar	Fruit Type	Seed Source
'X3R Aladdin'	Bell, yellow	Seminis
'X3R Aristotle'	Bell, red	Seminis
'Heritage' HMX 1640	Bell, red	Harris Moran
'Hungarian Hot Wax'	Hungarian Hot Wax	Dessert Seeds (Petoseed)
'Patriot' HMX 640	Bell, red	Harris Moran
'Pepper Grande'	Bell, green	Seminis – Asgrow

What's Up With All These Whiteflies?

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Introduction

The silverleaf whitefly (SLWF), *Bemisia argentifolii* Bellows & Perring [also know as the B strain of the sweetpotato whitefly, *B. tabaci* (Gennadius)], remains the key pest of tomatoes in southern Florida. *B. argentifolii* causes losses by inducing the irregular ripening (IRR) disorder of tomato fruit and by transmitting geminiviruses, the most damaging of which is tomato yellow leaf curl virus (TYLCV) (Schuster et al. 1996). Despite applications of the nicotinoid Admire 2F® (imidacloprid; Bayer CropScience, Kansas City, MO) to seedlings in plant production houses and additional soil applications of either Admire or Platinum® (thiamethoxam; Syngenta Crop Protection, Inc., Greensboro, NC), another nicotinoid, at transplanting or up to three weeks after transplanting, tomato growers in every production area in southern Florida experienced larger than normal numbers of whitefly adults during the past spring season. This was particularly true late in the season. Because of the threat of transmission of TYLCV by these whitefly adults, numerous applications of additional insecticides were applied, sometimes weekly or more frequently, even though the soil applications of Admire or Platinum were still providing control of whitefly nymphs.

Insecticides applied included Fulfill® (pymetrozene; Syngenta Crop Protection, Inc., Greensboro, NC), Monitor® (methamidophos; Valent U.S.A. Corporation, Walnut Creek, CA), Lorsban® 50-W (chlorpyrifos; Gowan Company, Yuma, AZ), several different pyrethroids, Phaser® (endosulfan; Bayer CropScience, Kansas City, MO), Thiodan® (endosulfan, FMC Corporation, Agricultural Products Group, Philadelphia, PA), soap and oil. Results were mixed and residual control was short. Some growers made foliar applications of nicotinoids including Provado® (imidacloprid; Bayer CropScience, Kansas City, MO), Actara® (thiamethoxam; Syngenta Crop Protection, Inc., Greensboro, NC), and Assail® (acetamiprid; Cerexagri, Inc., King of Prussia, PA), again with mixed results. This practice could encourage the development of resistance to the nicotinoid insecticides (Elbert and Nauen 2000).

Naturally, growers are asking why so many whitefly adults are present and persist despite these many insecticide applications. Are the whiteflies becoming resistant to the insecticides? Are there other cultural activities that are contributing? What can we do now and what are the control prospects for the future? What follows is an attempt to answer these questions.

Resistance and Resistance Monitoring

Certainly, the pyrethroids, endosulfan (Thiodan, Phaser) and organophosphates (Monitor, Lorsban) are not as effective against the SLWF as they once were, although no systematic or long-term monitoring of efficacy or resistance has been conducted in Florida. As early as 1991, up to an 80% reduction in efficacy of endosulfan and up to a 60% reduction in efficacy of Lorsban relative to a susceptible colony were observed in field populations using a laboratory bioassay (Stansly et al. 1991). There is no reason to expect a reversal of these trends, especially in light of the current heavy use of these insecticides.

A cut leaf petiole method was developed to compare the susceptibility of field populations of the SLWF to Admire with that of a highly susceptible laboratory colony (Schuster and Thompson 2001, Schuster et al. 2002). The method was used to evaluate the relative susceptibility of SLWF populations from 9 Admire-treated tomato fields in 2001, 14 fields in 2002, and 10 fields in the spring of 2003. At least three of the fields in 2003 were treated at transplanting with a soil application of Platinum rather than Admire. Bioassays were conducted using adults reared from foliage infested with nymphs that had been collected from each tomato field. Standard probit analyses (SAS Institute 1989) were used to estimate the LC_{50} values (the concentration estimated to kill 50% of the population) for the laboratory colony and for each field. The relative susceptibility (RS_{50}) of each field population compared to the laboratory colony was calculated by dividing the LC_{50} values of the field populations by the LC_{50} value of the laboratory colony. Increasing values greater than one suggest decreasing susceptibility in the field population.

Over 2001 and 2002, nearly 80% of the RS_{50} values of whiteflies collected from the Admire-treated fields were 8 or less, while in 2003, only about 20% of the fields had values of 8 or less (Tables 1 & 2). While values approaching 8 could indicate decreasing susceptibility of the whiteflies, such variability is not unexpected when comparing field-collected insects with susceptible, laboratory-reared insects. The laboratory colony used as a susceptible standard in this study has been in continuous culture since the late 1980's without the introduction of whiteflies collected from the field and, therefore, would be anticipated to be particularly susceptible to insecticides. RS_{50} values of 10 or greater were observed in three whitefly populations in 2001, four populations in 2002 and eight populations in 2003. This represent about 20% of the populations in 2001, 30% in 2002 and 80% in 2003. Values of 10 or greater are sufficiently high to draw attention, especially those of 20 or higher. Certainly, the higher proportion of high values observed in 2003 would suggest a decrease in susceptibility of the SLWF in 2003 relative to previous years. While this may be the case, there may be extenuating circumstances to explain the high values.

First, eight of the populations sampled in 2003 were all sampled in June within about 10 days of each other and when harvesting had been completed or was soon completed. Therefore, all of these whitefly populations would have had the maximum potential exposure to nicotinoid-treated tomato plants, and the movement of whitefly adults among senescing and abandoned fields could result in a mixing of whitefly populations, resulting in more homogeneous whitefly responses to Admire. This latter hypothesis would be supported by the low value observed in the whitefly population from Myakka City, which is isolated from the other populations sampled. On the other hand, the sites in Ruskin were adjacent to one another, yet one field had a low value and the other had a high value. In addition, when only considering fields sampled in June, the above percentages of fields with RS_{50} values of 10 or greater were about the same (Table 2). Thus, the time of sampling may have had an impact but is not the entire explanation.

The progeny of adults that survived the bioassay from the Duette site in 2001 and the SWFREC site in 2002 were reared for 6-8 wk (about 2-4 generations) on tomato in the laboratory and then bioassayed again. The RS_{50} value of the progeny of the bioassay survivors from the Duette site in 2001declined from 8 to less than 2 after being reared in the laboratory for about 8 wk without exposure to Admire (Table 3). Similarly, the RS_{50} value of the progeny of the bioassay survivors from the SWFREC site in 2002 declined from nearly 22 to less than 6 after being reared in the laboratory for about 6 wk. In addition, the RS_{50} value of the progeny of the bioassay survivors from a whitefly population collected from greenhouse-grown poinsettia in northwest Florida in 2002 likewise declined from 21 to less than 4 after being reared in the laboratory for about two generations (Schuster, unpublished data). At the Immokalee1 site in 2001, whitefly-free, greenhouse-grown tomato plants were placed on the field perimeter about 4 wk after the crop had been destroyed. One week later, the plants were returned to the laboratory and held 4-5 wk (about 2-3 generations) and the progeny bioassayed as before. The RS_{50} value for the whitefly population collected 4 wk after the end of the crops at the Immokalee1 was about 2 compared to 15 while the crop was still in the field (Table 3). Thus, decreased susceptibility to Admire indicated in these studies, especially late in the spring season, will probably dissipate or disappear during the off-season, if the off-season is sufficiently long enough.

Efficacy of Nicotinoids for Whitefly Control

The reduced susceptibility of the SLWF suggested in the monitoring study would suggest reduced control. Unfortunately, efficacy data were not collected in any of the fields sampled for the survey; however, none of the growers indicated a failure to control whitefly nymphs during the season and didn't note a large increase in the whitefly population until late in the crop when the controlling effects of the Admire or Platinum would have diminished. In addition, comparisons of soil applied Admire and Platinum at transplanting with check plots were conducted in experiments at two commercial farms and in one experiment at GCREC. In all of these trials, both Admire and Platinum generally kept the numbers of whitefly nymphs below the threshold of 5/10 leaflets (Schuster 2002) for at least 8 wk and usually beyond (Fig. 1). Significant differences were detected between the treated and non-treated plots in every experiment on at least some dates. The populations in the commercial fields were too low to acquire samples large enough to bioassay for susceptibility to Admire and heavy rains caused rapid destruction of foliage at GCREC.

Nicotinoid Availability and Application Methods

In 1994, imidacloprid formulated as Admire for soil applications and as Provado for foliar applications was the only nicotinoid insecticide available to Florida tomato growers. Since then, Platinum/Actara (soil and foliar formulations, respectively, of thiamethoxam) and Assail have become available. Essentially all tomato growers in south Florida use either Admire or Platinum applied to the soil to manage the SLWF and TYLCV. Because of the increasing numbers of whitefly adults and the increasing threat of TYLCV, some growers have followed these soil applications with foliar applications of Provado, Actara or Assail. All of these compounds are in the nicotinoid chemical class and cross-resistance has been documented in Spain to both imidacloprid and thiamethoxam (Elbert and Nauen 2000). Therefore, following soil applications of a nicotinoid insecticide with foliar applications of nicotinoid insecticides may contribute to the increasing RS_{50} values for Admire and are not recommended.

Nearly all, if not all, tomato seedlings are treated with Admire in the production house 7-10 days prior to transplanting to ensure that the seedlings have absorbed sufficient Admire to protect them against whiteflies that may infest them immediately after transplanting. The length of protection of this production house application may be up to 2-3 wk; therefore, some growers delay applying either Admire or Platinum to transplants in the fields for up to three weeks. These applications are made through the existing drip irrigation system established in the field. Some growers split applications of Admire or Platinum in an attempt to lengthen the period of control in the field. While there is no experimental evidence quantifying the efficacy of applying Admire or Platinum through drip irrigation tubing, anecdotal observations suggest that the nicotinoids are not as efficacious when applied through the drip tube as when they are applied in the transplanting water. Furthermore, repeated applications through the drip system lengthens the period of exposure of whiteflies to Admire or Platinum. Therefore, it is recommended that growers apply the nicotinoids in the transplanting water and switch to chemistries other than the nicotinoids as the controlling effect of the soil application diminishes.

Changes in Cropping Practices

The generalized changes in RS_{50} values over time are depicted as "Now" in Fig. 2. Relatively low RS_{50} values would be expected when tomatoes are planted in the fall and would increase during the fall and spring seasons, peaking in June as harvesting ends. There could even be an intermediate peak not depicted in Fig. 1 that would occur as crops planted in the fall are destroyed and whiteflies exposed to nicotinoid insecticides in the fall plantings migrate to spring plantings. At any rate, the level at which RS_{50} values occur at the beginning of the fall season probably are related to the level that occur at the end of the previous spring season and the length of the tomato off-season. Fig. 3 shows a generalized depiction of tomato production that occurred in west central Florida 5 or more years ago ("Then"). At that time, tomatoes generally were not planted until mid- to late August and fields were destroyed during mid-December. Spring plantings generally were delayed until late January to escape killing frosts and fields destroyed by the first week of June. Due to economic and crop considerations, the tomato cropping cycle has changed dramatically ("Now"). Planting begins in late July and fields are not destroyed until late December, if then. Spring plantings begin in early to mid-January and fields may still be in production in mid-June. The result of these changes is that there is little or no tomato-free period in the winter and only about one month in the summer. The trend toward an ever-shorter, tomato-free period in the summer may be causing, at least in part, the decreased susceptibility of whiteflies to Admire in the spring. If this trend is not reversed, growers may be facing even higher levels of reduced susceptibility to Admire in the future (Fig. 2, "When?"). While this generalized version of changes in cropping schedules is for west central Florida, similar changes have occurred in the other tomato producing areas of Florida.

There are many factors causing the changes in cropping schedules. Historically low prices during peak tomato production have encouraged growers to plant earlier in the fall to try and capitalize on the higher prices early tomatoes usually gain. Growers also may plant later spring crops and continue maintaining these crops late in the spring in hopes of capitalizing on higher prices sometimes experienced later in the spring season. U-pick operations are often continued to capture additional revenue from crops that may not have provided much return earlier in the season. U-pick fields from the fall season may still be in production when spring fields are being transplanted, thus erasing the crop-free period in the winter. Spring fields opened for u-pick may still be in production in mid-June or beyond, thus shortening the crop-free period in the summer.

Grape tomatoes are popular among consumers and, as a result, are popular among Florida tomato growers. Grape tomatoes are a longer-termed crop than slicing tomatoes and are often the first planted crop in the fall and the last destroyed crop in the spring. They may be planted adjacent to or near new tomato crops and crops planted later in the fall may still be in harvest as the spring fields are transplanted. Thus, grape tomatoes may bridge the fall and spring tomato crops, eliminating the crop-free period in the winter, and crops planted in the spring may be in production in mid-June, shortening the crop-free period in the summer. Because they are often planted adjacent to or near large-fruited tomatoes, they may serve as a reservoir for the shorter-termed tomato crop.

Another change that apparently is still developing, is the ability of the SLWF to colonize pepper. Ten years ago, whitefly adults could be found on pepper plants, but there was little or no reproduction on the crop. As a result, pepper was not a reservoir of whiteflies for tomato (Schuster et al. 1992). Today, whitefly nymphs are routinely observed in large numbers on pepper, which is a longer term crop than tomato. In addition, some pepper cultivars are susceptible to TYLCV (Polston unpublished data). Therefore, pepper might be serving more now than before as a source of whiteflies and TYLCV especially to bridge the fall and spring crops.

New Products for the Future

In an experiment conducted during the spring of 2002 at GCREC, a single application of MT-02-03, which is now revealed as Oberon (spiromesifen; Bayer CropScience, Kansas City, MO), resulted in numbers of SLWF nymphs below the threshold of 5/10 leaflets for up to four weeks (Schuster et al. 2002). Four applications of Diamond (novaluron; Crompton Uniroyal, Raleigh, NC) also reduced nymph numbers below the threshold. Additional experiments have been conducted during the fall of 2002 and spring of 2003.

In the fall 2002 experiment, Oberon 240SC (8.5 ozs/acre) was applied, following an at transplant application of Admire at 16 ozs/acre, when the threshold of 5 nymphs/10 leaflets was reached. The treatment was compared to Admire alone, to Admire followed by a weekly alternation of Baythroid 2 (2.8 ozs/acre) and Thiodan 50W (2 lbs/acre), or to a check. Control of whitefly nymphs with either Oberon or the weekly alternation of Baythroid and Thiodan were equivalent and significantly lower than the check; however, Oberon was applied twice while Baythroid and Thiodan were each applied five times (Fig. 4). Both treatments resulted in densities of SLWF nymphs below the threshold for five weeks, while densities in the check plots were above the threshold.

In the 2003 experiment, Diamond 0.83E (14.5 ozs/acre), Oberon 240SC (8.5 ozs/acre) or Courier 70W (0.5 lb/acre) were applied following an at-transplant application of Admire (16 ozs/acre), when the threshold of 5 nymphs/10 leaflets was reached, and were compared to Admire alone or to a check. A single application of Oberon reduced nymphal numbers to the threshold or below for at least two weeks. A single application of either Diamond or Courier resulted in significant reductions in the numbers of nymphs compared to the check within one week of the application. Further evaluations were precluded by the effects of heavy rains on the tomato foliage.

The high level of some RS_{50} values, especially in 2003, suggests a decline in the susceptibility of the SLWF to Admire; however, the apparent shift in susceptibility may be as much a reflection of changes in cropping practices and nicotinoid use patterns as a true trend in declining susceptibility. Furthermore, the reduced susceptibility appears to be unstable when whiteflies are no longer exposed to Admire. Therefore, lengthening a tomato free period in the summer to at least two months and making only a single application of a nicotinoid insecticide could help in managing the reduced susceptibility.

The high numbers of whitefly adults observed this past spring could be related to the reduced susceptibility of the SLWF to Admire, but this is probably not the whole answer. A shortened tomato-free period in the summer caused by economic concerns and increased acreage of grape tomatoes, and changes in suitability of pepper as a whitefly reservoir undoubtedly also have contributed. Although there are new products on the horizon for managing the SLWF, growers are encouraged to redouble their efforts in implementing a nicotinoid resistance management program that was first outlined by Schuster and Thompson (2001).

Nicotinoid Resistance Management Recommendations

- Reduce overall whitefly populations by strictly adhering to cultural practices including:
  - Plant whitefly-free transplants;
  - Delay planting new crops as long as possible and destroy old crops immediately after harvest to create or lengthen a tomato-free period;
  - Do not plant new crops near or adjacent to infested weeds or crops, abandoned fields awaiting destruction or areas with volunteer plants;
  - Use UV-reflective (aluminum) plastic soil mulch;
  - Control weeds on field edges if scouting indicates whiteflies are present and natural enemies are absent;
  - Manage weeds within crops to minimize interference with spraying; and
  - Avoid u-pick or post harvest pin-hooking operations unless effective control measures are continued.
- Do not use a nicotinoid like Admire on transplants or apply only once 7-10 days before transplanting; use other products in other chemical classes, including Fulfill, before this time
- Apply a nicotinoid like Admire (16 ozs/acre) or Platinum (8ozs/acre) at transplanting and use products of other chemical classes (such as the insect growth regulators Knack® (pyriproxyfen; Valent U.S.A. Corporation, Walnut Creek, CA) or Courier® (buprofezin; Nichino America, Inc., Wilmington, DE) as the control with the nicotinoid diminishes.
- Never follow an application (soil or foliar) of a nicotinoid with another application (soil or foliar) of the same or different nicotinoid on the same crop or in the same field within the same season (i.e. do not treat a double crop with a nicotinoid if the main crop had been treated previously).
- Save applications of nicotinoids for crops threatened by whitefly-transmitted plant viruses or whitefly-inflicted disorders (i.e. tomato, beans or squash) and consider the use of chemicals of other classes for whitefly control on other crops.

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

County/Site	Date	RS_{50}[1]
	2001	
Hendry/Devil's Garden	April	3.1
Collier/Immokalee1, Field 2	May	14.6
Collier/Immokalee2	May	5.1
Manatee/Duette	June	8.0
Hillsborough/Ruskin	June	4.6
Manatee/Ft. Hamer	June	13.1
Manatee/GCREC, Field	June	2.6
Hillsborough/Riverview	July	4.5
Manatee/Myakka City	Dec	4.7
	2002	
Collier/Immokalee1, Field 1	April	7.3
Palm Beach/Boynton Beach	April	2.6
Collier/Immokalee3	April	5.6
Collier/Immokalee4	April	2.9
Collier/Immokalee1, Field 2	May	3.9
Dade/Homestead	May	7.3
Collier/SWFREC	May	21.9
Manatee/Duette	June	35.2
Manatee/Ft. Hamer	June	5.7
Hillsborough/Ruskin	June	3.4
Manatee/GCREC, Field 1	June	14.8
Manatee/GCREC, Field 2	June	5.9
Manatee/Lorraine1	June	1.2
Manatee/Parrish	Nov	21.0
	2003	
Collier/Immokalee2	May	12.1
Hillsborough/Ruskin1	June	19.2
Hillsborough/Ruskin2	June	7.0
Manatee/Duette	June	14.8
Manatee/Ft. Hamer	June	17.8
Manatee/Lorraine2	June	12.8
Manatee/Lorraine3	June	20.6
Manatee/Myakka City	June	3.6
Manatee/Parrish	June	21.2
Manatee/Waterbury	June	17.4

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

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

	Year		
	2001	2002	2003
Overall			
No. sites	9	14	10
Range	2.6-146	1.2-35.2	3.6-21.2
No. Sites ≥ 10 (%)	2 (22)	4(29)	8 (80)
Avg.	6.7	9.9	14.7
June-July			
No. sites	5	6	9
Range	2.6-13.1	1.2-35.6	3.6-21.2
No. Sites ≥ 10 (%)	1 (20)	2 (33)	7 (78)
Avg.	6.6	11.0	14.9

Table 3. Changes in relative Admire susceptibility (RS_{50}) of silverleaf whitefly adults evaluated two to four generations following collection in the field.

Site	Date: Collected	Date: Evaluated	Estimated no. generations in lab[1]	RS_{50}[2]
		2001		
Immokalee 1	8 May	18 May	1	14.6
Immokalee 1	6-13 July[3]	18 Aug	2-3	2.2
Duette	13 June	21 June	1	8.0
Duette	13 June[4]	16 Aug	4	1.5
		2002		
SWFREC	21 May	31 May	1	21.7
SWFREC	21 May[4]	10 July	2-3	5.8

[1]One generation in the lab requires about 2 wk.
[2]Ratio of the LC_{50} of the field population to the LC_{50} of the lab colony. Increasing values greater than one indicate decreasing susceptibility to Admire relative to the laboratory colony.
[3]Collected as adults on whitefly-free tomato plants placed in the field about 4 wk after crop destruction.
[4]Survivors of the original bioassay were reared on tomato without selection in the lab for 6-8 wk.

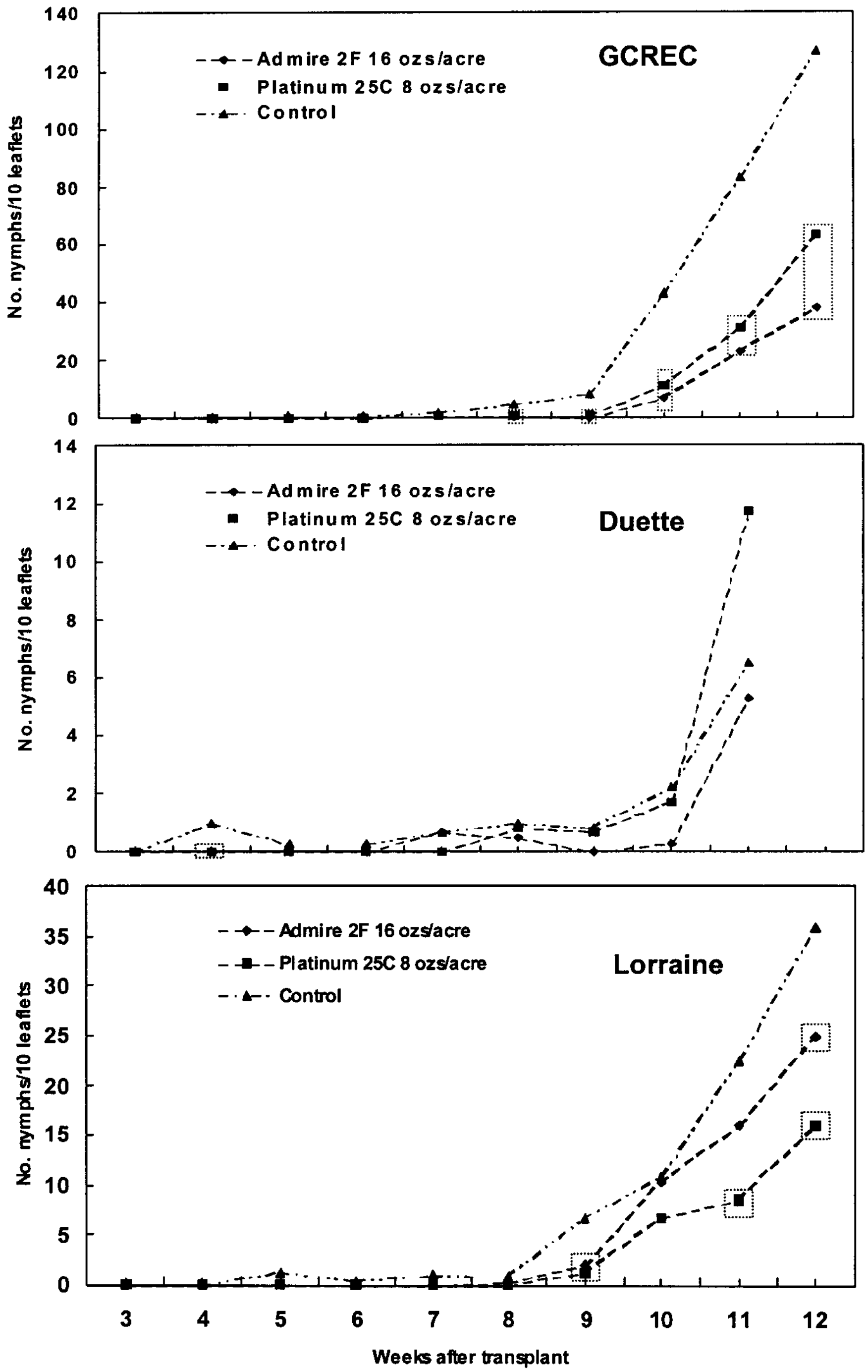

Fig 1. Control of silverleaf whitefly nymphs with soil applications of nicotinoid insecticides on tomato, Spring 2003. Data points within boxes are significantly different from the control.

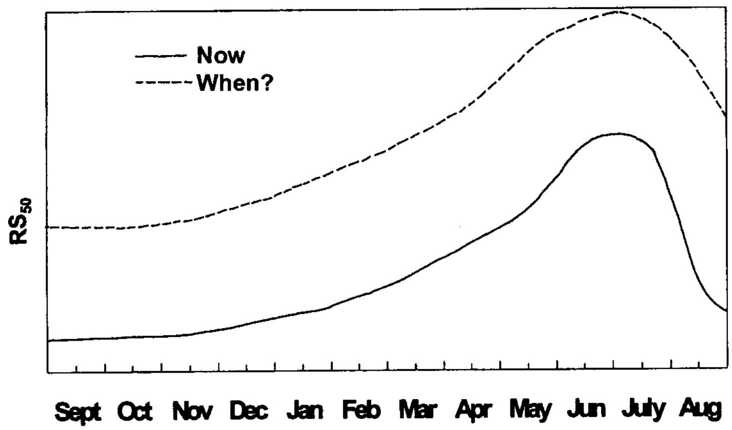

Fig. 2. Generalized depiction of the susceptibility of whitefly adults to Admire.

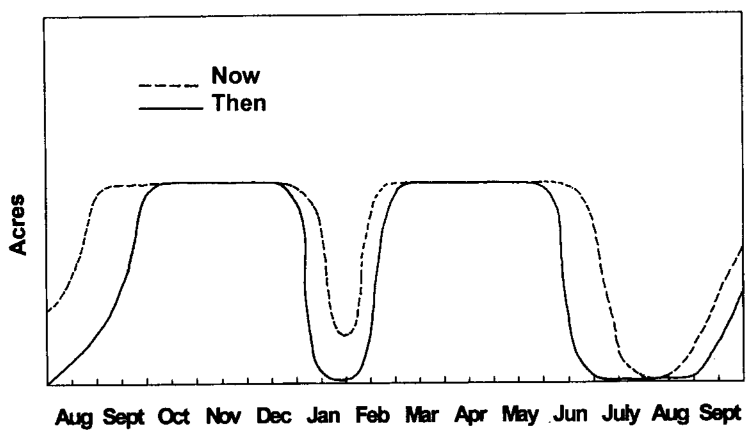

Fig. 3. Generalized depiction of relative, seasonal tomato acreage in west central Florida.

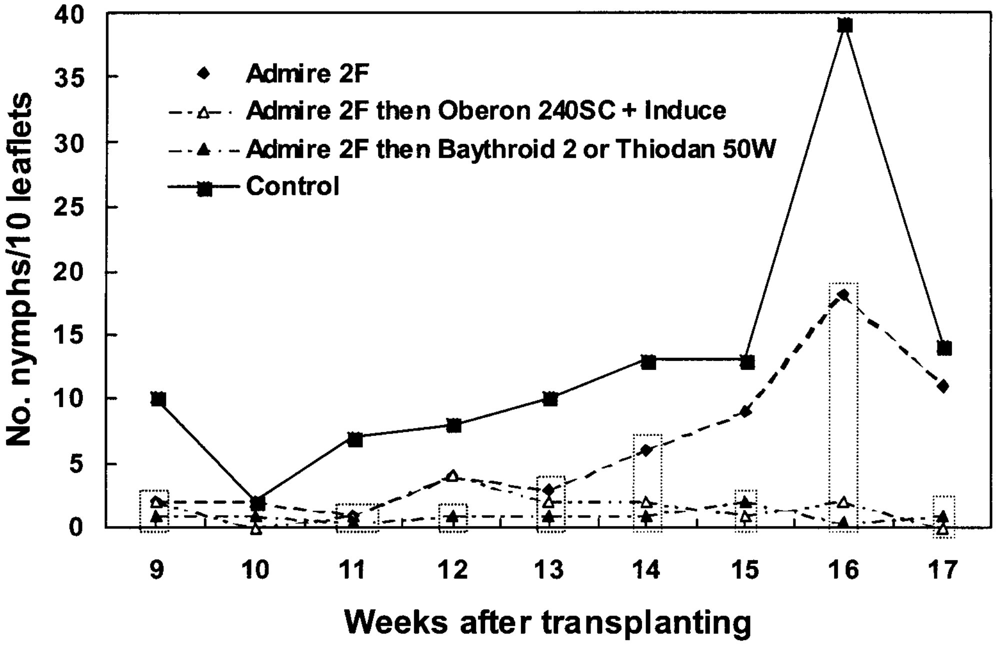

Fig 4. Control of silverleaf whitefly nymphs on tomato with soil and foliar applications of insecticide, GCREC, Fall 2002. Admire applied at transplanting. Applications of Baythroid and Thiodan were alternated weekly beginning 3 weeks after transplanting. Oberon was applied during week 12 and 13. Data points within boxes are significantly different from the control.

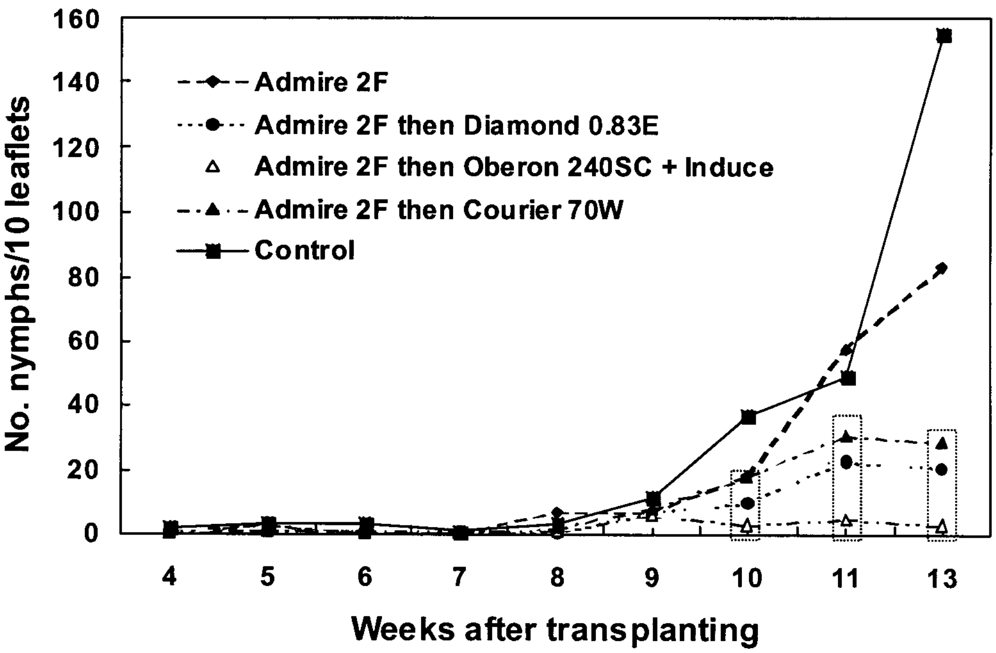

Fig 5. Control of silverleaf whitefly nymphs on tomato with soil and foliar applications of insecticides, GCREC, Spring 2003. Admire was applied at transplanting. Oberon was applied during week 10 and 12 and Diamond and Courier were applied during week 12. Data points within boxes are significantly different from the control.

Tomato Disease Update

Pam Roberts[1], Tom Kucharek[2], Phyllis Gilreath[3], Henry Yonce[4], Jeff Jones[2], and Gene McAvoy[5].
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Significant outbreaks of several diseases on tomato occurred in recent seasons. Gray Mold, caused by the fungus *Botrytis cinerea*, historically occurred quite commonly in Ft. Pierce, FL area in the early 1960s and was detected this spring, 2003, in the Manatee production region. White mold, caused by the fungus *Sclerotinia sclerotiorum*, was widespread on tomato and pepper in south Florida in the same season. A new race 4 of bacterial spot on tomato, caused by the bacterium *Xanthomonas campestris* pv. *vesictoria*, was identified. An aerial blight on tomato seedlings caused by *Pythium myriolotium* has been described. Specific information on each disease is presented.

Epidemics of disease are greatly influenced by environmental conditions. The average temperature in March 2003 was almost 6 degrees higher than the 30-year average. The average temperatures for April and May were almost identical for their 30-year averages. However, precipitation was higher compared to the 30-year average in March by almost 2 inches and only slightly higher compared to their 30-year averages in April and May. However, compared to only the past few years, precipitation in these two months was significantly higher. May 2003 had nearly 4 times as much precipitation as the previous year. The warmer weather and high rainfall in March and the relatively wet spring undoubtedly contributed to some of the atypical plant problems that were encountered.

Gray Mold (*Botrytis cinerea*)

An outbreak of gray mold on tomato was recorded in May 2003 that was widespread in the Manatee area. Several varieties of tomato, including rounds, roma, and grapes, were affected. Lesions on the foliage such as blighting were difficult to distinguish from other types of damage. However, the fungus was found associated with leaflets that wilted and died. Typical symptoms are V-shaped grayish-brown on the leaves. Stem lesions are large, elliptical, and water-soaked and also turn grayish-tan. The most significant damage occurred on the blossoms, which turned brown and became covered with the sporulating fungus. Tomato fruit showed typical soft rot symptoms with the soft center and expanding, watersoaked lesion. Under certain environmental conditions, a lesion that is a lightly-colored, circular ring called Ghost Spot occurs although this symptom was not evident in these outbreaks. In some fields surveyed, every plant that was inspected had infected blossoms and foliage with symptoms of gray mold.

Botrytis cinerea has a very wide host range so its presence on any one of many different plants could be the source of the initial inoculum. The fungus may also survive from season to season as a sclerotium (plural: sclerotia), an environmentally resistant fungal survival structure. In addition, it can survive saprophytically on plant debris in the soil. Therefore, there is no shortage of potential sources of inocula and means of survival for this pathogen.

The fungus is considered weakly pathogenic and initial infection is usually associated with wounded plant tissue. On the foliage, mature plants with a thick canopy will first show symptoms on the older tissue and then move onto younger tissue. Spores of the fungus, called conidia, are readily produced and easily windblown to new infection sites. Moderate weather in the mid-70s F favors production of conidia. The humidity within a mature tomato canopy is sufficient for disease development. Warmer weather may slow this disease. Gray mold is most severe on plants grown in acidic, sandy soils with high soil moisture.

The presence of the fungus should be confirmed prior to any control measures because its symptoms are difficult to distinguish from other disease and abiotic problems. Applications of labeled fungicides may aid in control. Adequate calcium should be available to plants. Acidic soils should be limed and uniform soil moisture should be maintained throughout the season for maximum calcium availability to the plant. A calcium-to-phosphorus ratio of 2 or higher in leaf petiole tissue has been demonstrated to aid in control.

White Mold (*Sclerotinia sclerotiorum)*

White mold was widely reported on tomato, pepper, eggplant, and bean in south Florida beginning in January 2003 and continuing throughout the rest of the spring growing season.

Like gray mold, the fungus that causes white mold has an extensive host range and is an economically important disease on many vegetable crops. In tomato, symptoms typically occur at flowering and begin as water-soaked lesions in leaf axils or stem joints where fallen flower petals collect. The stem becomes infected at this point and initially the tissue is soft but will die and become hardened and bleached. The black sclerotia are often found inside of the dead, infected stems. The presence of the small, black sclerotia is a sign of the fungus and is diagnostic for this disease. Another sign of the fungus is a white, cottony mycelium that is frequently present on diseased tissue. Because other pathogenic fungi produce white mycelia, this character, by itself, should not be relied upon for diagnosis in the field.

Overseasoning of the fungus is by sclerotia, which are also the source of initial inoculum. Sclerotia may be moved via irrigation water. The sclerotia germinate under cool (average 65 F) and wet environmental conditions and produce a type of spore, called an ascospore, that is carried by wind currents to the host tissue. The fungus becomes established initially on senescent tissue and can then colonizes adjacent healthy tissue. Long periods of continuous wetness (16-72 h) are required for infection.

Management options for control of white mold are limited. Although some research suggests that flooding or addition of organic soil amendments may suppress the disease, these options may not be practical or provide sufficient control. Fumigation of the soil and plastic mulch help to reduce the viability and eliminate direct contact of host tissue with sclerotia. A Section 18 (FIFRA) was recently granted for use of Topsin M fungicide in Florida for control of this disease on fruiting vegetables including tomatoes and is effective from July 3, 2003 to March 31, 2004.

Bacterial Spot, Race 4 (*Xanthomonas campestris* pv. *vesicatoria*)

Over the past couple of years, we received samples of bacterial spot disease of tomato from several locations. Isolations from the samples revealed the typical bacterial spot organism. Tomato race determinations were done on tomato differentials. The strains behaved like tomato race 2 (T2) strains rather than T1 or T3, both of which are normally present in Florida. This would be an unusual occurrence since T2 has never been detected in Florida. With the possibility of these strains being T2, the strains were then characterized using a genetic technique that differentiates T1, T2 and T3 strains. The new strains resembled typical T3 strains based on this technique. To further substantiate that this was a variant of T3, the tomato genotype, LA716 (*Lycopersicon pinnellii*), which contains a resistant gene that interacts with a gene (*avrXv4*) present in T3 strains, was inoculated with the new strains. This resulted in an incompatible (non-disease) reaction, which confirmed that the new strains were mutant T3 strains rather than T2. This new race is designated T4. The importance of this new race is not known.

Aerial Blight of Tomato Transplants (*Pythium myriotylum)*

An unusual disease outbreak involving an aerial infection of the typically soil-borne *Pythium myriotylum* was observed during the fall growing seasons of September 1996 and 1997, within commercial fields in Southwest Florida (Collier and Lee Counties) and West Central Florida

(Manatee County). The percentage of plants affected, or plant incidence, was approximately 15-18% about four weeks after transplanting. The disease was present mostly on young seedlings during an unusually high rainfall period.

Symptoms of the disease on tomato seedlings included aerial watery rots in leaves, petioles, and stems sometimes followed by plant death. Microscopic examination of symptomatic tissue revealed the presence of mycelia and oogonia typical of *Pythium* spp. *Pythium myriotylum* Drechsler was consistently isolated from four plants sampled from each site. The rainfall recorded at some sites, such as in Manatee Co. in Sept 1997, was 36% higher than the 40-year average. This high moisture situation likely contributed to the incidence of this foliar blight in tomato which has not been described previously.

Pythium myriotylum is a commonly found soil-inhabitant and is one of the most common species of Pythium causing damping-off of seedlings of many plant species in Florida. *Pythium myriotylum* is capable of producing motile spores, called zoospores, and oospores which are capable of surviving in soil and on crop debris from season to season. It does well under high temperatures ranging between 86 and 98 F and high soil moisture. The host range for *Pythium* spp. is extremely wide including most vegetables. Many species of weeds are hosts to *Pythium* spp. and serve as important sources of inocula.

Although outbreaks of this disease occurred in two consecutive years, only one additional outbreak was detected in subsequent seasons. However, if not detected during the water-soaking phase of the symptoms, it could be easily confused with other damping off or blight symptoms caused by other pathogens. Fumigation of the soil and fungicide applications to control damping-off may help to suppress populations of *Pythium myriotylum*. Also, one should use fields that drain well.

Additional information and photographs of many tomato diseases and diseases on other vegetable crops can be found at the following web sites.

Vegetable Disease Fact Sheets:
http://plantpath.ifas.ufl.edu/takextpub/FactSheets/pppvegetables.htm
http://edis.ifas.ufl.edu/VH056

Florida Tomato Scouting Guide:
http://ftsg.ifas.ufl.edu/index.htm

Tomato Herbicides: What we have gained, What We Have Lost and Possible Future Labels

William M. Stall
UF/IFAS, Horticultural Sciences Department, Gainesville

What We Have Gained

Several new herbicides have become available for use in tomato production. Research is still ongoing on their best use in a weed management system. Growers should check their individual labels for all instructions before use.

Matrix (rimsulfuron). Dupont has issued a supplemental label for the use of Matrix on fresh market tomatoes. At the present time, the preemergence application is for seeded tomatoes. We are working with Dupont to add a pretransplant statement. Matrix may be applied both preemergence and postemergence to tomatoes and weeds at 1-2 oz product (0.25-0.5 oz ai) in single or sequential applications. For POST (weed) applications, a non-ionic surfactant is required. Matrix may also be applied to row middles.

Sandea (halosufluron). Gowan has labeled Sandea for use in several vegetables including tomatoes. A total of two applications of Sandea may be applied as either one pre-transplant soil surface treatment at 0.5-0.75 oz product; one over-the-top application 14 days after transplanting at 0.5-0.75 oz product; a pre-transplant plus an over-the-top or a POST followed by a POST application of up to 0.75 oz product. Row middle applications may be made at up to 1 oz product. A non-ionic surfactant must be used with POST applications.

Dual Magnum (S-metolachlor). Syngenta has labeled Dual Magnum to be applied preplant non-incorporated to the top of pressed beds as the last step prior to laying plastic. It is also labeled for use in row middles. The rates labeled are 1.0 to 1.33 pints per acre if the organic matter is less than 3%. Research has indicated that the 1.33 pt rate may be too high in some Florida soils except in row middles. Good results have been seen at 0.6 to 1.0 pints especially in tank mix situation under mulch.

Goal (oxyfluorfen). Dow has labeled Goal for use as a fallow-bed treatment in several crops. Goal should be applied as surface treatment to preformed beds at 1-2 pints/A product. A 30 day treatment to planting interval must be maintained. Mulch may be applied any time during the 30 day interval.

Aim (carfentrazone). Aim is a broadleaf burndown herbicide from FMC that has a Section 18 label for postemergence control of emerged weeds in row middles. It is particularly effective on the control of paraquat resistant American black nightshade. The use rate is 1 to 2 fl oz product per acre. To control grasses, it must be tank mixed.

What We Have Lost

Two labels have been lost for use in tomatoes since last year. For vegetables in general, there have been several products lost. These are mostly older, seldom used products that had to be incorporated. For tomatoes the labels lost were:

Tillam (pebulate). Pebulate was scheduled for re-registration. No company registered the product for 2003 and the federal registration was canceled.

Boa (paraquat). Griffin decided to discontinue the Boa label. Paraquat is still available on tomatoes under the Gramoxone labels. The affect of the label loss will be more acute in vegetables other than tomatoes where Boa had a burndown label while Gramoxone does not. The pre and row-middle labels, as well as the burn down after final harvest, is still on the Gramaxone labels.

Possible Future Labels

There are a number of herbicides for which residue studies are being carried out in the IR-4 program. Potential labels for some of these may be less than a year to several years away. These are being listed for information purposes. They are:

Cobra (lactofen). Residue studies are being done for a Florida state label only. Cobra has both preemergence and postemergence activity of many broadleaf weeds in row middles, especially nightshade. There was a Section 18 label for Cobra several years ago, which was lost when the whole herbicide class chemistry came under review by EPA. Valent will petition EPA for a state label when the studies are completed and reviewed.

Valor (flumioxazin). Residue studies are being carried out nationally for tomato, pepper and eggplant row-middle application. Valor has both preemergence and postemergence activity on many broadleaf weeds. Two years of study in row middles in south Florida has shown that Valor has excellent safety and the widest range of weed control of any of the herbicides tested. A national label probably won't be available for several years.

Envoke (trifloxysulfuron). The tolerance packaged for tomatoes has been submitted to EPA with possible tolerance establishment this year. Envoke is an excellent nutsedge herbicide, with control of many broadleaf weeds applied POST. The potential label will probably be a post-directed application to established tomatoes.

Spartan (sulfentrazone). Efficacy studies have established that tomatoes and pepper are tolerant to applications of Spartan under mulch. Also, Spartan controls nutsedges pre to a great extent and has good control of many broadleaf weeds in Florida. Spartan cannot be registered in Florida until the soil dissipation studies submitted by FMC are reviewed by EPA.

Goal (oxyfluorfen). Pretransplant residue studies are underway in pepper with tomato to follow for reducing the preplant restrictions from 30 days to probably 5 days.

Weed Hosts, Field Distribution, and Sampling Strategies for Root-Knot Nematode

J.W. Noling[1], J.P. Gilreath[2], and P. R.Gilreath[3]

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Since 1994, there has been a considerable amount of field research conducted by University of Florida faculty to identify and evaluate alternatives to methyl bromide for soilborne pest and disease control. In our efforts to define alternatives to methyl bromide, we have observed how inconsistent and/or ineffective some pest management tactics can be for weed control, or how others after repeated use can select for resistant populations rendering the treatment ineffective. We have also observed how a single herbicide in the mix of pest management alternatives can provide no assurance for control of all grass and broadleaf weeds present in the field. As a result of these observations, our projection for the future and working research hypothesis is that weed density, species diversity, and the number of problematic fields will increase as we come to rely on less consistently effective, narrower spectrum, weed control measures.

Anticipating a future increase in weed pressures and problems, we began to question what other impacts besides the direct effects of competition for light, water, and nutrients weeds might have on crop growth. For example, we have observed how failure to adequately manage weeds within the field can not only affect crop yield, but serve as alternative hosts to nematodes, causing potential for additional crop production problems. A number of weeds have also been recently demonstrated in Florida studies to be excellent hosts to various soilborne disease pathogens. For example, a pathology review of the common weed, black nightshade (Solanum nigrum), shows that many of the most importance soilborne fungal, bacterial, and viral diseases of Florida vegetables are not only hosted by but are significantly increased by this common weed species in the field (Table 1). The first part of this article thus describes a joint research program, funded by the Florida Fruit & Vegetable Research Foundation, the objectives of which were to 1) characterize the host status of various weeds to root-knot nematode from commercial fields ; and 2) to evaluate field level impacts of weed growth on soil population density of root-knot nematode.

As a result of the expected higher incidence and severity of disease, weed, and nematode problems in the field, continued development of IPM strategies which include 1) guidelines for pest scouting / monitoring ; 2) crop loss assessment; and 3) decisions aids to minimize potential pest induced crop yield impacts are needed. As such, the second part of this article describes another project funded by the Florida Fruit & Vegetable Research Foundation, the objective of which was to develop and evaluate a grower conducted, field sampling protocol for root-knot nematodes using crop plants and root galling indices, rather than soil sampling, as a means of monitoring nematode populations in cropped fields.

Weed Hosts of Root-Knot Nematode

During 2002, comprehensive field surveys of eight commercial vegetable fields were conducted in east, southwest, and west-central Florida to evaluate the host status of various weeds to root-knot nematode (Meloidogyne spp.). Weed roots were collected from each field and returned to the laboratory where the weeds were identified and then stained with Phyloxine B to 'light-up' the egg masses of the root-knot nematode adhering to roots. The relative density of egg masses per gram of weed root was characterized according to an indexing scale of 0 = no egg masses; 1 = light or <10 per gram of root; 2 = moderate or 10-50 / gram root; 3 = heavy or 50-100 /gram root; and 4 = very heavy or >100 egg masses per gram of root. Simultaneous to the root staining operation, a subsample of aggregate weed roots was forwarded to the Florida Department of Agriculture and Consumer Services, Division of Plant Industry, for extraction and recovery of adult females for DNA fingerprinting and root-knot nematode species identification. Concurrent to the above studies, grower field demonstration experiments, consisting of treatments which manipulate weed densities into broad categories between high and low, were conducted to demonstrate the importance and direct linkage of weed density and management to nematode population suppression.

Results: In six of the eight fields surveyed, *Meloidogyne incognita* was the exclusive root-knot nematode species recovered from weed roots. A new root-knot nematode species, *Meloidogyne mayaguensis*, was recovered from one of the seven field sites. In a Myakka City, FL field location, a mixed population of *M. incognita* and *M. javanica* were recovered from weed root samples, while a field in Immokalee contained a mixed population of *M. incognita* and *M. arenaria*.

Fifteen weeds commonly found in the sandy soils of south Florida were evaluated for host suitability to root-knot nematode. In general, nematode galling and egg production was observed on the roots of all fifteen weed species from at least one of the seven field survey sites (Table 2). With some weed species such as ragweed, cudweed or goosegrass, root-knot nematode galling and egg production was variable between survey site locations and was not correlated with differences in nematode species. Six of the fifteen weeds species supported only low to intermediate levels of root-knot nematode reproduction at most sites. These included common ragweed, goosegrass, crabgrass, cudweed, and yellow nutsedge. Yellow nutsedge was not recovered from the nematode infested areas of all field survey sites. Nematode galling and egg production was highest and most efficient on various pigweed (Fig. 1) and nightshade (Fig. 2) species, common purslane (Fig. 3), clover, Sesbania, sand vetch, and carolina geranium. Although weed densities were not quantified at each field survey site, weed densities were typically very high, and in most cases, provided complete ground cover in areas between raised beds, the row middles (Fig. 4).

Once the discovery was made that the weed host range for root-knot nematode was so broad, we decided to begin quantifying the impact of weeds on nematode population growth in commercial fields. For this experiment, five treatments were evaluated in a nematode infested pepper field in Immokalee, Florida. Two of the treatments included mulch covered rows which were either 1) in-row fumigated with methyl bromide chloropicrin 67/33 (350 lb/a) or 2) received no fumigant treatment. The remaining treatments represent the impact of different cultural practices on weed growth in the row middles. The cultural practices or treatments included 3) row middles receiving pretransplant soil applications of glyphosate; 4) middles which were twice rotovated for early season weed control; and 5) middles in which a tightly woven, polypropylene nursery ground cloth fabric was installed to totally exclude weed growth in the row middles. At two other commercial field sites, rotovation of row middles was not included as a treatment for field evaluation. All treatments were initiated at the beginning of the cropping season and nematode samples collected at the end of the growing season after final pepper harvest.

As expected, methyl bromide significantly reduced but did not eradicate soil population density of root-knot nematode, and soil populations were near equivalent to those in the row middles receiving pretransplant glyphosate treatment (Fig. 5). At seasons end, weed growth in the glyphosate treated middles consisted of a near complete ground cover of various grasses, the most important of which was goosegrass and crabgrass. Root-knot soil populations built to their highest levels on peppers in the nonfumigated mulched covered beds, and on weeds in the rotovated middles. Weed densities were highest and most diverse in the rotovated middles, consisting of a complete 100% ground cover of various grasses and broadleaf weed species. No nematodes were recovered from soil below the ground cloth where no weeds were permitted to grow. In two other field studies, high density of weeds growing in the row middles significantly increased root-knot nematode soil population density compared to weed free middles of ground cloth treatments (Figs. 6 & 7), and in one study, in comparison to fumigant treatments with methyl bromide or Telone C35.

Research Summary

- The weed host range of root-knot nematode is extremely broad (Table 2), and nematode population growth is functionally related to the density, diversity, and root biomass of the weed species present in a field.
- Nematodes cannot be effectively managed unless weeds are also effectively and simultaneously managed in the field. Weeds which are allowed to grow and increase in numbers, particularly in-between mulch covered rows, serve to increase soil population densities of nematodes and perpetuate the nematode and quite possibly, disease problems from one cropping season to the next.
- Unmanaged weed growth can have a very destabilizing effect on pest populations and crop loss. It's not enough that weeds in themselves reduce crop growth, but they also serve to increase other pest densities which can even further limit crop growth and yield, and at the same time make overall pest management more difficult and costly.

Given the extent to which nematode population density increased in the presence of weeds in the row middles, we would ask growers to ponder the consequence and potential impact of such an effect. In the ground cloth experiment, nematode densities were nearly twice as high in the middles than in the fumigated, plastic mulch covered plant rows. Irrespective of what kind of pest control is achieved in the fumigated bed, when the season is over and mulch removed, the soil from all areas will be mixed by disking operations which follow. It is not inconceivable to easily produce doubling or even tripling effects to overall nematode and disease population levels when weeds are allowed to grow and increase pest population levels in the row middles (Fig. 8). One might even conclude that much of the need for soil fumigation may be predicated on the impacts weeds have on increasing and preserving soilborne pest populations at high levels at seasons end, or put another way, mandate the continued need for broad spectrum soil fumigants for nematode control. To account for potential interactions involving root-knot nematode, growers may well be advised to consider more suppressive weed management tactics and strategies for vegetable fields infested with the root-knot nematode. These results also should serve to reinforce our appreciation for truly integrating IPM practices.

Nematode Sampling Strategies

As indicated previously, various species of the root-knot nematode (Meloidogyne) are some of the most economically important nematode pests of field grown vegetables in Florida. In order to determine whether nematodes such as root-knot are the cause for poor crop performance or to determine the need for nematode management, some form of pest monitoring or sampling is required. Historically, laboratory assays of soil samples have been the principal method of detection and quantification of nematode density. Current methods of soil analysis can be accurate if sufficient numbers of representative soil cores and samples are removed from the field for the analysis. Regardless of sampling strategy, increased precision of the sample estimate can only be achieved with increased samples which translates to increased time and grower cost.

Due to the field patchiness (clumps) and low abundance of nematodes (a microscopic organism) in fallowed disturbed soil prior to planting, there is oftentimes no assurance of obtaining accurate estimates of field populations even with detailed sampling schemes, especially when large fields are involved. Currently the recommendation is to collect a single soil sample of twenty soil cores representing no more than 10 acres for relatively low value crops and no more than 5 acres for high value crops. The sample must also be collected well in advance of planting to insure time for processing and possible implementation of an appropriate management practice. Unfortunately, the lengthy time lags from sample collection to reporting often encourages wary growers, who oftentimes must act quickly, to adopt inappropriate nematode management strategies.

Use of Plants as BioIndicators of Nematode Problems

Recognizing that the root-knot nematode causes the formation of large swollen areas or galls on the root systems of susceptible crops, relative population levels and field distribution of this nematode can be largely determined by simple examination of the crop root system for root gall severity. Root gall severity is a simple measure of the proportion of the root system which is galled. Immediately after final harvest, a sufficient number of plants could be carefully removed from soil and examined to characterize the nature and extent of the problem within the field. In general, soil population levels increase in an exponential fashion with root gall severity. This form of sampling can in many cases provide immediate confirmation of a nematode problem and allows mapping of current field infestation. Currently, the detection of any level of root galling usually suggests a nematode problem for planting a susceptible crop, particularly within the immediate areas from which the galled plant(s) were recovered. The purpose of these studies was therefore to explore the use of root galling, rather than soil sampling, as a means of monitoring nematode populations in cropped fields.

Procedure. Eight fields in which crop production problems involving root-knot nematode (Meloidogyne sp.) were identified in the vegetable producing areas of west central and southwest Florida. In each of these fields, root-knot nematode infestation levels and patterns of field distribution were characterized by removing infested plants from mulch covered rows, acquired systematically from across each growers field after final harvest of the primary crop. At two sites, some of the excavated plants were individually weighed and root gall severity ratings recorded. The study area at each site consisted of a 3-4 acre subsection of infested field. The basic sampling unit within each field consisted of blocks of 6 plant rows (spray rows). In each 3 - 4 acre subsection, upwards of 500 crop plants were removed from the soil after final harvest. Plant removal followed a regular / systematic pattern of 50 foot increments within each plant row (Fig. 9). The actual number of plant samples removed was defined by row length and the number of rows within the 3-4 acre field site. Once uprooted, the specific field location (block, row, section) and root gall severity index value were recorded. The root galling index used consisted of a scale of 0 to 10, reflecting the proportion of root system galled (Fig. 10). Grower field personnel who participated in these studies were field trained and continually coached for all plant and root system rating evaluations.

Upon return to the laboratory, the data was entered to computer in spreadsheet format for statistical, simulation, and graphical analysis. Probabilities of detecting root-knot nematode infested plants (foci) for a range of sample sizes was computed for each 6 row block within each nematode infested field surveyed. Sample sizes were also computed and correlated with the range of field infestation level within blocks and fields. As indicated previously, the objective was to determine the smallest number of plant samples (how many) which maintain sampling error within acceptable limits. To minimize sample requirements, frequency distributions were also calculated and analyzed for specific sample site locations to identify any propensity for root-knot nematode infestation to specifically occur within certain areas of the field. This analysis was conducted to determine whether it might prove useful for instructing growers where to sample, i.e., within certain rows, blocks, subsections.

Results. Preliminary analysis of patterns of field distribution of root-knot nematode indicates a nonrandom, aggregated pattern of field distribution in most of the fields surveyed (Fig. 11). These same analyses also suggest that the crowned areas of the field or field center is oftentimes the site which recolonizes first with root knot nematode after soil fumigation.. This early recolonization by root-knot nematode may occur because these crowned areas are possibly the hottest and driest areas of field at the time of soil fumigation, and the more rapid escape of the fumigant may afford nematodes greater survival. At other experimental sites, root-knot nematode recolonization appears to occur along rows rather than between rows (Fig. 12). Interestingly, sampling precision was generally less variable, and often required fewer samples when plants were randomly obtained exclusively from the crowned areas or field middles rather than from plants acquired randomly throughout the entire field.

Preliminary analysis of these data also indicate that as overall root gall severity increases in the field, the numbers of plants which must be uprooted and examined for root galling for a given level of sampling precision decreases. For a given sample size, sampling precision increased significantly when overall root gall severity was greater than 5 (scale 0-10) in any given field. This was fortunate because the visual acuity of growers to detect the presence of galling on roots also appears to be at or near a root gall severity index of 5. At this overall level of root galling, growers must inspect a minimum of 4 to 6 plants per 6 row field block to achieve acceptable precision. When the nematode problem in the field is less severe and overall root gall severity less than 5, as many as 2 to 10 more plants must be inspected to accurately assess nematode problems within the field with the same level of sampling precision.

In summary, these field results and analyses suggest that use of crop plants as bioindicators of nematode problems can be a meaningful, informative, and grower acceptable means of nematode sampling. Rather than soil sampling, the results of these studies suggests that use of root galling indices of crop plants acquired systematically from grower fields after final harvest of the crop can be used to accurately characterize root-knot nematode infestation level and for revealing patterns of field distribution. Work continues to correlate whether root gall severity and foliar symptoms of plant health could also prove useful for determining which plants to select for root-knot nematode sampling. Non random sampling strategies directed at specific field locations and at plants showing decline symptoms are practical considerations which could improve detection and quantification of field distribution and nematode density with least grower cost and resource commitment.

Table 1. Fungal, bacterial, and viral diseases hosted by black nightshade.

Weeds as Hosts of Disease

Black Nightshade (*Solanum nigrum*)

Phytophthora capsici	*Colletotricum gleosporoides*
Phytophthora infestans	*Botrytis cinerea*
Phytophthora nicotiana	
Phythium sp.	*Erwinia carotovora*
Rhizoctonia solani	*Psuedomonas solanacearum*
Fusarium oxysporum	*Xanthomonas campestris*
Verticillium dahliae	
Verticillium albo atrum	*Tobacco Etch Virus*
Sclerotia rolfsii	*Tobacco Mosaic Virus*

French etal., 2002; Alfieri etal, 1994; Farr etal, 1989

Table 2. Results of Field Survey Demonstrating the Capacity of Different Weeds to Support Root-Knot Nematode Reproduction

Weed Species:	Reproductive Index (range)
◯ Pigweed	Heavy – Very Heavy
◯ Purslane	Very Heavy
◯ Nightshade	Few –Very Heavy
◯ Eclipta	Moderate - Heavy
Ragweed	None - Few
◯ Clover	Very Heavy
◯ Sesbania	Very Heavy
◯ Sand Vetch	Very Heavy
◯ Goosegrass	Few-Very Heavy
Crabgrass	None - Few
◯ Carolina Geranium	Very Heavy
◯ Cutleaf Primrose	Moderate
Gnaphalium	Moderate
Cudweed	None - Few
Yellow Nutsedge	Few

◯ Key Florida Species (Weed Density x Index)

Figure 1. Heavy galling of pigweed roots by root knot nematode, Melodigyne spp.

Fig.2. Heavy galling of black nightshade by root knot nematode, Melodigyne spp.

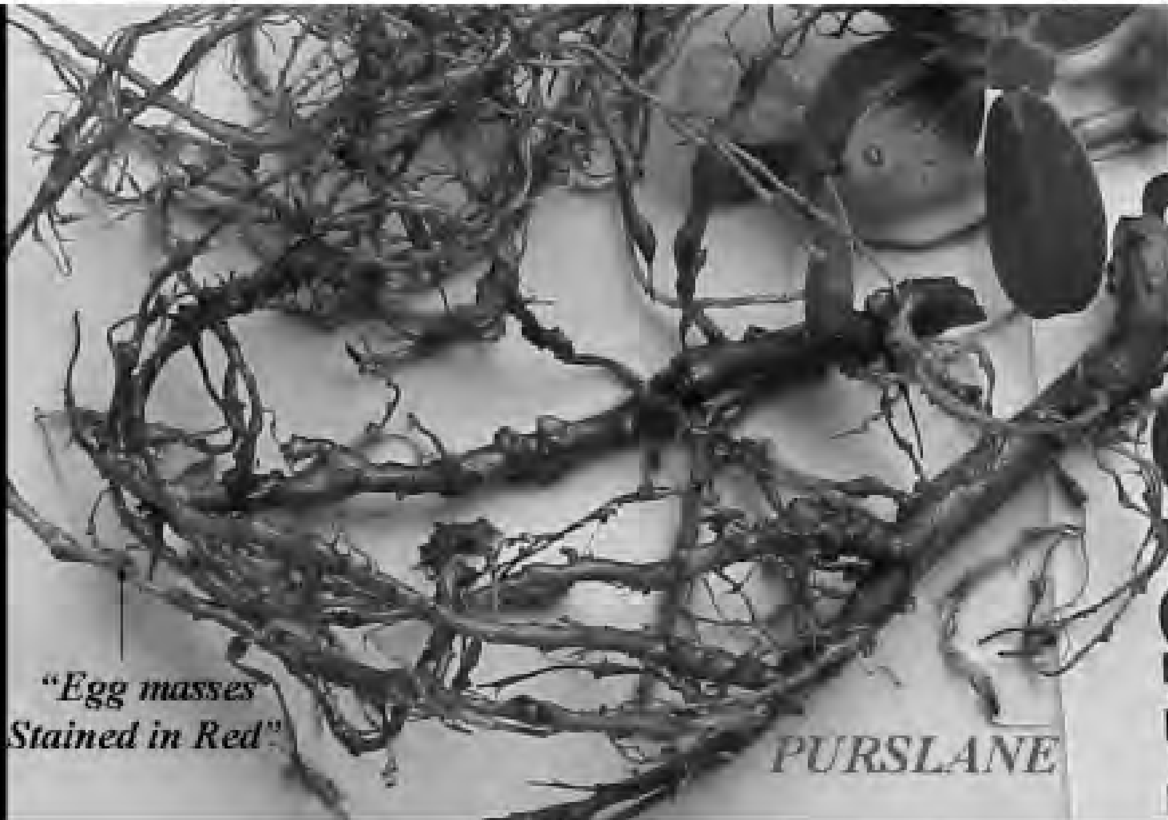


Figure 3. Heavy galling of purslane roots by root knot nematode, Melodigyne spp.

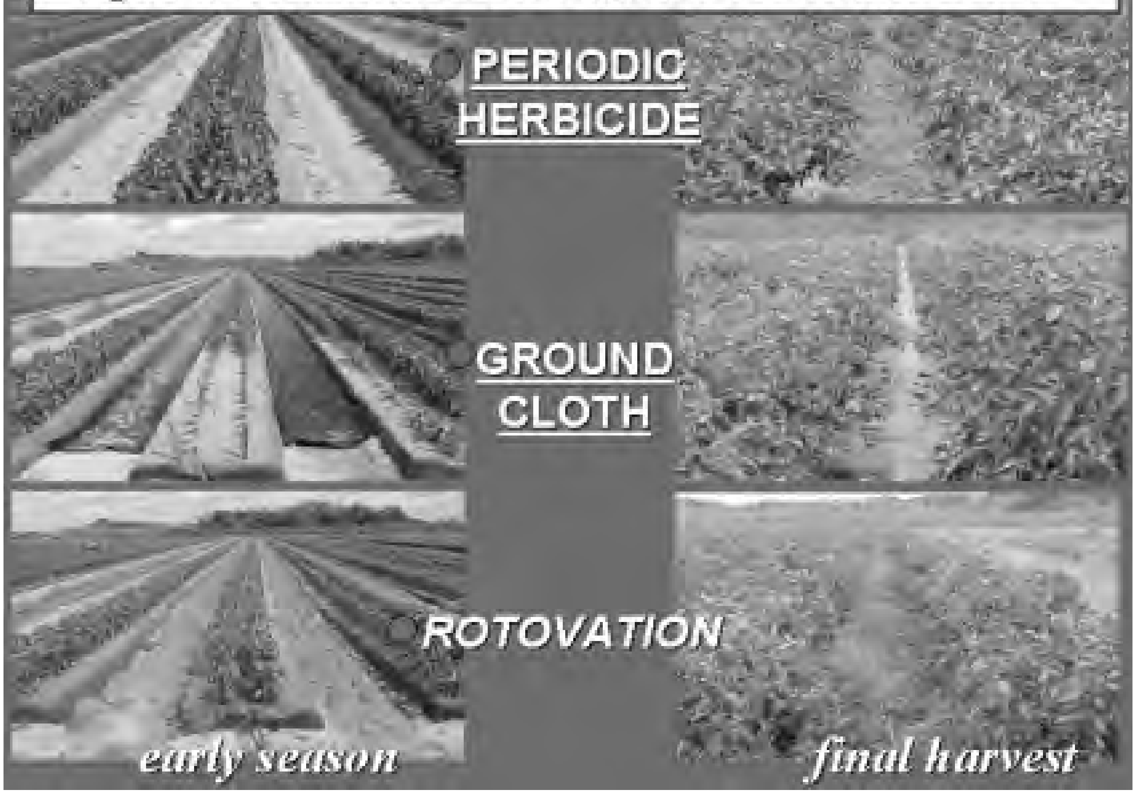
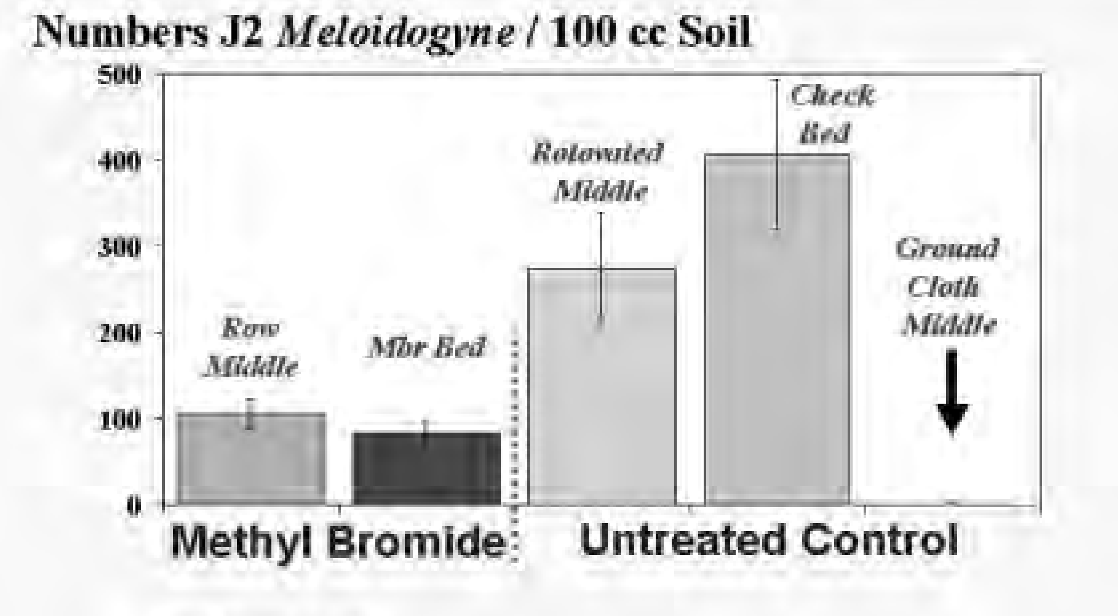


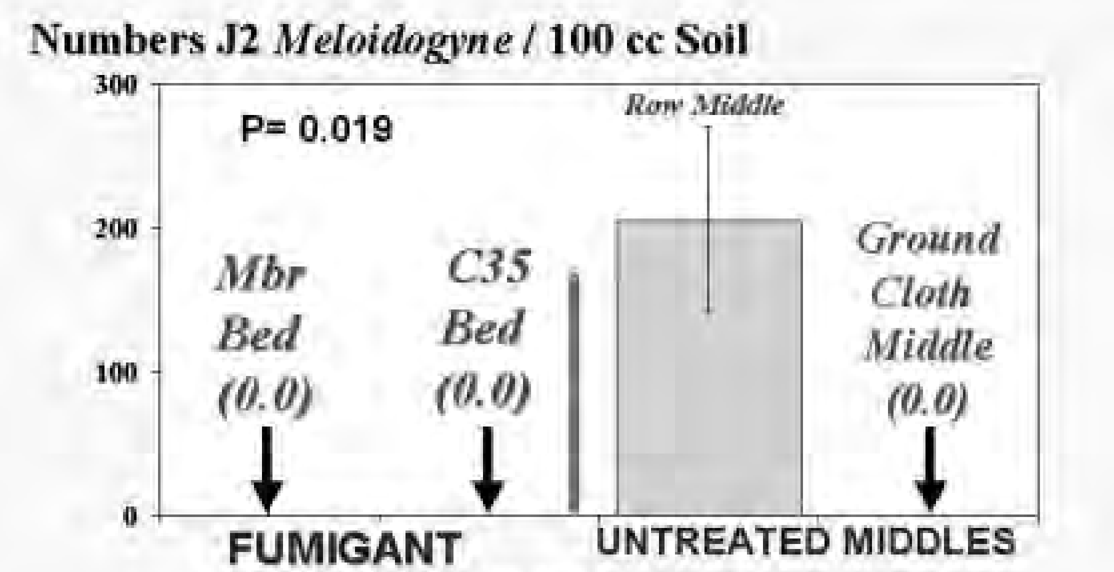
Figure 4. **-WEED MANAGEMENT-ROW MIDDLES-**

Fig. 5. Number of root-knot nematodes from row middles, raised plant beds, or below ground cloth cover in nonfumigated (check) or soil fumigated locations. Weed / Middles ManagementGround Cloth Trial - Fall 2002



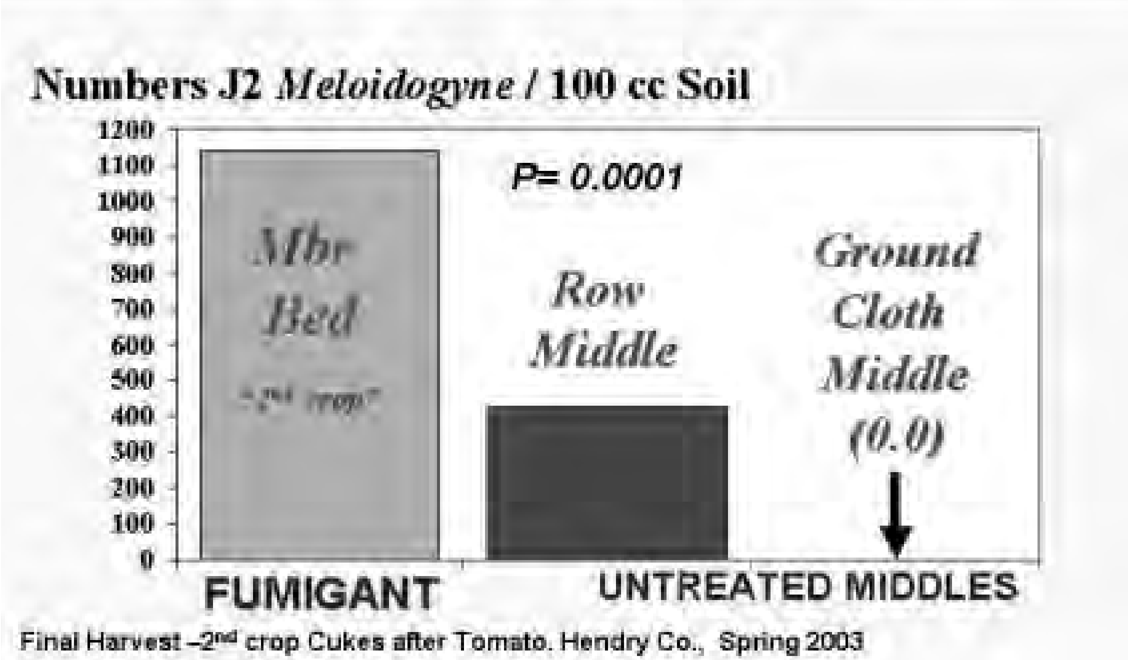
After 1st pepper crop

Fig. 6. Number of root-knot nematodes from row middles, raised plant beds, or below ground cloth cover in nonfumigated (check) or soil fumigated locations. Weed / Middles Management Ground Cloth Trial – Spring 2003



Final Harvest 1st crop tomato F&F Farms, Spring 2003

Fig. 7. Number of root-knot nematodes from row middles, raised plant beds, or below ground cloth cover in nonfumigated (check) or soil fumigated locations. Weed / Middles Management Ground Cloth Trial – Spring 2003



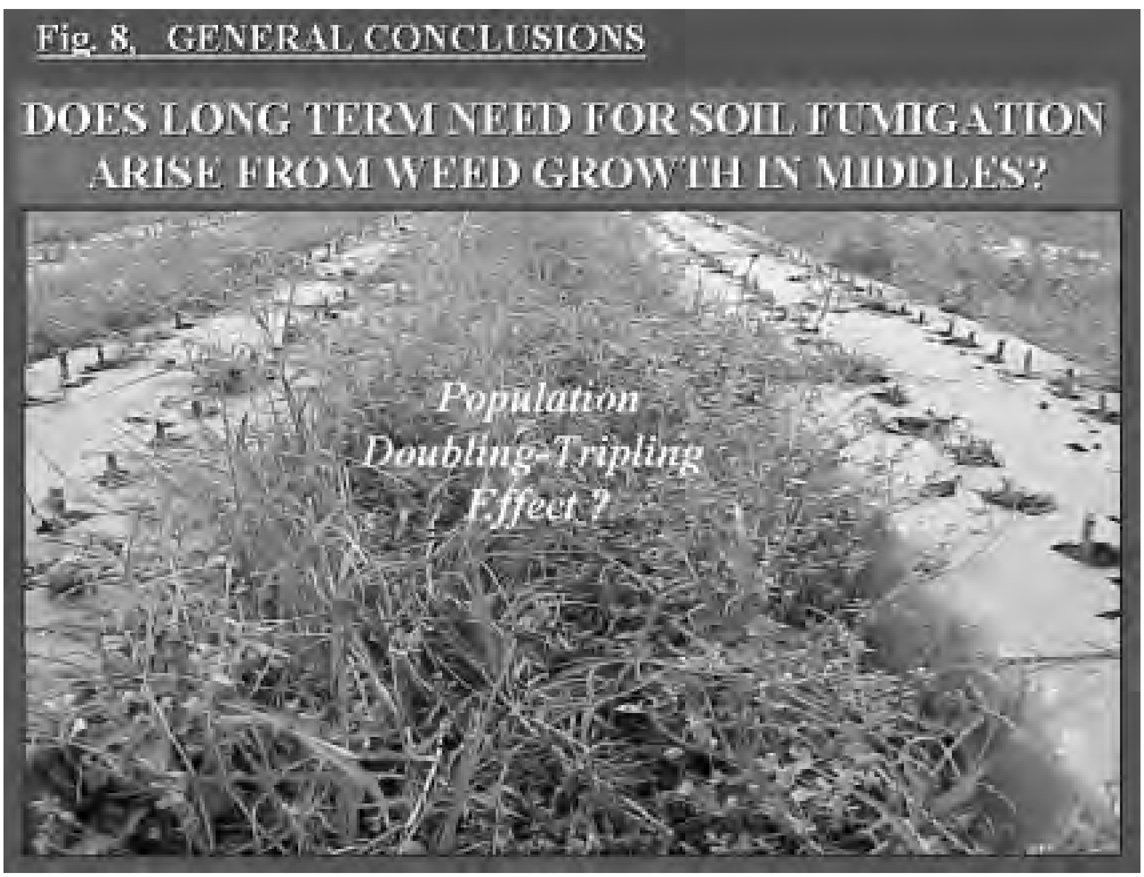
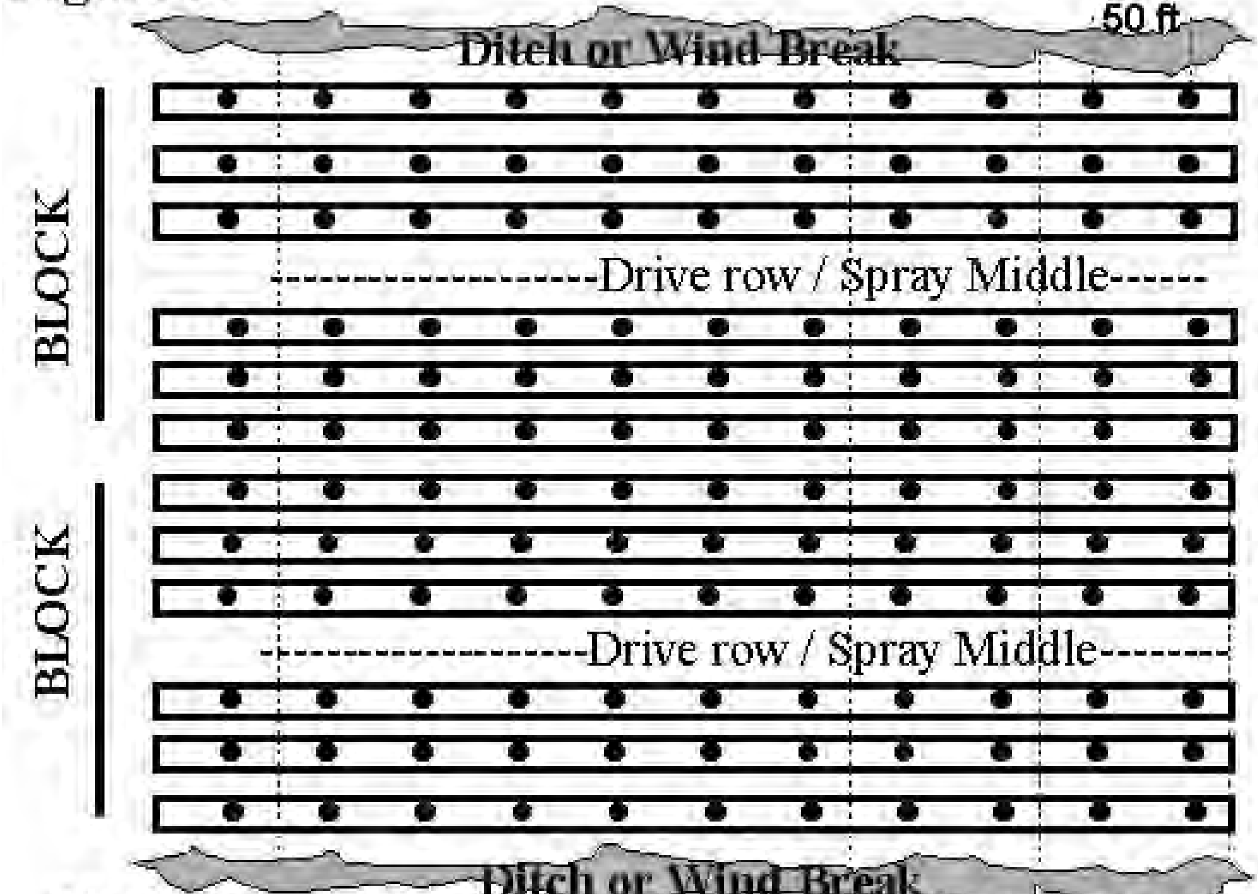


Figure 9.



The basic sampling unit: A grower defined spray block or land

● Sites for removal and gall indexing of a crop plant based on 50 ft increments of plant row.

Figure 10.
Rating scheme for evaluation of root-knot infestation

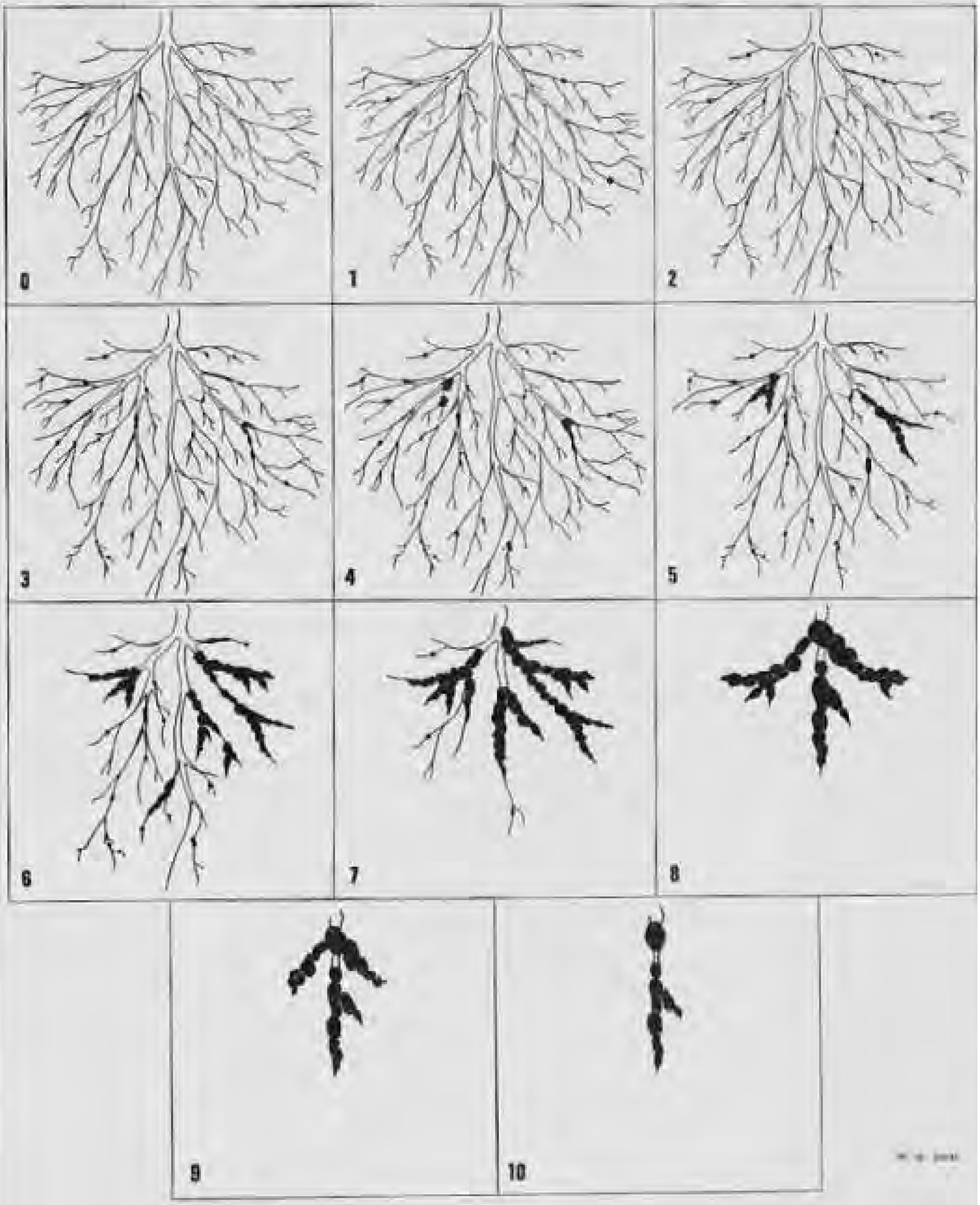


Figure 11. Spatial distribution of root knot nematode galling on roots of eggplant in a commercial field.

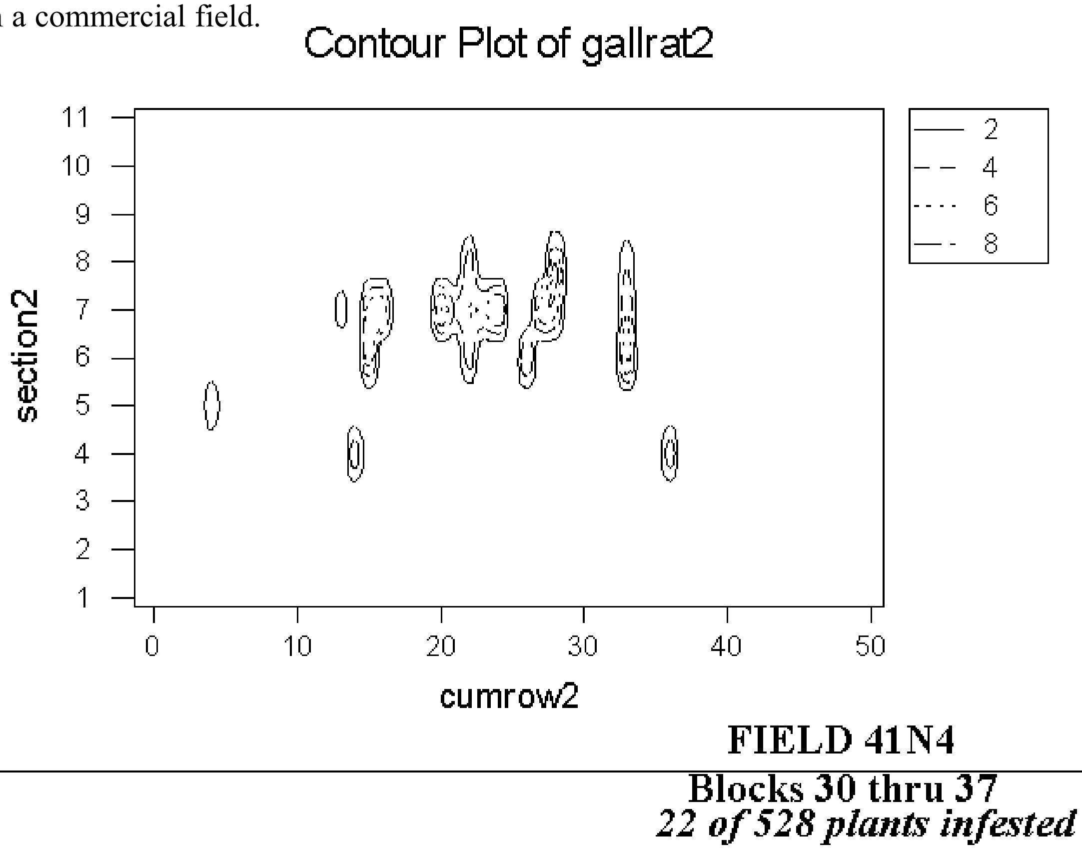
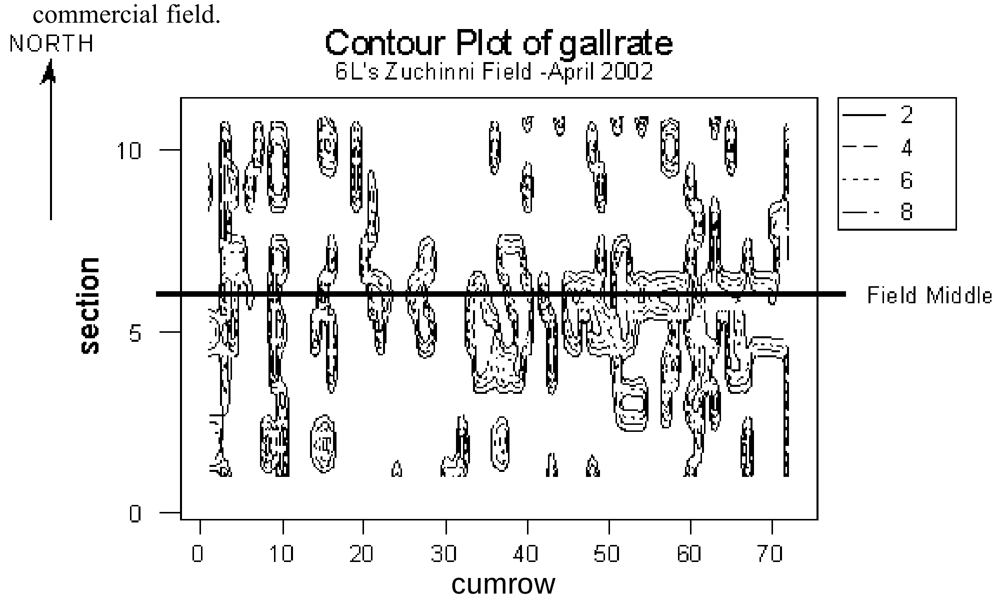


Figure 12. Spatial distribution of root knot nematode galling on roots of zuchinni in a commercial field.



Innovative Approaches for Soil Fumigation

Dan O Chellemi[1] and John Mirusso[2]
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New technology and application methods for soil fumigants are available to the Florida fresh market tomato industry. Growers can improve the performance of soil fumigants by using these advancements to take advantage of some key characteristics of fumigants. Examples are presented that have been supported by results from field trials conducted in Florida.

Fumigants are volatile materials that form vapors that are toxic to organisms (1). The effectiveness of a fumigant is a product of its concentration in the soil and the time of exposure (2,3). Most fumigants are effective against a wide range of organisms, when tested in the laboratory under controlled conditions where they are dispersed evenly throughout the soil profile (4). In the field, the performance of fumigants is often variable from site to site or year to year (5,6).

Vapor pressure is one characteristic of fumigants that describes their ability to move through air spaces in the soil. The greater the vapor pressure, the more easily the fumigant moves through the soil. The water/air ratio is another characteristic that can be used to describe the movement of fumigants through soil (7). Water/air ratio takes into account the water solubility of the fumigant and its concentration in the soil water and the soil atmosphere (7). As the water/air ratio increases, the ability of a soil fumigant to move through the soil profile decreases. For example, 1,3-dichloropropene (1,3-D or Telone) and methylisothiocyanate (metam sodium or Vapam) have similar vapor pressures but differ in their water solubility (Table 1). As a result, more 1,3-D remains in soil atmosphere than in the water phase, allowing it to move through the soil profile more easily. Compounds with a water/air ratio greater than 100 are not considered fumigants because they are not volatile enough to disperse uniformly in the soil (7).

For soil fumigants to be effective they must be given the opportunity to disperse through the soil profile yet they also must remain in the soil at a given concentration long enough to become toxic to the pest organism. In situations where broadcast applications are made, compacting the soil at the surface to create a barrier will improve the retention of the fumigant and its performance. In a field trial conducted at the USDA Header Canal Farm in Fort Pierce, retention of 1,3-D in soil following broadcast application was measured at daily intervals. Applications were made in soil that was tilled using a field cultivator and in soil where a water-filled roller was used to seal the surface. Concentrations of 1,3-D in the upper 5 inches of the soil profile were similar 24 hours after application (Figure 1). However, by 48 hours after application, 1,3-D concentrations were noticeably higher where the soil had been sealed, indicating that more of the fumigant was retained in the soil. In a large scale field trial of methyl bromide alternatives conducted on a commercial pepper farm in 2000, several sections of the field were inadvertently cultivated 24 hours after a broadcast application of Telone C-35. The resulting incidence of Phytophthora blight in the cultivated sections was 17% at first harvest, while disease incidence was less than 1% in the noncultivated or adjacent methyl bromide fumigated sections (8).

Placing a physical barrier at the soil surface to prevent the escape (emission) of fumigants into the atmosphere will increase their concentration in the soil and the time of exposure to pests, thus improving their performance. Polyethylene mulches are highly permeable to soil fumigants and thus marginally effective in preventing emission from fumigated soil to the atmosphere (9,10). Virtually impermeable films (VIF) prevent emission of fumigants. Several brands have been developed by plastic manufacturers and evaluated in research plots and on commercial tomato production farms in Florida (11). Use of VIF can have a dramatic impact on the retention of fumigants in the soil and the resultant control of key soilborne pests. In a replicated field trial conducted at the USDA Header Canal Farm, retention of 1,3-D in the upper soil profile was dramatically improved under a VIF film when it was injected into the beds after they were formed and the VIF applied (Fig. 2).

Allowing the pest organism to become more sensitive to fumigants (priming) can increase the effectiveness of fumigants. Subjecting pests to elevated soil temperatures for a short period of time can enhance the effectiveness of soil fumigants (12). An alternative is to create conditions that are conducive for germination of growth of pest propagules prior to fumigating. In field trials conducted at the USDA Header Canal Farm, control of yellow and purple nutsedge was significantly improved when Telone C-35 was injected into the beds 7 days after they were formed and covered with plastic mulch (Fig. 3).

Prior to 1999, the technology was not available for Florida growers to broadcast apply fumigants effectively unless soil was freshly disked. Development of the "Yetter 30 Avenger" (Yetter Equipment Co., Colchester, IL) allows growers to fumigate fields without disturbing the soil surface. Thus, fields can be fumigated after they have been laser leveled but before they have been disked for planting. Prior to 2002, the technology was not available for growers to fumigate existing plastic-mulched beds unless they had access to drip irrigation. Development of the "Mirusso-Chellemi Under Bed Fumigator" provides growers with the opportunity to apply fumigants under existing plastic-mulched beds or previously used beds prior to the planting of a double crop. A patent application was submitted to the United States Patent & Trademark Office on 3, October, 2002 (Serial No.: 10/263, 107 and Docket No.: 0113.02) for the Under Bed Fumigator.

Many years of research and on-farm trials have resulted in several alternative chemical programs that can provide control of soilborne pests equivalent to the standard practice of bed fumigation with methyl bromide. However, all of the alternative options will require increased knowledge of the history and biology of soilborne pests in individual fields and more detailed attention to the application technology used for alternatives.

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Table 1. Characteristics of selected fumigants (see reference 7).

Chemical name	Vapor pressure [a]	Water solubility(%)	Water/Air[b]
Methyl bromide	1380	1.60	4.1
Chloropicrin	20	0.195	10.8
1,3-dichloropropene	18.5 to 25	0.275	17.7 to 24.6
methyl isothiocyanate	21	0.76	92

[a] measured in mm Hg at 20° C

[b]ratio of weights of chemical in equilibrium, in equal volumes of water and air at approximately the same temperature.

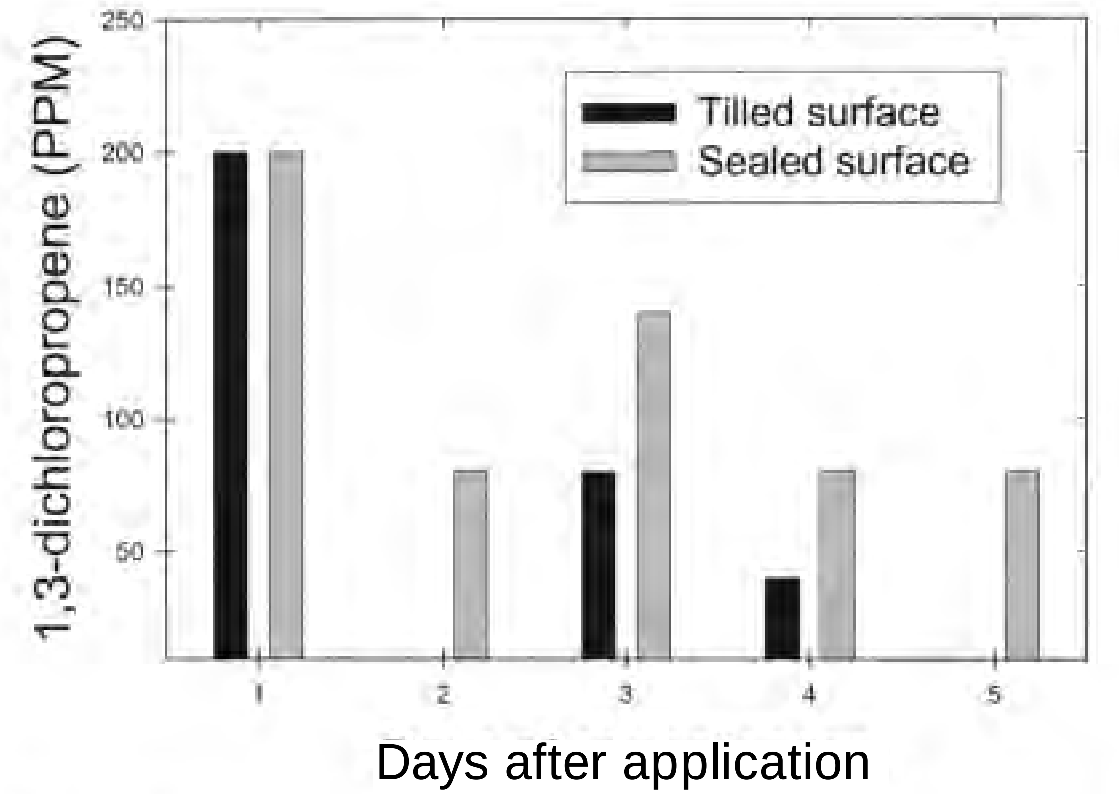

Figure 1. Concentration of 1,3-dichloropropene (Telone) in the upper 5 inches of soil following broadcast application using the Yetter 30" Avenger.

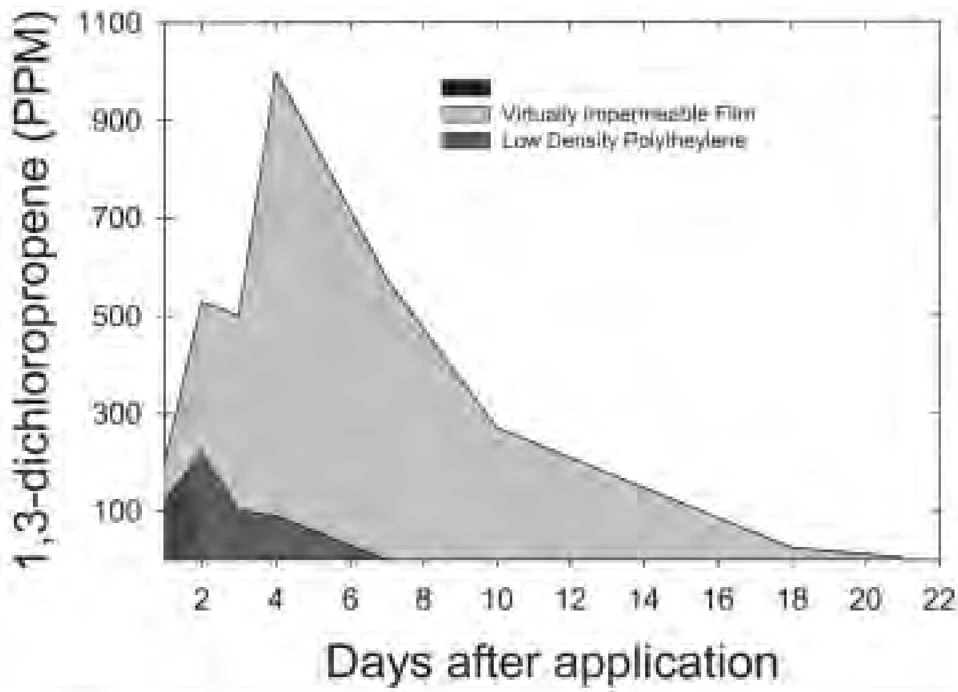

Figure 2. Concentration of 1,3-dichloropropene in the upper 5 inches of soil. Samples collected from the center of 36 inch wide by 10 inch tall beds.

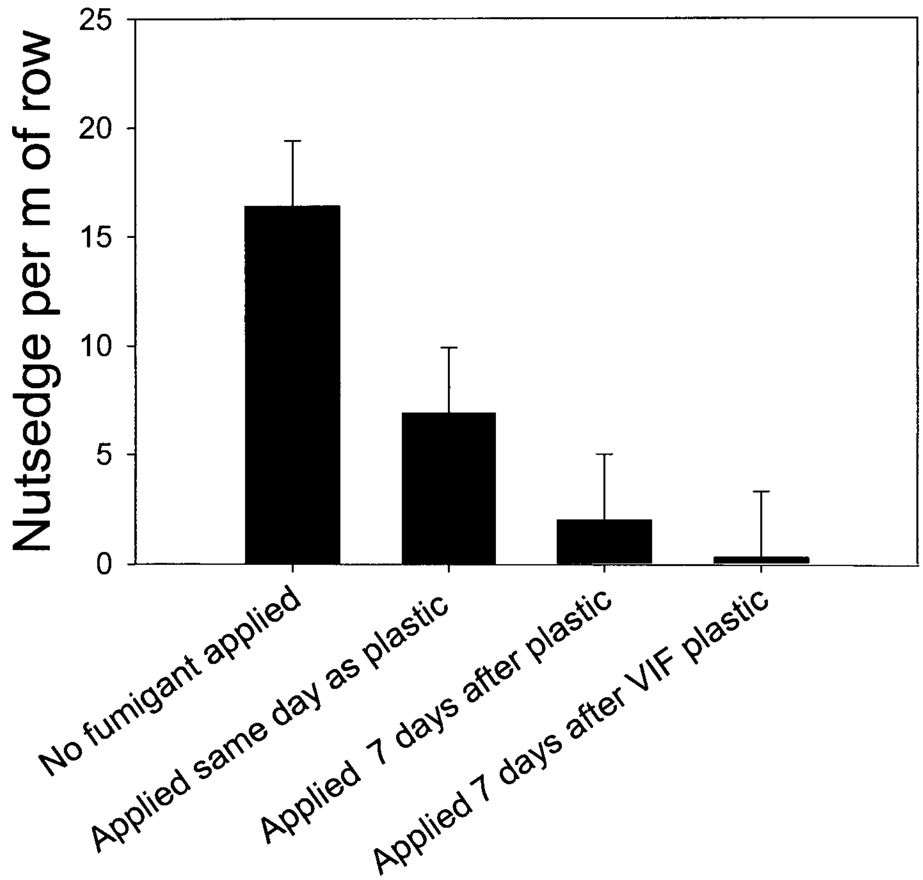

Figure 3. The number of nutsedge emerging through the plastic 37 days after application of 1,3-dichloropropene at 35 gal per acre. All plastic was low density polyethylene except for the VIF treatment.

VIF Research and Its Role in Methyl Bromide Phaseout and Update on Long Term Methyl Bromide Alternatives Study

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The impending loss of methyl bromide as a soil fumigant will impact the Florida tomato industry significantly because it will mean a change in the way we do things and the results we can expect. For the past 11 years we have researched chemical and nonchemical alternatives and we have studied various ways to improve the results we get with some of the more promising ones. We also have continued to evaluate new fumigants as they come along and have investigated the integration of herbicides with fumigants in an effort to provide the broadspectrum pest control required by the tomato industry. As a result, we know a lot more than we used to about many products, but we still have not found the "silver bullet" , nor are we likely to.

We have worked in cooperation with the Florida Fruit and Vegetable Association and the Florida Tomato Committee to prepare and submit Critical Use Exemption (CUE) petitions in an attempt to buy the industry some more time so we can provide the grower industry with the very best information about what is available and how to use it. Two criteria critical to any CUE petition are demonstration of existence of an active, scientifically valid research program to continue investigation of possible alternatives and serious attempts at emission reduction. Our research and extension programs are designed to do just that. This paper will provide you with an overview of what has been done as well as what is being done currently. It is our attempt to provide you with a report of "what we did with your money" since the Florida Tomato Committee has funded much of our research. While this may seem like a frivolous sub-title for a paper, it is one we take seriously as money is important to both the giver and the receiver. Furthermore, we would like to encourage you to attend field days and other activities where you can see what is being done with your money. We especially would like to see more direct participation by the members of the Florida Tomato Committee Research Committee since they are the ones making the funding decisions for the Committee. If field days are not convenient for research committee members, please contact us directly to select a time for a site visit so you can see the results of your investment in research designed to address your needs.

We completed the five year methyl bromide alternative study this spring (2003) at the Gulf Coast Research and Education Center in Bradenton and results have been very interesting. This study looked at 1) the impact of fall applications of methyl bromide (67/33), Telone C-17 + Tillam, and soil solarization on soilborne pests and fall tomato production, 2) residual pest control in spring cropping practices (double cropped cucumber, millet cover crop, and weed fallow), and 3) the effect of these spring cropping practices on the subsequent fall tomato crop. The population of all soilborne pests went up after the first year, then declined to varying degrees. For example, the number of nutsedge plants per square meter increased from 19 in the first year to 103 in the second year of tomato with no fumigant, then the number declined and leveled off at about 35 plants per square meter. Without fumigant, the amount of Fusarium wilt infested tomato plants jumped from 32% to 89% then declined slightly with a varying incidence level from one year to the next for the remaining three years of the study. We also observed large fluctuations in the population of rootknot and other nematodes from year to year. Tomato marketable fruit production also varied from year to year in the non-fumigated areas, but the general trend was that it declined each year. In the first year, marketable fruit production was only 32% of what was produced with methyl bromide, then it declined even further and was only about 10% by the fifth year. Fruit production declined with all treatments, including methyl bromide, which should be no surprise to a grower. You can not continue to grow tomatoes on the same ground year after year without expecting a yield decrease. Tomato production decreased after the first year, but became fairly stable after that time; however, the level at which it stabilized was only about 55% of what it was the first year with methyl bromide. Results with Telone C-17 + Tillam were very similar to what we obtained with methyl bromide and there were no significant differences between the two fumigants for soilborne pest control, with the exception of rootknot nematode control in the last year of the study when there were fewer rootknot nematodes where we used Telone C-17 than where we applied methyl bromide. Fruit yields were not different in any year with these two fumigants.

Soil solarization did not perform at all well. In some years we actually had more rootknot nematodes with solarization than where we used no fumigant. Nutsedge control was not that different from the fumigants because we sprayed the emerged nutsedge with paraquat a week before planting, effectively "burning off" a lot of the resident population. Four out of five years, tomato fruit production with solarization was only about one-half of what it was with methyl bromide and Telone C-17. As a result, soil solarization is not considered a viable option for mainstream agriculture. It might have a fit for an organic producer or a small grower who can not obtain or afford soil fumigants.

The effect of the spring cropping practices on fall pest populations and tomato production was a bit less complicated. Spring cropping practice had no effect on the amount of Fusarium wilt or rootknot nematode galling of tomato roots. There were fewer nutsedge plants following double -cropped cucumber the first year, but more the last year. Spring millet increased fall tomato production one year, but that was the only time that spring cropping practice had an influence on fall tomato yield.

As mentioned, we also looked at the effect of the fall alternative treatments on spring production of double cropped cucumbers and millet as a cover crop. Soil solarization reduced the number of nutsedge plants as well as methyl bromide each year. This probably was the result of allowing nutsedge to emerge and grow over the 8 week solarization period, then spraying it with paraquat to "burn it down" prior to transplanting in the fall. As a result, a lot of the nutsedge tubers sprouted in the fall and were damaged by that paraquat application and the additional two applications made at the end of the tomato crop and just prior to planting cucumber in the spring. Telone C-17 + Tillam provided residual nutsedge control equal to methyl bromide in 3 of the 4 spring cucumber crops. The number of rootknot nematodes in the soil around cucumber roots was only affected by fall treatment in the first spring of the study. At that time, the most rootknot nematodes were found in the nontreated control plots and where solarization was practiced. The fewest rootknot nematodes were recovered in soil previously fumigated with Telone C-17. Cucumber production was equal with methyl bromide and Telone C-17 + Tillam in each year of this study while production with solarization was as good as with methyl bromide during two years and worse during the other two years. Growth (plant height and fresh weight) of millet was not affected by Telone C-17 + Tillam, but solarization reduced millet plant height and weight some years. The occurrence of nutsedge, crabgrass and pigweed in millet was greater during the last year of the study with soil solarization.

Based on results of this study, we appear to have an option to methyl bromide. That was the good news. The bad news is that the herbicide component (Tillam) which provided nutsedge control is no longer registered for use in the U.S.A. It was the victim of the bankruptcy of its marketing agent, Cedar Chemical Co. When Cedar Chemical went bankrupt, no other company stepped forward to pay the registration fees which were due in December 2002. As a result, Tillam is gone, probably forever. Admittedly, Tillam had some short comings. Although it performed well in this and many other studies we have conducted, there have been a few where it caused injury or performed poorly. Cases of injury could almost always be explained based on operator error, but some of the instances of poor weed control could not. In order to be a replacement for methyl bromide, an alternative must be effective and it must provide consistent results. While there are other herbicides being investigated for use in combination with some of the alternative fumigants, we do not have the extensive experience with them that we have with Tillam; therefore, it will take time to identify the strengths and weaknesses of each and determine exactly how they fit with the more promising alternatives to achieve the ultimate goal of providing a replacement package which will allow a grower to continue producing tomatoes with minimal additional risk or costs.

As mentioned, additional research has been conducted on soil fumigants for tomato. This has ranged from fine tuning Telone products to exploration of new compounds. Since Telone has proven to be the most likely replacement for methyl bromide in the near future, we have investigated means of improving efficacy and consistency of performance. There has been a great deal of emphasis on broadcast applications of Telone C-35 as a means of reducing worker exposure and the impact of personal protective equipment (PPE) requirements and broadcast has appeared to work well in most situations in commercial scale trials; however, experiments on commercial farms seldom provide the high level of pest pressure one can attain in small plot research on an experiment station where pest levels have been developed for just such purposes.

Over the past 3 years we have conducted a study investigating the relative efficacy of Telone C-35 when applied broadcast versus in the bed and the impact of additional chloropicrin applied at the time of bed formation. We have determined that under conditions of moderate disease pressure Telone C-35 applied in the bed is more efficacious than broadcast Telone C-35. Application of additional chloropicrin in the bed following broadcast Telone C-35 improves soilborne disease control and nematode control. We included Tillam + Devrinol for weed control with all applications of Telone II and Telone C-35 in this study and determined that even with herbicide the same across treatments, in bed Telone C-35 provided better nutsedge control than any broadcast Telone treatment. We also found that adding chloropicrin back into the bed following broadcast Telone II or Telone C-35 improved nutsedge control. Tomato marketable fruit production followed the same trend. Methyl bromide was included as a grower standard and Telone C-35 in bed with Tillam + Devrinol applied broadcast provided soilborne pest control and tomato yield equal to methyl bromide. Recent changes in the PPE requirements and setbacks for Telone products have eased the impacts of those issues for growers wishing to make in bed applications, so it is felt that there will be less interest in broadcast application, although there are some very real benefits to broadcast that should be considered. The take home message for a grower is if you are going to apply Telone C-35 broadcast, you should apply another 125 to 150 pounds of chloropicrin per **treated** acre in the bed.

While we have spent time fine tuning Telone C-35 we also have continued to search for new compounds as well as older products which may have value for soil fumigation in tomato. By leveraging Florida Tomato Committee funds with funds obtained from the USDA /IR-4 Methyl Bromide Alternatives Program we have been able to conduct 4 large experiments over the past 2 years. Twenty-four treatments were evaluated in 2001 and 18 were investigated in 2002. One trial is being repeated this fall as a result of loss of the experiment due to pinworms. (Yes, even scientists have pest control problems that get out of hand.) As a result of these experiments, about 4 products have been dropped from further testing, 1 is awaiting labeling, and 3 are continuing to be evaluated. One of the success stories is fosthiazate. Registration of fosthiazate is being pursued by Syngenta and the combination of chloropicrin chiseled into the bed and fosthiazate applied through the drip irrigation system has been one of the best treatments for soilborne diseases and nematodes in these experiments.

A promising new product is sodium azide. Sodium azide has been around for over 30 years and was first investigated as a soil fumigant by PPG Industries in the early to mid 1970's. At that time it was formulated as a granular product and showed great promise. Unfortunately, PPG chose to shelve it because methyl bromide was firmly entrenched in the market place and azide is not without some risks. Today it is available for research purposes formulated as a liquid preparation. We have investigated 2 application procedures: spray on the soil surface and incorporate it with a rototill and apply it through the drip irrigation system. Drip application is preferable because it reduces potential worker exposure, but drip brings with it problems we have discussed before about the uneven distribution of water soluble products in sandy soils. In a trial on a commercial farm near Immokalee, sodium azide provided better control of Fusarium crown rot than methyl bromide, and it has performed well for control of Fusarium wilt race 3 in trials in Manatee county; however, results have not always been consistent. Nutsedge control has been good in some trials and poor in others, including trials with crops other than tomatoes. Some formulation changes have occurred which seem to have improved performance. Spray - rototill application has not been as effective as drip application. Work continues with sodium azide in collaboration with a scientist from Auburn and we hope to have more definitive results to present next year.

We also have investigated a new product from South Africa which is being developed under the trade name Multiguard Protect. This product is a contact nematicide and is being marketed in South Africa for tomatoes. Results in our trials have been mixed and we believe some of this is due to difficulty distributing it uniformly across the bed. One interesting aspect of this product is the crop safety which allows applications during the season. This would allow it to fit in both a first crop as well as a double crop or be used as a rescue treatment, if we can improve the efficacy and consistency in our sandy soils.

Vapam and K-Pam continue to be included in research because they can provide nutsedge control which is not possible with most other alternative fumigants and because we have seen improvement in efficacy and consistency as a result of research we conducted in the past 3 years to determine the movement of water soluble pesticides in soil water as a result of drip irrigation application. One promising treatment is the combination of Vapam or K-Pam with either chloropicrin or Telone C-35. Vapam / K-Pam would be delivered through the drip tubing in this combination.

Inline, an emulsifiable concentrate form of Telone C-35, has been included in some research and results have been mixed; again as the result of drip delivery problems. We have managed to make improvements and work continues. Probably the real place for Inline is in double cropping as a supplemental treatment just prior to planting the double crop.

One of the big concerns with alternatives to methyl bromide is the potential impact of the alternative on residual soilborne pest levels. This is particularly important for double cropping. The 5 year study we just completed did a lot to address growers' concerns about the potential for buildup following Telone C-17, methyl bromide and soil solarization. We determined that there was some increase in pest levels with all treatments, including methyl bromide, but solarization was far worse. Upon termination of that study we began a new study to measure the potential buildup of nutsedge, Fusarium wilt race 3, and nematodes following cessation of fumigation when the double crop was tomato. Tomato behind tomato is a recipe for disaster, but it allows you to better determine the impacts than double crop cucurbits because it allows a measure of Fusarium wilt in addition to nutsedge and nematodes. We found that there was tremendous resurgence with methyl bromide as well as Telone C-17 and that there was no difference in the extent of resurgence. We hope to expand this project to include additional alternatives this fall and spring.

Lastly we come to what was supposed to be the focus of this paper: VIF or virtually impermeable film. We have been working with VIF products for about 5 years now. Some are good and some are not. None are embossed, at this time. As a result, they do not stretch or have any "memory" which allows them to shrink and swell with temperature changes. Some are prone to linear shear. Before we say anything else, we need to define what VIF is. Virtually impermeable film is not impermeable to methyl bromide, but it is much less permeable than low density polyethylene (ldpe) film which is the standard mulch you use. Permeability can be on the order of more than 10 times less permeable. Today you may see "High Barrier" film on the market. This is not VIF. It is less permeable than standard ldpe but still much more permeable than VIF. How much more permeable? The published standard for High Barrier comes from the California Dept. of Agriculture and specifies a film which can be as much as 25 times more permeable than VIF. One of the problems with VIF is the lack of a international standard for this film's permeability. The only known published standard for VIF is provided by the French who state that to be classified as a VIF, a film must have a transmission rate of no more than 0.2 grams (or milliliters) per square meter of film per hour.

VIF can play an important role in rate and emissions reduction with methyl bromide. Recently completed research with pepper demonstrated just how effective VIF could be at improving efficacy of reduced rates of methyl bromide. This study was repeated over several years and clearly demonstrated that rates as low as 88 lbs of 67/33 per treated acre could provide nutsedge control equal to that obtained with 350 lbs of 676/33 when VIF was substituted for standard ldpe or High Barrier polyethylene film. We do not encourage growers to try such low rates, but we do feel that with a good VIF rates can be cut in half without suffering loss of efficacy.

Not all fumigants benefit from VIF. Telone C-35 does, but many others do not. It is difficult to comprehend the gas retention capacity of VIF relative to ldpe, but the following may help put it into perspective. In a study of Telone C-35 retention rates of various films, the transmission rate for standard ldpe black film was measured as 45% in 81 hours, while one of the more successful VIF products had a transmission rate of 4% in 81 hours in one study (data courtesy of Joseph E. Eger, Dow AgroSciences). Results of field experiments with Inline and Telone C-35 have demonstrated improved retention with VIF. Thus, one can see clearly that VIF can play an important role with Telone C-35 as well as methyl bromide. The longer retention time means more effective control of susceptible soilborne pests. It can also mean improvements in control of more difficult to control pests, like nutsedge. Results of research conducted over the past 2 years have illustrated this concept. By combining Telone C-35 or Inline with VIF we have greatly improved nutsedge control. Furthermore, drip application of Inline with ldpe has always suffered from poor control of nutsedge along the bed shoulder and control was restricted to an area about 6 inches on either side of the drip tubing. With VIF we have been able to achieve a much wider band of control and much better control within the impacted zone when we have applied Inline through the drip tubing. While VIF retains methyl bromide and Telone longer than standard ldpe or "High Barrier" films and results in greatly improved soilborne pest control, there is a down side. Most VIF does not lay that well. Laying speeds of 2 to 3 mph are common as faster speeds increase the risk of linear shear. This is too slow for most growers. Another problem observed has been loosening of the film as it heats up during the day. The inability to lay some VIF's tightly and the need for reduced laying speed make many of these films unacceptable to growers. Not all VIFs are the same. Just as there are differences in retention characteristics, there also can be differences in handling properties and we continue to trial new films as they are made available. Currently, we favor VIF manufactured by IPM of Italy. Their film is not quite as retentive as some, but it handles better than any of the other films we have laid. We have laid this film at 4 to 4.5 mph without mishap and have experienced no problem with linear shear or any other type of tearing action. We have noted that their white on black is not as white as we would like it to be, but they are working on improving the brightness of the product and we do not expect that to impact handling characteristics.

The current methyl bromide alternatives research program is a large one. We have worked to deliver what the industry needs - effective alternatives, data to support a CUE, and information on fumigant and mulch options so growers can make intelligent, informed decisions. We feel you have invested your money wisely and we hope you feel that you have received good value for that investment. Lastly, we would like to once again encourage tomato growers and their representatives to visit and view the research being conducted on your behalf. Direct involvement by the industry is important for all of us.

C O N T R O L   G U I D E S

Tomato Varieties for Florida

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

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

- **Yield -** The variety selected should have the potential to produce crops at least equivalent to varieties already grown. The average yield in Florida is currently about 1400 25-pound cartons per acre. The potential yield of varieties in use should be much higher than average.
- **Disease Resistance -** Varieties selected for use in Florida must have resistance to Fusarium wilt, race 1, race 2 and in some areas race 3; Verticillium wilt (race 1); gray leaf spot; and some tolerance to bacterial soft rot. Available resistance to other diseases may be important in certain situations, such as Tomato Spotted Wilt resistance in northwest Florida.
- **Horticultural Quality -** Plant habit, stem type and fruit size, shape, color, smoothness and resistance to defects should all be considered in variety selection.
- **Adaptability -** Successful tomato varieties must perform well under the range of environmental conditions usually encountered in the district or on the individual farm.
- **Market Acceptability -** The tomato produced must have characteristics acceptable to the packer, shipper, wholesaler, retailer and consumer. Included among these qualities are pack out, fruit shape, ripening ability, firmness, and flavor.

Current Variety Situation

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

Tomato Variety Trial Results

Summary results listing the five highest yielding and the five largest fruited varieties from trials conducted at the University of Florida's Gulf Coast Research and Education Center, Bradenton; Indian River Research and Education Center, Ft. Pierce and North Florida Research and Education Center, Quincy for the Spring 2002 season are shown in Table 1. High total yields and large fruit size were produced by Fla. 7926 at Bradenton; Florida 47, Fla. 7810, Agriset 761 and Sanibel at Fort Pierce; and SVR 1432427 and BHN 444 at Quincy. There was very little overlap between locations. The same entries were not included at all locations.

Table 2 shows a summary of results listing the five highest yielding and five largest fruited entries from trials at the University of Florida's Gulf Coast Research and Education Center, Bradenton; Indian River Research and Education Center, Ft. Pierce and the North Florida Research and Education Center, Quincy for the Fall 2002 season. High total yields and large fruit size were produced by Fla. 7810, Fla. 7885 B, Florida 47 and Florida 91 at Fort Pierce and by Solar Fire and Fla. 7885 B at Quincy. Solar Fire and Fla. 7885 B produced high yields at all three locations and Fla. 7885 B, Fla. 7810 and Florida 91 produced large fruit at two of three locations. Not all entries were included at all locations.

Tomato Varieties for Commercial Production

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

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

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

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

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. (Seminis).

Sebring. A late midseason determinate, jointed hybrid with a smooth, deep oblate, firm, thick walled fruit. Resistant: Verticillium wilt (race 1), Fusarium wilt (race1,2 and 3), Fusarium crown rot and gray leaf spot. For Trial. (Syngenta)

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

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

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. (Seminis).

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

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. (Seminis).

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, root-knot nematodes, gray leaf spot, and bacterial speck. (Sakata).

Plum Dandy. Medium to large determinate plants. Rectangular, blocky, defect-free fruit for fresh-market production. When grown in hot, wet conditions, it does not set fruit well and is susceptible to bacterial spot. For winter and spring production in Florida. Resistant: Verticillium wilt, Fusarium wilt (race 1), early blight, and rain checking. (Harris Moran).

Spectrum 882. Blocky, uniform-green shoulder fruit are produced on medium-large determinate plants. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), root-knot nematode, bacterial speck (race 0), Alternaria stem canker, and gray leaf spot. (Seminis).

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

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

Cherry Type Varieties

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

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

Reference

This information was gathered from results of tomato variety trials conducted during 2002 at locations specified in each table. Tomato variety evaluations were conducted in 2002 by the following University of Florida faculty:

D. N. Maynard. Gulf Coast Research & Education Center - Bradenton.
S. M. Olson. North Florida Research & Education Center - Quincy
P. J. Stoffella. Indian River Research & Education Center - Fort Pierce.

Table 1. Summary of University of Florida tomato variety trial results. Spring 2002.

Location	Variety	Total yield (ctn/acre)	Variety	Average fruit wt. (oz)
Bradenton	Fla. 7973	2967	RFT 0417	7.6
	Fla. 7926	2799	PX 150535	7.4
	HMX 1803	2787	XTM 0227	7.3
	BHN 591	2749	EX1405037	7.3
	BHN 586	2717[1]	Fla. 7926	7.2[2]
Fort Pierce	Florida 47	3528	Sanibel	6.4
	Fla. 7810	3286	Florida 47	6.4
	Agriset 761	3189	Fla. 7810	6.3
	Sanibel	3108	Florida 91	6.3
	Fla. 7973	3084[3]	Agriset 761	6.0[4]
Quincy	RFT 0849	2771	BHN 543	8.2
	BHN 640	2695	SVR 1432427	7.9
	SVR 1432427	2641	Sunpac	7.6
	BHN 444	2633	BHN 444	7.5
	BHN 577	2496[5]	Fla. 7973	7.5[6]

[1]19 other entries had yields similar to BHN 586.
[2]18 other entries had fruit weight similar to PX 150535.
[3]2 other entries had yields similar to Fla. 7973.
[4]2 other entries had fruit weight similar to Agriset 761.
[5]13 other entries had yields similar to BHN 577.
[6]14 other entries had fruit weight similar to Fla. 7973.

Seed Sources:
Agrisales: Agriset 761.
BHN: BHN 444, BHN 543, BHN 577, BHN 586, BHN 591, BHN 640.
Harris Moran: HMX 1803.
Seminis: Florida 47, Florida 91, Sanibel, Sunpac, PX 150535, EX 1405037, SVR 1432427.
Sakata: XTM 0227
Syngenta: RFT 0417, RFT 0849
University of Florida: Fla. 7810, Fla. 7926, Fla. 7973.

Table 2. Summary of University of Florida tomato variety trial results. Fall 2002.

Location	Variety	Total yield (ctn/acre)	Variety	Average fruit wt. (oz)
Bradenton	Solar Fire	1480	XTM 0231	6.9
	Solar Set	1461	Florida 91	6.9
	XTM 0231	1389	HMX 1803	6.8
	Lucky 13	1387	BHN 650	6.8
	Fla. 7885 B	1357[1]	XTM 0227	6.7[2]
Fort Pierce	Fla. 7810	1697	Florida 47	5.1
	Fla. 7885 B	827	Solar Set	5.0
	Florida 47	781	Florida 91	4.9
	Florida 91	630	Fla. 7810	4.9
	Solar Fire	565[3]	Fla. 7885 B	4.8[4]
Quincy	Solar Fire	1641	Solar Fire	6.4
	Fla. 7885 B	1548	Fla. 7885 B	6.3
	Solar Set	1398	XTM 0227	6.2
	XTM 0230	1321	BHN 640	6.2
	SVR 145037	1308[5]	Fla. 7810	6.1[6]

[1] 14 other entries had yields similar to Fla. 7885 B.
[2] 11 other entries had fruit weight similar to XTM 0227.
[3] 2 other entries had yields similar to Solar Fire.
[4] 2 other entries had fruit weight similar to Fla. 7885 B.
[5] 17 other entries had yields similar to SVR 145037.
[6] 11 other entries had fruit weight similar to Fla. 7810.

Seed Sources:
Agrisales: Lucky 13
BHN: BHN 640, BHN 650.
Harris Moran: HMX 1803.
Sakata: XTM 0227, XTM 0230, XTM 0231.
Seminis: Florida 47, Florida 91, Sanibel, Solar Set, SVR 1405037.
University of Florida: Solar Fire, Fla.7810, Fla. 7885 B.

Water Management For Tomato

Eric Simonne, *Horticultural Sciences Department, UF, Gainesville*

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

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

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

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

Tomato water requirement. Tomato water requirement (ETc) depends on stage of growth, and evaporative demand. ETc can be estimated by adjusting reference evapotranspiration (ETo) with a correction factor call crop factor (Kc; equation [1]). Because different methods exist for estimating ETo, it is very important to use Kc coefficients which were derived using the same ETo estimation method as will be used to determine ETc. Also, Kc values for the appropriate stage of growth and production system (Table 2) must be used.

By definition, ETo represents the water use from a uniform green cover surface, actively growing, and well watered (such as a turf or grass covered area). ETo can be measured on-farm using a small weather station. When daily ETo data are not available, historical daily averages of Penman-method ETo can be used (Table 3). However, these long-term averages are provided as guidelines since actual values may fluctuate by as much as 25%, either above the average on hotter and drier than normal days, or below the average on cooler or more overcast days than normal. As a result, SWT or soil moisture should be monitored in the field.

Eq. [1]

Crop water requirement = Crop coefficient x Reference evapotranspiration

$$ETc = Kc \times ETo$$

Tomato irrigation requirement (IR). Irrigation systems are generally rated with respect to application efficiency (Ea), which is the fraction of the water that has been applied by the irrigation system and that is available to the plant for use. In general, Ea is 60-80% for overhead irrigation, 20-70% for seepage irrigation, and 90-95% for drip irrigation. Applied water that is not available to the plant may have been lost from the crop root zone through evaporation or wind drifts of spray droplets, leaks in the pipe system, surface runoff, subsurface runoff, or deep percolation within the irrigated area. Tomato IR are determined by dividing the desired amount of water to provide to the plant (ETc), by Ea as a decimal fraction (Eq. [2]).

Eq. [2]

Irrigation requirement = Crop water requirement / Application efficiency

$$IR = ETc/Ea$$

In areas where real-time weather information is not available, growers use the '1,000 gal/acre/day/string' rule for drip-irrigated, winter production. As the tomato plants grow from 1 to 4 strings, the daily irrigation volumes increase from 1,000 gal/acre/day to 4,000 gal/acre/day. On 6-ft centers, this corresponds to 15 gal/100lbf/ day and 60 gal/100lbf/day for 1 and 4 strings, respectively.

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

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

It is necessary to monitor SWT at two soil depths when tensiometers are used. A shallow 6-in depth is useful at the beginning of the season when tomato roots are near that depth. A deeper 12-in depth is used to monitor SWT during the rest of the season. Comparing SWT at both depths is useful to understand the dynamics of soil moisture. When both SWT are within the 4-8 cb range (close to field capacity), this means that moisture is plentiful in the rooting zone. This may happen after a large rain, or when tomato water use is less than irrigation applied. When the 6-in SWT increases (from 4-8 cb to 10-15cb) while SWT at 12-in remains within 4-8, the upper part of the soil is drying, and it is time to irrigate. If the 6-in SWT continues to raise (above 25cb), a water stress will result; plants will wilt, and yields will be reduced. This should not happen under adequate water management.

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

Times domain reflectometry (TDR) is not a new method for measuring soil moisture but its use in vegetable production has been limited in the past. The recent availability of inexpensive equipment ($500 to $700/unit) has increased the potential of this method to become practical for tomato growers. A TDR unit is comprised of three parts: a display unit, a sensor, and two rods. Rods may be 4 inches or 8 inches in length based on the depth of the soil. Long rods may be used in all the sandy soils of Florida, while the short rods may be used with the gravelly soils of Miami-Dade county.

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

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

Guidelines for splitting irrigation. For sandy soils, a one square foot vertical section of a 100-ft long raised bed can hold approximately 24 to 30 gallons of water (Table 4). When drip irrigation is used, lateral water movement seldom exceeds 6 to 8 inches on each side of the drip tape (12 to 16 inches wetted width). When the volume of an irrigation exceeds the values in table 4, then irrigation should be split. Splitting will not only reduce nutrient leaching, but will also increase tomato quality by ensuring a more continuous water supply. Uneven water supply may result in fruit cracking.

Units for measuring irrigation water. When overhead and seepage irrigation were the dominant methods of irrigation, acre-inches or vertical amounts of water were used as units for irrigations recommendations. There are 27,150 gallons in one acre-inch; thus, total volume was calculated by multiplying the recommendation expressed in acre-inch by 27,150. This unit reflected quite well the fact that the entire field was wetted.

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

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

1. In the 2-acre field, there are 14,520 feet of bed (2 x 45,560/6). Because of the alleys, only 6/8 of the field is actually planted. So, the field actually contains 10,890 feet of bed (14,520x 6/8).

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

3. The drip tape flow rate is 0.30 gallons/hr/emitter which is equivalent to 30 gallons/hr/100feet. It will take 1 hour to apply 30 gallons/100ft, 2 hours to apply 60 gallons/100ft, and 2 ½ hours to apply 75 gallons. The total volume applied will be 8,168 gallons/2-acre (75 x 108.9).

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

Water Management Level	Rating	Irrigation scheduling method
0	None	Guessing (irrigate whenever)
1	Very low	Using the 'feel and see' method
2	Low	Using systematic irrigation (example: 2 hrs every day)
3	Intermediate	Using a soil moisture measuring tool to start irrigation
4	Advanced	Using a soil moisture measuring tool to schedule irrigation and apply amounts based on a budgeting procedures
5	Recommended	Using together a water use estimate based on tomato plant stage of growth, a measurement of soil water moisture, and a guideline for splitting irrigation

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

Tomato Growth Stage	Bare Ground, Overhead Irrigated	Plasticulture
1	0.20 to 0.40	0.30
2	0.20 to 0.40	0.40
3	1.15	0.90
4	1.15	0.90
5	1.00	0.75

[z] Actual values will vary with time of planting, length of growing season and other site-specific factors. Kc values should be used with ETo values in Table 2 to estimated crop evapotranspiration (ETc)

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

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

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

Table 4. Estimated maximum water application (in gallons per acre and in gallons/100lfb) in one irrigation event for tomato grown on 6-ft centers (7,260 linear bed feet per acre) on sandy soil (available water holding capacity 0.75 in/ ft and 50% soil water depletion). Split irrigations may be required during peak water requirement.

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

Fertilizer And Nutrient Management For Tomato

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

Calibrated Soil Test: Taking the Guesswork Out of Fertilization

Prior to each cropping season, soil tests should be conducted to determine fertilizer needs and eventual pH adjustments. Obtain 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, and extractants suitable to Florida soils. When used with the percent sufficiency philosophy, routine soil testing helps adjust fertilizer applications to plant needs and target yields. In addition, the use of the routine calibrated soil test reduces the risk of over-fertilization. Over fertilization reduces fertilizer efficiency and increases the risk of groundwater pollution. Systematic use of fertilizer without a soil test may also result in crop damage from salt injury.

The crop nutrient requirements of nitrogen, phosphorus, and potassium (designated in fertilizers as $N\text{-}P_2O_5\text{-}K_2O$) represent the optimum amounts of these nutrients needed for maximum tomato production (Table 1). Fertilizer rates are provided on a per-acre basis for tomato produced on 6-ft centers. Under these conditions, there are 7,260 linear feet of tomato row in an acre. When different row spacings are used or when a significant number of drive rows are left unplanted, it is necessary to adjust fertilizer application accordingly.

Fertilizer rates can be simply and accurately adjusted to row spacings other than the standard spacing (6-ft centers) by expressing the recommended rates on a 100 linear bed feet (lbf) basis, rather than on a real-estate acre basis. For example, in a 1-acre tomato field planted on 7-ft centers with one drive row every six rows, there are only 5,333 lbf (6/7 x 43,560 / 7). If the recommendation is to inject 10 lbs of N per acre (standard spacing), this becomes 10 lbs of N/7,260 lbf or 0.14lbs N/100 lbf. Since there are 5,333 lbf/acre in this example, then the adjusted rate for this situation is 7.46 lbs N/acre (0.14 x 53.33). In other words, an injection of 10 lbs of N to 7,260 lbf is accomplished by injecting 7.46 lbs of N to 5,333 lbf.

Liming

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

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

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

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

Fertilizer-related Physiological Disorders

Blossom-End Rot. At certain times, growers have problems with blossom-end-rot, especially on the first 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 occurs with the water (transpiration) stream. Thus, Ca moves preferentially to the leaves. As a maturing fruit is not a transpiring organ, most of the Ca is deposited during early fruit growth.

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

Factors that impair the ability of tomato plants to obtain water will increase the risk of BER. These factors include damaged roots from flooding, mechanical damage or nematodes, clogged drip emitters, inadequate water applications, alternating dry-wet periods, and even prolonged overcast periods. Other causes for BER include high fertilizer rates, especially potassium and nitrogen. High total fertilizer increases the salt content and osmotic potential in the soil reducing the ability of roots to obtain water, and high N increases leaf and shoot growth to which Ca preferentially moves, by-passing fruit.

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

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

Micronutrients. For virgin, acidic sandy soils, or sandy soils where a proven need exists, a general guide for fertilization is the addition of micronutrients (in 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 from the suggested literature list.

Properly diagnosed micronutrient deficiencies can often be corrected by foliar applications of the specific micronutrient. For most micronutrients, a very fine line exists between sufficiency and toxicity. Foliar application of major nutrients (nitrogen, phosphorus, or potassium) has not been shown to be beneficial where proper soil fertility is present. For more information on foliar micronutrient fertilization of tomatoes, consult the Commercial Vegetable Fertilization Guide, Circular 225E.

Fertilizer Application

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

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

2. Application of "starter" fertilizer or "in-bed" mix. This should comprise only 10 to 20 percent of the total nitrogen and potassium seasonal requirements and all of the needed phosphorus and micronutrients. Starter fertilizer can be broadcast over the entire area prior to bedding and then incorporated. During bedding, the fertilizer will be gathered into the bed area. An alternative is to use a "modified broadcast" technique for systems with wide bed spacings. Use of modified broadcast or banding techniques can increase phosphorus and micronutrient efficiencies, especially on alkaline (basic) soils.

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

4. Application of remaining fertilizer. The remaining 80 to 90 percent of the nitrogen and potassium is placed in narrow bands 9 to 10 inches to each side of the plant row in furrows. The fertilizer should be placed deep enough in the grooves for it to be in contact with moist bed soil. Bed presses are modified to provide the groove. Only water-soluble nutrient sources should be used for the banded fertilizer. A mixture of potassium nitrate (or potassium sulfate or potassium chloride), calcium nitrate, and ammonium nitrate has proven successful.

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/or 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 (see the water management for tomato production article for more information).

Mulched culture with overhead irrigation. For 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. Due to a low water and nutrient efficiency, this production method should be avoided and replaced with drip irrigation.

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

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

Suggested schedules for nutrient injections 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.

Sources of N-P_2O_5-K_2O. About 30 to 50 percent of the total applied nitrogen should be in the nitrate form for soil treated with multi-purpose fumigants and for plantings in cool soil. Controlled-release nitrogen sources may be used to supply a portion of the nitrogen requirement. One-third of the total required nitrogen can be supplied from sulfur-coated urea (SCU), isobutylidene diurea (IBDU), or polymer-coated urea (PCU) fertilizers incorporated in the bed. Nitrogen from natural organics and most controlled-release materials should be considered ammoniacal nitrogen when calculating the total amount of ammoniacal nitrogen applied.

Normal superphosphate and triple superphosphate are recommended for phosphorus needs. Both contribute calcium and normal superphosphate contributes sulfur. All sources of potassium can be used for tomatoes. Potassium sulfate, sodium-potassium nitrate, potassium nitrate, potassium chloride, monopotassium phosphate, and potassium-magnesium sulfate are all good K sources. If the soil test predicted amounts of K_2O are applied, then there should be no concern for the K source or its associated salt index.

Sap Test and Tissue Analyses

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

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

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

Supplemental Fertilizer Applications

In practice, supplemental fertilizer applications allow vegetable growers to numerically apply fertilizer rates higher than the standard IFAS recommended rates when warranted by growing conditions. The two main growing conditions that may require supplemental fertilizer applications are leaching rains and extended harvest periods. Applying additional fertilizer under the following three circumstances is part of the current IFAS fertilizer recommendations. Supplemental N and K fertilizer applications may be made under three circumstances:

1. For tomato crops grown with or without plastic mulch and with seepage irrigation, a 30 lbs/acre of N and /or 20 lbs/acre of K_2O supplemental application is allowed after a leaching rain. A leaching rain occurs when it rains at least 3 inches in 3 days, or 4 inches in 7 days. In this case, supplemental fertilizer application may be done using a fertilizer wheel.

2. For tomato grown with drip irrigation and one of the IFAS recommended irrigation scheduling methods, a supplemental fertilizer application is allowed when nutrient levels in the leaf or in the petiole fall below the sufficiency ranges. In this case, the supplemental amount allowed is 2.5 lbs/A/day for N and/or 3.0 lbs/A/day for K_2O for one week.

3. Supplemental fertilizer applications are allowed when, for economical reasons, the harvest period has to be longer than the typical harvest period. When the results of tissue analysis and/or petiole testing are below the sufficiency ranges, a supplemental 30 lbs/acre N and/or 20 lbs/acre of K_2O may be made for each additional harvest for production with seep irrigation. For drip-irrigated tomato, the supplemental fertilizer application is 2.5 lbs/A/day for N and/or 3.0 lbs/A/day for K_2O until the next harvest. A new leaf analysis and/or petiole analysis is required to document the need for additional fertilizer application for each additional harvest.

Levels of Nutrient Management for Tomato Production

Based on the growing situation and the level of adoption of the tools and techniques described above, different levels of nutrient management exist for tomato production in Florida. Successful production requires management levels of 3 or above (Table 5).

Suggested Literature

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(tables 1-5 on following pages)

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

		Nutrient requirements	Supplemental applications[z]	
Soil type	Number of expected harvests	lbs/A[y] N-P_2O_5-K_2O	lbs/A N-P_2O_5-K_2O	Number of applications
Mineral	2-3	200-150-225	30-0-20	0-2

[z] In case of incidental flood, sidedressing to replenish nitrogen and potassium can be accomplished by the use of a liquid fertilizer injection wheel.
[y] Approximately 7,200 linear bed feet of crop per acre (43,560 square feet); based on Mehlich 1 soil tests results.

Table 2. Schedules for N and K_2O injection for mulched tomato on soils testing low in K.

Crop development		Injection (lb/A/day)[z]	
stage	weeks	N	K_2O
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

[z] Total nutrients applied are 200 lb N and 225 lb K_2O per acre (7,260 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 weeks of injection can be reduced. IFAS recommendations also allow for supplemental fertilizer applications after a leaching rain, when plant nutritional status is low, or with extended harvest schedules.

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

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

[z]MRM=Most recently matured leaf.

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

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

Table 5. Progressive levels of nutrient management for tomato production.[z]

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

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

Weed Control in Tomato

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

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

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

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

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

Use of rye as a windbreak has become a common practice in the spring; however, in some cases, adverse effects have resulted. If undesirable insects such as thrips 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 then others and herbicide labels may specify a minimum active ingredient rate for the adjuvant in the spray mix. Before selecting an adjuvant, refer to the herbicide label to determine the adjuvant specifications.

Postharvest Vine Dessication

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

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

Chemical Weed Controls: tomatoes

Herbicide	Labeled Crops	Time of Application to Crop	Rate (lbs. A.I./Acre) Mineral	Muck
Clethodem (Select 2 EC)	Tomatoes	Postemergence	0.9-.125	—
Remarks: Postemergence control of actively growing annual grasses. Apply at 6-8 fl oz/acre. Use high rate under heavy grass pressure and/or when grasses are at maximum height. Always use a crop oil concentrate at 1% v/v in the finished spray volume. Do not apply within 20 days of tomato harvest.				
DCPA (Dacthal W-75)	Established Tomatoes	Posttransplanting after crop establishment (non-mulched)	6.0-8.0	—
Remarks: Controls germinating annuals. Apply to weed-free soil 6 to 8 weeks after crop is established and growing rapidly or to moist soil in row middles after crop establishment. Note label precautions of replanting non-registered crops within 8 months.				
Diquat (Reglone)	Tomato Vine Burndown	After final harvest	0.375	—
Remarks: Special Local Needs (24c) label for use for burndown of tomato vines after final harvest. Applications of 1.5 pts. material per acre in 60 to 120 gals. of water is labeled. Add 16 to 32 oz. of a non-ionic spreader per 100 gals. of spray mix. Thorough coverage of vines is required to insure maximum burndown.				
Diquat (Reglone)	Tomato	Pretransplant Postemergence directed-shielded in row middles	0.5	—
Remarks: Diquat can be applied as a post-directed application to row middles either prior to transplanting or as a post-directed hooded spray application to row middles when transplants are well established. Apply 1 qt of Diquat in 20-50 gallons of water per treated acre when weeds are 2-4 inches in height. Do not exceed 25 psi spray pressure. A maximum of 2 applications can be made during the growing season. Add 2 pts non-ionic surfactant per 100 gals spray mix. Diquat will be inactivated if muddy or dirty water is used in spray mix. A 30 day PHI is in effect. Label is a special local needs label for Florida only.				
Halosulfuron (Sandea)	Tomatoes	Pre-transplant Postemerglance Row middles	0.024 - 0.036	
Remarks: A total of 2 applications of Sandea may be applied as either one pre-transplant soil surface treatment at 0.5-0.75 oz. product; one over-the-top application 14 days after transplanting at 0.5-0.75 oz. product; and/or postemergence applications(s) of up to 1 oz. product (0.047 lb ai) to row middles. A 30-day PHI will be observed. For postemergence and row middle applications, a surfactant should be added to the spray mix.				
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.				
S-Metolachlor (Dual Magnum)	Tomatoes	Pretransplant Row middles	1.0 - 1.3	—

Herbicide	Labeled Crops	Time of Application to Crop	Rate (lbs. AI./Acre) Mineral	Muck
Remarks: Apply Dual Magnum preplant non-incorporated to the top of a pressed bed as the last step prior to laying plastic. May also be used to treat row-middles. Label rates are 1.0-1.33 pts/A if organic matter is less than 3%. Research has shown that the 1.33 pt may be too high in some Florida soils except in row middles. Good results have been seen at 0.6 pts to 1.0 pints especially in tank mix situations under mulch. Use on a trial basis.				
Metribuzin (Sencor DF) (Sencor 4)	Tomatoes	Postemergence Posttransplanting after establishment	0.25 - 0.5	---
Remarks: Controls small emerged weeds after transplants are established direct-seeded plants reach 5 to 6 true leaf stage. Apply in single or multiple applications with a minimum of 14 days between treatments and a maximum of 1.0 lb ai/acre within a crop season. Avoid applications for 3 days following cool, wet or cloudy weather to reduce possible crop injury.				
Metribuzin (Sencor DF) (Sencor 4)	Tomatoes	Directed spray in row middles	0.25 - 1.0	---
Remarks: Apply in single or multiple applications with a minimum of 14 days between treatments and maximum of 1.0 lb ai/acre within crop season. Avoid applications for 3 days following cool, wet or cloudy weather to reduce possible crop injury. Label states control of many annual grasses and broadleaf weeds including, lambsquarter, fall panicum, amaranthus sp., Florida pusley, common ragweed, sicklepod, and spotted spurge.				
Napropamid (Devrinol 50DF)	Tomatoes	Preplant incorporated	1.0 - 2.0	---
Remarks: Apply to well worked soil that is dry enough to permit thorough incorporation to a depth of 1 to 2 inches. Incorporate same day as applied. For direct-seeded or transplanted tomatoes.				
Napropamid (Devrinol 50DF)	Tomatoes	Surface treatment	2.0	---
Remarks: Controls germinating annuals. Apply to bed tops after bedding but before plastic application. Rainfall or overhead-irrigate sufficient to wet soil 1 inch in depth should follow treatment within 24 hours. May be applied to row middles between mulched beds. A special Local Needs 24(c) Label for Florida. Label states control of weeds including Texas panicum, pigweed, purslane, Florida pusley, and signalgrass.				
Oxyfluorfen (Goal 2XL)	Tomatoes	Fallow bed	0.25 - 0.5	
Remarks: Must have a 30 day treatment-planting interval. Apply as a preemergence broadcast or banded treatment at 1-2 pt/A to preformed beds. Mulch may be applied any time during the 30-day interval.				
Paraquat (Gramoxone Extra) (Gramoxone Max)	Tomatoes	Premergence, Pretransplant	0.62 - 0.94	---
Remarks: Controls emerged weeds. Use a non-ionic spreader and thoroughly wet weed foliage.				
Paraquat (Gramoxone Extra) (Gramoxone Max)	Tomatoes	Post directed spray in row middle	0.47	---
Remarks: Controls emerged weeds. Direct spray over emerged weeds 1 to 6 inches tall in row middles between mulched beds. Use a non-ionic spreader. Use low pressure and shields to control drift. Do not apply more than 3 times per season.				
Paraquat	Tomato	Postharvest		

Continued...

Chemical Weed Controls: tomatoes (continued)

Herbicide	Labeled Crops	Time of Application to Crop	Rate (lbs. AI./Acre) Mineral	Muck
(Gramoxone Extra) (Gramoxone Extra)		dessication	0.62-0.93 0.46-0.62	
Remarks: Broadcast spry over the top of plants after last harvest. Label for Boa states use of 1.5-2.0 pts while Gramoxone label is from 2-3 pts. Use a nonionic surfactant at 1 pt/100 gals to 1 qt/100 gals spray solution. Thorough coverage is required to ensure maximum herbicide burndown. Do not use treated crop for human or animal consumption.				
Pelargonic Acid (Scythe)	Fruiting Vegetable (tomato)	Preplant Preemergence Directed-Shielded	3-10% V/V	---
Remarks: Product is a contact, nonselective, foliar applied herbicide. There is no residual control. May be tank mixed with several soil residual compounds. Consult the label for rates. Has a greenhouse and growth structure label.				
Rimsulfuron (Matrix)	Tomato	Posttransplant and directed-row middles	0.25 - 0.5 oz.	---
Remarks: Matrix may be applied preemergence (seeded), postemergence, posttransplant and applied directed to row middles. May be applied at 1-2 oz. product (0.25-0.5 oz ai) in single or sequential applications. A maximum of 4 oz. product per acre per year may be applied. For post (weed) applications, use a non-ionic surfactant at a rate of 0.25% v/v. for preemergence (weed) control, Matrix must be activated in the soil with sprinkler irrigation or rainfall. Check crop rotational guidelines on label.				
Sethoxydim (Poast)	Tomatoes	Postemergence	0.188 - 0.28	---
Remarks: Controls actively growing grass weeds. A total of 42 pts. product per acre may be applied in one season. Do not apply within 20 days of harvest. Apply in 5 to 20 gallons of water adding 2 pts. of oil concentrate per acre. Unsatisfactory results may occur if applied to grasses under stress. Use 0.188 lb ai (1 pt.) to seedling grasses and up to 0.28 lb ai (12 pts.) to perennial grasses emerging from rhizomes etc. Consult label for grass species and growth stage for best control.				
Trifluralin (Treflan HFP) (Treflan TR-10) (Trilin) (Trilin 10G) (Trifluralin 480) (Trifluralin 4EC) (Trifluralin HF)	Tomatoes (except Dade County)	Pretransplant incorporated	0.5	---
Remarks: Controls germinating annuals. Incorporate 4 inches or less within 8 hours of application. Results in Florida are erratic on soils with low organic matter and clay contents. Note label precautions of planting non-registered crops within 5 months. Do not apply after transplanting.				
Trifluralin (Treflan HFP) (Treflan TR-10) (Trilin) (Trilin 10G) (Trifluralin 480) (Trifluralin 4EC) (Trifluralin HF)	Direct-Seeded tomatoes (except Dade County)	Post directed	0.5	---
Remarks: For direct-seeded tomatoes, apply at blocking or thinning as a directed spray to the soil between the rows and incorporate.				

Chemical Disease Management for Tomato. Tom Kucharek, Plant Pathology Department, Gainesville

Chemical	Maximum Rate/Acre/ Application	Maximum Rate/Acre/ Crop	Minimum Days to Harvest	Pertinent Diseases	Select Remarks
**For best possible chemical control of bacterial spot with a copper fungicide, a maneb or mancozeb fungicide must be tank-mixed with the copper fungicide in the spray tank.					
Ridomil Gold EC	2 pts/trtd acre	3 pts/trtd acre		Pythium diseases	See label for use at and after planting.
Kocide 101, Blue Shield or Champion WP's	4 lbs		1	Bacterial spot Bacterial speck	
Kocide LF, Blue Shield 3L, or Champion FL's	5 a pts		1	Bacterial spot Bacterial Speck	
Kocide 2000 53.8DF	3 lbs.		1	Bacterial spot Bacterial speck	
Champ 4.6 or Kocide 4.5 LF FLs	2 b pts		1	Bacterial spot Bacterial speck	
Basicop or Basic Copper 53	4 lbs		1	Bacterial spot	
Cuprofix Disperss 36.9 DF	6 lbs		1	Bacterial spot Bacterial speck	
Cuprofix Disperss MZ Disperss	7.25 lbs		5	Bacterial spot Bacterial speck	See label for avoiding excess use of mancozeb
Manex 4F	2.4 qts	16.8 qts	5	Early & late blights, Gray leaf spot, Bacterial spot[1]	Field & greenhouse use
Kocide or Blueshield DF's	4 lbs		2	Bacterial spot Bacterial speck	
Maneb 80 WP	3 lbs	21 lbs	5	Same as Manex 4F	Field & greenhouse use
Dithane F45 or Manex II 4 FLs	2.4 pts	16.8 qts	5	Same as Manex 4F	
Dithane, Penncozeb or Manzate DF's	3 lbs	21 lbs	5	Same as Manex 4F	
Echo 720 6 FL	3 pts	20 pts	0	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 4F	Field & greenhouse use
Echo 90 DF	2.3 lbs	16.7 lbs	0	Early and late blight, Gray leaf spot, Target spot	Use higher rates at fruit set and lower rates before fruit set.

Chemical	Maximum Rate/Acre/		Minimum Days to Harvest	Pertinent Diseases	Select Remarks
	Application	Crop			
Bravo 500, Echo 500, or GK Chloro Gold 4.17 FL's				Gray leaf spot, Target spot	set and lower rates before fruit set.
Ridomil Bravo 81W	3 lbs		2	Early and late blight, Gray leaf spot, Target spot	Limit is 4 appl/crop
Ridomil MZ68WP[2]	2 lbs	8 lbs	5	Late blight	Limit is 3 appl/crop
JMS Stylet Oil	3 qts		NTL	Potato Virus Y, Tobacco Etch Virus	See label for specific info on appl. technique (e.g. use of 400 psi spray pressure)
Ridomil/Copper 70W	2.0 lbs	See label	14	Late blight	Limit is 3 appl/crop.
Sulfur			1	Powdery mildew	
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.
Bravo Ultrex 82.5 WDG	2.75 lbs	18.3 lbs	0	Early and Late blights, Gray leafs pot, Target spot, Botrytis, Rhizoctonia fruit rot	Use higher rates at fruit set.
Bravo Weather Stik 6 FL	2 3/4 pts	20 pts	0	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	Do not make more than 2 sequential appl. with Quadris. Limit is 6 appl. Alternate with compounds other than Cabrio
Cabrio 2.09 FL	16 fl oz	96 fl oz	0	Same as Quadris	Limit is 6 appl./crop. Alternate with compounds other than Quadris.
Botran 75W	1 lb	4 lbs	10	Botrytis	Greenhouse tomato only. Limit is 4 applications. Seedlings or newly set transplants may be injured.
Gavel 75 DF	2.0 lbs	16 lbs	5	Buckeye rot, Early blight, gray leaf spot, late blight, & leaf mold	
Nova 40 W	4 oz	1.24 lbs	0	Powdery mildew	Note that a 30 day plant back restriction exists.

Chemical	Maximum Rate/Acre/		Minimum Days to Harvest	Pertinent Diseases	Select Remarks
	Application	Crop			
Exotherm Termil	1 can/1000 sq. ft.		2	Botrytis, Leaf mold, Late & Early blights, Gray leaf spot	Greenhouse use only. Allow can to remain overnight and then ventilate. Do not use when greenhouse temperature is above 75F.
Actigard 50 WG	1/3-3/4 oz	4 oz	14	Bacterial spot Bacterial Speck	Do not use highest labeled rate in early sprays to avoid a delayed onset of harvest. Begin with 1/3 oz rate and progressively increase the rate as instructed on the label. Limit is 6 appl./crop/season. Do not exceed a concentration of _ oz/100 gal. of spray mix. Begin spray program before occurrence of disease.
ManKocide 61.1 DF	5.3 lbs	112 lbs	5	Bacterial spot Bacterial speck	

[1]When tank mixed with a copper fungicide.

[2]Do not exceed limits of mancozeb active ingredient when using more than one product (Dithane, Penncozeb, Manex II, or Manzate.)

Selected insecticides approved for use on insects attacking tomatoes. S.E. Webb, Entomology and Nematology Department, UF, Gainesville.				
Chemical Name	**REI (hours)**	**Days to Harvest**	**Insects**	**Notes**
Admire 2F (imidacloprid)	12	21	aphids, Colorado potato beetle, flea beetles, thrips (foliar feeding thrips only), whiteflies	Most effective if applied to soil at transplanting.
***Agri-Mek 0.15EC** (abamectin)	12	7	Colorado potato beetle, *Liriomyza* leafminers, spider mite, tomato pinworms, tomato russet mite	Do not make more than 2 sequential applications. Do not apply more than 0.056 lb ai per acre per season.
***Ambush 2EC, 25W** (permethrin)	12	up to day of harvest	beet armyworm, cabbage looper, Colorado potato beetle, granulate cutworms, hornworms, southern armyworm, tomato fruitworm, tomato pinworm, vegetable leafminer	Do not apply more than 1.2 lb active ingredient per acre per season. Not recommended for control of vegetable leafminer in Florida.
***Asana XL 0.66EC** (esfenvalerate)	12	1	beet armyworm (aids in control), cabbage looper, Colorado potato beetle, cutworms, flea beetles, grasshoppers, hornworms, potato aphid, southern armyworm, tomato fruitworm, tomato pinworm, whiteflies, yellowstriped armyworm	Not recommended for control of vegetable leafminer in Florida. Do not apply more than 0.5 lb ai per acre per season.
Assail 70WP (acetamiprid)	12	7	aphids, Colorado potato beetle, whiteflies	Begin applications for whiteflies when first adults are noticed. Do not apply more than 4 times per season or apply more often than every 7 days. Do not apply to a crop that has been already treated with imidacloprid or thiamethoxam at planting.
Avaunt (indoxacarb)	12	3	beet armyworm, hornworms, loopers, southern armyworm, tomato fruitworm, tomato pinworm	Do not apply more than 14 ounces of product per acre per crop. Minimum spray interval is 5 days.

Continued...

Azatin XL Plus (azadirachtin)	4	0	aphids (suppression), armyworms, beetles, caterpillars, cutworms, leafhoppers, leafminers, loopers, thrips, whiteflies	Use with oil for leafminers. Insect growth regulator and feeding deterrent.
Bt (*Bacillus thuringiensis*) Agree, Biobit HP, Crymax, Dipel DF, Javelin WG, Lepinox WDG(1), Xentari	4 12(1)	see label	armyworms, cabbage looper, corn earworm, cutworms, hornworms, loopers, tomato fruitworm	
***Baythroid 2** (cyfluthrin)	12	0	beet armyworm (1), cabbage looper, Colorado potato beetle, dipterous leafminers, European corn borer, flea beetles, hornworms, potato aphid, southern armyworm (1), stink bugs, tomato fruitworm, tomato pinworm, variegated cutworm , western flower thrips, whitefly (2)	(1) lst and 2nd instars only (2) suppression Do not apply more than 0.26 lb ai per acre per season. Maximum number of applications: 6.
***Capture 2EC** (bifenthrin)	12	1	aphids, armyworms, corn earworm, cutworms, flea beetles, grasshoppers, mites, stink bug spp., tarnished plant bug, thrips, whiteflies	Make no more than 4 applications per season. Do not make applications less than 10 days apart.
Checkmate TPW, TPW-F (pheromone)	0	0	tomato pinworm	For mating disruption - See label.
Confirm 2F (tebufenozide)	4	7	armyworms, black cutworm, hornworms, loopers	Do not apply more than 1.0 lb ai per acre per season. Product is a slow-acting IGR and will not kill larvae immediately.
Courier (buprofezin)	12	7	whitefly nymphs	Apply when a threshold is reached of 5 nymphs per 10 leaflets from the middle of the plant. Product is a slow-acting IGR that will not kill nymphs immediately. No more than 2 applications per season. Allow at least 28 days between applications. See label for plantback restrictions.

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***Danitol 2.4 EC** (fenpropathrin)	24	3 days, or 7 if mixed with Monitor 4	beet armyworm, cabbage looper, fruitworms, potato aphid, silverleaf whitefly, stink bugs, thrips, tomato pinworm, twospotted spider mites, yellowstriped armyworm	Use alone for control of fruitworms, stink bugs, twospotted spider mites, and yellowstriped armyworms. Tank-mix with Monitor 4 for all others, especially whitefly. Do not apply more than 0.8 lb ai per acre per season. Do not tank mix with copper.
Dimethoate 4 EC, 2.67 EC (dimethoate)	48	7	aphids, leafhoppers, leafminers	Will not control organophosphate-resistant leafminers.
***Diazinon 4 E; *50 W; *14 G; *5 G** (diazinon)	24	1	**foliar application:** aphids, beet armyworm, banded cucumber beetle, *Drosophila*, fall armyworm, dipterous leafminers, southern armyworm **soil application at planting:** cutworms, mole crickets, wireworms	Will not control organophosphate-resistant leafminers. Do not apply more than five times per season.
Extinguish ((S)-methoprene)	4	0	fire ants	Slow-acting IGR (insect growth regulator). Best applied early spring and fall where crop will be grown. Colonies will be reduced after three weeks and eliminated after 8 to 10 weeks. This is the only fire ant bait labeled for use on cropland. May be applied by ground equipment or aerially.
Fulfill (pymetrozine)	12	0	green peach aphid, potato aphid, suppression of whiteflies	Do not make more than two applications. 24(c) label for growing transplants also.

Continued...

***Fury** (zeta-cypermethrin)	12	1	beet armyworm, cabbage looper, Colorado potato beetle, cutworms, fall armyworm, flea beetles, grasshoppers, green and brown stink bugs. hornworms, leafminers, leafhoppers, lygus bugs, plant bugs, southern armyworm, tobacco budworm, tomato fruitworm, tomato pinworm, true armyworm, yellowstriped armyworm. Aides in control of aphids, thrips and whiteflies.	Not recommended for vegetable leafminer in Florida. Do not make applications less than 7 days apart. Do not apply more than 0.3 lb ai per acre per season.
Kelthane MF 4 (dicofol)	12	2	mites	Do not apply more than twice a year or more than 1.6 pt. per season.
Knack IGR (pyriproxyfen)	12	14	immature whiteflies	Apply when a threshold is reached of 5 nymphs per 10 leaflets from the middle of the plant. Product is a slow-acting IGR that will not kill nymphs immediately. Make no more than two applications.
Kryocide 96 WP; Prokil Cryolite 96 (cryolite)	12	14	blister beetle, cabbage looper, Colorado potato beetle larvae, flea beetles, hornworms, tomato fruitworm, tomato pinworm	Minimum of 7 days between applications. Do not apply more than 64 lb. per acre per season.
***Lannate LV, *SP** (methomyl)	48	1	aphids, armyworms, beet armyworm, fall armyworm, hornworms, loopers, southern armyworm, tomato fruitworm, tomato pinworm, variegated cutworm	Do not make more than 16 applications per crop.
Malathion 5 EC, 57 EC, 8 EC (malathion)	12	1	aphids, *Drosophila*, mites	Can be used in greenhouse.
***Monitor 4EC** (methamidophos) [24(c) labels]	48	7	thrips (North Florida only), whiteflies(1)	(1) Use as tank mix with a pyrethroid for whitefly control. Do not apply more than 10 pt. per acre, or 18 pt. per acre in North Florida per season.
M-Pede 49% EC (Soap, insecticidal)	12	0	aphids, leafhoppers, mites, plant bugs, thrips, whiteflies	

Continued...

Neemix .25 (azadirachtin) **Neemix 4.5**	4 12	0 0	aphids, armyworms hornworms, psyllids, Colorado potato beetle, cutworms, leafminers, loopers, tomato fruitworm (corn earworm), tomato pinworm, whiteflies	
NoMate MEC TPW (pheromone)	0	0	tomato pinworm	For mating disruption - See label.
Phaser 3EC, 50 WP (endosulfan)	24	2	aphids, blister beetle, cabbage looper, Colorado potato beetle, flea beetles, hornworms, stink bugs, tomato fruitworm, tomato russet mite, whiteflies, yellowstriped armyworm	Do not exceed a maximum of 3.0 lb active ingredient per acre per year or apply more than 6 times. Can be used in greenhouse.
Platinum (thiamethoxam)	12	30	aphids, Colorado potato beetles, flea beetles, leafminers, whiteflies	Soil application. See label for rotational restrictions.
***Pounce 3.2 EC** (permethrin)	12	0	beet armyworm, cabbage looper, Colorado potato beetle, dipterous leafminers, granulate cutworm, hornworms, southern armyworm, tomato fruitworm, tomato pinworm	Do not apply to cherry or grape tomatoes (fruit less than 1 inch in diameter). Do not apply more than 1.2 lb ai per acre per season.
Provado 1.6F (imidacloprid)	12	0 - foliar	aphids, Colorado potato beetle, leafhoppers, whiteflies	Do not apply to crop that has been treated with imidacloprid or thiamethoxam at planting. Do not apply more than 18.75 oz per acre as foliar spray.
Pyrellin EC (pyrethrin + rotenone)	12	12 hours	aphids, Colorado potato beetle, cucumber beetles, flea beetles, flea hoppers, leafhoppers, leafminers, loopers, mites, plant bugs, stink bugs, thrips, vegetable weevil, whiteflies	
Sevin 80S; XLR; 4F (carbaryl)	12	3	Colorado potato beetle, cutworms, fall armyworm, flea beetles, lace bugs, leafhoppers, plant bugs, stink bugs**, thrips**, tomato fruitworm, tomato hornworm, tomato pinworm, sowbugs	**suppression Do not apply more than seven times.

Continued...

Sevin 5 Bait (carbaryl)	12	3	ants, crickets, cutworms, grasshoppers, mole crickets, sowbugs	
SpinTor 2SC (spinosad)	4	1	armyworms, Colorado potato beetle, flower thrips, hornworms, *Liriomyza* leafminers, loopers, *Thrips palmi*, tomato fruitworm, tomato pinworm	Do not apply to seedlings grown for transplant within a greenhouse or shadehouse. Leafminer and thrips control may be improved by adding an adjuvant. Do not apply more than three times in any 21 day period. Do not apply more than 29 oz. per acre per crop.
Spod-X LC (beet armyworm nuclear polyhedrosis virus)	4	0	beet armyworm	Treat when larvae are young (1st and 2nd instar). Follow label instructions for mixing. Use only non-chlorinated water at a pH near 7 for mixing.
Sulfur	24	see label	tomato russet mite	
***Telone C-35** (dichloropropene + chloropicrin)	5 days (See label)	preplant	garden centipedes (symphylans), wireworms	See supplemental label for restrictions in certain Florida counties.
Trigard (cyromazine)	12	0	Colorado potato beetle (suppression of), leafminers	No more than 6 applications per crop.
Ultra Fine Oil (oil, insecticidal)	4	0	aphids, beetle larvae, leafhoppers, leafminers, mites, thrips, whiteflies	Do not exceed four applications per season.
***Vydate L 2EC** (oxamyl)	48	3	aphids, Colorado potato beetle, leafminers (except *Liriomyza trifolii*), whiteflies (suppression only)	Do not apply more than 32 pt. per acre per season.
***Warrior** (lambda-cyhalothrin)	24	5	aphids(2), beet armyworm(1), cabbage looper, Colorado potato beetle, cutworms, fall armyworm(1), flea beetles, grasshoppers, hornworms, leafhoppers, leafminers(2), plant bugs, southern armyworm(1), stink bugs, tomato fruitworm, tomato pinworm, whiteflies(2), yellowstriped armyworm(1)	(1) for control of 1st and 2nd instars only. (2) suppression only Do not apply more than 0.36 lb ai per acre per season.

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

*** Restricted Use Only**

Nematicides Registered for Use in Florida Tomatoes

J. W. Noling, UF, IFAS, Extension Nematology, CREC, Lake Alfred

Row Application (6' row spacing - 36" bed)[4]					
Product	Broadcast (Rate)	Recommended Chisel Spacing	Chisels (per Row)	Rate/Acre	Rate/1000 Ft/Chisel
FUMIGANT NEMATICIDES					
Methyl Bromide[3]					
67-33	225-375 lb	12"	3	112-187 lbs	5.1 - 8.6 lb
Chloropicrin[1]	300-500 lb	12"	3	150-250 lbs	6.9 - 11.5 lb
Telone II[2]	9-12 gal	12"	3	4.5-9.0 gal	26 - 53 fl oz
Telone C-17	10.8-17.1 gal	12"	3	5.4-8.5 gal	31.8-50.2 fl oz
Telone C-35	13- 20.5 gal	12"	3	6.5-13 gal	22-45.4 fl oz
Metham Sodium	50-75 gal	5"	6	25 - 37.5 gal	56 - 111 fl oz
NON-FUMIGANT NEMATICIDES					
Vydate L - treat soil before or at planting with any other appropriate nematicide or a Vydate transplant water drench followed by Vydate foliar sprays at 7-14 day intervals through the season; do not apply within 7 days of harvest; refer to directions in appropriate "state labels", which must be in the hand of the user when applying pesticides under state registrations.					

1. If treated area is tarped, dosage may be reduced by 33%.
2. The manufacturer of Telone II, Telone C-17, and Telone C-35 has restricted use only on soils that have a relatively shallow hard pan or soil layer restrictive to downward water movement (such as a spodic horizon) within six feet of the ground surface and are capable of supporting seepage irrigation regardless of irrigation method employed. Higher label application rates are possible for fields with cyst-forming nematodes. Consult manufacturers label for 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 25, 2003, 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.