

1997 Florida Tomato Institute Proceedings

September 1997

Compiled By: C.S. Vavrina,
P.R. Gilreath and J.W. Noling



Citrus & Vegetable
MAGAZINE



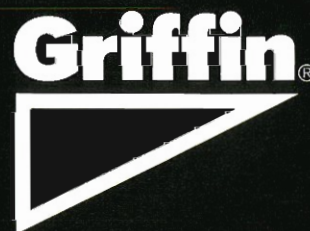
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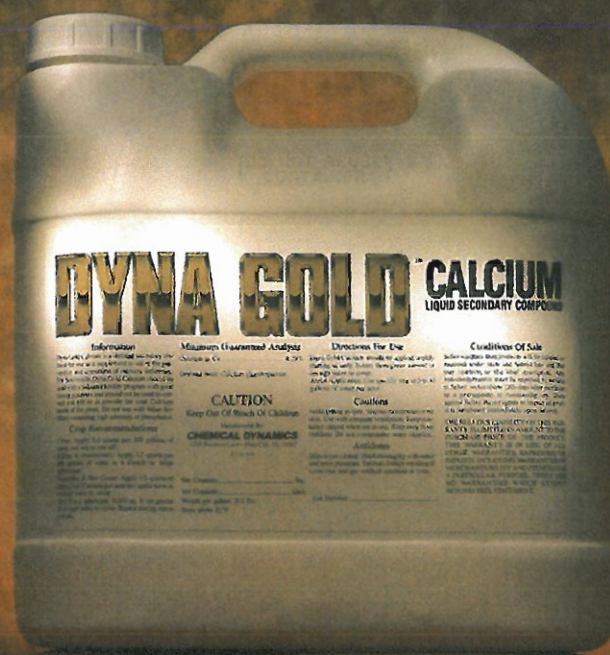


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Tomato Institute Program

Ritz Carlton Hotel • Naples, Florida • September 3, 1997

- 09:00 Introductions - C.S. Vavarina, SWFREC, Immokalee
- 09:10 Impressions of Mexico's Fresh Market Vegetable Agriculture, Pre and Post NAFTA - D. Cantliffe, UF, Gainesville, **Page 5**
- 09:40 The Future of Food Safety Regulations for the Fresh Produce Industry - D. Archer, UF Gainesville, (**paper not available**)
- 09:55 Plum Tomato Variety Evaluations - T. Howe, GCREC, Bradenton, **Page 7**
- 10:10 Heirloom Tomatoes - C. Vavrina, SWFREC, Immokalee, **Page 12**
- 10:25 Cluster Tomatoes - R Hochmuth, Suwannee REC, Live Oak, **Page 16**
- 10:40 Ethylene and Symptom Formation in Bacterial Speck and Spot Diseases - H. Klee, UF, Gainesville, **Page 20**
- 11:00 Gassing Green-Harvested Tomatoes for Optimal Quality - S. Sargent, UF, Gainesville, **Page 22**
- 11:15 Agricultural Weather Forecasting: What It Is, What It Isn't - R. Getz, Agricultural Weather Information Service, Inc., Auburn, AL, **Page 25**
- 11:30 - 1:00 LUNCH
- 01:00 Methylbromide and the Teap Report - D. Botts, FFVA, Orlando, (**paper not available**)
- 01:15 Alternatives to Methylbromide for Nematode Management - J. Noling, CREC, Lake Alfred, **Page 27**
- 01:30 Alternatives to Methylbromide for Soilborne Disease Management - D. Chellemi, USDA, Ft. Pierce, **Page 32**
- 01:45 Alternatives to Methylbromide for Weed Management - J. Gilreath, GCREC, Bradenton, **Page 34**
- 02:00 Alternatives to Methylbromide From A Plant Breeding Perspective - M. Barineau. Petoseed, Felda, **Page 36**
- 02:15 Current Situations With Gemini Viruses or What Will Blow in on the Next Hurricane? - J. Polston, GCREC, Bradenton, **Page 38**
- 02:30 The Late Blight Update - P. Weingartner, REC, Hastings, **Page 43**
- 02:45 Tomato Spotted Wilt Virus and Vector Update - S. Webb, CFREC, Sanford, (**paper not available**)
- 03:00 Silver Leaf White Fly Threshold Levels for Irregular Ripening in Tomato - D. Schuster, GCREC, Bradenton, **Page 47**
- 03:15 Bay Friendly Farming - Dade County Perspectives - P. Cockrell, Florida Farm Federation, Gainesville and M. Lamberts, Dade County Extension, Homestead, (**paper not available**)
- 03:30 Effect of N/K fertigation on Tomato Yield and Graywall in Dade County - J. Carranza and S. O'Hair, TREC, Homestead and G. Hochmuth, UF, Gainesville, **Page 53**
- 03:45 Phosphorus Nutrition for Tomato in Calcareous Soils - Y. Li and H. Bryan, TREC, Homestead, **Page 56**
- 04:00 Industry Updates (5 minute presentations)

ADJOURN

Appendix Tomato Control Guides, **Pages 65 - 92**

IMPRESSION OF WEST MEXICAN FRESH MARKET VEGETABLE AGRICULTURE PRE AND POST NAFTA (1982 - 1997)

Daniel J. Cantliffe

Professor and Chair

Horticultural Sciences Department

University of Florida, IFAS

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There are three areas in which dramatic change has taken place in Mexican vegetable agriculture during this period. Dramatic change has occurred in 1) outside financing, 2) technology, and 3) pesticide use. Other areas are trucking, roads and labor. With regard to the first area, financing, a tremendous input of dollars to finance large Mexican production operations has occurred. For example, internally, the Pulsar Group, which is part of ELM (owner of DNAP, Asgrow, Peto, and Royal Sluis Seed Companies), a tobacco company, has bought 50% interest in RB Packing. RB Packing runs operations in Culiacan, Baja and packinghouse operations in Nogales, Arizona. Changes include the conversion and expansion of these operations to modern production facilities, including improvements in packing houses, physical facilities, and in the current adoption of greenhouse production for vegetables. A second group, which was in Mexico before NAFTA, is Meyer Tomato Company out of California. Meyer has been using four growers, approximately 250 hectares per grower, which equates to somewhat over 1,000 hectares in tomatoes, each in a different location from Los Mochis to Culiacan. Each grower has separate packinghouse facilities. This equates to about 2500 acres of tomatoes. Meyer is using mature green tomatoes; he is one of the last of two growers in West Mexico to use mature green tomatoes. RB Packing uses ESL (extended shelf-life) tomatoes for vine ripe, where Meyer uses ESL tomatoes for mature green. A third group, and one which we did not visit but who has also given a like infusion of money into Mexico, is the Gargiulo/Monsanto Group.

The second area of change is related to technology. Many practices have changed over the last 5 years, most notably the use of ESL (extended shelf-life) tomatoes from Israel. Seeds of these varieties can cost in excess of \$10,000 - \$12,000 per kilogram. These varieties have allowed Mexican producers to ship vine-ripe tomatoes like the Florida producers ship mature-green tomatoes. Presently, Mexican producers are place-packing ESL tomatoes, however, their hope is to go to a 25-lb box wherein tomatoes are simply dumped into the box as are mature greens. The second most notable technological change is the use of drip-irrigation. Mexican producers in general do not use plastic mulch. This is because of the expense, and they also have not found any apparent yield or quality increases. It was also witnessed that most Mexican producers do not fumigate. This is because of the difficulties in application technology, expense, and lack of any observed benefits to fumigation. These (mulch and fumigation) are some management techniques they simply do not want to be bothered with and they see no need because of the large expanse of land from Los Mochis to Culiacan on which to grow tomatoes. This allows Mexican producers to use ordinary crop rotation techniques to abate nematode and pathogen build-up.

Improvements in all the packing houses have taken place, including use of modern design and equipment, color sorters, and the like. All of this is imported from a Texas manufacturer who is a major manufacturer for most of our U.S. packing house equipment. Dump tank technology has also improved, wherein chlorine is metered into the wash tanks on a constant basis daily.

The greatest revolution in Mexican agriculture apparently appears to be on the horizon. This is with the use of protective culture and greenhouse production of vegetables. All of the big producers told us that they were looking at this as their future; greenhouse production. They felt they could increase their yields dramatically per unit area, decrease their use of pesticides dramatically over the same unit area, and get the biggest benefit of all, a dramatic increase in product quality.

It is my opinion that because of the infusion of money, Mexican producers have been able to integrate more closely with world and global agricultural practices. All of the producers told us of their visits to the Netherlands, Spain, and Israel. It is from these sources that I believe they are looking at this most recent change into protected agriculture, because in all three areas, greenhouse production is applied for the majority of their export-marketed vegetables. Some Mexican producers were looking at glass houses, and have in fact, imported them directly from Holland, including all of the technology to operate them. Some producers were growing for Canadian outfits, and there were numerous greenhouse operations growing European cucumbers for direct shipment to Canada. Many producers are now using plastic greenhouses such as they use in Israel for protected agriculture production. Most houses had fans. Not all were totally computerized, but most of them had much of the modern technology found in Israeli and/or Dutch systems. The use of bumble bees for pollination was prevalent. Some producers were using flat plastic houses as used in Spain in the Almería area; however, this was in a minority group (more in Baja). Most houses were tall in structure, many had methods to heat the house, and many of the newer houses that were being built, if not all of all of them, were plastic and were locally made. This was further evidenced at the Expo in Culiacan where they had several greenhouse manufacturers, some of them local, showing their wares. It is obvious that financing has allowed the Mexican producer to buy technology.

The third area is the use of pesticides. What I have seen over the years is the decreased use in pesticides which are not labeled for use in the American market. Because of the high dependence of the export market into the U.S. and Canada, and with Mexicans now looking at Asia as well as potentially Europe, they are more cognizant of pesticide regulations and problems obtained when pesticides which are illegal in certain countries are used in Mexico. If the crop is then transported to an outside port wherein the pesticide is deemed illegal, problems and continued checks for pesticide residues are made by regulatory agencies. Because of the sophistication of the market and the high level of financing (I personally believe because of the outside influence of outside investors) and the sophistication in general of the industry, Mexican producers have greatly decreased their use of pesticides which are illegal for export into the U.S. Two noted exceptions are what appears to be the continued use of methyl parathion and Captan. We did not witness any instances of use of methyl parathion, but we did see various empty containers or at least containers with labels on them. Both of these chemicals at one time were registered for use in the U.S. for vegetables; however, they are no longer legal for field production of vegetables. We saw the potential use of Captan wherein producers were using it on beans as a dip after the beans were in the packing house to prevent the spread of fungus.

More tractor-operated spray rigs are in operation than in the past. This is probably, again, related to the greater sophistication of the industry as well as the infusion of dollars to be able to buy equipment. We did not see, however, safety precautions of the sprayer operators with regard to various protective clothing and other items normally used or worn in the U.S. We were not privy to any of the spray operations per se, and thus, can only assume that some of it is still done by hand, as seen in some fields. It does not appear that in the vegetable operations, Mexican growers use a lot of herbicides because hand labor, especially the use of children, is prevalent for weed removal. As previously stated, they use very little fumigants, as they tend to get little response from the fumigation procedures.

With regard to the last two areas of change - transportation or trucking and roads, we found that their trucking is deplorable. They put their trucks on the highways, but the condition of the trucks (and roads) is atrocious. It was also observed that the cost of trucking produce from Culiacan to Nogales is exorbitant. It is costing about \$1000 per load of tomatoes. We were told, and as we evidenced ourselves, that the tolls are extremely expensive. We were told by one Nogales producer that it costs \$300 in tolls to get a truck up to Nogales. The trucks themselves are in very poor condition, and it is a wonder that some of them make it.

The one thing that NAFTA was to provide was that trucking would be consistent from Culiacan to any place in North America, and that this was supposed to take effect in or about the first quarter of 1996 or 1997. This has not taken place, and from all indications, will not take

place for some time for two reasons. President Clinton denied this factor because of border security. The problem with security is the running of drugs from Mexico directly into the U.S. Presently, many of the produce trucks have to be off-loaded for inspection. The second area is the condition of Mexican trucks. If they can pass American inspection, they would be permitted to be driven on American roads. Personally, I do not see where more than 10% of their trucks could be road-worthy for U.S. roads. One thing we did not see, however, was a lot of trucks broken down on the side of the road, nor did we see a lot of accidents with trucks. I am quite sure this is prevalent, due to the condition of the trucks and the drivers.

Another problem Mexicans have with trucking is that as they bring full trucks to the border, they then have to generally return them empty. That, of course, increases the costs of bringing produce to the border in Nogales. Originally NAFTA was to allow trucks to move freely along the border states by 1996. This also has not taken effect. It is unclear at this time when changes in trucking will take effect, and generally, the President has decided national security is a problem. The fifth area of discussion was labor. This is one area that I can truthfully say, since 1982, nothing has changed. Basically, in fact, the labor is paid at the same rate as 1982 or less, approximately \$5.00 per day. The quality of labor is in fact worse, so it has gone down, and a lot of it is imported from the southern states of Mexico. Many workers are of Indian decent, and some workers may even be coming from Guatemala. They pay each worker approximately \$5.00 per day in the field. They do freely use children because of cultural problems and problems with the families and parents. The parents insist that the children work with them or go to the field. If the children go to the field or work with them, they are paid a like amount. This is the same type of situation we saw pre-NAFTA. Thus, a family with five children will get \$35.00 per day. Packinghouse labor for most cases is local labor, and they are paid about the same, generally \$5.00 - \$7.00 / day. Packing house work is generally clean. The workers are well-dressed. One thing that was noticed, regardless of whether the workers were local or imported and whether working in a packing house or field, most of them for most cases were happy. They seem to smile, do their work and not complain about it.

The living conditions (we saw at least one housing unit) looked like substandard housing compared to that found in the U.S. for migrant workers. In watching the workers go in and out of the housing, it seemed that they were used to living in the open or in sheltered cardboard/tin shacks. One of the things that I noticed was that they were moving cardboard in and out of these structures, almost feverishly as an ant colony building a hill. With regard to packinghouse labor, one thing we noticed on the vine-ripe tomato lines was that they would use 500-600 people, and on Meyer's mature green tomato lines, a maximum of 150 people were used. So they are using about 1/3 of the population of labor by shipping mature green tomatoes. In any event, the quality of labor, compared to U.S. Mexican labor, was still inferior, and generally, extremely poor.

LAND, SOIL, AND WATER

There seems to be a large abundance of land throughout the desert valley region from Nogales, Arizona to Culiacan, Mexico. We found that there are several areas in the states of Sonora and Sinaloa with fertile valleys for growing a wide variety of crops. Although Sonora is north, and thus, out of direct winter production for warm season crops, the land is expansive, highly fertile, and water appears to be plentiful. The quality of the water appears to be outstanding. Much of that area, about 250,000 hectares, is devoted to wheat production. With the advent of full NAFTA adoption, wheat producers in the U.S. will have a direct advantage over wheat producers in Mexico. It is my opinion that much of that area will be looking for alternative crops, as they already are, for production during winter months. This, of course, leads into cole crop production - broccoli, cauliflower, cabbage - and potentially into the future, even into potato production and/or protected agricultural production. The Sinaloa area is again transversed by highly fertile soil, and the soil types vary from rather heavy to light and partially sandy. Water quantity and quality, again, appear to be no problem even through drought years. Most of the water in Sinaloa is through river backup and reservoirs while water in Sonora can be through wells, as well as stored water. In both cases, water quantity and quality seem to be no problem. Should water use be in question, many of the producers have been converting to drip-irrigation, thus, relieving pressure from water needs.

In order to expand their season, many of the producers almost holistically are going to year-round production. They have looked at other areas to continue production into the summer months, and to expand production during spring, winter and summer. As such, Baja production is increasing, especially for crops such as tomatoes, peppers, and other warm season crops. In the Baja, water quantity and quality can be a problem, however, deep well feeds have been good, and by the use of drip-irrigation, water conservation has allowed producers to expand in this area. More recently, producers such as RB Packing are looking at their expansion through greenhouse production in the area. The greenhouses will be low-energy, high-tech greenhouses to produce crops for a longer portion of the season under protected culture giving them the highest yields per unit area as well as the highest quality per crop grown.

'As of April 1997, ELM has purchased 100% of RB Packing and their label 'Masters Touch'.

PLUM TOMATO VARIETY EVALUATIONS

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Plum tomatoes are a growing proportion of fresh tomato production. Separate production figures for Florida-grown plum tomatoes are not available, but are incorporated within production figures for standard tomatoes (Fla. Agr. Stat. Serv., personal communication). However, the importance of the plum tomato market is reflected in the fact that the acreage of two major growers in the Manatee County area have shifted to 20% plum tomatoes. Overall, Manatee County has approximately 10% of its tomato production in plum tomatoes (Gilreath, P., personal communication). Separate pricing reports for standard, cherry and plum tomatoes in market Internet services also indicate the significance of plum tomatoes in the marketplace. Recently, more shelf space in supermarkets is devoted to plum tomatoes on a regular basis. Regional interest in plum tomato varieties centers on an oval, elongated, cylindrical-shaped fruit, frequently referred to by growers as a Roma tomato. Saladette type plum tomatoes are in the strictest definition plum to globe shaped (Leaper, 1977). However, this shorter, rounder shape is at a distinct disadvantage in the Florida market, which demands the more elongated type. To further complicate the issue of defining plum tomato shape characteristics, seed companies have their own vernacular, where a Saladette can mean any shape of plum tomato intended for a fresh market product. For the purposes of this discussion, the term plum will refer to the elongated fruit type. Two plum tomato variety trials were conducted in fall 1996 and the spring of 1997 at the Gulf Coast Research & Education Center in west-central Florida to evaluate fresh market plum tomato varieties and breeding lines. Eight entries were evaluated in both seasons in replicated yield trials with additional entries evaluated visually in unharvested, observational plots.

MATERIALS & METHODS

Bed Preparation: The 33-inch wide, 8-inch high beds were spaced on 5 ft centers with 6 beds between seepage irrigation ditches. Fertilizer included 15-0-30 (N-P₂O₅-K₂O) at 1742 lb/A (A = 8712 linear ft of bed) distributed in two narrow bands in shallow grooves on the bed surface 10 inches to either side of the bed center. In addition, in the fall only, a banded false bed application was made of superphosphate (0-20-0 with 80 lbs per ton minor elements as F503) at 174 lb/A. This fertilizer regime provided a 1:2 ratio of N:K₂O with approximately 260 lb N/A and 523 lb K₂O/A. Beds were fumigated with methyl bromide:chloropicrin (67:33) at 189 lb/mulched A (mulched acre = 23,522 sq ft) and covered with white on black polyethylene film in the fall and black polyethylene film in the spring.

Transplant Production: Seeds were sown on July 15, 1996 and January 10, 1997 directly into planter flats (1.5 x 1.5 x 2.5-inch cells) containing vermiculite and Canadian peat (1:1,v:v) amended with dolomite, superphosphate, and hydrated lime (11.3, 5.6 and 2.8 lb/cu yd, respectively) then covered with a layer of coarse vermiculite and germinated in a greenhouse. Plants were hardened before transplanting by limiting water and nutrients in the final phase of production.

Crop Production: Transplants were set in the field on August 26, 1996 and February 24, 1997 and spaced 24 inches apart in single rows in the center of each bed. Transplants were immediately drenched with water containing imidacloprid to control silverleaf whitefly populations. Fields were also baited for mole crickets after transplanting. Three replications of 10 plants per entry were arranged in a randomized complete block design in the replicated trial and single 10-plant plots were used in the observational trial. Plants were staked and tied without pruning. Disease pressure was minimal during the fall season. However, during the spring, bacterial leaf spot was severe. Late blight and powdery mildew were also present, but effectively controlled.

Fruit of the replicated entries were harvested at the breaker stage or beyond on November 6, 13, 20, 27, and December 10, 1996 for the

fall crop and May 13, 21 and 30, 1997 for the spring crop. Breaker stage or beyond were selected to assure maximum fruit size was obtained for each variety. Tomatoes were graded as cull or marketable by U.S. standards for grades (USDA, 1981) and marketable fruit were sized into extra-large, large, medium, and small by visual examination (see footnotes Tables 1 and 2 for specifications). Sizing was consistent under this method based on calculated fruit weights of each size category for each season, and was nearly identical for both seasons. Both cull and marketable fruit were counted and weighed. Subjective ratings of plant and fruit characteristics were given to the observational entries.

RESULTS & DISCUSSION

In the fall, average maximum daily temperatures were normal or slightly above normal and rainfall was well below average. The sparsity of rainfall reduced disease pressure and fruit disorders. In the spring, daily temperatures were 6 degrees above normal during February and March, normal thereafter. Average minimum daily temperatures were also higher than normal in February and March, while near or at normal in April and May. Rainfall was high in April, nearly 7 inches above the 42-year average (Stanley, 1995).

REPLICATED TRIALS

Fall 1996: Early yields, a combination of the harvested fruit from November 6 and 14, ranged from 73 cartons/A for 'Plum Dandy' to 670 cartons/A for 'Marina' (Table 1). 'Spectrum 882', 'Supra' and 'Veronica' were not significantly different from 'Marina' in total early yield. Extra-large fruit were defined as too large (approaching the old 7x7 size category for standard tomatoes), with an average fruit weight of 4.0 oz, and usually poorly shaped (out of class for the variety), but undamaged. These were included in marketable yield to track the proportion of all fruit free of physical damage. Early extra-large fruit yields ranged from 5 cartons/A for 'Plum Dandy' to 73 cartons/A for 'Supra'. Only three entries were significantly different from 'Supra' in extra large fruit yield. Fruit in the large category were judged to be the ideal size and quality, and individual fruit averaged 3.3 oz. Large fruit yield ranged from 25 cartons/A for 'Plum Dandy' to 255 cartons/A for 'Marina'. The average fruit weight for all medium fruit was 2.6 oz, and along with large fruit were deemed optimal size for shipment. Medium fruit yields ranged from 34 cartons/A for 'Plum Dandy' to 290 cartons/A for 'Marina'. Small fruit were judged too small with an average weight of 1.9 oz, but as with the extra large fruit they were included in marketable yield figures as undamaged fruit. Extremely small fruit, as would fall through the excluder line in a packing house, were not considered as marketable. Average marketable fruit size for the early harvests ranged from 2.8 to 3.1 oz with no differences among the entries. Cull percentages ranged from 27 to 40% with no differences among the entries.

Total marketable yield for the season among the eight plum entries from five harvests ranged from 1595 cartons/A for 'Plum Dandy' to 2593 cartons/A for 'Marina' (Table 1). 'Veronica', 'Spectrum 882' and 'Supra' were not significantly different than 'Marina' in total seasonal yields. Yields were similar to those obtained in trials completed in Boynton Beach, FL during the winter/spring of 1995-96 (Shuler, 1996) and in Quincy, FL during the spring of 1996 (Olson and Snell, 1997). An average seasonal fruit weight of a 2.6 oz to 2.9 oz per fruit would pack out at 153 to 138 fruit per box, respectively. The market will not accept 180 to 200 fruit per box, and is satisfied with 150 fruit per box. These seasonal yields would be acceptable in the packing house (personal communication, Taylor & Fulton). Yield of extra-large fruit ranged from 110 cartons/A for 'Plum Dandy' to 274 cartons/A for 'Supra'. Large fruit yield ranged from 571 cartons/A for 'Plum Dandy' to 1057 cartons/A for 'Marina'. Medium fruit yield ranged from 709 cartons/A for 'Agriroma' to 1089 cartons/A for 'Spectrum 882'. Yields of small fruit for the season ranged from 138 cartons/A for 'Puebla' to 323 cartons/A for 'Hybrid 882'. Cull fruit accounted for between 23 and 44% of the total fruit harvested. Attributes which culled fruit included nipple tipped blossom ends, poorly shaped fruit, damaged fruit and very small fruit, in order of importance. The number of small fruit and cull fruit increased substantially at the fifth harvest and these increases were used as indicators to terminate the trial.

Spring 1997: The earliest variety was 'Spectrum 882', based on total first harvest yield on May 13 (Table 2). Total early yields ranged from 149 cartons/A for 'Plum Dandy' to 549 cartons/A for 'Spectrum

882'. Yields of large fruit were not significantly different among the entries, but yield of medium fruit was greatest for 'Spectrum 882'. As mentioned above, these two fruit sizes account for the most desirable fruit for shipment. Average marketable fruit size at the first harvest ranged from 2.8 oz for 'Veronica' and 'Marina' to 3.2 oz for 'Puebla' and 'Supra'. Culls ranged from 25 to 39% of the total fruit harvested and were not different among the entries.

Total seasonal yield among the eight plum entries from three harvests ranged from 1419 cartons/A for 'Agriroma' to 2032 cartons/A for 'Spectrum 882' (Table 2). All entries except 'Agriroma' and RPT 1570 were not significantly different than 'Spectrum 882' in total seasonal yields. Yields were slightly lower than those obtained in trials completed in Boynton Beach, FL during the winter/spring of 1995-96 (Shuler, 1996) and in Quincy, FL during the spring of 1996 (Olson and Snell, 1997), and the previous season at this location. The unusual rainfall in April likely played a key role in depressing marketable yields, since bacterial leaf spot caused severe foliar damage. An average seasonal fruit weight of a 2.3 oz to 2.7 oz per fruit would pack out at 174 to 148 fruit per box, respectively. These seasonal yields would be acceptable in the packing house. These lower pack-out figures, as compared to the fall of 1996, were due to the number of smaller fruit at the second and third harvests. Yield of extra-large fruit ranged from 34 cartons/A for 'Marina' to 104 cartons/A for 'Spectrum 882'. Large fruit yield ranged from 311 cartons/A for 'Marina' and RPT 1570 to 463 cartons/A for 'Supra'. Medium fruit yield ranged from 700 cartons/A for 'Plum Dandy' to 1008 cartons/A for 'Spectrum 882'. Yields of small fruit for the season ranged from 238 cartons/A for 'Agriroma' to 648 cartons/A for 'Marina'. Cull fruit accounted for between 27 and 44% of the total fruit harvested. Attributes which culled fruit included nipple-tipped blossom ends, poorly shaped fruit, damaged fruit and very small fruit, in order of importance.

Fruit Quality: Observations in the field and during grading for both seasons indicated that some entries had distinguishing attributes. 'Agriroma' fruit were highly variable in shape (very elongated to oxheart-shaped which were not round in cross-section), had a concentric type of zippering, and nipple-tipped blossom ends. This variety was the poorest for consistency of fruit shape and had the greatest number of nipple-tipped fruit. 'Plum Dandy' produced fruit with some nipple-tipped blossom ends when fruit was immature, most of which smoothed out later in the fall season. However, in the spring nipple-tipped fruit was more noticeable particularly later in the season. 'Plum Dandy' also had many concentric type zippers which appeared by midseason during the fall, but this was not a predominant feature in the spring. In the fall, 'Spectrum 882' was variable in fruit shape, showed a slight amount of nipple-tipped fruit, a tendency toward producing fruit with a narrow "neck" (fruit tapered at the stem end, pear shaped), and a small amount of blossom-end rot the first three harvests. In the spring, blossom-end rot was the predominant fruit disorder of 'Spectrum 882' at the first harvest, and this disorder remained a factor for the entire season. During the fall, 'Puebla' displayed very few nipple-tipped fruit, but had a slight amount of narrow "neck", variable fruit shape, and radial cracks which appeared later in the season. In the spring 'Puebla' also showed very little evidence of nipple-tipped fruit, but had concentric and radial zippering, blossom-end rot, and slight rain checking. In the fall, 'Supra' was slightly pear shaped, had nipple-tipped fruit, which became worse as the season progressed, and concentric type zippers. In the spring, 'Supra' was free from most defects until seasons end when nipple-tipped fruit became more prominent. 'Marina' had some fruit with indented blossom ends and a definite lack of nipple-tipped fruit in both seasons. In the fall, some fruit had a slight "neck" and variable fruit shape and size. 'Veronica' produced slightly pear shaped fruit and variable fruit shapes in the fall, and had assorted minor defects in the spring. It distinctly lacked nipple-tipped blossom ends. Sunre 6249 was examined only in the fall and had a high amount of nipple-tipped fruit, concentric type zippers, and slightly pear shaped fruit. RPT 1570, only examined in the spring, had blossom-end rot, concentric type and radial zippers, "necky" fruit, and graywall as serious defects. In the fall, at the final harvest rain checking appeared in 'Spectrum 882', 'Puebla', 'Supra', 'Marina' and 'Veronica'. At the second harvest in the fall, subjective notes were made on the most attractive fruit. They were produced by 'Puebla', 'Supra' and 'Veronica'.

UNHARVESTED OBSERVATIONAL TRIAL

Horticultural Evaluation: Eight entries in the fall and fourteen entries in the spring were rated for numerous horticultural characteristics (Table 3). Plant and fruit attributes were rated at the end of each season. Ratings provide general indications of crop performance at a particular location and time.

SUMMARY

Based on grower acceptance of shape, only the elongated plum type should be considered for west-central Florida. Of those plum entries investigated in the fall, 'Marina', 'Veronica', 'Spectrum 882', and 'Supra' had the best total, large, and medium fruit yields for the season. These entries also were similar in earliness. Of these 'Marina' and 'Veronica' had the least incidence of fruit with nipple-tipped blossom ends. Of those entries examined in the spring, 'Spectrum 882' was the earliest entry. Best seasonal performance in total, large and medium fruit yields came from 'Spectrum 882', 'Marina', 'Supra', 'Puebla' and 'Veronica'. Nipple-tipped fruit were absent in 'Veronica' and 'Marina'.

Note: The information contained in this report is a summary of experimental results and should not be used as recommendations for crop production. No discrimination is intended nor endorsement implied where trade names are used.

Acknowledgment: The author wishes to thank the following organizations/firms which donated funds toward vegetable cultivar research during 1996 and 1997: Abbott & Cobb Inc., Agrisales, American Takii, Seminis-Asgrow Seed Co., Daehnfeldt Inc., Ferry-Morse, Harris Moran Seed Co., Pepper Research, Rogers Seed Co., Sakata Seed America Inc., Samen Mauser, Shamrock Seed Co., and Sunseeds.

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Table 1. Early and seasonal yields, average fruit size and cull percentages for plum tomato entries in fall trial of 1996. (Harvest dates: November 6, 13, 20, 27 and December 10, 1996).

Entry	Seed ^z Source	Marketable Yield (cartons/A) ^{y,x}					Average Marketable Fruit	
		Total	Extra Large	Large	Medium	Small	Wt (oz)	Culls ^w (%)
Early - November 6 and 13, 1996								
Marina	SA	670 a ^v	48 a-c	255 a	290 a	78 ab	2.9 a	27 a
Spectrum 882	PS	614 a	56 ab	168 ab	277 ab	114 a	2.8 a	31 a
Supra	RO	546 ab	73 a	235 ab	188 bc	51 bc	3.1 a	28 a
Veronica	SA	530 ab	27 bc	225 ab	223 a-c	55 b	3.1 a	32 a
Puebla	PS	439 bc	53 ab	184 ab	165 c	37 bc	3.1 a	28 a
Sunre 6249	SU	383 bc	19 bc	118 bc	186 bc	60 b	2.9 a	39 a
Agriroma	AG	355 c	39 a-c	116 bc	154 c	46 bc	2.9 a	40 a
Plum Dandy	FM	73 d	5 c	25 c	34 d	9 c	3.1 a	35 a
Seasonal - November 6, 13, 20, 27 and December 10, 1996								
Marina	SA	2593 a	182 a	1057 a	1047 ab	308 a	2.6 a	40 ab
Veronica	SA	2379 ab	206 a	961 ab	952 a-c	260 ab	2.7 a	30 ab
Spectrum 882	PS	2297 ab	204 a	680 bc	1089 a	323 a	2.6 a	27 ab
Supra	RO	2119 a-c	274 a	868 a-c	788 bc	190 ab	2.7 a	32 ab
Puebla	PS	1952 bc	202 a	794 a-c	818 a-c	138 b	2.9 a	40 ab
Sunre 6249	SU	1877 bc	214 a	673 bc	790 bc	200 ab	2.8 a	42 a
Agriroma	AG	1735 c	199 a	546 c	709 c	183 ab	2.7 a	44 a
Plum Dandy	FM	1595 c	110 a	571 c	724 c	190 ab	2.6 a	23 b

^zAG = Agrisales; FM = Ferry-Morse; PS = Petoseed; RO = Rogers;

^yA = Sakata; SU = Sunseed.

^xCarton = 25 lb. A = 8712 linear ft of bed, beds on 5 ft centers.

^ySized by visual inspection. Extra-large fruit = 4.0 oz, large fruit = 3.3 oz, medium fruit = 2.6 oz, small fruit = 1.9 oz.

^wBy weight.

^vMean separation by Duncan's multiple range test, 5% level.

Table 2. Early and seasonal yields, average fruit size and cull percentages for plum tomato entries in spring trial of 1997.
(Harvest dates: May 13, 31 and 30, 1997).

Entry	Seed Source	Marketable Yield (cartons/A) ^{z,y}				Average Marketable Fruit		Culls ^x (%)
		Total	Extra Large	Large	Medium	Small	Wt (oz)	
Early - May 13, 1997								
Spectrum 882	PS	549 a ^v	70 a	171 a	268 a	41 a	3.0 a-c	29 a
Puebla	PS	353 b	59 ab	143 a	132 bc	19 ab	3.2 a	36 a
Marina	SA	345 b	24 bc	128 a	155 b	38 ab	2.8 bc	26 a
Agriroma	AG	325 b	27 bc	150 a	126 bc	22 ab	3.2 a	39 a
RPT 1570	RO	299 b	33 bc	138 a	112 bc	16 ab	2.9 bc	35 a
Supra	RO	287 b	30 bc	158 a	89 bc	10 b	3.2 a	25 a
Veronica	SA	278 b	22 c	126 a	103 bc	27 ab	2.8 c	28 a
Plum Dandy	FM	149 b	8 c	79 a	51 c	12 b	3.1 ab	26 a
Seasonal - May 13, 21 and 30, 1997								
Spectrum 882	PS	2032 a	104 a	444 a	1008 a	476 b	2.5 bc	28 b
Marina	SA	1921 ab	34 b	311 a	928 ab	648 a	2.3 c	27 b
Supra	RO	1712 a-c	84 ab	463 a	776 ab	389 b	2.5 b	33 b
Puebla	PS	1699 a-c	91 ab	461 a	803 ab	345 bc	2.6 ab	36 ab
Veronica	SA	1670 a-c	54 ab	350 a	825 ab	440 b	2.3 c	30 b
Plum Dandy	FM	1650 a-c	81 ab	407 a	700 b	462 b	2.4 c	30 b
RPT 1570	RO	1527 bc	36 b	311 a	774 ab	406 b	2.3 c	35 ab
Agriroma	AG	1419 c	49 ab	394 a	737 ab	238 c	2.7 a	44 a

¹ AG = Agriromas; FM = Ferry-Morse; PS = Petoseed; RO = Rogers; ⁵ A = Sakata.

² Carton = 25 lb. A = 8712 linear ft of bed, beds on 5 ft centers.

³ Sized by visual inspection. Extra-large fruit = 4.0 oz, large fruit = 3.2 oz, medium fruit = 2.6 oz, small fruit = 1.8 oz.

⁴ By weight.

Mean separation by Duncan's multiple range test, 5% level.

Table 3. Late season ratings of fruit and plant characteristics for observational entries in trial, fall 1996 and spring 1997.

Source/Entry	Plant Height ^z	Fruit Shoulder ^y	Stem ^x	Fruit Set ^w	Fruit Size ^v	Maturity ^u	Fruit Shape ^t	Blossom End ^w	Fruit Firmness ^w	Internal Quality ^w	Blotchy ^s	Gray Wall ^s	Zipper ^s	Radial Cracks ^s	Concentric Crack ^s	Rain Check ^s	Persistent Green Shoulder ^s	Comments ^r
FALL 1996																		
North Carolina State University																		
NC 96153	mt	5.0 ug	jo	4.5	3.0	4.5	2.0 short egg	5.0	3.0	3.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	spider track
NC 96159	s	5.0 ug	jo	4.5	3.5	4.0	4.0 short plum	3.0	2.5	3.0	5.0	5.0	5.0	4.7	5.0	5.0	5.0	nipple tip
NC 96161	m	4.0 ug	jo	4.5	4.5	2.5	3.0 lg plum	3.0	4.0	1.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	necky, pers nipple tip
NC 96164	s-m	4.0 ug	jo	4.0	3.0	3.5	3.0 sl. pear	4.5	4.0	3.5	5.0	5.0	5.0	5.0	4.9	4.5	5.0	v. necky, sl. spider track
NC 96185	vs	4.0 ug	jo	4.0	4.0	3.0	4.0 plum	5.0	3.0	4.5	5.0	5.0	5.0	5.0	5.0	4.5	5.0	
Paramount																		
DPSX 93796	m	4.0 ug	j2	4.0	4.0	2.5	2.5 oval	5.0	4.0	3.0	4.5	5.0	5.0	4.5	5.0	4.0	5.0	ripens from bottom
DPSX 93596	m	4.5 ug	j2	4.0	4.0	2.5	3.0 round	5.0	3.5	3.0	4.5	5.0	5.0	4.9	5.0	4.5	5.0	indented be
Sunseeds																		
Sure 6241	s	4.0 ug	jo	4.5	4.0	4.5	4.0 plum	5.0	3.0	2.5	5.0	5.0	4.9	5.0	4.9	4.7	5.0	conc. cracks, conc. zippers
SPRING 1997																		
North Carolina State University																		
NC 96102	vs	5.0 ug	jo	3.5	3.0	4.5	4.0 short plum	5.0	3.0	3.0	5.0	5.0	5.0/5.0	5.0	5.0	5.0	5.0	slightly necky, nipple tip,
NC 96200	s	5.0 ug	jo	4.0	4.5	4.0	3.0 long plum	4.5	4.0	2.0	5.0	5.0	4.9/5.0	5.0	4.9	5.0	5.0	yellow around calyx
NC 9688	vs	5.0 ug	jo	3.5	3.0	4.0	4.0 short plum	4.9	3.5	2.0	4.9	5.0	4.9/5.0	4.9	4.9	4.9	4.7	yellow around calyx
NC 96161	m	5.0 ug	jo	3.0	3.0	2.5	4.5 plum	4.0	4.5	2.0	4.5	5.0	4.7/4.7	4.7	4.5	4.9	5.0	nipple tip, irregular splits
Petoseed																		
FSR 62495	m	3.0 ug	jo	3.5	3.5	4.0	4.0 heart-plum	4.0	4.0	3.0	4.5	5.0	5.0/5.0	4.5	5.0	4.7	5.0	spider tracks, indented be
Harris Moran																		nipple tip, sl. indented be,
HMDX 4878	vs	4.0 ug	jo	4.5	3.0	4.0	3.0 short plum	4.5	4.5	3.5	4.7	5.0	5.0/5.0	4.9	5.0	4.9	5.0	spider tracks
Deetefeldt																		
LDB 958054	s	4.0 lgb	j2	3.5	4.0	4.0	2.0 long plum	1.5	4.5	4.0	4.7	5.0	4.7/4.9	5.0	5.0	4.9	5.0	nipple tip
LDB 958057	s	4.0 lgb	j2	4.0	4.0	4.0	3.5 long plum	1.5	4.5	3.0	4.7	5.0	5.0/5.0	5.0	5.0	4.7	4.5	necky, sv nipple tip,
LDB 958060	s	3.5 lgb	jo	4.0	3.0	4.0	2.5 plum	4.5	4.5	3.5	4.5	5.0	5.0/5.0	5.0	5.0	5.0	4.7	spider tracks
LDB 958061	m	3.5 lgb	j2	3.5	4.5	4.0	3.0 long plum	4.0	4.5	3.5	4.5	5.0	5.0/4.7	5.0	5.0	5.0	5.0	yellow around calyx
LDB 958064	s-m	4.0 lgb	j2	3.5	3.0	4.0	2.0 plum	4.0	5.0	1.5	3.5	5.0	4.9/5.0	5.0	5.0	5.0	5.0	necky, off shape, ber
LDB 958077	m	3.0 lgb	j2	4.0	3.0	4.0	2.0 long plum	4.0	4.5	2.0	4.0	5.0	4.9/5.0	5.0	5.0	5.0	5.0	ber, off shape
LDB 958078	s	3.5 lgb	jo	3.5	4.0	4.0	3.5 long plum	4.0	4.5	1.5	4.5	5.0	4.9/5.0	5.0	5.0	5.0	4.7	off shape, ber
LDB 958079	s	3.0 lgb	jo	3.5	3.5	4.5	2.5 plum	4.0	4.5	3.5	4.5	5.0	4.7/4.7	4.9	4.7	4.9	5.0	fit pinched in the middle
																		fit pinched in the middle,
																		cat face, nipple tip &
																		indented be

^z Abbreviations: s = short, m = medium, t = tall, v = very.
^y 1 = rough, 5 = smooth, gb = green base; ug = uniform green.
^x jo = jointed, j2 = jointless.
^w 1 = poor, 5 = excellent.
^v 1 = small, 5 = extra large

^u 1 = late, 5 = early.
^t 1 = inconsistent, 5 = very consistent, lg = large, sl = slight.
^w 1 = severe, 5 = absence of defect. First rating = radial zippers; second rating = concentric zippers.
^r Abbreviations: be = blossom end; ber = blossom end rot; conc. = concentric; fit = fruit; pers = persistent; sl = slight;

sv = severe; var = varies or variable; v = very; w/ = with.
 Definitions: catface = distorted shape, scars and gaps at blossom end and/or sides of fruit; necky = pear shaped, narrow at stem end of fruit; nipple tip = pointed blossom end; spider track = small, white, tan or green streaks on fruit radiating from stem.

HEIRLOOM TOMATO CULTIVAR TESTING AT THE SOUTHWEST RESEARCH AND EDUCATION CENTER

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INTRODUCTION

Cultivars for the gassed-green tomato market are by necessity, designed to withstand the considerable physical stresses imposed by the industry's picking, packing and shipping techniques. However, in a recent issue of *The Packer*, the voice of the fresh fruit and vegetable industry, it was noted that "specialty tomatoes" are gaining favor with the American public, especially plum (Roma), yellow, and cluster-style tomatoes.

Today's cuisine demands variety, and the addition of specialty tomatoes pleases not only the eye but the palate as well. For the grower willing to go the extra mile to properly pack and ship these specialties, rewards abound. Heirloom varieties, those long-forgotten predecessors of our modern day gassed-green, may also offer specialty market opportunities. With these varieties, the grower must be aware of the fruit quality, harvesting, and shipping constraints that may outweigh the rewards!

METHODS

A subsurface seepage irrigation trial was established at the Southwest Florida Research and Education Center of the University of Florida in Immokalee, FL to test heirloom cultivars supplied by Linda Sapp of Tomato Growers Supply (Ft. Myers, FL). Ten cultivars were assayed for appropriateness under FL environmental, cultural, and commercial conditions:

Aunt Ruby's German Green - 80 days, beefsteak type, green

Black Prince - 70 days, Siberian heirloom, deep garnet

Cherokee Purple - 80 days, Tennessee heirloom, dusky rose to purple fruit

Eva Purple Ball - 70 days, German heirloom, dark pink

Flamme - 70 days, French heirloom, small bright orange fruit

Garden Peach - 80 days, fuzzy fruit, yellow-pink

Green Zebra - 75 days, amber green with dark green stripes

Lemon Boy - 72 days, a hybrid, lemon yellow fruit

Mary Ann - 78 days, classic beefsteak, deep pink to orange red

Nebraska Wedding - 90 days (or longer), Nebraska heirloom, meaty, pale orange fruit

A standard methyl bromide fumigated (320 lbs./A, broadcast), granular fertilized (220N-78P-300K), plastic mulched (black, 3 ml), 32" wide bed was prepared for the heirloom trial. Holes were punched in a single row (18" in-row pattern on 6' centers), and transplants were set on February 26, 1997. Four replications were set out (twelve plants per replication) in a randomized complete block fashion. Soil and air temperatures during that time ranged from the high 70s to low 80s. A rotation of weekly fungicide applications was employed to prevent the advancement of late blight, *Phytophthora infestans*. Various Bt insecticides were also applied to reduce worm infestation. Seven harvests occurred beginning on May 7 and ending on June 6 to accommodate the varying cultivar maturity dates. Fruits were picked at breaker stage (to satisfy a vine-ripe market), and sized according to

FL Tomato Exchange standards. Fruit physical characteristics (average fruit weight, diameter, number and weight per plant) and defects (blossom-end scar, gray wall, odd shape, zipper scar, cat facing, blossom-end rot, concentric cracks, calyx cracking) were determined for each cultivar. Additionally, breaker fruit from each cultivar were held at 50° F until soft to determine storage shelf life. Incidence of late blight prompted rating the plots to determine cultivar susceptibility. Three ratings were taken during the week prior to initial harvesting.

RESULTS

All heirloom cultivars were indeterminant and required hedging three weeks prior to harvest. Fruit characteristics of most heirloom cultivars were generally inappropriate for the gassed-green market (Table 1). Aunt Ruby's German Green, Mary Ann, and Cherokee Purple were generally extra-large in size (>3.0 inches), had rough shoulders, and often leaked from the blossom end scar when ripe (Table 2). Nebraska Wedding attained extra-large size having smoother shoulders. Lemon Boy, Garden Peach, Green Zebra, Black Prince, and Eva Purple Ball were of medium to large size. Flamme was small fruited (<2.0 inches), slightly larger than a cherry tomato. Most cultivars produced 8 to 12 pounds of fruit per plant and breaker fruit could be stored for 7 to 10 days at 50° F (Table 1).

All heirloom cultivars showed physical defects that would render them unmarketable by Florida gassed-green standards (Table 2). Aunt Ruby's German Green, Mary Ann, and Cherokee Purple were completely unmarketable, exhibiting 100% cull fruit mostly from blossom-end scar and calyx cracking. Black Prince and Nebraska Wedding had 30% culls while Green Zebra and Lemon Boy had about 20% culls. Both of these groups showed defects from concentric and calyx cracking. Garden Peach, Flamme, and Eva Purple Ball showed 6%, 6%, and 12% culls, respectively.

Late blight infested the heirloom test block more or less uniformly late in the season (Table 3). Although disease development was not rapid, tolerance to late blight was apparent in Cherokee Purple and Eva Purple Ball. Disease seemed to advance more rapidly with Lemon Boy and Green Zebra. Most other cultivars fell in an intermediate range in tolerance to late blight under a twice-weekly spray regime.

DISCUSSION

The heirloom cultivars tested in this trial would not stand up to the picking, packing, and shipping rigors of the FL gassed-green market. However, for the "vine ripe" specialty market, a few cultivars were notable. Eva Purple Ball stored extremely well (14 days), was thick walled, presented good color, and produced few culls under spring conditions in FL. The other low-cull cultivars, Garden Peach and Flamme, were very thin walled and had low shelf life. Green Zebra and Lemon Boy, while having a fairly high cull rate (1 in 5), offered excellent color, thick walls, and suitable storing capacity. All cultivars grew and produced well in spring 1997. Further testing of heirloom cultivars is necessary before recommendations can be made concerning the appropriateness of these tomatoes for a commercial market in Florida.

Table 1. Heirloom variety trial at SWFREC, Immokalee, FL Spring 1997. Fruit Characteristics

Variety	Average Fruit Wt. (oz.)	Diameter (in.)	Average Fruit Size	Fruit Number	Fruit Wt (lbs./plt)	Mean Days to Soft Stage
Aunt Ruby's German Green	8.4 b*	3.6 a	XL	22 e	11.6 cd	10.6 b-d
Garden Peach	2.1 g	2.3 c	M	92 ab	12.0 cd	6.4 f
Mary Ann	9.2 b	3.5 a	XL	22 e	12.8 c	11.6 a-c
Green Zebra	3.6 f	2.5 c	M-L	46 d	10.4 cd	12.8 ab
Nebraska Wedding	6.9 c	3.3 ab	XL	18 e	8.0 d	13.6 a
Flamme	1.9 g	1.9 d	S	99 a	11.9 cd	7.6 ef
Black Prince	3.7 f	2.5 c	M-L	59 cd	13.7 bc	9.7 c-e
Cherokee Purple	10.3 a	3.5 a	XL	19 e	12.5 c	11.0 a-d
Lemon Boy	5.9 d	2.9 b	M-L	50 d	18.3 a	8.8 d-f
Eva Purple Ball	4.7 e	2.5 c	M-L	43 d	12.7 c	13.5 a

* Values followed by the same letter(s) are not significantly different from one another via mean separation by Duncan's Multiple Range Test ($p<0.5$).

Table 2. Descriptive categories: percent by fruit number for all harvests.

Variety	Blossom- End Scars	Grey Wall	Odd Shape	Zipper Scars	Cat Facing	Blossom- End Rot	Concentric Cracks	Cracking At Calyx
Aunt Ruby's German Green	36.4 a*	0.0 b	6.1 a	0.7 a-c	1.5 b	2.0 ab	3.0 bc	60.0 b
Garden Peach	1.6 b	0.2 b	0.7 cd	0.1 c	1.8 b	0.2 b	0.1 c	1.1 e
Mary Ann	36.8 a	0.0 b	4.0 a	3.3 a	1.8 b	0.0 b	3.1 bc	50.4 b
Green Zebra	0.5 b	0.0 b	0.6 cd	2.1 a-c	0.5 b	2.7 a	7.0 b	6.5 de
Nebraska Wedding	4.3 b	0.0 b	0.6 cd	1.2 a-c	0.9 b	0.0 b	1.9 bc	26.0 c
Flamme	0.2 b	0.0 b	0.1 d	0.3 c	0.1 b	3.2 a	1.6 bc	0.8 e
Black Prince	0.5 b	0.0 b	0.3 d	3.1 ab	1.4 b	0.1 b	17.8 a	9.2 de
Cherokee Purple	30.5 a	0.0 b	3.3 bc	3.4 a	7.4 a	0.0 b	4.1 bc	73.3 a
Lemon Boy	0.9 b	0.0 b	1.1 cd	0.4 bc	0.9 b	0.3 b	3.6 bc	15.1 cd
Eva Purple Ball	0.4 b	2.8 a	0.2 d	0.4 bc	0.4 b	0.3 b	1.0 bc	6.3 de

* Values followed by the same letter(s) are not significantly different from one another via mean separation by Duncan's Multiple Range Test ($p < 0.5$).

Table 3. Heirloom Late Blight Rating. 0=None, 10=Heavy

Variety	May 2, 1997	May 5, 1997	May 8, 1997
Aunt Ruby's German Green	3.2 a-c*	3.5 a-c	3.8 a-e
Garden Peach	2.2 b-d	2.5 b-d	3.0 c-f
Mary Ann	4.5 a	5.0 a	5.2 a
Green Zebra	3.5 a-c	4.5 a	4.8 a-c
Nebraska Wedding	2.2 b-d	2.2 b-d	3.0 d-f
Flamme	2.8 a-d	3.2 a-c	3.2 b-e
Black Prince	2.5 b-d	2.5 b-d	3.2 b-e
Cherokee Purple	1.2 d	1.2 d	1.2 f
Lemon Boy	4.0 ab	4.8 a	5.0 ab
Eva Purple Ball	1.8 cd	1.8 cd	2.2 ef

* Values followed by the same letter(s) are not significantly different from one another via mean separation by Duncan's Multiple Range Test ($p < 0.5$).

CLUSTER TOMATOES

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INTRODUCTION

A new and popular tomato product is a cluster of vine ripened fruit still attached to the stems. These products are known as cluster tomatoes, cluster-harvested tomatoes, truss tomatoes, or on-the-vine tomatoes. The term truss tomatoes is frequently used in Europe and cluster tomatoes in the United States. Cluster tomatoes are currently grown as a greenhouse crop throughout the world, although some limited trials are being conducted with outdoor production. This new way of marketing tomatoes is credited to Italian producers who first began testing in 1989. The popularity of this vine ripened product quickly swept through the European greenhouse tomato industry, and more recently the North American industry (Naegely, 1997). The large greenhouse tomato industry in Holland began its shift toward cluster tomatoes in 1992 and 1993 (Anon, 1995). Holland production of cluster tomatoes was 900 acres in 1996 which was 38% of the greenhouse tomato industry (Anon, 1996). It is reported over half of the greenhouse tomatoes to be grown in Holland and three quarters of the greenhouse tomatoes in Italy in the 1997-98 season will be cluster types. Other major European countries producing cluster tomatoes include Israel, Spain, and Portugal. Production in Canada, the United States, and Mexico has also expanded in the last three years. An estimated 150 acres of greenhouse space will be dedicated to cluster cultivars in Canada and the United States in the 1997-98 season. Major cluster tomato producing states in the United States include: Texas, Arizona, California, and, Colorado. A few small growers in Florida have grown cluster tomatoes in the last two years and more space is planned for 1997-98.

CULTURAL PRACTICES

Greenhouse culture of cluster tomatoes is similar to that used for traditional large beefsteak types. Crop production includes hydroponic systems such as nutrient film technique (NFT) or media such as rock-wool, glasswool, perlite, and peat mixes. The crop is trained and supported by strings on an overhead trellis system. Most currently grown cultivars tend to have taller plants requiring high trellis systems. The top trellis cable is generally eight to ten feet high for cluster tomatoes. In addition, the fruit remains on the plant longer because the fruit is more mature at harvest. Other crop management tasks such as: leaning and lowering, pruning of lower leaves, crop nutrition, and irrigation management are similar to those growers have used in production of traditional beefsteak types (Hochmuth, 1990; Hochmuth, 1991; and Hochmuth and Hochmuth, 1996).

Excellent pollination is very important for cluster tomatoes due to the importance of uniform fruit set on each cluster. Most growers now use bumblebees for pollination. Commercial hives of the bumblebee, *Bombus impatiens*, are sold or leased to growers, and this method has replaced most hand pollination methods except with some smaller operations. A very important practice in the production of cluster tomatoes is the removal of certain tomatoes from the cluster when the fruit is very small. This practice is known as cluster pruning and is also used in beefsteak tomato production. Cluster pruning beefsteak types is usually done to remove culls and manage for large fruit size. Cluster pruning in cluster tomatoes likewise removes culls from the plant early, but also is important to provide the best presentation of remaining fruit on a cluster. Most cluster tomato cultivars are

produced to provide four to five tomatoes per cluster, however, some cultivars are small cherry tomato types and have eight to ten fruit per cluster.

The clusters are harvested by clipping the main cluster stem from the plant. All tomatoes on the cluster remain attached and range in maturity from breaker to ripe. Harvested clusters are usually marketed in a mesh bag or in a one layer box. Prices vary, as with other tomato products, but were frequently sold in grocery stores for \$2.99 per pound in 1997.

Many cluster tomato cultivars have outstanding flavor and appearance to compete with the best of the vine-ripe tomatoes sold. In addition, consumers are highly attracted to the tomato aroma provided by the stems of the cluster. Consumers also enjoy harvesting the fruit from the cluster themselves. Outstanding fruit quality and shelf life allow the consumer to pick tomatoes from the cluster over several days. The post harvest quality of the calyx is therefore an important characteristic, in the appearance of the cluster.

Most greenhouse tomato crops are grown today with very little pesticide sprays applied to the crop. This is especially true in northern states in the United States and also in Canada. Environmental controls are important in managing diseases and biological pest control has become a standard practice. Insect and disease management in Florida greenhouses is much more challenging due to the climatic conditions and high pest populations. This is given special note here because the presentation of the cluster of tomatoes means everything to the rise in popularity to cluster tomatoes. The clusters are generally free of any visible pesticide residue. If routine applications of pesticides are to be required in any production system, inside or outside of a greenhouse, the residue could be a significant detraction. At the least, it would face great competition from the current production free of visible residues. Washing of clusters of tomatoes to remove the residue from the stems and fruit would be very difficult.

CLUSTER TOMATO CULTIVARS

Tomato cultivars used today are almost all from European breeding programs, especially Holland and Israel. Traditional genetic, as well as extended shelf life (ESL) cultivars are used commercially. Very little ESL tomato production is currently used in Canada or the United States. The most popular cluster tomato cultivar in Canada and the United States is 'Tradiro' and the most popular one in Europe is 'Ambiance'. European tomato seed companies have developed many new cultivars of standard cluster types and have recently added several other specialty types including: cherry sizes, plums, and yellow colors.

CULTIVAR TRIAL RESULTS

A cluster tomato cultivar trial was conducted during the 1996-97 season at the University of Florida, Suwannee Valley Research and Education Center, near Live Oak, Florida (Hochmuth, 1997). The trial included several cluster tomato cultivars and the standard beefsteak cultivar, 'Trust', as comparison. Most cultivar trials have shown slightly higher yields for beefsteak over cluster tomato cultivars. The trial at Live Oak resulted in very similar total yield between 'Trust' and the best yielding cluster tomato cultivars including: 'Ambiance', 'Jamaica', 'Durasol', 'Tradiro', and '73-15 RZ' (Table 1). Number of fruit per cluster and average fruit size are also reported in Table 1. Several fruit quality characteristics are also important in selecting a cluster tomato cultivar. Comparisons of several cultivars for fruit luster, russetting, and calyx quality are presented in Table 2. Highest luster was found in '73-15 RZ', an extended shelf life cultivar. Poorest luster was found in 'Triton'. Differences in russet ratings were found in only one of three dates (1 May). 'Durasol' and 'Jamaica' had the highest level of fruit russetting. Observations on calyx quality were taken on 18 December, 1996. These observations were taken on fruit that had been stored at room temperature for seven days. Excellent calyx quality was found in 'Ambiance', 'Durasol', and 'Aranca'. Poorest calyx quality was found in '73-15 RZ' and 'Jamaica'.

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Table 1. Evaluation of one beefsteak and seven cluster tomato cultivars for early yield, total yield, and fruit size.

Cultivar	Seed source	Fruit class	Greenback trait ²	Total yield		Total no.		Early no. ^y		Average no.	
				per plant (lbs)	clusters per plant	clusters per plant	wt. (lbs)	fruit per cluster ^x			
Ambiance	Deruiter	Cluster	N	21.3	24.9	1.8	0.22	4.0			
Jamaica	Rijk Zwaan	Cluster	N	19.7	22.0	2.2	0.21	4.4			
Durasol (E29194)	Enza Zaden	Cluster	N	19.5	20.3	1.4	0.24	4.0			
Tradiro	Deruiter	Cluster	N	19.3	21.2	2.1	0.23	3.9			
73-15 RZ ^w	Rijk Zwaan	Cluster	N	18.8	24.8	1.8	0.16	4.6			
Triton (E29351)	Enza Zaden	Cluster	N	18.1	24.4	2.8	0.16	4.6			
Aranca	Enza Zaden	Cluster	GB	15.2	30.3	3.9	0.07	7.5			
Trust	Deruiter	Beefsteak	N	21.6	----	----	0.38	----			
LSD (P=0.05)				3.0	3.4	.09	0.02				

² Greenback trait is either greenback (GB) or nongreenback (N).

^y Early yield is from first ten harvest dates (December 2-31, 1996).

^x Average number of fruit per cluster was calculated by dividing total number of fruit by total number of clusters.

^w '73-15 RZ' is the only extended shelf life (ESL) cultivar of those reported.

Table 2. Evaluation of several fruit quality parameters for seven cluster tomato cultivars at Live Oak, Florida.

Cultivar	Fruit luster rating ^z (1-5)	Russet rating ^y (1-5)			Observational calyx uniformity	
		1 May	23 May	28 May	rating ^x (1-5)	rating ^w (1-5)
Ambiance	3.0	4.7	3.7	3.0	5.0	2.9
Jamaica	3.0	3.7	4.0	2.3	2.5	2.5
Durasol (E29194)	3.0	3.0	4.3	3.7	5.0	2.9
Tradiro	3.0	5.0	5.0	4.0	3.5	2.7
73-15 RZ	4.3	5.0	5.0	4.0	1.5	3.4
Triton (E29351)	2.3	5.0	3.7	2.7	4.0	3.2
Aranca	3.0	5.0	5.0	5.0	5.0	3.1
LSD (P=0.05)	0.6	1.3	NS	NS		

^z Luster rating scale was 1-5, 1=poor luster and 5= excellent luster.

^y Fruit russet rating was made on fruit from three harvest dates in May of 1997. Rating scale was 1-5; 1= excessive russet, 5= no russet.

^x Calyx rating scale was 1-5; 1=poor calyx appearance, 5= excellent calyx appearance.

^w Observational ratings were taken on uniformity of tomato size within clusters. Ratings were 1=poor uniformity of size, 5=excellent uniformity of size.

ETHYLENE AND SYMPTOM FORMATION IN THE SUSCEPTIBLE TOMATO DISEASE RESPONSE

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Plants have many mechanisms, both active and passive, to defend against pathogenic organisms to ensure long term survival. Plant responses to pathogen infection have been actively studied due to the huge significance to agriculture. Plant-pathogen interactions can be broadly categorized as either compatible or incompatible. In an incompatible interaction, the plant mounts a massive and rapid response to the pathogen that leads to death of the plant cells in the immediate vicinity of the infection. It is referred to as an incompatible interaction because it triggers a resistant response that limits growth of the pathogen and subsequent damage to the plant. For the resistant response to occur, the plant must contain a resistance gene for the specific race of pathogen. When the appropriate resistance gene is not present, a compatible interaction leads to a susceptible response that is not limited. The pathogenic organism can grow to quite high titers in and on the plant. Unchecked growth of the organism can in many cases lead to death of the entire plant.

Our work has focused on developing a greater understanding of the susceptible response in tomato. We have examined the interaction of tomato with three distinct organisms to date, but have characterized one in the greatest detail, *Xanthomonas campestris* pv. *vesicatoria* (bacterial spot). The organism typically causes lesions that appear 4-5 days after bacteria enter the plant tissue. In a susceptible response, the cells within the lesions die and a chlorotic halo appears around the primary lesions. The halo expands into adjacent healthy tissue and can, in extreme circumstances, become confluent and ultimately cause foliar death by 14 days. The mechanism for the enlargement of the chlorotic halo is not known but clearly involves ethylene (see below). The hormone ethylene has a role in many well defined developmental processes in plants such as abscission and fruit ripening (1). Its role in fruit ripening is familiar to anyone in the tomato industry since it is essential to normal fruit ripening and its effects on ripening are commonly manipulated. Ethylene also plays a major role in controlling a plant's response to a diverse array of environmental stresses such as high and low temperatures, drought, flooding, and mechanical damage. Generally, the role of stress-induced ethylene is to slow down plant growth in times of suboptimal environmental conditions. Of particular interest to us is the ethylene that is produced in response to pathogen infection. Plants make large amounts of ethylene following infection by many pathogens, including *X. c. pv. vesicatoria*. In the case of pathogens that are systemic or slowly spreading, this ethylene can have an obvious survival advantage to the plant; for example, the ethylene can trigger abscission of the infected organ. Maintenance of this defense response has obvious evolutionary implications for the survival of a species, but as we will show, aspects of that response are apparently counterproductive in an agricultural context.

The main focus of our laboratory over the last several years has been to identify the proteins involved in recognizing ethylene in tomato, the ethylene receptors, and to understand the roles of these receptors in mediating developmental and environmental effects of ethylene in the tomato life cycle. We identified a mutant of tomato, *Never ripe* (*Nr*), that is nearly insensitive to ethylene (2) and showed that the molecular basis for this phenotype is a single amino acid change in one of the ethylene receptors. We have used this nearly ethylene-insensitive mutant as well as varieties engineered for reduced ethylene synthesis as tools to understand the role of ethylene in controlling a variety of developmental processes, including fruit ripening and disease symptom formation.

We chose to examine the response of *Nr* to several tomato pathogens. We treated *Nr* and its isogenic wild type parent, cv. Pearson, with three virulent tomato pathogens: *X. c. pv. vesicatoria*, *Pseudomonas syringae* pv. *tomato* (bacterial speck) and *Fusarium oxysporum* f. sp.

lycopersici (Fusarium wilt). The first two are bacterial pathogens that nonsystemically infect foliage and fruits while the latter is a fungus that infects roots and spreads systemically through the vascular system. Infection by all of these pathogens induces ethylene evolution in plants. Thus, we looked at the role of ethylene insensitivity on disease symptom development in response to three different compatible organisms. In every case we observed a large reduction in disease symptom formation. For Fusarium wilt, we observed 0% survival in Pearson compared to 70% survival to maturity with *Nr*. We wish to emphasize that the *Nr* plants were not free of symptoms. But they were greatly reduced in symptoms and most plants survived an infection that caused 100% death of the ethylene sensitive controls. With *X. c. pv. vesicatoria* and *P. s. pv. tomato*, we observed no significant difference in the number, size or timing of the primary lesions. However, there was virtually no expansion of the chlorotic halos surrounding the lesions in *Nr*. Disease development was greatly reduced in the ethylene insensitive mutant compared to its isogenic control. This reduction was quantitated by measuring ion leakage from dying cells in infected leaves. We detected a four-fold reduction in *Nr* compared to Pearson at day 15. Since the titer of bacteria in the leaves was the same in both genotypes, we concluded that the *Nr* gene is acting to confer tolerance to *X. c. pv. vesicatoria*. The exciting result that *Nr* causes a large reduction in symptom development in response to compatible infections with three distinct pathogens indicates a central role for ethylene and its perception in the susceptible response in tomato.

At this time, we know that we can greatly reduce the degree of disease symptom development for several important tomato pathogens by eliminating ethylene sensitivity. To date, the experiments have been limited to greenhouse conditions with artificial inoculations which are performed by dipping plants into suspensions of bacteria. Our next challenge is to demonstrate a significant degree of tolerance to these pathogens under field conditions. Should we be able to show that the ethylene insensitivity does confer a selective advantage in the field, we will then face one additional challenge. Since the plants are ethylene insensitive, the fruit do not fully ripen. In its present state, the gene is unsuitable for commercial cultivars. We feel that there are a few ways to tackle this problem. First, the *Nr* mutant is partially dominant. This means that a hybrid with only one *Nr* parent maintains some but not all of the ethylene insensitivity. Fruits from the hybrid show different degrees of ripening, depending on the parents. It is possible that we may be able to achieve an acceptable degree of ripening with appropriate parental selections. We would likely also gain the benefit of extended shelf life due to partial ethylene insensitivity. We do not know at this point whether this is a feasible approach. An alternative approach would be to use genetic engineering to limit ethylene insensitivity to vegetative tissues and away from fruits. This approach would have all of the advantages that we see in *Nr* leaves but would permit normal fruit ripening.

It should be noted that there are many vegetable crops that never need to respond to ethylene to produce a marketable crop. For example, peppers are highly susceptible to the same Xanthomonads that cause bacterial spot in tomato. We would expect that ethylene insensitivity would also have a major effect on disease in pepper. But pepper fruits do not seem to require ethylene for ripening. Thus, the technology that we are developing for tomato may have an immediate impact on other important crops like pepper. We are examining some of these possibilities.

CONCLUSIONS

The susceptible response of plants to pathogens is a highly important process. While a great deal of progress has been made in defining the nature of Resistance gene-mediated defense, relatively little is known about the susceptible response. While there have been hints that ethylene has a major role in this environmental response in plants, definitive information has been lacking. Our results with *Nr* clearly indicate that ethylene is critical for disease symptom development. Further, we can alleviate much of the damage that occurs from these economically important pathogens. In an agricultural setting, this defensive response by the plant is, in the cases we have examined, counterproductive to agriculture. The broad effect of *Nr* on symptom reduction in response to bacterial and fungal pathogens suggests that this is a fundamental aspect of many diseases. The fact that it is a tolerance and not a resistance phenomenon also makes it less likely to break down in an agricultural setting. We have a chance to make a major contribution to knowledge of this important plant: pathogen interaction and at the

same time, potentially improve plant productivity. An understanding of how ethylene insensitivity attenuates symptom development to a range of pathogenic organisms also offers the possibility of broad and durable host tolerance that would have significant applications to agriculture.

Acknowledgements: This work has been supported by a grant to HJK from the USDA National Research Initiative and by an endowment from the L. C. Dickman family to the University of Florida.

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HARVEST MATURITY, STORAGE TEMPERATURE AND INTERNAL BRUISING AFFECT TOMATO FLAVOR

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As consumer demand increases for high-quality tomatoes, many breeding programs, such as that of the University of Florida, have in recent years focused on development of plant material with better flavor and color while incorporating other traits to sustain high yields. The ability of Florida shippers to consistently supply tomatoes with that "homegrown" flavor was described as a key component of the Florida Premium-Quality Tomato Program (Sargent and VanSickle, 1996).

In April of this year about 18 panelists were selected and training sessions were initiated by Fernando Maul, a doctoral student in the Horticultural Sciences Department under the supervision of Dr. Charles Sims of the Food Science & Human Nutrition Department. The goal is to train AND develop a descriptive sensory panel which will be capable of accurately describing subtle differences in tomato quality attributes. In preparation for the training of this panel, valuable insights and suggestions were also provided by Dr. Elizabeth Baldwin (USDA/ARS, WinterHaven), Dr. Jay Scott (GCREC, Bradenton) and Margery Einstein, M.S. (Sensetek, Tampa). The panel will function as a research tool which will be available to regularly describe the quality attributes for promising breeding lines, commercial cultivars and, equally important, the effects of different handling scenarios such as harvest maturity, gassing treatments and shipping/storage time/temperature interactions on table-ripe quality. In this report, we describe the results of preliminary training sessions conducted in May and June of this year in which flavor differences were determined for tomatoes at table-ripe stage which had been handled in several manners simulating commercial conditions. The Difference From Control Test (Aust et al., 1985) was selected for these sessions. The treatments were designed to directly compare tomato flavor as affected by the length of gassing required to reach breaker stage (an indication of harvest maturity), storage at chilling temperatures and the presence of internal bruising.

(A) SENSORY ANALYSES OF TOMATOES FROM DIFFERENT HARVEST MATURITIES OR STORED AT CHILLING TEMPERATURES

In the first test, panelists were asked to rate the degree of difference in flavor between the control ("vine-ripe" sample) and four coded samples, one of which was also a control sample (Difference From Control Test). The other three coded samples were tomatoes which were harvested green and required either one, three or five days of gassing in 100 ppm ethylene to reach breaker stage followed by ripening at 20°C (68°F). For this test panelists were presented with five samples of tomatoes ("SolarSet") at table-ripe stage which had been coarsely chopped. One of the samples was labeled as a control (harvested "vine-ripe" at light-red stage) and the rest of the samples were coded using three-digit numbers. Panelists tasted each of the unknown samples and compared the flavor with that of the known control. They marked the relative difference on a 15-centimeter (cm) unstructured line on a score sheet, in which the left side was rated as not different (0 cm) and the right side as very different (15 cm). The scores for each panelist were determined by measuring the distance in cm from 0 (no difference) to the mark made for each sample on the score sheet.

The results showed that panelists were able to perceive significant differences between the tomato samples presented in the difference from control test. There was a slight, but significant difference between the

vine-ripe harvested control and green-harvested tomatoes which required 2 days gassing to reach breaker stage (Table 1). There was also a significant difference perceived between tomatoes which required 2 and 3 days gassing.

Table 1. Mean difference ratings by panelists for ripe tomatoes harvested at either light red stage or green stage and requiring 1, 2 or 3 days ethylene treatment to reach breaker stage (Difference From Control Test).

	Mean Difference (cm)
Vine-ripe tomatoes (hidden control)	3.10 A*
Tomatoes requiring 1 day ethylene gassing	4.25 AB
Tomatoes requiring 2 days ethylene gassing	4.55 B
Tomatoes requiring 3 days ethylene gassing	6.65 C

*Mean rankings followed by a different letter are significantly different as determined by Duncan's Multiple Range Test ($P \leq 0.05$).

In the second test, panelists were presented with four samples of table-ripe tomatoes ("SolarSet") as described above and asked to rate the degree of difference between a control (vine-ripe-harvest at a light red stage) and tomatoes which required four days ethylene gassing to reach breaker stage and those which required five days gassing to reach breaker stage. Panelists perceived significant differences between the vine-ripe harvested tomato samples and those which required 4 or 5 days gassing to reach breaker stage (Table 2). However, they did not detect any differences between the samples from two gassing periods.

Table 2. Mean difference ratings by panelists for ripe tomatoes harvested at either light red stage or green stage and requiring 4 or 5 days ethylene treatment to reach breaker stage (Difference From Control Test).

	Mean Difference (cm)
Vine-ripe tomatoes (hidden control)	2.57 A*
Tomatoes requiring 4 days ethylene gassing	4.64 B
Tomatoes requiring 5 days ethylene gassing	4.29 B

*Mean rankings followed by a different letter are significantly different as determined by Duncan's Multiple Range Test ($P \leq 0.05$).

The third test compared vine-ripe tomatoes ("SolarSet") (harvested at pink stage) with tomatoes which were gassed and stored at 5°C for 7 days at either breaker or red stages. Green-harvested tomatoes which required 2 days gassing to reach breaker stage, were either placed directly at 5°C for 7 days then allowed to ripen completely at 20°C (68°F) or allowed to ripen prior to storage for 7 days at 5°C plus 1 day at 20°C.

Panelists found significant flavor differences between the tomatoes harvested at pink stage and held constantly at 20°C and those which were gassed and ripened prior to storage under chilling conditions (Table 3). Although not significantly different, the gassed tomatoes which were chilled prior to ripening were rated between the control and the ripe-chilled tomato in flavor.

Table 3. Mean difference ratings by panelists for ripe tomatoes harvested at either pink stage or green stage, gassed 2 days to breaker stage and stored at either breaker stage or red stage at 5°C for 7 days (Difference From Control Test).

	Mean Difference (cm)
Vine-ripe tomatoes (hidden control)	2.00 A*
Chilled (5°C) for 7 days at breaker stage	4.45 AB
Chilled (5°C) for 7 days at red-ripe stage	6.54 B

*Mean rankings followed by a different letter are significantly different as determined by Duncan's Multiple Range Test ($P \leq 0.05$).

(A) SENSORY ANALYSIS OF TOMATO FRUITS WITH INTERNAL BRUISING

Internal bruising (IB) is a physiological disorder caused by mechanical injuries that results in disruption of normal ripening process in the pericarp, locule and placental tissues of tomato fruits. Hatton & Reeder (1963) described IB in red-ripe tomatoes, observing that bruised fruits had a cloudy, greenish, disorganized gel, and in more severe cases, the locule tissue became dry. There were also clear signs of water-soaked areas in the placental tissue. According to Halsey & Showalter (1953), Halsey (1955), McColloch (1962) and Sargent et al. (1989a; 1989b), incidence and severity of IB is dependent on impact energy, number of impacts, cultivar and maturity stage. Incidence and intensity of IB is cumulative during handling. Fruits are more susceptible at breaker stage than at mature green. Sargent et al. (1992) also verified that three different cultivars responded differently to the same impact tests. Since IB is an internal disorder, it is apparent only after slicing by the consumer. Therefore, incidence of IB must be minimal for premium-quality tomatoes.

Besides visual effects, mechanical injuries cause severe metabolic alterations in tomato fruits. MacLeod et al. (1976) concluded that increasing the number of impacts from a height of 40-cm increased CO₂ and ethylene evolution. Nakamura et al. (1977) observed an alteration in organic acid metabolism while Miller et al. (1987) and Ishii et al. (1993) verified alterations in pigment synthesis and degradation and in enzyme metabolism, respectively. Moretti et al. (1997a) observed that impact bruising altered chemical composition and physical properties of tomato fruits, resulting in poorer quality. They found that locule gel is more affected than pericarp and placental tissues by determining that total carotenoids, vitamin C content, titratable acidity, density and viscosity of locule gel were altered after impact bruising.

In another set of experiments, Moretti et al. (1997b) verified that impact bruising caused by impact forces significantly altered the 16 major volatiles for each of the three different tissues, indicating an alteration on tomato flavor. As they previously observed for metabolic alterations, locule gel was again the most affected when compared to pericarp and placental tissues.

Although a substantial amount of work has been done regarding the effects of internal bruising on the physiology, appearance and quality of tomato fruits, there is still a lack of information regarding its effects on consumer acceptance. Will the consumer be able to tell the difference in flavor between a bruised and a healthy fruit? Aiming to answer this question, we used a sensory taste panel to compare the flavor of bruised and unbruised tomatoes.

Two tests were carried out to study the effects of IB on tomato flavor. Fruits were harvested at mature-green stage in the Bradenton area ('SolarSet') and at the Horticultural Research Unit in Gainesville ('Agriset'). The same day of harvest the tomatoes were treated with 50 ppm ethylene at 20°C (68°F). At breaker stage, fruits were removed from gassing and immediately dropped from 40 cm (about 16 inches) so that the equator of each fruit impacted onto a smooth, solid surface. This drop height was sufficient to induce development of IB. Following the impacts the tomatoes were ripened along with undropped fruits at 20°C and 85% relative humidity.

At table-ripe stage, the fruits were prepared as outlined above and presented to 20 panelists. The undropped control was identified while the three remaining samples consisted of a hidden control and two samples from tomatoes with IB labeled with random numbers. Panelists were asked to compare the flavor of the labeled (undropped) sample to the three unknown samples, on a numerical scale ranging from 1 (no difference) to 12 (very different).

Panelists readily distinguished between tomatoes with and without IB for both varieties (Table 4). The IB samples were rated equally different from the sound sample. Some panelists also provided additional descriptive information, saying that bruised fruits had "bland" or "watery" flavor when compared with unbruised tomatoes. Another remark was a perceptible difference in color between the samples.

Table 4. Mean difference ratings by panelists for ripe tomatoes with and without internal bruising (IB) using Difference From Control Test.

	Hidden Control	IB Sample 1	IB Sample 2
'SolarSet'	2.20 b*	6.40 a	6.10 a
'Agriset'	2.11 b	5.88 a	5.83 a

*Means within the same row with different letters are significantly different at 5% level of significance (Tukey test).

CONCLUSIONS

The results obtained in these tests, along with other findings from physical and chemical analysis in previous reports, strongly indicate that harvest maturity, storage temperature and internal bruising negatively affect tomato fruit flavor and quality. Although the flavor differences noted in these preliminary training tests were not quantified, further training currently underway involves the identification of flavor descriptors which will be used to document actual flavor differences in sensory evaluations during the upcoming months.

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AGRICULTURAL WEATHER FORECASTING - WHAT IT IS, WHAT IT ISN'T

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INTRODUCTION

Weather services for agriculture underwent a major change in the spring of 1996. Weather forecasting, data collection, and other services for agriculture that had been provided by the National Weather Service (NWS) for more than 30 years were discontinued. Funding for the service was not included in the NWS budget by the Administration and Congress voted to terminate the program. The service was eliminated as part of the privatization and downsizing efforts of Congress and the Administration. Now that agricultural weather forecasting is only available as a paid service from the private sector, agricultural users must adapt and have a better understanding of the capabilities of weather forecasting.

THE NWS FORECAST SERVICE

Most Florida growers probably recall the annual "save the farm weather" battle. For most of the past 20 years, the NWS funding for agricultural weather forecasting was either eliminated or greatly reduced in each annual Federal budget. A few strong members of Congress, primarily from Southern agricultural states, sat on the relevant committees and were able to restore funding each year. Although funding was always restored, constant uncertainty prevailed and resulted in limited resources being dedicated to the service. Poor NWS staffing levels, undertrained forecasters, and general poor support for agricultural weather forecasting plagued the service. Agricultural weather forecasting was limited mainly to the South and Midwest, leaving most states with no forecasts. With declining support in Congress towards all special programs for agriculture, the demise of the NWS service was just a matter of time. The future of agricultural weather forecasting is now in the hands of growers and others in agribusiness.

PRIVATE SECTOR FORECAST SERVICES

The commercial weather industry is relatively young. A few firms were started after World War II. Most of the industry has developed over the past 10-15 years. There are two reasons for this change. First, several Federal laws were passed which forced the NWS to cease services which competed with the private sector. In the past, the NWS actually did television and radio broadcasts. The second reason is the availability of powerful desktop computers and inexpensive communications. Prior to the "information age", only the NWS had the huge mainframe computers required to process data and operate computer models. These tasks can now be done with readily available computer technology.

Few private weather forecasters have specialized in agriculture. This was due to the competition from the free service provided by the NWS. Now that this competition has been eliminated, there will be greater opportunities for private agricultural weather forecasters. The author was an NWS agricultural weather forecaster and recognized that this was a unique opportunity to start a private company providing agricultural weather services. With four other former NWS colleagues, the Agricultural Weather Information Service (AWIS) was incorporated in April 1996. AWIS is one of the few private forecasting firms to specialize in agriculture and provides forecast and information services to agriculture nationwide.

THE FUTURE OF AGRICULTURAL WEATHER FORECASTING

Now that agricultural weather forecasts are only available from the private sector, the future of the service will be determined by the agricultural industry. If growers and the industry at large recognize that agricultural weather forecasts are essential to their operations and take advantage of the service, private forecasting will thrive. If the agricul-

tural industry fails to support private forecasters, no specialized service will be available. The January 1997 freeze which devastated Florida crops is a perfect example of this problem. Very few Florida growers made the *business decision* to hire a weather forecast service. Few growers would risk not spraying to control insects, weeds, and diseases. Yet they were willing to risk their crop by not using affordable and readily available private weather forecasters. Apparently, many of these growers used local TV weathercasters or national cable weather services because they were free. While these groups provide excellent general information, it is geared towards the *general public*, not for agriculture. The non-agricultural weather forecaster is typically forecasting for airport locations. This is where the observations are taken and are the locations forecast for in the NWS computer models. Agricultural weather forecasters use their knowledge to produce forecasts for the growing areas.

UNDERSTANDING THE RISKS OF FORECASTING

The January 1997 freeze demonstrated that forecasting is still not an exact science. The reality is that forecasting remains an educated guess! One major problem uncovered by the freeze was the lack of basic weather observation coverage over the southern Florida Peninsula. There are no real time weather observation points over the interior, south of Avon Park. It is extremely difficult to make adjustments in a temperature forecast when you have no information from the area being forecast! The only data available was along the coastal areas. Growers should also recognize that even the "official" weather observations are now viewed with question. The temperature sensors now being used by the NWS and other agencies has a accuracy of ± 2 °F. The dewpoint temperature sensor has a ± 4 to 7 °F accuracy. Human observers are no longer monitoring and adjusting the data. Most temperature sensors available to growers have similar accuracy problems. The proper exposure of a temperature sensor is also critical. All official measurements are taken at a height of five feet. Temperatures can be 5-10 degrees colder near the ground under perfect radiational cooling situations.

The science of forecasting has improved but has also become more complicated for the forecaster. In recent years, forecasters have had to contend with at least six operational weather forecast models. Each model generates forecasts for different periods (some are designed for periods out to ten days while others only produce forecasts for 48 hours in advance) and they don't all forecast for the same parameters. The spatial scales used are also different. Some models are high resolution and compute forecasts on a small spacing of every ten miles, while others use a large spacing on the order of hundreds of miles. It is rare for all the models to converge on the same solution for the forecast. The forecaster must determine which solution is best. This is often very difficult!

One benefit of agricultural weather forecasts now being provided by private sector forecasters is that they are not forced to use only the NWS models. In fact, many private forecasters have developed their own forecast models and techniques. New and improved forecast models can be expected from private forecasters if the market for their services is realized.

GROWER EDUCATION

To take full advantage of agricultural weather forecasts, growers must educate themselves on basic elements of meteorology and how to incorporate weather forecasts into their decision process. Almost every decision involving a crop has some interaction with the weather. All aspects of crop growth and pest problems are weather-based. While models such as growing degree day accumulations to simulate crop growth and TOMCAST for monitoring late blight in tomatoes are not perfect, they are useful tools that more growers need to utilize. These are examples of information readily available from private forecasters. Since freezes are of major concern to Florida growers, special effort must be made to understand how temperature forecasts should be used.

Every grower should have an intimate knowledge of their growing areas. This can be taken for granted and can account for one area sustaining major freeze damage while other areas are untouched! This knowledge base should include soils, topographic features, soil moisture, windbreaks, etc. Basic weather monitoring is also essential.

Maximum and minimum temperature and rainfall should be observed daily and from as many representative sites as possible. These data will be helpful for comparing to forecast points. When concerned about a freeze, growers should watch the extended temperature forecasts which are available for ten days in advance. Whenever the temperature is forecast to be 40 degrees or less, growers should put themselves on an early "alert". However, it must be understood that temperature forecasts 5-10 days in advance often show sharp changes from forecast to forecast. If the trend remains about the same as the event approaches, the level of "alert" by the grower should increase. Depending on the form of freeze protection used, growers may be forced to make decisions well in advance of the event. As a possible freeze event nears, growers should look at more detailed weather forecast information. Getting some idea of the forecast winds, cloud cover, dew points, etc. in addition to the temperature is vital. Finally, minimum temperature forecasts should be locally interpreted by the grower. Do not look just at the forecast for the nearest site. Look at forecasts all around your area and even well to the north of your vicinity. There may be clues in the forecasts for other locations that would not be seen if only focusing on your immediate area. Also, routinely monitor temperature forecasts so that you can get a better feel for how the forecasts tend to go for your location and other "key" sites that you are monitoring. Good records will allow you to make more precise local adjustments to the forecast based on the wind, clouds, soil moisture, and other factors that can impact the temperature. Ask your private weather forecaster to provide you with some written material explaining the different kinds of freezes and how local conditions can influence your temperature.

CONCLUSIONS

Agricultural weather forecasts are now available exclusively from private services. While this will be an extra cost to users, the benefits more than exceed the cost. Users of private services can make better decisions and reduce their weather-related losses. It will take a close relationship between users and the private services to learn what forecasts can do and what they can not do to help them. Private forecasters will be more responsive to the needs of the user and will readily invest in new science and technology if the market for their services appears to be promising. Ultimately, the future and reliability of private agricultural weather forecasting is in the hands of agriculture.

ALTERNATIVES TO METHYL BROMIDE FOR NEMATODE CONTROL

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Soilborne plant pathogens, plant parasitic nematodes, and weeds are all capable of causing extensive damage to Florida tomato. The proposed ban on methyl bromide in the U.S.A. in 2001, and later in other countries of the world, will no doubt create a void for us in the chemical arsenal currently used for soilborne pest and disease control. This fact is made quite clear from a review of recent field research trials conducted in Florida which shows that no single, equivalent replacement (chemical or nonchemical) currently exists which exactly matches the broadspectrum efficacy of methyl bromide. This suggests that the future success for development of effective soilborne pest and disease control will require a more integrated approach, combining multiple tactics to achieve satisfactory pest control and tomato crop yields. The objective of this paper and presentation is to review some of the research, both chemical and nonchemical, being evaluated as alternatives to methyl bromide for nematode control in Florida.

RESISTANT VARIETIES

Use of nematode-resistant tomato varieties has not been extensively evaluated in Florida, but is often viewed as the foundation of a successful integrated nematode management program on all high value crops in which methyl bromide is currently used. In tomato, a single dominant gene (subsequently referred to as the Mi gene) has been widely used in plant breeding efforts and varietal development which confers resistance to all of the economically important species of root-knot nematode found in Florida, including *Meloidogyne incognita*, *arenaria*, and *javanica*. In a resistant tomato variety, nematodes fail to develop and reproduce normally within root tissues, allowing plants to grow and produce fruit even though nematode infection of roots occurs. Unlike California, where nematode resistant processing tomatoes varieties have been available for some time, commercially resistant fresh market varieties, climatically and horticulturally adapted for Florida, have only become recently available in the Peto Seed tomato variety 'Sanibel'.

Unfortunately, in previous research with resistance tomato varieties, the resistance has often failed as a result of the heat instability or apparent temperature sensitivity of the resistant Mi gene. For example, previous research has demonstrated threshold soil temperatures and incremental reductions in nematode resistance with each degree above 78 F, such that at 91 F tomato plants are fully susceptible. This would suggest that in Florida, use of these varieties may have to be restricted to spring plantings when cooler soil temperatures prevail. Even with spring plantings, it may also be necessary to consider eliminating the use of black plastic mulch in favor of other colored or highly reflective mulches, which may pose other problems to Florida tomato growers.

In addition to problems of heat instability, the continuous or repeated planting of resistant tomato varieties will almost certainly select for virulent races of *Meloidogyne* capable of overcoming the resistance. Therefore the duration and/or utility of the resistance may be time-limited. In previous studies with resistant tomatoes, resistance breaking nematode races have been shown to develop within 5-12 planting cycles (ca. 1 year). Since new races of the nematode can develop so rapidly, a system of integrated control usually mandates the rotation of resistant and non-resistant varieties to slow the selection process for new virulent races. If this situation develops, the combination of a nematocide and resistant variety may also comprise an option to reduce nematode populations to nondamaging levels.

Not only is crop loss within the present crop minimized, but use of resistant varieties can confer advantages to subsequent crops in rotation as a direct result of suppressed nematode population growth. Reduced end-of-season pest population levels could allow growers to

reduce the need for undesirable rotations of nonprofitable crops, allowing preferred crops to be grown more frequently on land best suited for their production without relying exclusively upon soil fumigation to resolve all of their soilborne pest and disease problems.

During fall 1996 and spring 1997, two field microplot experiments were performed to study the influence of increasing soil population levels of the southern root-knot nematode, *Meloidogyne incognita* on fruit yield of susceptible (Agriset 761) and nematode resistant (Sanibel) tomato varieties. The results of the fall study showed that for both varieties, tomato yields decreased with initial soil population level of *M. incognita* (Figure 1.). However, Sanibel was damaged less and was significantly more tolerant of root infection by *M. incognita* than that of Agriset 761, particularly at the highest soil population levels. Although root gall severity was typically high and generally increased with initial inoculum level for both varieties, the galling response of Sanibel was always less than that of the susceptible Agriset 761 (Figure 2.). No differences in tomato yield or root gall severity were observed between either variety or soil population level of *M. incognita* during the spring 1997 experiment.

The results of these preliminary experiments have demonstrated that even with a resistant variety, some consideration of initial soil population level of *M. incognita* must be observed to minimize tomato yield losses. Use of a resistant tomato variety should also not be considered in itself a stand alone, direct replacement strategy for the benefits of methyl bromide soil fumigation. Given Sanibel tomato yield reductions of 40% at the highest inoculum level, combined efforts to manage soil populations to low levels prior to planting must still be considered, particularly if tomatoes are planted as a fall crop. These experiments have also demonstrated that root galling alone is not necessarily indicative of the nematodes ability to reproduce on a plant and that field evaluations based exclusively on this criteria can be misleading. Although root galling always appeared severe with that of the resistant variety Sanibel, reproduction was inhibited, and final harvest soil population levels were always significantly less than that of the susceptible variety, which in itself may better permit the growing of a second susceptible crop after tomato.

ORGANIC AMENDMENTS

Composted urban and agricultural crop residues have been used to amend soil and improve soil fertility, water holding capacity, nutrient retention and cation exchange capacity. Field research conducted in Florida and other parts of the world have also shown that composts can be suppressive to soilborne pathogenic fungi and plant parasitic nematodes. Suppression of soilborne pathogens via the incorporation of composted amendments is reputedly based on enhanced microbial activity and increased numbers of antagonists generated by decomposition of the amendment in soil. Weed suppression has also been demonstrated with some types of composted materials via content and production of organic acids with phytotoxic properties.

A study conducted during spring 1997 was conducted to determine the influence of increasing application rate of a municipal solid composted waste (composted yard wastes fortified with municipal sludge-West Palm Beach Authority) on the ability of tomato plants to tolerate root-infection by the southern root-knot nematode, *Meloidogyne incognita*. This single study showed that in a sandy soil, poor in organic matter content (less than 2%), tomato yields increased dramatically with soil amendment application rate in both the nematode free and infested microplots (Figure 3.). The impact of the root-knot nematode on tomato yield was effectively constant, although there was a tendency for crop losses to decrease with soil amendment application rate. Based on this single study, it would appear that application of the soil amendment did not enhance the ability of the tomato plant to tolerate root-infection by *M. incognita*. Much of the previous and ongoing research in Florida also seems to indicate that the major effects of soil amendments to crop yields appear to be less related to nematode or soil pathogen control than to enhanced plant nutrition and nutrient and water availability.

SOIL SOLARIZATION

Soil solarization is a pest control technique in which moist soil is covered with a transparent plastic mulch to trap incoming solar radiation under the plastic so as to heat the soil to levels thermally lethal to

soilborne pests and pathogens. Many different pests have been suppressed and or controlled by soil solarization, particularly within areas with intense sunshine, and limited cloud cover and rainfall. Plant parasitic nematodes have generally proved to be more difficult to control with soil solarization. In some studies, effective use of solarization for nematode control has required an integrated systems approach, coupling solarization with other chemical or nonchemical approaches. For example, the combined use of soil solarization with various pesticides have improved nematode control and crop yield. In addition, use of virtually impermeable, photo-selective plastic mulches may also complement low dose fumigant treatments to reduce weed germination and growth in the event of extended periods of cloud cover occurring during the solarization regime.

Work in our laboratory has focused on quantifying the thermal sensitivity of the southern root-knot nematode, *M. incognita*, to different temperatures and durations of exposure. This work has shown that the time required to kill *M. incognita* decreases with temperature, such that at temperatures above 120 F only a few minutes is required. We believe we now have the information required to predict when death occurs to the nematode in soil after being subject to regimes of sub-lethal temperatures. Hopefully this information will be useful in grower management decisions determining when the solarization treatment period can be reliably discontinued in the field.

OTHER CULTURAL AND BIOLOGICAL METHODS

At present there are no effective, commercially available, biological control agents which can be successfully used to control nematodes. Flooding has been shown to suppress nematode populations. Alternating 2-3 week cycles of flooding and drying have proven to be more effective than long, continuous flooding cycles. At present, only limited areas within the state are situated to take advantage of flooding as a viable means of nematode control. Other cultural measures which can be important in reducing nematode problems include rapid destruction of the infested crop root system following harvest. Fields which are disked as soon as possible after the crop is harvested will not only prevent further nematode population growth but subject existing populations to desiccation by sun and wind. In most cases, a combination of these management practices will substantially reduce nematode population levels, but will not consistently bring them below economically damaging levels. This is especially true of lands which are continuously planted to susceptible crop varieties. In these cases, some additional chemical or nonchemical form of assistance may still be necessary to improve tomato crop production.

ALTERNATIVE CHEMICALS

In preparation for the phase-out and loss of methyl bromide, university research programs within Florida have been intensified to identify and evaluate more robust strategies which minimize cropping system impacts, accounting for a diverse range of pest pressures and environmental conditions. Previous field research conducted in Florida during 1993 and 1994 demonstrated that a separate, but complementary herbicide treatment would be required to achieve satisfactory weed control and tomato production with any of the alternative fumigants (see Proceeding 1994 Tomato Institute). Since the spring of 1994, at least ten new field experiments have been conducted to evaluate the performance of as many as five alternative fumigants applied in combination with the preplant applied herbicide Tillam (Pebulate; 4 lb a.i./a). For purposes of this presentation, the data from these new studies were analyzed and compared with regard to overall pest pressures encountered in each experiment. Individual pest pressure ratings of low to high for weeds, nematode, and disease were individually considered and summarized in the formulation of an overall pest pressure rating for treatment comparison across experimental locations.

For field studies performed since the spring of 1994, and where the additional herbicide treatment was included, chloropicrin, dazomet (Basamid), and metham sodium (Vapam) once again ranked as the worst treatments for nematode control (Figure 4.). Use of dazomet and metham sodium resulted in root gall severity ratings which were on average 18% and 40% greater than that of the untreated control. Chloropicrin, demonstrating only weak nematocidal activity, reduced final harvest root gall severity on average by 27% relative to the untreated control. Telone C-17 was again rated the best alternative treatment to methyl bromide for nematode control. Root gall severity was reduced 77% relative to the untreated control and only 16% higher

than methyl bromide. The application of Tillam did not influence the expression of root galling for any of the alternative fumigants.

For the untreated control, relative tomato yields decreased with overall pest pressure (Figure 5.). In studies where overall pest pressures were very high (rating=heavy), tomato yields were reduced 79% relative to the methyl bromide treatment. In combination with pebulate (Tillam), only Telone C-17 (Figure 5.) and chloropicrin resulted in near equitable marketable tomato yields to that of methyl bromide across the full range of experimental pest pressures encountered. Of the two, chloropicrin was observed to be the more variable in response than that of Telone C-17. Similar yields and response variation were observed with extra-large tomato fruit for these treatments.

Based on summary and comparison of the alternative chemical trials results in Florida during the period 1994-1996, Telone C-17, now in combination with Tillam, has again been identified as the best alternative replacements for methyl bromide. This has also been demonstrated in large scale, commercial field trials around the state. Use of all of the alternative fumigants, except Telone C-17 and chloropicrin in combination with Pebulate, resulted in lower yields than that of methyl bromide with increasing pest pressure. Telone C-17 also demonstrated superior nematocidal activity and on average, when combined with Pebulate, allowed development of fewer nutsedge plants in the field at final harvest than that of chloropicrin. Relative tomato yields were also more consistently equivalent to that of methyl bromide with Telone C-17 than that of chloropicrin across the complete range of overall pest pressures.

In general however, the majority of these studies reported herein did not reflect situations of high disease severity, and as such, disease pressures were unsuitable for a fair assessment of the disease control properties of any of the alternatives, particularly chloropicrin. The future utility for inclusion of chloropicrin may exist with higher, custom formulations with that of 1,3-D (the primary nematocidal constituent of Telone) for situations in which additional disease control maybe required. Under conditions of high pest pressures (nematodes, disease), other IPM practices might also be required and combined to achieve adequate control and economic crop productivity.

It should also be recognized that 1,3-D has been detected in shallow groundwater and that ground water contamination could be a concern in some areas if 1,3-D is not applied properly or where there is a high water table. At present, the manufacturer of 1,3-D products (DowElanco) has suspended sale, distribution, and use in areas of south Florida which do not possess an impermeable soil layer capable of supporting seep irrigation. 1,3-D has also been detected in air at concentrations considered unhealthful to field personnel, and was temporarily suspended for use within California until new application methodologies could be developed. The future availability of Pebulate (Tillam) is in itself not immune from potential regulatory actions if current labeling restrictions involving hand transplanting are not resolved.

Due to the lower vapor pressure of Telone C17 relative to methyl bromide, a longer exposure / soil aeration time is required for preplant soil fumigation with both the Telone (1,3-D) and chloropicrin constituents of the formulation, which could result in a delay in planting and thus yield. Planting too soon after fumigation could result in phytotoxicity to crop plants, especially if higher rates of chloropicrin are required to control soil-borne pests. Use of increased rates of chloropicrin within the formulation may also be required to achieve acceptable soilborne disease control. Given the sensitivity of the human eyes and nose to chloropicrin, future problems and conflicts with field workers and urban residents may occur due to problems of pesticide drift.

POST PLANT REMEDIATION

Nematode management must be viewed as a preplant consideration because once root infection occurs and plant damage becomes visible it is generally not possible to resolve the problem completely so as to avoid potentially significant tomato yield losses. An experiment conducted during spring 1997 evaluated the extent to which tomato plant growth and yield could be 'rescued' from root-knot nematode via early detection and treatment by post plant applications of Vydate L (Oxamyl) (Figure 6.). In the experiment, tomato was planted into

either nematode free or nematode infested microplots and soil treatments with Vydate L initiated 4, 6, 8 and 10 weeks prior to harvest. Vydate L application rates were held constant for all treatments at one gallon product per acre per season. Applications were made once per week as a soil drench or foliar treatment in one gallon of water resulting in concentrations of Vydate L in irrigation water of 20 to 57 ppm. The results of this experiment clearly showed that it was not possible to completely resolve the problem and avoid tomato yield losses with post plant applications of Vydate L (Figure 6). This was particularly obvious in tomato yield responses with foliar applications of Vydate L attempting to resolve a soilborne problem. If an attempt is going to be made to rescue the crop, the sooner the nematode problem is recognized and soil applications of Vydate L started, the greater the improvement in tomato yields relative to plants maintained nematode free.

Fig. 1 Influence of initial inoculum levels of *Meloidogyne incognita* on tomato fruit yield of susceptible (Agriset 761) and nematode resistant (Sanabel) tomato varieties in field microplots, fall 1997, Lake Alfred, FL

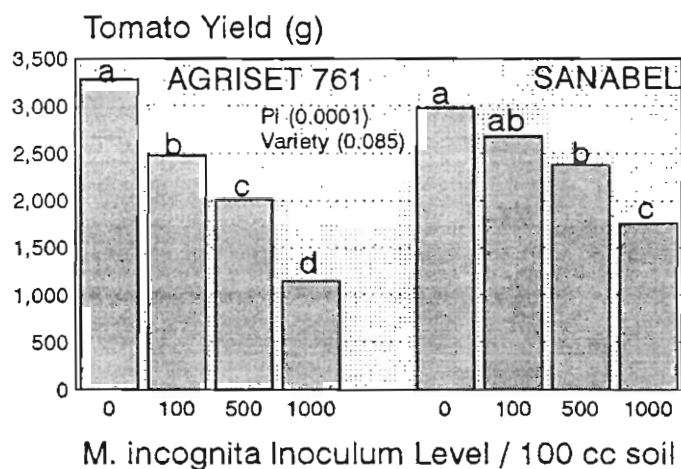


Fig. 2 Influence of initial inoculum levels of *Meloidogyne incognita* on root gall severity of susceptible (Agriset 761) and nematode resistant (Sanabel) tomato varieties in field microplots, fall 1996, Lake Alfred, FL

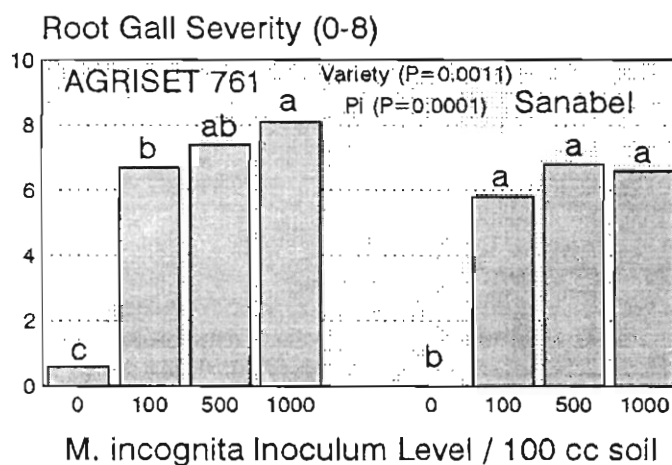
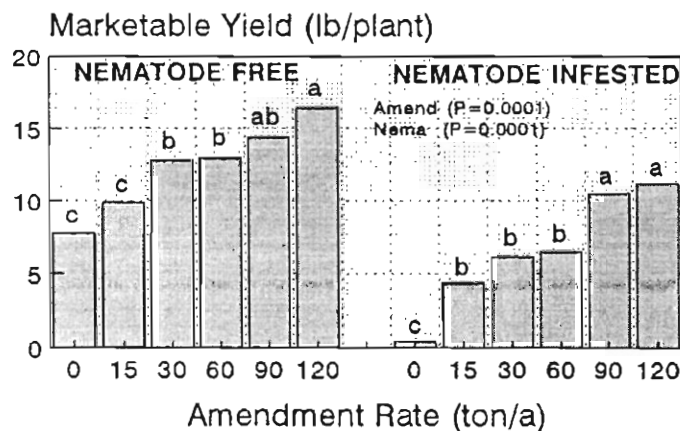


Table 3 . Effect of amending soil with composted municipal solid wastes on marketable tomato yields in nematode free and infested field microplots during spring 1997, CREC, Lake Alfred, FL



each bar the mean of 9 reps, compost provided by West Palm Beach Authority

Fig. 4 Summary of three Florida field research trials (1994-95) comparing relative root gall severity obtained after soil treatment with various alternative fumigant treatments to methyl bromide.

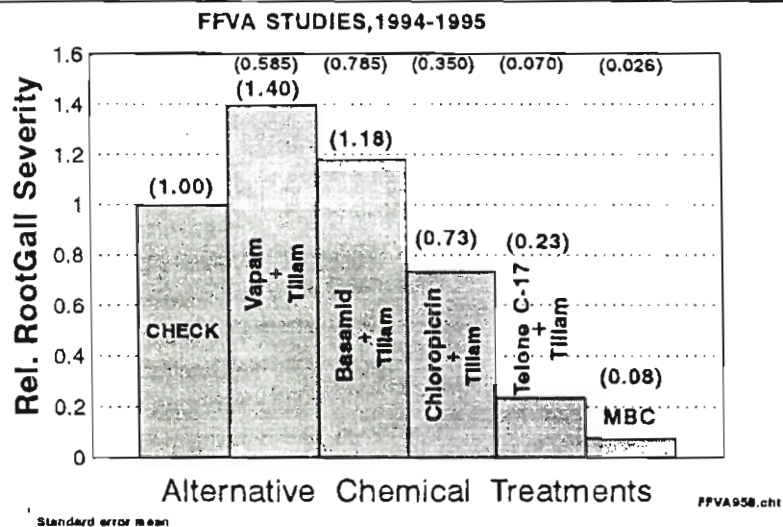
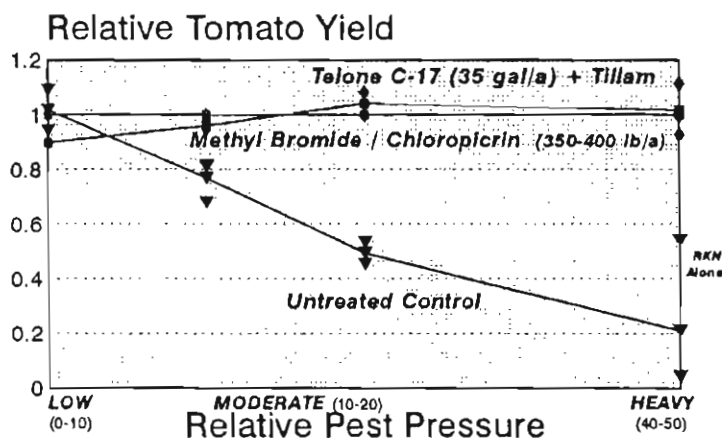
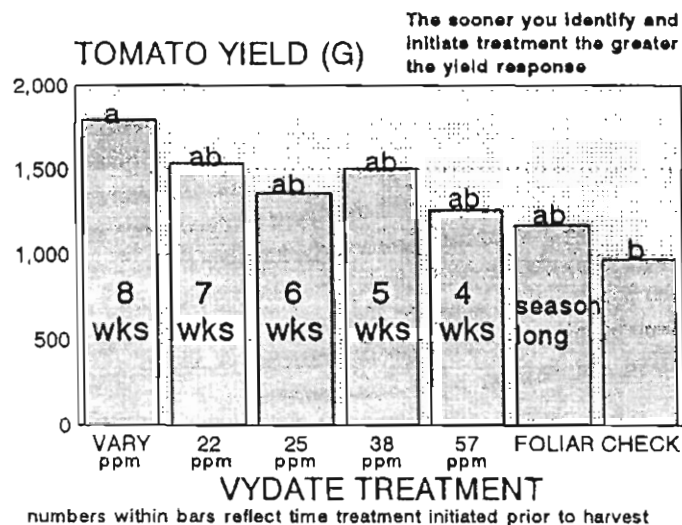


Fig. 5 Summary of eight Florida field research trials (1994-1995) comparing relative tomato yield obtained within the untreated control, Telone C17 and Pebulate, or methyl bromide soil fumigation treatment under varying pest pressure regimes.



Tomato Field Research Trials: Dickson, Gilreath, Locasio, Nolling, Olson, Rich unless noted otherwise, primarily nutsedge as pest pressure

Fig. 6 Response in tomato yields to post plant applications of Vydate L applied at different concentrations in irrigation water and initiated as weekly treatments at various times prior to final harvest in field microplots, spring 1997.



ALTERNATIVES TO METHYL BROMIDE FOR THE MANAGEMENT OF SOILBORNE DISEASES

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Soilborne diseases remain a major limiting constraint for the production of fresh market tomatoes in Florida. Even with the use of methyl bromide as a preplant fumigant, epidemics of bacterial wilt, Fusarium wilt, Fusarium crown rot, and southern blight have occurred in commercial production fields. With the impending loss of methyl bromide, management of soilborne diseases will present an even greater challenge for Florida tomato producers.

In Florida there are four major soilborne diseases of tomato. This article will discuss alternative nonchemical approaches for the management of each disease and their potential for integration into an integrated pest management (IPM) approach for the management of soilborne pests of tomato in Florida.

BACTERIAL WILT

Bacterial wilt is caused by the bacterium *Ralstonia solanacearum* (formerly *Pseudomonas solanacearum*). This bacterium is endemic to Florida, often causing epidemics on newly planted land, and can persist indefinitely in the infested fields by surviving in the root systems of a wide range of host plants including native weeds and rotational crops such as small grains. Another feature of this bacterium which makes it especially difficult to control is its explosive reproductive potential. Populations of *R. solanacearum* can increase by several orders of magnitude in a period of several days, limiting the effect of control strategies which focus on reducing populations in the soil. Failure of chemical fumigants to provide season long control in the field (Enfinger et al., 1979) can be attributed to the explosive reproductive potential of this pathogen.

The most logical approach for managing this disease is to enhance the expression of resistance in tomato. This can be accomplished in three ways: development of genetic resistance, altering plant resistance through calcium nutrition, and cultivation during cooler months to slow down the expression of disease. In Florida, the development of genetic resistance began in 1898 (Rolf, 1898) and is still in progress. Resistance is mediated by at least 6 quantitative trait loci (QTL) which are located on five different chromosomes of the tomato plant (Thoquet et al., 1996). Multiple resistance genes coupled with variability in expression of symptoms in the field have hampered breeding efforts. An open-pollinated cultivar with moderate resistance and good internal fruit quality was developed by Jay Scott at the U.F., IFAS, Gulf Coast Research and Education Center (Scott et al., 1995). However, the percentage of extra-large-sized fruit and blossom end scarring was found to be unacceptable for Florida producers. Work is continuing both at the University of Florida and at private seed companies to develop a resistant cultivar. Unfortunately, it is doubtful that a horticulturally acceptable cultivar will be available to Florida producers by 2001.

Calcium nutrition can reduce the incidence of disease in the field. In field experiments conducted in Florida, lime (CaCO_3) applied at 1 ton/A resulted in a slight reduction in the incidence of disease (Locascio et al., 1988). When a rate of 7.2 tons/A was uniformly incorporated to a depth of 24 inches, the incidence of bacterial wilt was significantly reduced for up to two years (Ssonkko, 1993). While this procedure is impractical for commercial producers, some benefit in disease control can be obtained using heavy applications of calcium prior to planting.

Soil temperature can have a profound effect on the onset of disease symptoms in plants. Several studies have shown that bacterial wilt resistance in moderately resistant cultivars will break down between soil temperatures of 80 - 90 F (Krausz and Thurston, 1976; Mew and Ho, 1977). Development of symptoms in susceptible cultivars was delayed at soil temperatures of 80 F when compared to 90 F. Tomato growers in the Quincy production region have used this information to

schedule plantings in bacterial wilt infested fields for the cooler (spring) production season. In general, avoid planting into infested fields during the fall production season when soil temperatures are greater than 80 F.

SOUTHERN BLIGHT

Southern blight is caused by the fungus *Sclerotium rolfsii*. Resistance has been identified in breeding lines but has not been integrated into cultivars with horticulturally acceptable characteristics (Leeper et al., 1992). Development of resistance cultivars is not likely in the immediate future. Soil solarization can significantly reduce the incidence of southern blight in both pepper and tomato (Chellemi et al., 1997; Ristaino et al., 1996). Incorporation of the biological control agent *Gliocladium virens* also significantly reduced the incidence of southern blight in tomato and pepper (Ristaino et al., 1991; Ristaino et al., 1996). When *G. virens* was combined with soil solarization, additional reductions in the incidence of southern blight were obtained. Thus, soil solarization in combination with the biological control agent *G. virens* can provide significant levels of control for southern blight. *Gliocladium virens* is available commercially (Gliogard, Scotts-Sierra) and should be incorporated into the transplant media at seeding.

FUSARIUM WILT

Fusarium wilt is caused by the fungus *Fusarium oxysporum* f.sp. *lycopersici*. Three races of this fungus exist in Florida (races 1, 2, and 3). The races differ in their ability to infect tomato. Race 1 has been observed in Florida since the beginning of commercial tomato production. Race 2 was discovered in Florida in 1961 and Race 3 in the early 1980's. Races 1 and 2 are disseminated primarily through infested soil and farm implements such as infested stakes. Race 3 also appears to be disseminated by windblown spores (Chellemi, unpublished data), which make it more of a threat to Florida producers. A rotation of 5 or more years will significantly reduce (but not eliminate) the pathogen from the soil, rendering this option impractical for Florida producers. Biological control using nonpathogenic strains of *Fusarium oxysporum* has shown potential in laboratory studies but has not been evaluated in the field.

Fortunately, Fusarium wilt can be controlled through a combination of resistant cultivars and cultural practices. Genetic resistance to all three races is conferred through single dominant genes. Most of the tomato cultivars presently used by the Florida industry have resistance to races 1 and 2. Hybrid cultivars are available which have resistance to all three races and have been evaluated by growers in Florida. These include PS 8432 (Petoseed Co.) and FL 7307 and FL 7658 (University of Florida, IFAS).

Plant nutrition and soil pH can also have a significant impact on disease development in the field. Fertilizers with a higher proportion of nitrate nitrogen (NO_3) than ammoniacal nitrogen (NH_4) will significantly reduce the incidence of disease. For example, a fertilizer blend containing an 80:20 blend of NO_3 : NH_4 will result in significantly lower disease levels than a 25:75 blend of NO_3 : NH_4 . Increasing soil pH will result in a lower incidence of disease. This relationship is most evident at a soil pH below 6.0. Above 6.0, additional increases in soil pH will have only a slight effect on disease.

FUSARIUM CROWN ROT

Fusarium crown rot is caused by the fungus *Fusarium oxysporum* f.sp. *radicis-lycopersici* (FORL), which is identical in appearance fungus *Fusarium oxysporum* f.sp. *lycopersici* (FOL). However, the fungi and their associated diseases differ in a few key aspects of their biology, which will impact their management program.

Development of Fusarium wilt is favored by air and soil temperatures around 82 F while development of Fusarium crown rot is favored by cooler environmental conditions, around 70F. Thus, planting in warmer months (fall production season) will minimize the impact of Fusarium crown rot.

Crop rotations are impractical for Fusarium wilt because the fungus can survive in field soil for 5-10 years. By contrast, a crop rotation of 2 years will effectively eliminate crown rot because the fungus does not survive in infested soils longer than 1-2 years.

Because spores of the crown rot pathogen are easily disseminated by

wind, infected transplants are a primary source for introducing inoculum into the field. Use of high quality transplants which have been inspected for the incidence of crown rot will prevent the introduction of inoculum into the field.

Biological control using various combinations of *Glomus intraradices*, *Streptomyces griseovirdis*, and *Trichoderma harzianum* have been shown to reduce the incidence of disease in the field. Finally, resistance to Fusarium crown rot is also conferred by a single dominant gene and has already been incorporated into a commercially available cultivar (Conquest, Rogers NK Seed Co.). Work is in progress to develop additional resistant cultivars and these should be available by 2001.

SUMMARY

The incidence of all four diseases can be significantly reduced, and in some cases eliminated, through the application of multiple disease management tactics. The most important step towards the management of these diseases is to correctly identify the pest. Assistance in disease diagnosis can be provided by professional scouting firms and University of Florida Extension faculty. Diagnosis can be confirmed by sending plant samples to the University of Florida, Plant Diagnostic Clinics.

Once the pest complex has been identified, selection and integration of multiple pest management tactics into the crop production system will be essential for successful management. Flexibility to assign planting dates among the production fields is recommended. Host resistance should be utilized whenever possible. Sanitation including removal of cull piles, and clean-up of fields coupled with practices which exclude the introduction of inoculum should be implemented as a general production practice.

Mention of a trademark, warranty, proprietary product, or vendor does not constitute a guarantee by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

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ALTERNATIVES TO METHYL BROMIDE FOR MANAGEMENT OF WEEDS

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What significance does the date January 1, 2001 have for you? For me, it means the end of soil fumigation as we once knew it, unless something changes, and I don't believe that will be the case. On that date, methyl bromide will no longer be available in this country and tomato growers will be forced to learn the strengths and weaknesses of the alternatives. Those growers who have tried the alternatives will be ahead of those who waited and let others do the ground work, hoping that science and political lobbying would change that which appears to be destined to occur. Scientists with the University of Florida and the U.S. Dept. of Agriculture have been working to find viable alternatives for Florida vegetable producers. Research on chemical alternatives at the Gulf Coast Research and Education Center in Bradenton began in 1992. Work at other locations was initiated at about the same time or shortly thereafter and an organized program under the leadership of the Florida Fruit and Vegetable Association was instituted shortly thereafter. The progress made to date has been the result of the collaborative efforts of many scientists from all over the state and focus on our work alone is not meant to slight their contributions, for some of our work is based on the work of others. Our research has focused primarily on chemical alternatives, with emphasis on those materials which are currently available. We have looked at fumigants and herbicides, alone and in combination. Some work has been done with experimental products, but due to the lengthy delay in registration of a new fumigant, we have felt that the immediate needs of the industry would have to be served by readily available materials. Today I want to review with you some of the previous results from research that have led us to what we currently feel is the "package" for tomatoes, results of on-farm research over the past several seasons with that "package" and other possible alternatives for the future of soilborne pest management in tomato production in Florida.

We began in 1993 by looking at any and everything which was available. Along the way a few new products were included, but none of these proved acceptable. What works and what does not? Well, the list of what does not work is longer than the list of what does. Early on we discovered one very important limitation with all of the fumigants; none of them controlled nutsedge. Nutsedge control is, and will be, the most difficult aspect of any alternative program. Vapam was studied in great detail, and although it often provided the highest yields when nutsedge was controlled and has performed well in other parts of the U.S., it never provided consistent control of nematodes or soilborne diseases in Florida studies; therefore, Vapam was not considered a viable alternative. Vapam is a liquid and could be injected through the same chisels we use for methyl bromide, but it does not move far from the point of injection in the soil, unlike methyl bromide. Considerable research was conducted to determine the best method for Vapam application and that was found to be spray application to the soil surface followed immediately by rototiller incorpora-

tion. Basamid was supposed to be the answer, according to some of the manufacturer's representatives, but it was very erratic and often provided poor control of all pests in most of our tests. Additionally, use of Basamid would require special application equipment because it is a very fine granule (more like a powder) and has to be incorporated with a rototiller. Chloropicrin has been included in most tests and it provides excellent control of soilborne diseases, but does not control nematodes unless you go to high rates, and then the control is erratic. Chloropicrin would fit well into the existing application system, but without nematode and weed control it is not a viable candidate under most circumstances. The price of chloropicrin is a factor also. Use of chloropicrin alone is an excellent way to find out just how much nutsedge you have in a field as it seems to stimulate tuber germination. Enzone was supposed to be THE answer and could be applied through the drip tube after planting to maintain nematode control. Unfortunately, it did not work and, in fact, in some cases it was phytotoxic to tomatoes. Needless to say, it was dropped from future work early on. That left us with the combination of Telone and chloropicrin sold under the trade name Telone C-17. Although this product has provided good control of nematodes and diseases, as good as methyl bromide in many cases, it does not provide weed control. Telone C-17 "fits" well into our existing fumigant delivery system in that it is delivered to the farm in a pig and is applied with our existing flow meter based system. No changes are required for the application of Telone C-17, but a herbicide must be applied to the bed to control weeds.

Recognizing that weed control was going to be a serious limitation of all of the fumigant alternatives, research was conducted to look at existing and experimental herbicides for nutsedge control in tomato. The one promising experimental product was dropped by the manufacturer. Of those commercially available products which were tested, the most effective were Tillam and Dual. Tillam is the only one of the two which is labeled. Dual provides better nutsedge control but sometimes is phytotoxic. Devrinol is labeled for application to tomato, but results with it have been quite erratic. Parallel studies were conducted at the same time with combinations of fumigants and the more promising herbicides and it is from these studies that the most likely replacement or alternative treatment was derived. That treatment consisted of application of Tillam (4 lb.a.i./acre) in the bed followed by injection of Telone C-17 (35 gal/acre) into the bed through typical chisels. Repeatedly in research in small plots on the experiment station, this combination has provided nutsedge, nematode and disease control similar to methyl bromide and yields have been about the same as what were obtained with methyl bromide. Thus, the use of Tillam became a critical element in the alternative "package". One of the questions which remained was how to best apply Tillam. Most of the research at that point had been conducted with incorporation of Tillam into the bed with a rototiller. The Tillam label specifies that it must be thoroughly soil incorporated and the proper way is with a rototiller or by cultivating it in at right angles with a disk or some other tillage implement. Rototillers are not a common piece of equipment on large tomato farms and they require more horsepower than a disk. Disking is an available option, but field ditches limit it to a unidirectional process. How important is that second disking at right angles to the first or more precisely, can unidirectional operation of a disk or a field cultivator provide nutsedge control equal to rototiller incorporation? Since some mixing of soil appears to occur during the bedding process, it was felt that bedding up might suffice for a second incorporation. Research determined that any of these three methods could provide effective nutsedge control, if the Tillam was incorporated deep enough.

Subsequently, large scale grower demonstrations were established during the spring and fall of 1996 and the spring of 1997 to compare the combination of Tillam and Telone C-17 to the grower standard of methyl bromide, using whatever formulation and rate of methyl bromide was typical for that grower. These trials generally consisted of 5 acres of Tillam/Telone C-17 in the same field with methyl bromide. Eight trials have been completed to date; one in Naples, six in the Ruskin/Palmetto area, and one near Plant City. In each trial, the grower cooperators recorded the yields from the two areas and we harvested fruit from 20-plant plots selected at random from within the methyl bromide and Tillam/Telone C-17 treated areas for comparison purposes. We also monitored weed populations and incidence of nematodes and soilborne diseases. In most trials, Tillam was applied and incorporated immediately in one pass with a field cultivator with the application performed by J. P. Gilreath. Application of Telone C-17 was

performed by the grower with his fumigation rig. The only change necessary was a small increase in the flow rate setting of the flow meter to deliver the required amount of C-17. In general, the results have been fairly consistent across all trials and have reflected what we found previously in small plots on the experiment station. Unfortunately, most growers either don't have "problem" blocks which are infested with soilborne pests, or they avoid them or continuous useage of methyl bromide has minimized their existence. Thus, we were not able to give the system the acid test we had hoped for. Still, side by side, Tillam and Telone C-17 appear equal to methyl bromide in efficacy and yield. What we have had good data on has been nutsedge as several farms had nutsedge infested areas in which we were located. As scientists, we have been disappointed with the lack of nematode and disease infestations, but we recognize that not everyone shares our glee over such pests. Additional grower trials are underway on tomato and we are expanding to a few other commodities.

As we have seen with methyl bromide, a pesticide-based system of soilborne disease control may not survive in the current "environment" and we should not allow ourselves to be caught in this same pinch again. Other scientists are working on different approaches to soilborne pest control. Hopefully a number of options will be available for growers in the future. Today the most likely other option appears to be solarization, the process of elevating the soil temperature to greater than 130 degrees Fahrenheit by covering the individual beds with a clear plastic mulch. This process has worked well in Quincy and in a fall trial (August - September) at our location in west central Florida we had good results for nutsedge control with certain clear mulch films. It appears that one weakness may be nematode

control; it is questionable how effective solarization is for controlling root knot nematodes. It seems to be fairly effective for soilborne disease control, but not enough research has been done on this aspect of solarization. Unfortunately, solarization is practical only during the warmer months of the year as it requires at least 6 weeks of heating. Thus, it would only be applicable to fall tomatoes in the Palmetto/Ruskin area, but might have a wider use window in more southerly locations or for crops grown during summer. It is not clear what would happen if the solarization period consisted of an abnormally prolonged period of cloudy, rainy weather; however, it does appear to have some potential, especially for nutsedge control. One problem which has not been adequately researched to date is the effect on rotational or double crops. Limited research suggests that the efficacy of methyl bromide is longer lasting than that of other alternatives, as resurgence of nematodes has been observed in double cropped cucumbers. Subsequent control of nutsedge has been about as good with Tillam as with methyl bromide in the double crop, but these results are still preliminary and more research is needed in this area. Actually, the more we research this issue, the more questions arise. What will happen when we no longer have methyl bromide; will we see a steady increase in soilborne pests as time passes even where we use other fumigants, as some have suggested? What role will double cropping, cover cropping or allowing the land to lay fallow after a tomato crop have on subsequent pest levels in the soil? How will these cropping schemes interact with the emerging replacements for methyl bromide? These are some of the questions we are attempting to answer through research on experiment stations and grower farms. The answers are important to the overall success of our industry. Your participation is invited.

ALTERNATIVES TO METHYL BROMIDE FROM A PLANT BREEDING PERSPECTIVE

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ABSTRACT

Much of the research in recent years to find suitable alternatives to methyl bromide has focused mainly on chemical strategies. Recent advances in the area of tomato breeding have allowed for the development and commercialization of varieties carrying genes which mediate tolerance/resistance to several economically important soil-borne pathogens that often attack tomatoes in Florida. The deployment of such genes could have an impact on the choice of alternative chemicals and thus provide the farmer with additional options for coping with these pathogens in the absence of methyl bromide. This paper will attempt to give a (non-exhaustive) summary of the named varieties which have the genetic makeup to complement most chemical strategies and offer the grower maximum options for crop protection.

The impending loss of methyl bromide dictated by the 1990 Clean Air Act resulted in a flurry of research activity into alternative strategies for soil fumigation. Much of this work has focused on finding chemical alternatives which act alone or in combination with other chemicals such as herbicides to give a broad spectrum of control. Reports from various researchers to past Florida Tomato Institutes indicated that although many other soil fumigants exist, when compared to methyl bromide, few can be considered equivalent alternatives on their own. Many must be used in combination with one or more complementary materials to give levels of control comparable to that of methyl bromide or combinations using it. Thus, the important question regarding the relative costs/acre of the alternative control options comes into play for the grower.

Test data presented during the 1994 Tomato Institute showed that in several instances, the alternative chemical treatments displayed variation with respect to duration of control as well as efficacy against certain pathogens and weeds. In other words, observable crop losses were related to infection severity which was a function of the choice of chemical treatments. Tillam + Telone + C17 was considered to be the best overall alternative for reducing soil born pathogens and weeds, but other chemicals showed good control for a more narrow range of pathogens. Thus, these other chemicals if properly complemented either chemically or **genetically** might be as useful as the former treatment group in certain settings. Further testing of this hypothesis could prove interesting from both a cost and control standpoint.

In 1994, Noling and others concluded in their report to the Florida Tomato Institute that the alternatives to methyl bromide which were evaluated in the spring trials of 1994 were generally less effective than that of the current industry standard, methyl bromide. They also reported that several of the chemicals required longer aeration periods to prevent phytotoxicity and late season buildups of root-knot nematodes were observed in most treatments. In short, the alternatives were not without their shortcomings and were of potential impact both to the primary and in some cases to double-cropped plantings of susceptible items like squash, melons and cucumbers. This however assumed that the tomato variety used could serve as an effective host for the colonization and reproduction of the offending pathogen. Such build-ups may not be problematic for some pathogens if genes for resistance are present and properly functioning in field-grown varieties. More testing is needed to clarify this.

A considerable body of work exists regarding the range of pathogens and pests which can infest commercial tomato plantings. Unfortunately, tomatoes are a suitable host for a wide range of plant pathogenic fungi, bacteria, viruses, nematodes, plus many insect species. Several of the most potentially devastating pathogens are soil-borne and have demonstrated a capacity to cause damage in com-

mmercial tomato fields even in the presence of higher rates of methyl bromide. Symptoms were often worse in fields which employed varieties that did not have a full array of genetic resistances to these commonly found soil organisms. In some instances, growers were forced to abandon fields with high populations of soil-borne organisms despite the availability of methyl bromide. To complicate matters further, new races of these organisms have developed over time in one or more areas of Florida and caused further flight from infected fields.

In recent years, we have seen a proliferation of problems with soil borne organisms on tomatoes and several are likely to become more significant problems for Florida growers in relation to the loss of methyl bromide. We have already seen damage in commercial fields throughout the state even with the use of methyl bromide. This fact is not of great encouragement for the future given present options.

The list of potentially problematic pathogens on Florida tomatoes includes: **Verticillium, Fusarium Races 1,2,3, Fusarium Crown and Root Rot, Bacterial Wilt, and Root Knot Nematodes**. There may well be others residing in the soil that will present additional problems, but this group represents the "most likely to succeed" category in terms of grower headaches.

One has only to look at the recent spread of Fusarium Race 3 across the eastern U.S. or the rapid rise of Fusarium Crown Rot in the largely unfumigated growing areas of Sinaloa in Mexico to see the potential for trouble in the future, especially if the ability to maintain effective controls is reduced significantly. Bacterial wilt and nematodes could well be sleeping giants as they are devastating in many tomato growing areas of the world which lack good controls and the situation is further complicated by the many variants of the organism which exist. A new (Mi) resistance breaking strain of nematode has been observed in California over the last three years. Such mutations are to be expected over time, but present more challenges to the grower in terms of control options.

Since it is unlikely that all fields will have all of the problematic pathogens at once, the potential exists for matching or tailoring the soil treatment to the specific range of pest problems known to occur within given areas. More than one treatment strategy may then be open to the grower and cost vs. benefit analyses can follow for given fields or farms.

For many years, a considerable effort in the breeding community has been specifically dedicated to identifying and introgressing genes for resistance or tolerance to various tomato pathogens including those listed above. The level of genetic complexity for resistance or tolerance to the eight pathogens above ranges from simple (single gene) to highly complex (multigenic). In some cases more than one source of the gene(s) mediating resistance for the same pathogen may exist, thus allowing breeders to combine genes and improve the range of efficacy in certain varieties.

In recent years, refined methods of plant breeding and powerful new testing technologies have allowed tomato breeders to more rapidly find, manipulate and combine multiple genes for disease resistance in hybrid varieties. As a result, during the past five years, several commercially adapted varieties have been developed to simultaneously address at least four of the pathogens which are likely to be most problematic for Florida growers in the future. More pyramiding of genes is expected in the future as the various breeding programs progress.

Table 1 provides a (non-exhaustive) summary of tomato varieties adapted to Florida growing conditions and specifies which of the genetic resistances or tolerances each carries. By supplying this information, it is hoped that those who are faced with making treatment decisions or recommendations with respect to soil-borne pathogens of tomatoes will be better able to integrate the existing chemical and genetic technologies to the benefit of the Florida tomato industry. Tomato varieties and their resistance packages are changing at an ever increasing rate. A two-pronged approach between the chemical and seed industries should provide a greater buffer for the Florida grower in the face of rising costs and stiff competition. More dialogue and interaction between the respective research groups is suggested in order to meet the challenges that lie ahead.

Table 1. Soil-Borne Pathogens and Corresponding Commercial F1s Carrying Genes Mediating Resistance or Tolerance to Those Pathogens

Pathogen	Genes	Variety	Res/Tol.	Efficacy	Status
Vert.	Ve	Sunny	V,F1,F2	Res.	Comm.
Fus. R1&2	I ₁ I ₂	Agriset 761	"	"	"
		Sunbeam	"	"	"
		Merced	"	"	"
		Solar Set	"	"	"
		Leading Lady	"	"	"
		FTE 30,47	"	"	"
		Experimental	"	"	Test
Fus. R3	I ₃	Captiva	V,F1,F2,F3	Res.	Comm.
		Floralina	"	"	"
		Experimental	"+(?)	"	Test
Nematode	Mi*	Sanibel	V,F1,F2,N	Res.*	Comm.
		Suncrest	"	"	"
		Experimental	"+(?)	"	Test
Fus.Crown Comm. &Root Rot	Frl	Conquest	V,F1,F2,FCR	Res?	
		Experimental	"+(?)	"	Test
Bact. Wilt	(?)*	Neptune(IBL)	(?)	Tol.	G'plasm
		Experimental	"	(??)	Test

*Genes are temperature sensitive and efficacious against specific species or strains. High populations may cause limited to severe damage.

THE EXPLOSION OF WHITEFLY-TRANSMITTED GEMINIVIRUS IN TOMATO IN THE AMERICAS

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SUMMARY

Before the mid 1980's, only three whitefly-borne geminiviruses were known to cause problems for tomato producers. However, since then, geminiviruses have appeared in tomato throughout most of the Western Hemisphere, causing reductions in yields, abandonment of production areas, and increases in costs of disease management. Since the late 1980's most of the tomato producing areas of Florida, the Caribbean, Mexico, Central America, Venezuela, and Brazil, have suffered from high incidences of whitefly-borne geminiviruses with devastating economic consequences for their respective tomato industries. This explosion of geminiviruses has resulted from the spread of the silverleaf whitefly, the vector of geminiviruses, which feeds and reproduces on tomato, as well as, many other crops and weeds. This vector has increased the movement of viruses from other crops and weeds into tomato. Many of these geminiviruses appear to be new and may be the result of rapid evolution. Others are the result of expansion of known viruses into new areas through the movement of infected transplants.

The whitefly-transmitted geminiviruses have become a major group of pathogens of vegetables in the subtropics and tropics over the last 10 years. In addition to tomato, crops such as beans, cotton, melon, peppers, and squash are also affected by geminiviruses. However, tomato appears to be the crop where the greatest increase in these viruses have occurred.

There are more than 39 viruses known to infect tomato in the Americas, of which 17 are whitefly-transmitted geminiviruses. Symptoms of geminivirus infection in tomato often resemble those caused by other viruses. Symptoms can vary with the viruses and strains, cultivar, plant age at the time of infection, and environmental conditions. Symptoms can include the following in various combinations: a bright yellow mosaic, chlorotic mottle, chlorotic leaf margins, leaf rolling, leaf distortion, puckering of leaves, reduction in leaf size, stunting of the infected plant, and flower abscission. Fruit size and number are often reduced.

HISTORY

Until the mid 1980's only three geminiviruses had been reported from tomato. The first report occurred in the early 1960s in Brazil when 30 to 40% of the tomato crop was affected with a virus later named tomato golden mosaic virus (TGMV). At approximately the same time, tomato yellow mosaic virus (TYMV) was reported for the first time in tomato in Venezuela, and was viewed as a limiting factor for tomato production in several Venezuelan states. TYMV was identified as the most prevalent virus in tomatoes in Venezuela. The epidemic in 1961 forced many producers to eliminate their tomato plantings and re-plant. In Mexico in 1970-71, a virus, now called chino del tomate virus (CdTV), was reported infecting tomatoes on the west coast of Sinaloa. TGMV, TYMV and CdTV remained the only tomato-infecting geminiviruses reported from the Americas, until the mid to late 1980s, when geminivirus epidemics in tomatoes began to emerge.

Though specific data is unavailable for most countries in the Western Hemisphere, it is apparent that until the mid 1980's, many of the *B. tabaci* biotypes which were present in this hemisphere, fed and reproduced on tomato to a limited extent, minimizing transmission of geminiviruses to and from tomato plants. However, in the mid 1980's a new whitefly biotype or species was introduced from the Mediterranean, possibly through the movement of infested ornamental plants. Although this whitefly was morphologically indistinguishable from the existing *B. tabaci* biotypes, there were significant biological differences. Among other differences, the new whitefly fed readily and reproduced abundantly on tomato.

After its introduction, the B biotype is believed to have spread within the Western Hemisphere through the movement of ornamental plants. By 1988/89 the B-biotype had established and displaced the indigenous populations of *B. tabaci* in Florida and Texas. By 1990, the same had occurred in Arizona and California. The B biotype was subsequently identified from Antigua, Barbuda, the Dominican Republic, Grenada, Guadeloupe, Puerto Rico, Trinidad and Tobago, St. Kitts and Nevis, and Mexico (state of Quintana Roo) by 1990/91; by 1992 it had spread to western Mexico (Sonora), Belize and Nicaragua; by 1993 was found throughout most of Central America, and had moved into Brazil; and by 1994 was found throughout Venezuela, and was moving south along the west coast of Mexico into Sinaloa and Tamaulipas. The B biotype has recently been reported from Colombia and Guyana in South America. The appearance of this whitefly in tomato has been followed within three to five years, by the appearance of one or more previously unreported geminiviruses.

At the same time that the whitefly was introduced, changes were taking place in tomato production in the tropics. Processing tomatoes have traditionally been produced throughout the Western Hemisphere tropics for local consumption and for conversion into paste. Much of this production was by small farmers with minimal financial input. However, the production of fresh-market tomatoes is potentially a much more profitable business and has been expanding over the last decade. The last few decades have seen an increase in the production of this type of tomato, 1) for export to northern countries during the northern hemisphere winter season, and 2) to meet increases in demand from expanding local tourist industries. Fresh market tomato production requires a greater financial input, and therefore much of these tomatoes are produced by larger growers.

ECONOMIC IMPACT OF GEMINIVIRUSES IN TOMATO

Geminiviruses have caused economic losses in almost every production area where they have occurred. However, documentation of this pattern of devastating epidemics and losses is lacking. While no formal crop loss assessment studies have been undertaken for these tomato diseases, the empirical data are impressive. Diseases caused by geminiviruses are repeatedly referred to as the limiting biotic constraint to tomato production. In 1988 in the Dominican Republic, multiple geminiviruses began to affect tomato production in the south central and the northwestern zones of the country. Crop damage from 1988-1995 ranged from 5-95%. Economic losses in 1988 were estimated at US \$10 million dollars, with losses from 1989-1995 totaling an estimated US \$50 million dollars. In Florida, the disease caused by tomato mottle virus (ToMoV) was found in all tomato production areas of Florida, with reported incidences as high as 95%. ToMoV was conservatively estimated to have reduced the value of the 1990-91 southwestern Florida tomato crop by 20% or US \$125 million. From 1989-1995, Puerto Rico suffered an estimated US \$40 million in losses due to whiteflies, of which a significant portion was attributed to losses in tomatoes from whitefly-transmitted geminiviruses. Tomato producers in the Comayagua Valley of Honduras lost an estimated US \$4.6 million in 1992, due to diseases caused by geminiviruses. In some countries (e.g. Nicaragua), entire zones have gone out of tomato production. In Venezuela, the area of tomato production has been reduced by 50%.

THE GEMINIVIRUSES

Tomatoes are infected by geminiviruses which are transmitted by the whitefly *Bemisia tabaci*, of which one biotype, B, is also known as *B. argentifolii*. Though there are biological differences among the various whitefly biotypes, studies have shown that in general almost all the biotypes tested could transmit almost all the geminiviruses tested. Geminiviruses are acquired in as little as 30 minutes by adult whitefly, and are transmitted for as long as the whitefly lives. There is some

limited data which suggests the possibility that these viruses may replicate in the whitefly but this is still controversial. None of these viruses are transmitted through seed nor by casual contact between workers or machinery and plants.

For many of the tomato-infecting geminiviruses, few to no biological characteristics are known. There are few reports of alternate, cultivated field hosts. Data on the weed hosts for most tomato geminiviruses are also lacking. This is due in part because many of the viruses described in this report have only been recognized in tomato within the last 10 years. The geminiviruses presented in Table 1 represent most of those that are known to infect tomato in the Western Hemisphere and which are characterized to some extent.

Since there are no set of symptoms characteristic for geminiviruses, accurate diagnoses depend on the use of diagnostic assays. Assays which are used to accurately detect geminiviruses are inclusion body visualization assay, ELISA, dot spot hybridization assay, squash blot assay, polymerase chain amplification reaction (PCR). Several of these assays can be used to identify known geminiviruses. New viruses are identified primarily through the genomic sequence.

TOMATO GEMINIVIRUSES IN THE U.S.

Geminiviruses were not a problem in Florida's agricultural production until the appearance of ToMoV in tomatoes in 1989. Agricultural production in Florida has been closely monitored for more than 40 years so it is unlikely that geminivirus disease incidences had been overlooked. The presence of *B. tabaci* in Florida has been known since the late 1800's. The existence of several weeds with golden mosaic symptoms were known since the 1950's and their recognition as geminivirus hosts has been known since the early 1980's. High populations of whiteflies, later identified as *B. tabaci* B biotype, were first noticed in tomatoes in the field in 1987. Tomato plants with virus-like symptoms were first seen at low incidences in southwestern Florida in the spring crop of 1989, and high incidences were observed in the fall crop of the same year. Within a few months the cause of the disease had been identified as a whitefly-transmitted geminivirus and within a year the virus had been sequenced and found to be unique and new and was called **tomato mottle virus (ToMoV)**. The virus was found to have a narrow range of hosts. No significant weed hosts were found. Incidences of ToMoV-infected plants varied from year to year, with incidences in production fields as high as 100% at the close of some growing seasons. High incidences occurred despite the frequent application of insecticides, as often as five to seven times per week. At the present time disease incidences are low. This has been attributed primarily to the use of imidacloprid, a systemic insecticide.

The origin of ToMoV is believed to be Florida. However, ToMoV has been found outside of Florida, in a few plants in Virginia, in epidemics in South Carolina and Tennessee, and more consistently from Puerto Rico. It is possible that these introductions are the result of the movement of infected tomato transplants from Florida to these other locations. No further epidemics of ToMoV have been reported from either South Carolina or Tennessee since the 1994 production season.

Diseases caused by **Texas pepper virus (TPV)** were first observed in epidemic proportions in tomato and pepper in Texas in 1987 and were associated with high populations of *B. tabaci* B-biotype. The epidemic lasted only a few years and the virus has not been reported in epidemic proportions in tomato in Texas since that time. However epidemics of this virus occur routinely in tomato and pepper in the state of Tamaulipas, northeastern Mexico. The virus associated with these epidemics was originally named **pepper jalapeno virus (PJV)**, but has recently been re-classified as a strain of TPV. This virus has been found in tomato in Sinaloa, and in pepper in several other states in Mexico.

Pepper huasteco virus (PHV) has been detected in peppers in the U.S. since 1987. Like TPV, PHV is capable of infecting tomato and has been detected in tomatoes in Mexico. Presumably these viruses can be found in tomato in Texas although there are few reports of epidemics. One epidemic of a geminivirus which may have been TPV or PHV, did occur in the spring of 1997 in greenhouse tomatoes near Davis, Texas. A similar situation exists in Arizona, where TPV was detected in pepper, and **serrano golden mosaic virus (SGMV)** was detected in pepper and tomato. Although both viruses are capable of infecting tomato, no epidemics of these viruses in tomato have been reported in Arizona.

TOMATO GEMINIVIRUSES IN MEXICO

Epidemics of **chino del tomate virus (CdTV)** have occurred in Sinaloa from 1976 through 1983, and every year from 1988 to the present in conjunction with high populations of *B. tabaci*. The symptoms caused by CdTV in tomato are severe, and can resemble those of TYLCV. The host range is broad and includes other crop and weed plants. The virus can be found in both pepper and tomato in the field. CdTV has been reported from all tomato production areas of Mexico. Chino del tomate virus has been found in tomato with at least two other geminiviruses, PHV and TPV. This has complicated not only detection and identification, but management as well. It is believed that the distribution of CdTV may have increased due to the movement of tomato transplants from Sinaloa to other production areas in Mexico.

Several other geminiviruses have been reported to infect tomato in Mexico. These are **Sinaloa tomato leaf curl virus (STLCV)**, **serrano golden mosaic virus (SGMV)**, **tomato leaf crumple virus (TLCrV)**, and the viruses causing rizado amarillo and tigre disease. Many of these viruses have also been found in pepper, a crop which is more widely grown than tomato in Mexico, and the importance of some of these viruses to tomato production is unclear at this time. Rizado amarillo disease was determined to be the result of infection by two geminiviruses. The tomato leaf crumple virus appears to be a strain of CdTV. A strain of **pepper huasteco virus (PHV)**, a virus which is widely distributed throughout peppers in Mexico, was found for the first time in tomatoes collected in Sinaloa in 1990. Another virus, SGMV, which also infects tomato and pepper in Sinaloa, appears to be closely related to TPV and PJV. The geminiviruses which infect tomato in Mexico often occur in complexes with other geminiviruses, and these complexes vary among production seasons and locations.

TOMATO GEMINIVIRUSES IN CENTRAL AMERICA

Although geminiviruses are causing significant yield losses in tomato-producing zones throughout Central America, less is known about these viruses in comparison with those from elsewhere in this hemisphere. Economically significant tomato diseases associated with *B. tabaci* were reported from Nicaragua in 1983-84, Guatemala in 1987, El Salvador and Costa Rica in 1988, Honduras in 1989, and Panama in 1991. A geminivirus was confirmed in tomatoes from Sebaco Valley in Nicaragua in 1986, and in 1989, another was identified from the Central Valley of Costa Rica. The geminivirus from Costa Rica appears to be a distinct geminivirus, and is now referred to as **tomato yellow mottle virus (TYMoV)**. **Texas pepper virus**, was recently identified from tomatoes in Guatemala (D.P. Maxwell, pers. comm.). Additional geminiviruses, with temporary designations, have been identified in Guatemala (**TomGV1**, **TomGV2**), Honduras (**TomGV1**) and Nicaragua (**TomGV1**). At least one geminivirus has been found in Belize, and at least one other has been detected in tomato samples from Panama.

TOMATO GEMINIVIRUSES IN SOUTH AMERICA

Beginning in the 1970's, **tomato yellow mosaic virus (TYMV)** was a problem in tomato production throughout Venezuela. In 1990-91 *B. tabaci* B biotype and irregular ripening were found for the first time in Venezuela tomato fields and within a few years were followed by new virus-like symptoms. In 1997, a strain of **potato yellow mosaic virus (PYMV)** was identified from affected tomatoes. PYMV had first been found in the mid 1980's in potato in Venezuela. A second virus was also identified in tomato in the same areas where PYMV was found. It is not known at this time what relationship these viruses have to TYMV.

The B biotype was first observed in 1990/91 in São Paulo, Brazil and in 1993 in the Federal District. This whitefly biotype has also been reported in the States of São Paulo, Paraná, Rio de Janeiro, Bahia, and Pernambuco. Since 1994, a series of distinct tomato geminiviruses have appeared in Brazil. Geminiviruses have been detected in over 75% of the states producing tomatoes (both fresh market and processing). In Minas Gerais State, two geminiviruses, provisionally named **TGV-BZ-Ig** and **TGV-BZ-Ub**, were found to cause yellow mosaic symptoms in tomatoes. Another geminivirus, named **tomato yellow vein streak virus (ToYVSV)**, has been detected in tomatoes in São Paulo State. Tomato geminiviruses have also been isolated from the states of Rio de Janeiro, Bahia, Pernambuco and the Federal District.

Preliminary results indicate that these are different from previously described geminiviruses. The first tomato geminivirus known in the Americas was **tomato golden mosaic virus (TGMV)** from Brazil. Interestingly, recent surveys in Brazil have not found this virus.

TOMATO GEMINIVIRUSES IN THE CARIBBEAN

High populations of *B. tabaci* B biotype have been present in the Dominican Republic since 1987. In 1988, indigenous geminiviruses began to appear and affect tomato production in the south and north-western production areas. Several new viruses, which are in the process of being characterized, have been found in tomatoes from these areas. The severe symptoms of **tomato yellow leaf curl virus (TYLCV)** were first noticed in the northwestern production region in 1992. TYLCV has been found in home gardens, in weed species, and appears to have established in the agroecosystem. From discussions with tomato growers, it appears that TYLCV may have been unknowingly introduced by a tomato producer located in the northwestern region of the Dominican Republic. This grower was producing tomatoes in a greenhouse using a fresh-market, greenhouse cultivar which was only available as transplants from Israel. The virus was identified as TYLCV-Is in 1994 based on blot hybridization and a partial genomic sequence. TYLCV was subsequently identified in Jamaica and Cuba. It is not clear yet, if these epidemics are the result of separate introductions or spread from a single introduction.

The distribution of **potato yellow mosaic virus (PYMV)** in tomato appears to be widespread and may still be expanding. This virus was first described in potato in 1986 from Venezuela. Tomato was determined to be a host in greenhouse experiments, but natural infections of this virus in tomato were not reported. Whiteflies were observed in the Guadeloupe and Martinique in tomato beginning around 1990. In 1992, virus-like symptoms of chlorotic mottling, leaf distortion, and leaf rolling caused by a strain of PYMV were seen for the first time in tomato in Martinique. The incidence of this virus ranged from 15% in the southern production region to as high as 68% in the northern production region. This same virus appeared in Guadeloupe in 1993. The symptoms were first observed in the southwestern edge of Guadeloupe and by 1996 had spread to the eastern half of the island. PYMV has also been found in tomato in Trinidad and Tobago where epidemics with high incidences of infected plants have occurred over the last several years.

It is not known how PYMV came to be distributed so widely and in so many locations in the eastern Caribbean, and moreover, with little genomic variation. It is possible that the virus has been disseminated recently, either through the movement of infected tomato transplants, infected potato tubers, or through the movement of plant material harboring viruliferous whiteflies. It is also possible that viruliferous whiteflies were distributed by one or more of the hurricanes that occur between June and October every year.

Over the last several years, two geminiviruses, **ToMoV** and **PYMV**, have been reported from tomato fields in Puerto Rico. Other geminiviruses present on the island have been shown capable of infecting tomato in greenhouse studies, but had never been detected in the field. Within the last year two geminiviruses have been reported in tomato from Cuba, **TYLCV** and **Taino tomato mottle virus (TaTMoV)**. The TYLCV is the same as the one seen in the Dominican Republic and Jamaica.

ECOLOGY, EPIDEMIOLOGY, AND MANAGEMENT

Geminiviruses are dependent upon the movement of their whitefly vector for opportunities to infect new plants. While weeds play a role in maintaining whiteflies in the agroecosystem, cultivated hosts are the most important source of whiteflies. A field of crop plants provides millions of breeding and feeding sites, and gives rise to large populations of adult *B. tabaci*. Reports of host preferences of whitefly biotypes which were present before the introduction of the B biotype, are scarce and unavailable for most countries. Those that were made indicate that tomato was not a good host for many of the whitefly biotypes. During the past decade the B biotype of *B. tabaci* has been observed colonizing and reproducing on crop plants such as tomato, peppers, eggplant, lettuce and cabbage, which were marginal hosts for the indigenous biotypes. Greater abilities to reproduce, to disperse, and to colonize tomato, all contribute to an increased capacity of the B biotype to acquire and transmit tomato geminiviruses.

Geminiviruses in tomato are difficult and expensive to manage. The reduction of sources of whiteflies and, where possible, reduction of virus reservoirs would contribute to management at a regional level. This would include such approaches as rapid removal of crops at the end of the season, and regional crop-free periods. In terms of crop-oriented management, the two tactics most frequently implemented to protect crops from insect-transmitted viruses, including whitefly-transmitted geminiviruses, are insecticides and resistant crop varieties. Management of the whitefly vector using insecticides is the most often employed and most expensive approach to geminivirus management. A number of insecticides, oils and soaps have been applied to reduce whitefly populations and reduce the incidence of infected plants in both transplant production houses and the field. In some places and in some seasons the use of insecticides can reduce the incidence of infected plants to economically satisfactory levels.

However, there are times and locations where the use of insecticides is insufficient to guarantee economic success. In much of the tropical Americas, few effective insecticides are available, due to insecticide resistance in the whitefly populations, and in the case of small growers, to the high cost of the insecticides. In many areas (i.e. Dominican Republic, Florida, Sinaloa, Mexico), geminivirus management is still completely dependent upon the use of insecticides. One recently introduced insecticide, imidacloprid, has had a major impact over the last few years on whitefly populations and incidence of geminiviruses. This insecticide is systemic in tomato, and is applied most effectively as a soil drench. Recently, resistance to imidacloprid has been reported from Spain and Arizona. The efficacy of insecticides can be increased when different types are applied in rotation, and in conjunction with regular scouting.

At present, there are no commercially-available cultivars with resistance to the whitefly vector. Likewise, no tomato cultivars are commercially available with immunity or even moderate tolerance to any of the geminiviruses (with the exception of TYLCV). In general, cultivars with TYLCV tolerance do not perform as well against most other geminiviruses present in the Americas. Therefore, most of the tomatoes produced in the Americas are completely vulnerable to the indigenous geminivirus complexes. Commercial and university breeding programs are in progress to develop resistance to tomato geminiviruses. Some inbred tomato lines reported to be tolerant to TYLCV have been evaluated in field assays and appeared to be promising sources of resistance to geminiviruses in Brazil, Florida, and the Dominican Republic. To date, the resistances that have been found are of two broad types. Genes for resistance have been derived from several species of *Lycopersicon* and resistance is usually multi-genic. Genes from geminiviruses (pathogen-derived resistance) have been tested in transformed plants and have been shown to be useful, though tomato hybrids with transgenic resistance and superior horticultural qualities are still in development. In general, commercially available resistance to TYLCV can be overcome 1) by many other geminiviruses, 2) when moderate to high populations of viruliferous whitefly are present, and 3) if plants are inoculated in the transplant bed or house or within the first few weeks in the field. Thus, vector management is and will be for some time an essential complement to the use of resistant cultivars.

In addition, several cultural and legal tactics pertaining to crop removal and crop-free periods have successfully decreased the incidence of geminivirus-infected plants. However, these practices do not appear to be sufficiently effective unless used in combination with insecticides or resistant cultivars. Crop free periods reduce whitefly populations and in some cases decrease the numbers of viruliferous vectors. Tomato transplants should be produced at least several miles from tomato fruit production areas. Row covers over young tomatoes can help delay the onset of infection. New fields of tomatoes should not be planted near or downwind from older fields. Colored plastic mulches, especially UV-reflective, have been shown to decrease the incidence of virus-infected tomato plants early in the season.

Economically viable management has not been achieved regularly in most areas where geminiviruses infect tomato. However, two production areas, Florida and the Dominican Republic have achieved successful management for several years.

MANAGEMENT IN FLORIDA

Florida produces fresh-market type tomatoes primarily in large fields of plastic-covered raised beds which support staked tomato plants. Planting is generally more synchronized than in the tropics and production is not year-round. Only one geminivirus, ToMoV, is known. As a result of the host range and field studies which concluded that old tomato crops and volunteers were the most important sources of ToMoV, tomato growers were encouraged to rapidly remove plants at the end of the season and to voluntarily comply with tomato-free periods between production seasons. These practices decreased crop reservoirs for ToMoV but due to lack of implementation by some growers this approach was not as effective as it could have been. In addition, many growers stopped producing their own transplants and instead began to purchase them from commercial producers who were not located near field production areas. However, the most significant management tactic has been the use of a systemic insecticide, imidacloprid, which has efficacy against all life stages of the whitefly. Since 1994, this insecticide has been used on almost all tomatoes, and is often applied as a soil drench both in the transplant production house and at the time of planting in the field. The majority of growers use a rate that kills whiteflies for about eight weeks in the field, after which time they apply a rotation of different foliar insecticides. The incidence of ToMoV-infected plants was reduced the first season and continued to decline until the incidence of ToMoV was less than 1% in 1997. Incidence has remained low to the present (1997). This approach to virus management is expensive but effective for one virus with a relatively simple disease cycle, in a context of relatively synchronized planting seasons, and will remain effective until the whiteflies build up resistance to imidacloprid.

MANAGEMENT IN THE DOMINICAN REPUBLIC

Until recently, tomato production here was characterized by both small and large producers of primarily processing type tomatoes, which were planted year-round. Generally transplants were produced in the soil next to production fields, and expensive inputs such as plastic mulches, raised beds, and staking were not employed. After the arrival of the B biotype, several geminiviruses appeared in tomato including TYLCV. Successful management of TYLCV is more difficult than many other geminiviruses. TYLCV is transmitted more readily than many other geminiviruses, and the virus has alternate hosts both in the weeds and in backyard gardens. A government-enforced three month crop-free period, enacted to reduce the populations of a geminivirus in bean, was continued in order to aid the tomato growers. Compliance was compulsory but enforcement was uneven. Economically successful management was achieved by large tomato growers in the Dominican Republic who had the necessary financial resources. These growers now produce their transplants in an area removed from tomato production. Occasionally growers are able to use fields that are isolated from other tomato fields. In addition, most growers are using TYLCV-tolerant hybrid cultivars which are expensive but which can often produce an acceptable yield in the Dominican Republic. In addition, these growers rely upon several applications of imidacloprid throughout the season, beginning with transplant production. A significant decrease in damage caused by tomato geminiviruses beginning in 1994/95 was attributed to the deployment of tolerant cultivars, the introduction and use of imidacloprid, and the occurrence of heavy rains which reduced *Bemisia* population levels.

In contrast to the success of the large growers, many of the small tomato growers in Dominican Republic no longer produce tomatoes. These growers did not have the economic resources to employ the management tactics used by the large growers. However, small plot production is characteristic of the tropics. These growers could be helped by the availability of resistant open-pollinated cultivars and by the development of appropriate cultural practices which would reduce both whiteflies and virus. The management of geminiviruses by numerous growers with small plots and limited resources, in the context of year-round tomato production, is the greatest challenge for geminivirus management.

CONCLUSION

This article has presented a summary of the dynamic changes that have and are occurring in the whitefly-transmitted geminiviruses which infect tomato in the Americas. That geminiviruses are emerging is not a new phenomenon, however, the speed with which they are arising is of concern. In the 1970's only CdTV, ToYMV, and TGMV

were known to infect tomatoes, and there were few oral or written reports of problems with geminiviruses in tomato from that time. By 1996, at least 17 geminiviruses, not including new strains, were recognized. Numerous others had been reported but their taxonomic status awaits clarification. Reports of escalating yield losses have become more frequent as well. Whitefly-transmitted geminiviruses in tomatoes have become widespread geographically, resulting in devastating epidemics throughout the Americas.

It is apparent that the geographic range of individual geminiviruses is expanding. This is true for TYLCV in the Caribbean, CdTV, PHV and TPV in Mexico, and PYMV in the Caribbean. Although the means of expansion are varied, the primary reason is the introduction of a new vector, *B. tabaci* biotype B, which can exploit solanaceous hosts for both feeding and reproduction. Another factor which has contributed to the dissemination of these viruses is the use and long distance movement of transplants of tomato and other solanaceous virus hosts. Often tomato transplants infected with a geminivirus do not show any symptoms, leading to the erroneous conclusion by growers that their transplants were virus-free. This is most likely the method by which some of the geminiviruses within Mexico have expanded their geographic range. It also may be possible that hurricanes or prevailing winds may move viruliferous whiteflies long distances over water. Evidence for this possibility is the observation that the same strain of PYMV, with few sequence variations, can be found in islands 600 km apart in the Caribbean, the appearance of TYLCV in Jamaica within a year of its appearance in the Dominican Republic, and the appearance of a strain of bean golden mosaic virus in southern Florida within two months of Hurricane Andrew. Other unknown means for long distance movement may also be important.

Many of the geminiviruses reported in the past decade do not appear to be due to expansion of geographic range (emergence) but to recent evolution. Geminiviruses can and often occur in mixed infections in tomato. Mixtures of genomic components can also occur. These mixtures and mixed infections obscure recognition of viruses by symptoms, and confuse characterization, diagnosis, and detection and may be an important source of new viruses. Such complexes of geminiviruses and strains are not unique to tomato, and have been reported in pepper and cucurbits. Pseudorecombination and recombination of tomato geminiviruses have been demonstrated in the laboratory, and mixtures of genomic DNA components which are necessary for such phenomenon have been found in infected field plants. These mixtures may play an important role in the exchange of genetic information and therefore in the evolution and creation of new viruses and strains. Few weeds have been identified that are infected with the same geminiviruses found in tomato plants, so it is possible that at least some of these geminiviruses may have evolved from viruses in weeds. Many of these tomato geminiviruses are similar to geminiviruses which infect numerous species of the weed *Sida*, and may have evolved from them. There is some good preliminary evidence which suggests that ToMoV may have evolved from a geminivirus in a species of *Sida*. More work will be needed to confirm this suspicion.

The cornerstone of crop protection for whitefly-transmitted geminiviruses is the use of resistant cultivars. Development of host resistance in both fresh-market and processing tomato is vitally necessary. However, breeding programs work best with a thorough knowledge of the pathogens being targeted. Thus, geminivirus characterization is a critical first step for successful breeding programs. Deployment of improved resistant cultivars must be accompanied by appropriate vector management schemes, which currently rely almost solely on chemical insecticides. Whitefly populations are already developing resistance to the widely used and relatively recent imidacloprid. However, our lack of vector management strategies is directly related to our lack of knowledge of the epidemiology of geminivirus pathosystems.

The distribution of the B biotype of *B. tabaci* is continuing to expand throughout South America. The most recent reports from Colombia and Guyana will likely be followed soon by reports of new geminiviruses in tomato. In those areas where whiteflies and geminiviruses are already a concern, it is expected that geminiviruses will remain a major problem for tomato growers for some time to come. Successful management will likely depend upon a multi-faceted approach. Resistant cultivars as well as much information concerning the vector and the viruses is needed before these viruses can be managed efficiently.

Table 1. Distribution of known whitefly-transmitted geminiviruses in tomato in the Western Hemisphere in 1997.

REGION	VIRUS	LOCATION
United States	Pepper huasteco virus (PHV)	Texas
	Serrano golden mosaic virus (SGMV)	Arizona
	Texas pepper virus (TPV)/ Pepper jalapeno virus (PJV)	Arizona, Texas
	Tomato mottle (ToMoV)	Florida (occasional in other states)
Mexico	Chino del tomate (CdTV) / Tomato leaf crumple virus (TLCrV)	Chiapas, Morelos, Sinaloa, Tamaulipas
	Pepper huasteco virus (PHV)	Guanajuato, Quintana Roo, Sinaloa, Tamaulipas
	Serrano golden mosaic virus (SGMV)	Sinaloa
	Sinaloa tomato leaf curl virus (STLCV)	Sinaloa
	Texas pepper virus (TPV)/ Pepper jalapeno virus (PJV)	Coahuila, Sinaloa, Tamaulipas
Central America	Texas pepper virus (TPV)/ Pepper jalapeno virus (PJV)	Guatemala
	Tomato yellow mottle (ToYMoV)	Costa Rica
	Tom GV1	Guatemala, Honduras, Nicaragua,
	Tom GV2	Guatemala
Caribbean	Potato yellow mosaic virus	Guadeloupe, Martinique, Puerto Rico, Tobago, Trinidad,
	Taino tomato mottle virus (TTMoV)	Cuba
	Tomato mottle (ToMoV)	Puerto Rico
	Tomato yellow leaf curl (TYLCV)	Cuba, Dominican Republic, Jamaica
South America	Potato yellow mosaic virus	Venezuela
	Tomato geminivirus BZ -Ub	Minas Gerais (Brazil)
	Tomato geminivirus BZ - Ig	Minas Gerais (Brazil)
	Tomato golden mosaic virus (TGMV)	Brazil
	Tomato yellow vein streak virus (ToYVSV)	São Paulo (Brazil)
	Tomato yellow mosaic (TYMV)	Venezuela

LATE BLIGHT STATUS IN FLORIDA POTATOES AND TOMATOES

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INTRODUCTION

The current late blight epidemic existing in North American potatoes and tomatoes was first recognized by producers as a major problem in 1992 and 1993 when outbreaks of the disease were reported in most production regions of the U.S. and Canada. Although not widely publicized, these outbreaks coincided with exceptionally wet growing conditions in many regions resulting from a strong "El Nino" effect in the Pacific Ocean during those seasons. It is presently believed that these highly favorable weather conditions for development of late blight coupled with the hypothesized migration of new strains of the late blight pathogen, *Phytophthora infestans* from Mexico into North America resulted in the present late blight epidemic.

CHANGES IN WORLD POPULATIONS OF PHYTOPHTHORA INFESTANS

The initial indication of shifts in world populations of *P. infestans* came from western Europe, Israel, and Egypt during the early 1980's (3, 4, 5) with the first reports of the A2 mating type of the pathogen outside of Mexico. By the 1990's new genotypes of the pathogen had been reported in Europe, Africa, and some South American countries (3, 4).

In North America the first published reports which signaled changes in populations of *P. infestans* came in 1991 with discovery of the A2 mating type in isolates of *P. infestans* collected in Pennsylvania and in British Columbia in 1987 and 1989, respectively (2). There were also during the early 1990's reports of widespread resistance to metalaxyl (Ridomil®) in samples of *P. infestans* from potatoes in northwestern Washington (1).

Since these initial reports in the early 1990's, late blight has rapidly swept through most potato and tomato producing regions of the US and Canada. As observed previously in Europe, the newly introduced genotypes of *P. infestans* throughout North America have rapidly displaced the historical genotype (i.e. US-1) which is believed to have predominated for nearly 100 years. The mechanisms resulting in the rapid displacement of established genotypes are not fully understood, however, the situation is highly dynamic, and additional shifts in populations are likely.

LATE BLIGHT IN FLORIDA

The first signs of potential changes in the late blight situation in Florida were detected in 1991. Isolates of *P. infestans* resistant to metalaxyl were collected from tomatoes grown near Naples. Interestingly this was the only report of late blight in the entire state of Florida during 1991 and 1992. These isolates were later identified as US-6.

The first modern widespread outbreak of late blight occurred in Florida potatoes and tomatoes in 1993. The disease was reported in most production areas of the state and was more prevalent in potatoes than in tomatoes. Several genotypes, US-1, US-6, and US-7 were identified in Florida. As the 1993 season progressed, US-7, which is aggressive on both potato and tomato became the most prevalent genotype. This genotype was the most widespread also during 1993 in most potato production regions of the eastern U.S.

The dynamic qualities of the late blight pathogen and the 1990's epidemic were reinforced in 1994. A new (at that time) genotype, US-8, displaced US-7 in Florida and in most eastern U.S. potato producing states. During 1994, 1995, and 1996, US-8 predominated in most Florida samples. Exceptions were US-7 reported in Manatee County in 1994 and 1995 and US-1 in a single Hastings area potato field in 1996.

During 1997 major changes in the distribution of *P. infestans* genotypes occurred in S. Florida. Although US-8 was found in some early season samples, US-1, US-7, and one, and possibly two new genotypes were detected in commercial potato and tomato production

regions of the state located south of I-4. The new genotype(s) has not been fully characterized, however, it differs from US-8 in that it is the A1 mating type and was reported by field scouts to be equally as aggressive on tomato and potato. The new genotype(s) of *P. infestans* predominated in late season samples from South Florida and was still active in late May in Ft. Pierce area tomatoes.

Populations of *P. infestans* in the Hastings area during 1997 were distinct from those in South Florida. Although late blight was present in the Hastings potato crop as soon as plants emerged in late January and rapidly spread throughout the region, US-8 was the only genotype detected.

The most important observations regarding the new genotype(s) are its enhanced aggressiveness on tomato relative to US-8 and the fact that it is an A1 mating type. It is likely that the increased aggressiveness of this genotype on tomato resulted in its rapid increase and spread in South Florida. At this writing analyses of the new genotype are incomplete, however, identification data suggest that the new strain has been introduced into Florida. We do not, however, have sufficient data to eliminate the possibility that the late blight pathogen has become established in South Florida tomato production regions and that new strains are developing there. This possibility will be investigated during the 1997-98 season.

Control and management strategies for the new genotype of *P. infestans* are the same as for older strains: Plant only certified seed or transplants, destroy all cull piles, and volunteer tomato and potato plants. Adhere to a recommended fungicide program. Early prevention is important in managing late blight. Avoid long duration of leaf wetness when irrigating.

FUNGICIDES

Several protectant fungicides (Dithane®, Manzate®, Polyram®, Mancocide®, Champ®, and Supertin®) have been compared to the "Section 18" products (Curzate®, Manex® C-8, Tattoo® C, and Acrobat® MZ) for late blight control in potato during the past two seasons. Data are summarized in Table 3 and Figure 1. In this study, and in similar experiments performed across North America during 1996, late blight control following appropriately applied protectant fungicides was generally equal to that of the Section 18 compounds. For maximum effectiveness all fungicides presently available for control of late blight in the US must be applied before the first appearance of late blight.

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Acknowledgments

Samples for allozyme analysis were provided by Glades Crop Care, Phyllis Gilreath, Manatee County, University of Florida/IFAS Cooperative Extension, Plant Pathology Plant Diagnostic Clinic, University of Florida, Gainesville. Allozyme analysis and mating tests were performed by S. B. Goodwin, S. Sujkowski, and W. E. Fry, Cornell University; T. Young, Novartis Corp., Vero Beach, FL; K. L. Deahl, R. W. Goth, USDA, Beltsville, MD; H. W. Platt and R. Peters, Agriculture Canada, Charlottetown, PEI, and M. Little, University of Florida, Hastings REC, Hastings, FL.

Table 1. Chronology of changes in world populations of *Phytophthora infestans* leading to the present late blight epidemic.

Year	Event
1984	First report of A2 mating type in western Europe.
1991	First report of A2 mating type in Pennsylvania (1987) and Vancouver, British Columbia, Canada (1989).
1993	First report of widespread metalaxyl insensitivity in commercial potatoes (Washington 1989 and 1990).
1991	First report of metalaxyl insensitivity in Florida. (Tomatoes near Naples, later identified as US-6).
1992	Severe late blight in midwest. No reports of late blight in Florida.
1993	Widespread late blight in Florida. Multiple genotypes detected, US-1, US-6, and US-7 which was the prevailing genotype by the end of the season. Late blight widespread in eastern US potato regions. US-7 predominant genotype, US-1 still common in some regions.
1994	Late blight widespread in Florida, but less intense than in 1993; aside from US-7 in Manatee county, all isolates were US-8. Late blight widespread in North America, severe in northeast. US-8 predominated, US-1 less common.
1995	Late blight widespread in Florida potatoes, minor disease pressure in tomatoes. Predominate genotype was US-8 with US-7 found in Manatee county tomatoes and potatoes. Late blight common in many N. American producing regions. US-8 most common genotype in most potato regions. Multiple genotypes reported in the Pacific Northwest potatoes and California tomatoes.
1996	Late blight again widespread in Florida, more intense in potato than in tomato and more intense in south Florida than in the Hastings area. Most isolates US-8, one field in Hastings with US-1. Late blight still widespread in US potato production, intensity less in northeast than in midwest and northwest. US-8 most common genotype in northeast and midwest potatoes, and much of northwest. US-11 prevailed in parts of Washington.
1997	Late blight widespread in both Florida tomatoes and potatoes. Multiple genotypes observed early (US-1, US-7, US-8, and other(?)); as season progressed in south Florida other (?) genotype(s?) prevailed; US-8 was the only genotype detected in the Hastings area.

Table 2. Summary of *Phytophthora infestans* genotypes identified in Florida.

Genotype	Sensitivity to metalaxyl	Mating type	Relative aggressiveness	
			Potato	Tomato
US-1	Sensitive	A1	+++	++
US-6	Intermediate to resistant	A1	+++	+++
US-7	Intermediate to resistant	A2	+++	+++
US-8	Intermediate to resistant	A2	++++	+
US-?	Intermediate to resistant	A1	++++*	++++*

* Aggressiveness has not been studied experimentally and degree is estimated from field scout reports.

Table 3. Application dates, percentage late blight, area under disease progress curve, and tuber yields in 1997 fungicide experiment 5, National Fungicide Trial.

Fungicide Treatment	Formulation per acre	Application dates										Late blight					AUDPC* (cwt / acre)	Yield Size A					
		3/19	3/25	3/31	4/7	4/14	4/21	4/29	5/5	5/13	3/24	3/31	4/11	4/22	5/1								
Bravo Weather Stik 6F	1.5 pt	X	X	X	X	X	X	X	X	X	0	6.0	12.9	19.5	28.4	55.3	8.81	180					
Kocide 2000 + Manex	3.0 lb 1.6 qt	X	X	X	X	X	X	X	X	X	0	3.9	13.7	19.9	27.1	59.0	8.87	142					
Polyram 80DF Super Tin 80 WP	2.0 lb 2.5 oz	X	X	X	X	X	X	X	X	X	0	5.4	12.8	21.0	30.3	54.3	8.69	159					
Bravo Weather Stik 6F	1.5 pt	0	0	0	0	0	0	0	0	X	0												
Dithane DF	1.0 lb	X	0	0	0	0	0	0	0	0	0	5.8	12.3	18.0	25.2	52.2	7.77	182					
Dithane DF	2.0 lb	0	X	X	X	X	X	X	X	X	0												
Curzate 72% + Manzate 200	1.25 lb 0.65 lb	X	X	X	X	X	X	X	X	X	0	2.3	5.4	10.8	13.4	45.4	5.18	218					
Acrobat MZ	2.25 lb	X	X	0	0	0	0	0	0	0	0	1.9	7.1	10.6	18.1	40.8	5.24	193					
Bravo Weather Stik 6F	1.5 pt	0	0	X	X	X	X	X	X	X	X(1)												
Tattoo C	2.3 pt	X	0	X	0	X	0	X	0	X	0	2.4	7.4	10.6	14.7	40.2	5.00	204					
Bravo Weather Stik 6F	1.5 pt	0	X	0	X	0	X	0	X	0	0												
Control		0	0	0	0	0	0	0	0	0	0	4.5	20.6	48.3	79.0	92.9	19.61	63					
LSD	0.05																2.1	4.9	13.4	8.6	10.2	3.12	34

* AUDPC=Area under disease progress curve. First lesions were observed 3/17/97.
1/ Applied with vine desiccant.

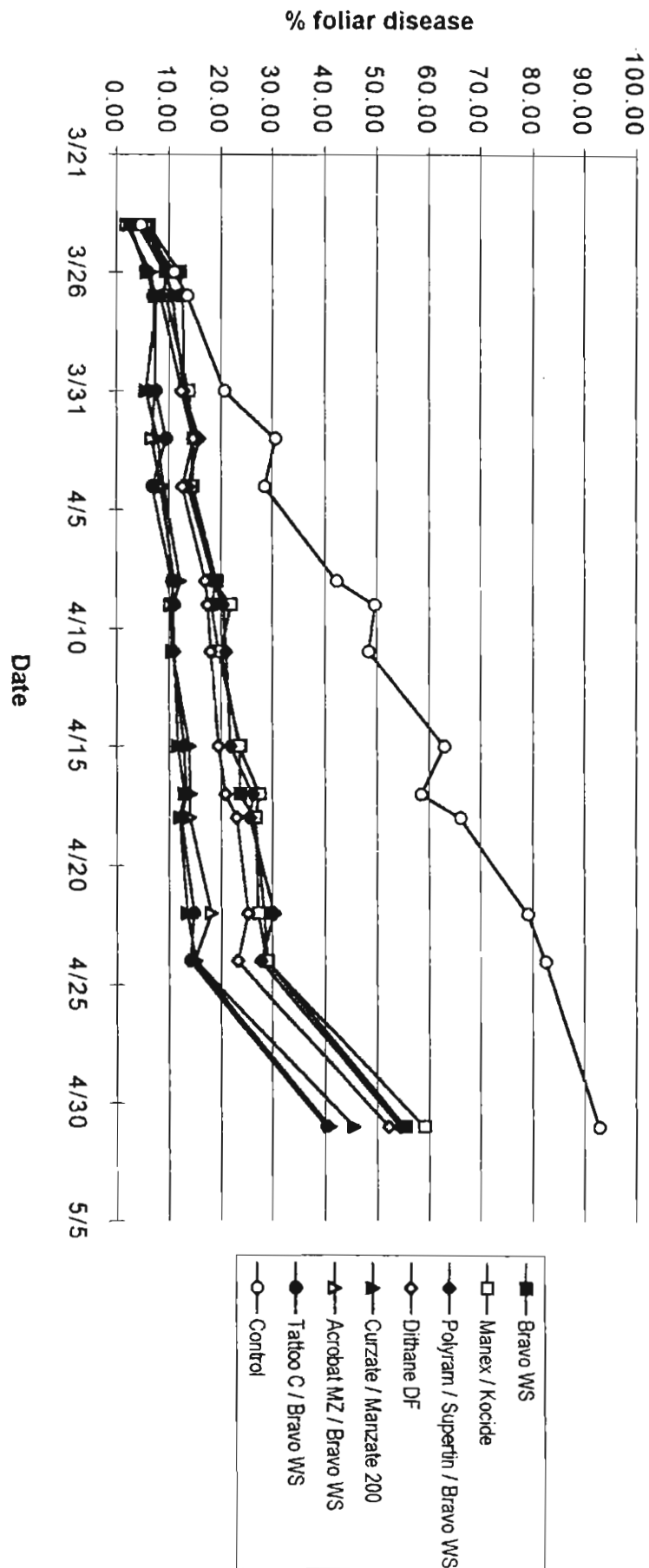


Fig. 1. Disease progress of late blight following fungicide treatments in 1997.

RELATIONSHIP OF SILVERLEAF WHITEFLY DENSITY TO IRREGULAR RIPENING

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INTRODUCTION

The silverleaf whitefly (SLWF), *Bemisia argentifolii* Bellows & Perring, has been an important insect pest of tomatoes in Florida since 1988 (Schuster et al. 1989). Losses of \$18-125 million per year have occurred since due to irregular ripening (IRR), increased costs for whitefly control and reduced yields due to tomato mottle geminivirus (TMoV) infection (Schuster et al. 1989, 1993). Recently, the incidence of SLWF and TMoV have declined to very low levels due at least in part to the availability of a new insecticide, imidacloprid (Admire TM). Heavy reliance on this chemical alone for managing the whitefly will likely lead to reduced efficacy; resistance has occurred already in Spain (Cahill et al. 1996). As part of a resistance management program, growers are encouraged not to rely on imidacloprid for season-long control of the SLWF but to apply imidacloprid for early to mid-season control followed by applications of insecticides in different chemical classes as required by whitefly incidence. In order to time applications, an action threshold based upon the relationship between SLWF density and IRR severity must be developed. The objective of this research was to examine the relationship between SLWF density and IRR in small plot, field-grown tomatoes and to evaluate different SLWF nymphal densities as thresholds for two new insect growth regulator insecticides.

METHODS

Five experiments were conducted at the Gulf Coast Research & Education Center, Bradenton: one each in the spring and fall of 1995 and 1996 and the spring of 1997. Plots were three 30 ft long rows with 20 plants/row. Plots were separated by 20 ft and were replicated four times in each experiment in randomized complete blocks. The numbers of sessile nymphs and pupae of the SLWF were counted weekly on the terminal leaflet of the 7-8th leaf from the tops of 10 plants from the middle row of each plot. In the spring of 1995, counts also were made on 20-15mm disks (two each from each terminal leaflet). Weekly counts of SLWF adults were made on the terminal three leaflets of the third leaf of 20 terminals of 10 plants from the middle row of each plot. When predetermined densities of SLWF nymphs or pupae were reached or exceeded (Table 1), insecticide or insecticide combinations were applied (Table 2). The densities selected were based upon preliminary research conducted previously in field cage studies. Check plots with no insecticide applications were included in the spring 1995 experiment and check plots treated with Admire at transplanting were included in all experiments. In 1995 and 1996, the Admire was applied at 16 ozs/acre and was followed by weekly applications of either Danitol and Monitor or Warrior and Monitor. In 1997, Admire was applied at 32 ozs/acre and was not followed by foliar applications of insecticides. Red ripe fruit were harvested weekly and rated 1-4 for external symptoms of IRR and 1-5 for internal symptoms (Table 3). Using regression methods, the mathematical relationship (coefficient of determination r^2) between the number of SLWF nymphs/pupae and subsequent severity of IRR and the relationship between the number of SLWF adults observed on foliage and the number of nymphs/pupae was determined for 1995 and 1996.

RESULTS

The relationship between the number of sessile nymphs/pupae and the external IRR rating for the two spring seasons was closest, as indicated by highest r^2 values, when fruit ratings were compared to whitefly counts taken one week previously (Table 4). In the fall experiments, the closest relationships were observed when fruit ratings were compared to whitefly counts taken three weeks previously. Thus, the impact of whitefly feeding was delayed in the fall relative to the spring and the relationships between immature numbers and external IRR within the spring and fall seasons were very similar (Fig. 1). Similar relationships were observed with internal IRR ratings except

that, when considering both spring seasons, the highest r^2 values were observed when IRR ratings were taken two weeks after nymphal and pupal counts were taken (Table 4). Considering both fall experiments, the closest relationships were observed when fruit ratings were compared to whitefly counts taken three weeks previously. Again, the impact of whitefly feeding was less in the fall than in the spring although the two spring seasons were dissimilar in slope (Fig. 2). In the fall 1995, there was a poorer relationship between immature counts and internal IRR than between counts and the external IRR ratings (Table 4).

The relationship between the number of SLWF adults and the number of nymphal and pupal SLWF subsequently observed was best when immature counts were taken two weeks after adult counts in the spring seasons and when immature counts were taken three weeks after adult counts in the fall (Table 4). The relationships in the spring seasons were very similar and indicated that a greater number of nymphs and pupae would result in the spring relative to the fall for any given number of adults observed (Fig. 3).

When the insect growth regulators (IGR) Applaud and Knack were applied when densities of SLWF nymphs exceeded predetermined thresholds, no decreases in marketable yield or increases in cull fruit or external irregular ripening were observed (Table 5). As few as four and as many as seven applications of the IGR's were made; however, a breakdown with the high clearance sprayer early in the season resulted in one spray being missed and a two week gap between sprays. Therefore, more timely application early in the season could have delayed the SLWF population and resulted in fewer applications. Furthermore, the thresholds may have been too low which also would have resulted in increased spraying. Higher thresholds will be evaluated in future experiments, especially in the fall.

DISCUSSION

The data indicate a significant relationship between the density of SLWF nymphs and pupae and subsequent expression of IRR symptoms, especially external symptoms. Even when no nymphs or pupae were present, the mathematical relationships predicated external ratings of about 1.1 for spring and fall 1995 and 1.6 for spring and fall of 1996 (Fig. 1). This was even more pronounced for internal symptom ratings which ranged from as low as 2.1 for fall 1995 to as high as about 3.0 for spring 1995. The external rating of "2" is given when a pronounced yellow "star" is present on the blossom scar on fruit. This star is present to some extent on most fruit and there is a certain degree of subjectivity in determining whether the star is more apparent than what would normally be expected. The internal ratings are based upon the degree of white tissue. Nearly all fruit have some degree of white tissue even when whiteflies are not present. Furthermore, the amount of white tissue can be affected by other factors such as temperature. Therefore, it is not unexpected for ratings to be greater than "1" when whiteflies are not present.

There were strong seasonal effects on the severity of symptoms and on the time delay following infestation until symptoms appeared. For example, in order to attain an average external rating of 2.0, approximately 4-8 nymphs or pupae per terminal leaflet would be required in the spring but approximately 18-46 nymphs or pupae would be required in the fall. These results are not unexpected since temperatures increase as a tomato crop reaches maturity in the spring and decrease as the crop reaches maturity in the fall. As temperature increases to 35°C, developmental times of SLWF immature lifestages decrease and, presumably, feeding rates increase.

The seasonal influence also presents interesting challenges for growers. Spring grown tomatoes would tolerate fewer SLWF immatures thus requiring quicker and more effective action on the part of a grower. Fall grown tomatoes could tolerate more whiteflies with more time to take corrective action. In addition, it has been shown previously that more samples are required to precisely estimate lower immature densities than higher densities (Schuster 1997).

Nevertheless, the IGR's Applaud and Knack were shown to be effective when applied on demand in a spring experiment. This is particularly encouraging since IGR's affect primarily nymphs by interfering with normal growth and development and are, therefore, inherently slow acting. In addition, thresholds might be higher than those evaluated, especially in the fall.

Acknowledgements: The author wishes to thank the Florida Tomato Committee for partial support of the research and Emily Vasquez, Kevin Hearne, Oswaldo Toribio, Emerson Alder, and Tim Davis for the many hours spent applying treatments, counting whiteflies and evaluating fruit.

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Table 1. Densities of silverleaf whitefly nymphs and pupae at which insecticide treatments were applied.

Spring 1995	Fall 1995, Spring 1996	Spring 1997
≤160/20 disk	≥4/leaflet	≥2/leaflet
≤ 80/20 disks	≥2/leaflet	≥1/leaflet
≤ 40/20 disks	≥1/leaflet	≥5/10 leaflets
	≥5/10 leaflets	

Table 2. Insecticides applied when pre-determined thresholds of silverleaf whitefly nymphs and pupae were equalled or exceeded on tomato.

Material	Formulation	Rate(AI)/acre
Spring 1995		
Danitol + Monitor	2.4EC	0.2 lb
	4EC	0.75 lb
Fall 1995		
Warrior + Monitor	1EC	0.03 lb
	4EC	0.75 lb
Provado	1.6F	0.05 lb
Spring 1996		
Danitol + Monitor	2.4EC	0.2 lb
	4EC	0.75 lb
CGA 215994 + fenoxycarb + Silwet	50WP	105 gm
	25WP	70 gm
	----	0.05%
Fall 1996		
Danitol + Monitor	2.4 EC	0.2 lb
	4 EC	0.75 lb
Knack + Phaser	0.86 EC	20 gm
	3 EC	1.0 lb
Spring 1997		
Knack or Applaud	0.86EC	30 gm
	70WP	0.25 lb

Table 3. The rating scale used for quantifying the extent of irregular ripening symptoms in tomato fruit.

Rating	Symptom Expression
External symptoms	
1	no symptoms
2	distinct 'star' on blossom end with points radiating up fruit
3	≤30% of fruit surface affected
4	>30% of fruit surface affected
Internal symptoms	
1	no internal white tissue(IWT)
2	trace of IWT on inner fruit walls
3	<30 of the fruit walls with IWT
4	30-70% of the fruit walls with IWT
5	>70% of the fruit walls with IWT

Table 4. Coefficients of determination (r^2 values) for the relationship between the numbers of SLWF adults and SLWF nymphs and the relationship between the numbers of SLWF nymphs and subsequent IRR severity.

Week after sampling*	Spring 1995	Fall 1995	Spring 1996	Fall 1996
No. SLWF nymphs vs external IRR				
1	0.62	0.05	0.64	0.11
2	0.53	0.30	0.35	0.21
3	0.43	0.42	<0.01	0.71
No. SLWF nymphs vs internal IRR				
1	0.70	0.05	0.22	0.24
2	0.66	0.09	0.41	0.39
3	0.46	0.17	<0.01	0.35
No. SLWF adults vs no. nymphs				
1	0.52	0.01	0.12	0.56
2	0.49	0.05	0.54	0.54
3	0.11	0.27	0.09	0.73

*Sampling data (either no. of SLWF adults or nymphs) collected on any given week were compared to opposing data (either no. nymphs or IRR symptoms) collected either one, two or three weeks later.

Table 5. Yield and irregular ripening (IRR) of tomato following applications of insect growth regulators at various thresholds of silverleaf whitefly nymphal densities.

Insecticide	Action threshold	Applications	Marketable fruit		Culls		IRR rating
			No.	Wt.	No.	Wt.	
Admire	-----	1	333	125.0	123	37.1	1.94
Applaud	$\geq 2/\text{leaflet}$	6	316	115.9	109	34.5	2.01
Applaud	$\geq 1/\text{leaflet}$	5	333	114.3	120	31.9	1.95
Applaud	$\geq 0.5/\text{leaflet}$	7	321	111.5	120	31.8	1.95
Knack	$\geq 2/\text{leaflet}$	5	324	113.1	143	37.0	2.01
Knack	$\geq 1/\text{leaflet}$	4	314	112.6	108	29.1	1.97
Knack	$\geq 0.5/\text{leaflet}$	6	328	122.8	89	27.8	1.99

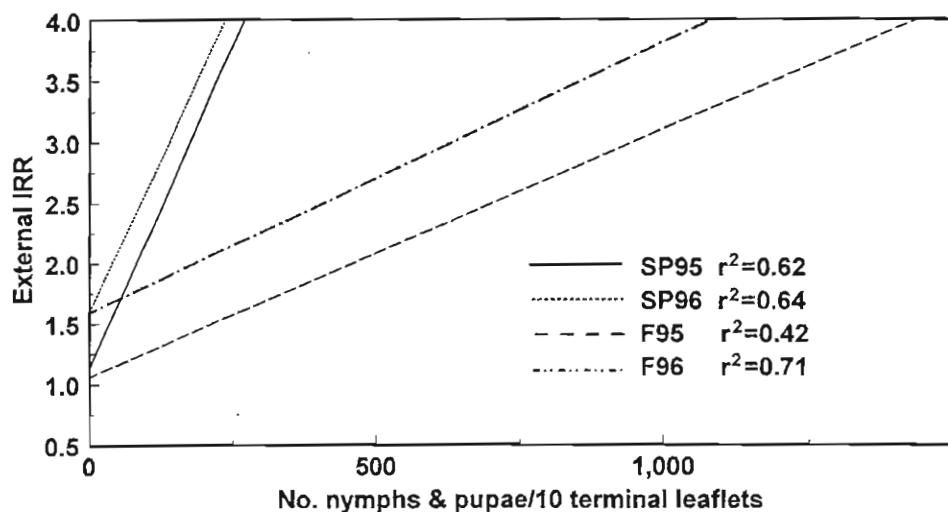


Fig. 1. Relationship between the number of silverleaf whitefly nymphs and pupae/10 terminal tomato leaflets (7-8th leaf from the top of a main or lateral stem) and the external symptoms of irregular ripening (IRR) either one week later for Spring 1995 and 1996 or three weeks later for Fall 1995 and 1996. IRR symptoms were rated 1-4 for increasing severity.

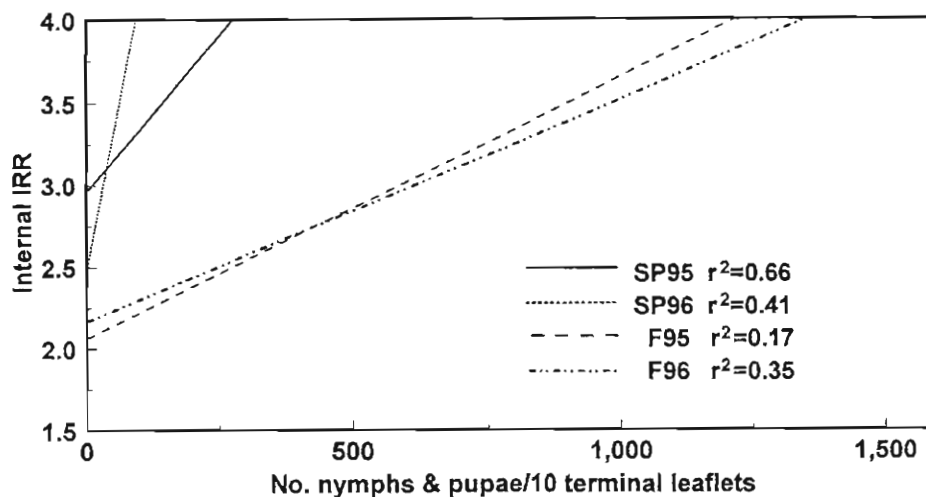


Fig. 2. Relationship between the number of silverleaf whitefly nymphs and pupae/10 terminal tomato leaflets (7-8th leaf from the top of a main or lateral stem) and internal symptoms of irregular ripening (IRR) either two weeks later for Spring 1995 and 1996 or three weeks later for Fall 1995 and 1996. IRR symptoms were rated 1-5 for increasing severity.

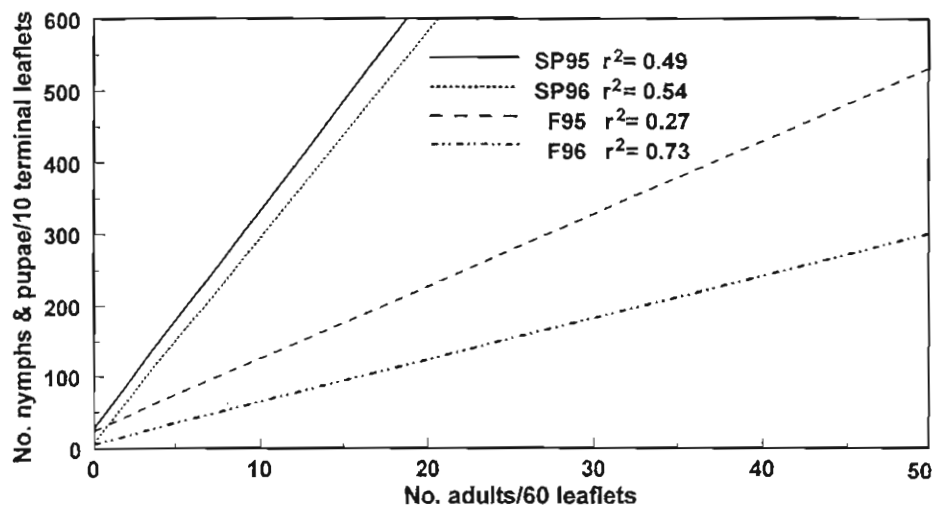


Fig. 3. Relationship between the number of silverleaf whitefly (SLWF) adults on the terminal three leaflets of 20 tomato leaves (3rd leaf from the top of main or lateral stems) and the number of SLWF nymphs and pupae/10 terminal tomato leaflets (7-8th leaf from the top of a main or lateral stem) either two weeks later for spring 1995 and 1996 or three weeks later for Fall 1995 and 1996.

EFFECTS OF NITROGEN AND POTASSIUM FERTIGATION ON TOMATO YIELD AND GRAYWALL IN DADE COUNTY

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INTRODUCTION

Graywall and other, possibly related, ripening disorders are responsible for widespread losses in marketable yields and for reduced quality of Florida tomatoes. Cullage due to graywall has been estimated to be above 50% for some commercial plantings in Florida. Losses of 10 to 20% are common in commercial fields.

Scientists and growers believe that high nitrogen (N) and low potassium (K) fertilizer application rates are associated with graywall incidence, abnormal ripening, and subsequent reduced yields. It is also believed that certain environmental conditions combined with improper fertigation rates enhance the occurrence of graywall. This problem is particularly important for Dade County tomato growers, who have shown considerable interest in finding solutions to this malady.

Current fertilizer recommendations for fertigated tomatoes in Dade County are "best guesses" based on data from sandy soils in other parts of Florida and dry fertilizer application rates for Dade County tomatoes grown without plastic mulch. Tomato fertigation recommendations have not been calibrated for the rocky soil types found in Dade County.

The objectives of this study were to evaluate the effects of N and K fertigation on tomato fruit yield, graywall incidence, and fruit quality. This report summarizes results of the second season of tomato fertilization research partially funded by the Florida Tomato Committee.

MATERIALS AND METHODS

This study was conducted in a Dade county grower's field on Rockdale soil during the fall/winter season of 1996-1997. A random pre-plant soil sample was taken and analyzed at the University of Florida, IFAS, Analytical Research Laboratory (ARL) to determine pre-plant fertilizer needs and to develop a base line for available nutrients. The results indicated that the soil concentration of P was high to very high, suggesting that there would not be a yield response to the addition of P. As a result, no P was applied to the experimental plots. Soil samples were taken from the top 2 in. from 4 randomly selected locations within each plot, prior to applying the fertilizer treatments. They were also analyzed at the ARL for N and K concentrations.

Fertilizer treatment main plots were 50 ft. long and were arranged following a 4 x 4 factorial design with 4 N rates and 4 K rates resulting in 16 treatments (Table 1). There were 4 replications of each treat-

ment resulting in a total of 64 fertilizer plots. Ammonium nitrate and potassium chloride were selected as the sources of N and K, respectively. The total fertilizer rates were 0, 75, 150, and 225 lb. N/acre and 0, 50, 100, and 150 lb. K₂O/acre. Twenty percent of the total fertilizer was applied pre-plant by hand as dry fertilizer and incorporated into the bed. The remainder was injected through the drip tube in a graduated system (Table 2). Beds were laid out with 2 drip tubes, one for irrigation purposes and the other for applying the liquid fertilizer treatments. Fertigation was applied to each fertilizer plot on a weekly basis using a CO₂ gas injection system. During early growth stages, the first three weeks after transplanting, a total of 7 pounds of N or K₂O per acre per week was injected through the drip system. After the 4th week, this amount increased to 14 pounds per acre per week (Table 2).

Two commercially-grown cultivars, 'Agriset 761' and 'Sunny', were selected for use in this experiment. The two were transplanted by hand on November 12, 1996, in single rows within each fertilizer treatment following a split plot design. Each cultivar was planted in a plot 25 ft. long with a between plant spacing of 20 inches. Bed spacing was 6 feet center to center.

All of the pesticide control and cultural practices, except fertilization and irrigation, were managed by the farmer. An irrigation pump was placed in the experiment that was independent from the grower's system. Four irrometers (tensiometers) were randomly placed in the field to be used as a reference for soil moisture content and to determine irrigation needs. Irrigation amounts depended on the stage of plant growth, averaging 1,200 gal. per acre per day over the season. During the growth phase of the crop, three leaf petiole samples were collected from each variety in each plot and analyzed for NO₃-N and K+ sap concentrations using portable Cady meters. A second companion set of leaf samples was collected, dried and analyzed in ARL for N and K concentrations.

Fruits were harvested 3 times during the season in combination with the grower's harvest schedule. The harvest dates were February 17, February 26, and March 10, 1997. Tomatoes were graded for graywall and for fruit size using USDA guidelines.

RESULTS

The pre-fertilization soil samples were analyzed and found to be in the medium to high range for K, indicating that little K response was expected. There was no fruit yield or quality response observed that could be related to the level of K fertilization (Table 3). About 5 to 10% of fruits harvested were affected by graywall, but the occurrence of graywall was not related to K fertilization. Enough K was supplied from the unfertilized soil to satisfy tomato growth and provide optimum yield and quality.

Total season marketable yield and extra large fruit yields increased quadratically with an increase in N fertilization (Table 3) and peaked around 160 lb N/acre (Table 4). Graywall incidence increased linearly with N fertilizer rate. The linear increase in graywall with N means that graywall incidence would be worsened with N rates higher than those used in this study. 'Agriset 761' had significant higher yields of extra large and total marketable fruit than 'Sunny' over the season (Table 3).

SUMMARY

This study had some notable findings: (1) the lack of yield response to K fertilization, (2) the incidence of graywall was related to high N and not to low K fertilization rates, (3) the yield response to N fertilization supports the current University of Florida extension recommendations for tomato N fertilization, and (4) these results are the same as results from a similar study conducted during 1995-1996 (Carranza et al., 1996).

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Table 1. Total dry and liquid fertilizer rates (lbs./acre) for the season, Homestead, winter 96-97.

	Treatment															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Nitrogen (N)	0	0	0	0	75	150	225	75	75	75	150	150	150	225	225	225
Potassium (K ₂ O)	0	50	100	150	0	0	0	50	100	150	50	100	150	50	100	15

Table 3. The effects of N and K fertilizer and cultivar on total fruit yield and graywall incidence (25 lbs. boxes/acre) over the season, Homestead, winter 96-97.

N	K ₂ O	Cultivar	Tot. mkt.	Tot. mkt. lrg.	Graywall	Tot.cull
0			1438	978	88	242
75			1824	1245	116	232
150			1856	1331	75	194
225			1833	1294	134	207
Significance			L**Q**	L**Q**	L**	ns
	0		1675	1176	129	196
	50		1723	1200	159	206
	100		1789	1257	122	208
	150		1764	1215	111	232
	Significance		ns	ns	ns	ns
		Agriset 761	1794	1341	150	193
		Sunny	1682	1083	111	228
		Significance	**	**	ns	**

*=sig. 5% level; **=sig. 1% level; ns= not significant

Table 4. Models and predicted maximum yield and optimum N rate for three tomato yield variables.

Variable	Model	Maximum yield ^y	Optimum N ^z
Total marketable	5.723N-0.0182N ² +1452	1900	157
Total large	4.411N-0.01347N ² +981	1340	164
Graywall	0.3161N+94.95	n/a	n/a

^y yield is number of 25-lb ctn/acre

^z N is lb/acre (6-ft. bed spacing)

Table 2. Total and weekly N and K₂O fertilizer rates (lbs/acre) for each fertilizer treatment, Homestead, winter 96-97.

Ttt	Week																											
	Total		1-3		4		5		6		7		8		9		10		11		12		13		14			
	N	K	N	K	N	K	N	K	N	K	N	K	N	K	N	K	N	K	N	K	N	K	N	K	N	K		
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
2	0	30	0	7	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
3	0	80	0	7	0	14	0	14	0	14	0	14	0	3	0	0	0	0	0	0	0	0	0	0	0	0		
4	0	130	0	7	0	14	0	14	0	14	0	14	0	14	0	14	0	14	0	11	0	0	0	0	0	0		
5	55	0	7	0	14	0	14	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
6	130	0	7	0	14	0	14	0	14	0	14	0	14	0	14	0	14	0	11	0	0	0	0	0	0	0		
7	205	0	7	0	14	0	14	0	18	0	18	0	18	0	20	0	18	0	18	0	18	0	14	0	14	0		
8	55	30	7	7	14	9	14	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
9	55	80	7	7	14	14	14	14	6	14	0	14	0	3	0	0	0	0	0	0	0	0	0	0	0	0		
10	55	130	7	7	14	14	14	14	6	14	0	14	0	14	0	14	0	14	0	11	0	0	0	0	0	0		
11	130	30	7	7	14	9	14	0	14	0	14	0	14	0	14	0	14	0	11	0	0	0	0	0	0	0		
12	130	80	7	7	14	14	14	14	14	14	14	14	14	3	14	0	14	0	11	0	0	0	0	0	0	0		
13	130	130	7	7	14	14	14	14	14	14	14	14	14	14	14	14	14	14	11	11	0	0	0	0	0	0		
14	205	30	7	7	14	9	14	0	18	0	18	0	18	0	20	0	18	0	18	0	18	0	14	0	14	0		
15	205	80	7	7	14	14	14	14	18	14	18	14	18	3	20	0	18	0	18	0	18	0	14	0	14	0		
16	205	130	7	7	14	14	14	14	18	14	18	14	18	14	20	14	18	14	18	11	18	0	14	0	14	0		

K=K₂O

K=K₂O

PHOSPHOROUS NUTRITION OF TOMATO IN CALCAREOUS SOILS

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ABSTRACT

Three experiments were conducted to evaluate phosphorous nutrition of tomato grown on Rockdale and marl soils in Dade County. Soil phosphorous (P) testing had been calibrated with a pot study at various rates of P fertilizer (0, 25, 50, 100, 150 and 200 lb P₂O₅/Ac). Increasing P fertilizer rates linearly increased ammonium bicarbonate - diethylenetriaminepentacetic acid (AB-DTPA) extractable P in soils and concentrations of P in tomato leaves and roots. Significant correlation were found between AB-DTPA extractable P in soil and concentrations of leaf and root P ($R^2 = 0.80 - 0.95$). Mean concentrations of water soluble, AB-DTPA extractable and non-extractable P in 15 agricultural soil samples collected from Dade County were 3, 73 and 2034 ppm, respectively. The field study was conducted in a commercial tomato field with a Krome very gravelly loam soil with 3 rates of P fertilizer (37, 63, 100% of grower rates). Phosphorous fertilization increased AB-DTPA extractable P in the soil but did not affect the concentration of leaf P, yield and quality of tomato.

INTRODUCTION

Tomatoes in Dade County are grown on calcareous soils, Krome or Chekika very gravelly loam series. Those soils are characterized by an alkaline pH 7.4 - 8.4, very gravelly texture (35 - 70 % limestone fragments), shallow soil depth (< 8 inches). Therefore, soils have very low holding capacities for nitrogen (N) and other water soluble nutrients. Frequent applications of fertilizer are necessary to ensure high yields. Balanced fertilizers with a certain ratio of N P K are commonly used in this area. More and more researchers and growers have realized no or little response of tomato to phosphorous fertilizer. The reason for this is the high levels of available P which have accumulated from previous fertilizer application. Phosphorous has much less mobility compared to N or K. Phosphorous fertilizers applied in those soils is fixed by calcium carbonate (Calcite) through adsorption. This chemical reaction is reversible and P is slowly released into the soil solution and become available to plant roots. Phosphorous removal via the harvested fruit usually accounts for less than 38 lb. P₂O₅ for 1000 cartons of tomato (Lorenz and Maynard, 1980). A large portion of the applied P remains in the soil and this should be considered when growers make fertilizer decisions for the following crop. Soil testing and plant analysis are always recommended to determine availability of P nutrient in the soil and nutritional condition in the plant. However, soil testing and plant analysis have not been commonly used as tools to make decisions for fertilizer application due to the lack of information concerning P calibration in Rockdale and marl soils and laboratory extraction procedures for soil P. Hanlon et al (1996) have modified and recommended recently the AB-DTPA method to extract available P from Rockdale and marl. The objectives of this study were to calibrate soil P testing, survey soil P levels in Dade County and conduct field demonstration with various P fertilizer rates.

MATERIALS AND METHODS

Three experiments were conducted in this project.

Experiment 1: The calibration of soil P testing. A Krome very gravelly loam soil (Loamy - skeletal, carbonatic, hyperthermic lithuic udorthents) and a Biscayne marl soil (loamy, carbonatic, hyperthermic shallow typic fluvaquents) were collected from uncultivated pineland and grassland, respectively. Ten pounds of each soil were packed into 2-gal-pots. Phosphorous fertilizer was applied before transplanting at six rates (0, 25, 50, 100, 150, or 200 lb. P₂O₅/Ac) as superphosphate. All of the treatments were replicated four times. One

“Sunbeam tomato plant was transplanted into each of the pots. The plants were irrigated 5 min. every day with drip irrigation and treated once every week with a P-free nutrient solution.

At the end of each experiment plants were cut and separated into leaves, stems, and roots. Leaves and roots from each pot were washed sequentially with tap water, 1% detergent, 1% HCl and deionized water. Tissue samples were dried at 70° C for 48 hours, ground using a Wiley mill, and dry-ashed in a muffle furnace at 550°C for 6 hr and 8 hr for leaf and root samples, respectively. Next the ash was cooled and dissolved in diluted HCl. Concentrations of P were measured using an inductively coupled plasma emission spectroscopy instrument (ICPES). A soil sample was collected from each pot, air dried, ground and sieved with a 2-mm sieve. Ten grams of each soil sample was extracted with 20 ml of AB-DTPA solution. The extracted solution was analyzed with ICPES. (Hanlon et al., 1996).

Experiment 2: Fifteen vegetable fields on Rockdale and marl soils in Dade County were identified as representative fields for fertilization practices. A surface soil sample (0 - 6 inch depth) and a leaf sample (twenty youngest fully expended leaves) were collected from each field. The soil and leaf samples were prepared and analyzed as described in experiment 1.

Experiment 3: A commercial tomato field on a typical Krome very gravelly loam soil was chosen for this study. A typical polyethylene covered raised-bed was 36 in wide, 6 inch high and 72 inches apart. Fertilizer was applied on December 12, 1996 at three rates of P (37, 63, or 100% of the grower rate, equivalent to 96, 163, 260 lb P₂O₅/ac) with 6 replications. Tomato plants were transplanted in a single row in the center of each bed with 20 inches between plants. Soil samples were taken on one day prior to (Dec. 12, 1996), and on April 26, 1997 about 15 weeks after fertilizer application. Leaf samples were collected on April 7, 1997. Soil and leaf samples were prepared and analyzed for P as described in experiment 1. Tomatoes were harvested three times (March 31, April 14, April 25, 1997) from 10 plants in each plot. Total number, total weight and color of fruit from each plot were recorded.

Data were analyzed by analysis of variance and means were compared using Duncan's Multiple Range Test, 5% level.

RESULTS AND DISCUSSION

Experiment 1: Increasing P fertilizer rates linearly increased AB-DTPA extractable P in soils (Fig. 1). The similar effects of fertilizer rates on concentrations of tissue P were shown on Fig. 2. The data indicate that fertilizer application not only increased plant available P in the soil but also increased the uptake of P by plants. Plateaus were not reached in these curves because soils used for this study had never been fertilized before. The concentration of soil AB - DTPA extractable P before fertilizer application were only 10 and 12 ppm P for the Krome and the Biscayne Marl, respectively. For most cultivated soil, leaf P levels would not respond in this manner because of the accumulation of P in the soil. After application of 200 lb. P₂O₅/acre, soil P reached 51 and 39 ppm in Biscayne marl and Krome soils, respectively. Concentration of AB -DTPA extractable P in Biscayne marl soils was about 22% higher than that in Krome soils. However, leaf P concentration in the Biscayne marl was about 38% higher than in the Krome soil. Perhaps soil structure and texture, and root distribution may contribute to this difference.

Significant correlations were found between AB-DTPA extractable P concentrations in soil, leaf and root samples and the R^2 values ranged from 0.80 to 0.95 (Fig. 3). Therefore, AB-DTPA extractable P concentrations in soils are highly representative of available P in marl and Rockdale soils. Concentrations of AB-DTPA extractable P in soils can be used to make recommendations for fertilizer application.

Experiment 2: Average concentrations of water soluble P in soil samples collected from various vegetable fields and fruit groves were 2.7 ppm P soil and ranged from 0.3 to 7.9 ppm P soil (Fig. 4). The high concentrations of water soluble P may be derived from recently applied fertilizer. Water soluble P is available to the crop, however, this type of P is also subject to leaching out of the root zone through excessive irrigation or heavy rainfall.

Concentrations of AB-DTPA extractable P in these soils ranged from 12.5 to 106.7 ppm with a mean concentration of 73.2 ppm (Fig. 4).

AB-DTPA extractable P is plant available and highly correlated to the uptake rate by the crop. Hochmuth et al (1995) reported that P fertilization did not affect sweet corn yield and quality with soil AB-DTPA extractable P concentration of approximately 70 ppm in marl and Rockdale soils in Dade County.

Nonextractable P in soils represents the P residue in soils that is not directly available to plants. About 96% of total P in 15 soil samples were nonextractable. Concentrations of non-extractable P ranged from 494 to 4812 ppm with a mean concentration of 2110 ppm. Concentrated acids have to be used to extract this type of P from soil. The level of non-extractable P increases with increasing age of cultivation of soils. Thus phosphorous fertilizer applied to soils will transform from water soluble to AB-DTPA extractable P and eventually a portion of this P becomes nonextractable. However, these chemical reactions are reversible. Depletion of extractable soil P usually causes non-extractable P to slowly become extractable again. Therefore, both extractable and non-extractable P in the soil should be considered when making fertilizer recommendations.

Experiment 3: Soil samples were collected prior to fertilizer application and the concentration of AB-DTPA extractable P was 108 ppm. Soil samples taken from plots treated at 63 and 100% of grower rates 15 weeks after application showed significant increase AB-DTPA extractable P concentrations with increasing rates of application (Fig. 5). However, the lowest level (37% of the grower rate of P fertilizer) failed to elevate the soil AB-DTPA extractable P concentration. The data indicates that applied fertilizer had transformed into the non-extractable form of P during 15 weeks. Phosphorous fertilizer rates did not affect P concentrations of leaves collected 15 weeks after fertilizer application (Fig. 6). High rates of P fertilizer significantly increase red fruit yield at the first harvest (Table 1). However, the economic impact was insignificant because of the small percent of red fruit compared to total marketable fruit. Other quality parameters and yield were not affected by fertilizer rates. Plants from soils with high P treatment (100% grower rate) showed symptoms of micronutrient deficiency in late stages of plant growth. Bryan et al. (1967) planted tomato on Rockdale soil with P fertilizer rates of 215-644 lb P₂O₅/Ac and reported that fruit yield decreased with increasing P fertilizer rate. They also reported that leaf chlorosis ratings increased from 1.8 to 5.0 when fertilizer rates increased from 215 lb P₂O₅/ac to 644 lb P₂O₅/ac. Precipitation of phosphorous and of micronutrients (Fe, Zn, Mn etc.) in soil solutions may occur at high concentration of P. Further investigations on this subject will be conducted during this year's study.

SUMMARY

1. AB-DTPA extractable P concentrations are highly correlated to leaf and root P concentrations of tomatoes grown in Rockdale and marl soils.
2. High levels of AB-DTPA extractable P were found in most rock and marl soils collected during this survey of agricultural land in Dade County.
3. The application of P fertilizer to a Rockdale soil with relatively high levels of AB-DTPA extractable P increased the level of available P but did not affect leaf P level, fruit yield and quality with the exception that the quantity of red fruit at the time of first harvest was increased slightly.

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Table 1. Effects of phosphorus fertilizer on fruit yield and quality of tomato in 1997.

Variable	Fertilizer rate as % of grower rate		
	33	66	100
Fruit yield (cartons/Ac)			
Early yield:			
Red	54 ^{bz}	64 ^{ab}	93 ^a
Green	541	524	651
Total large fruit	406	393	436
Total Mkt.	1474	1235	1403
Cull yield	210	195	226
Avg. fruit wt. (lb)	0.37	0.36	0.37

^z: Each mean represents the average of 6 observations. Values followed by different letters are significantly different from each other at $p < 0.05$ according to Duncan's Multiple Range Test.

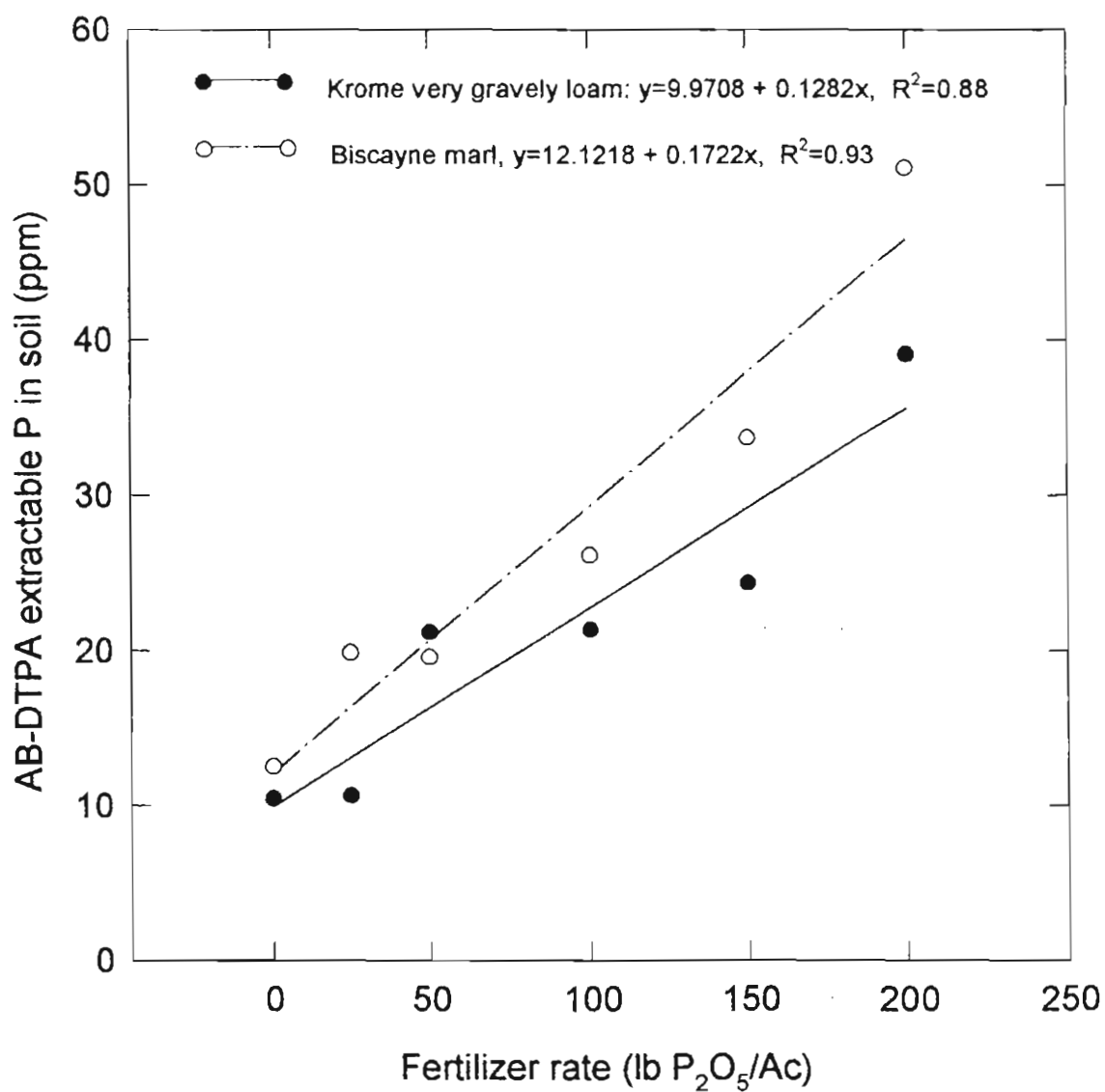


Fig. 1. Effects of phosphorus fertilizer rates on AB-DTPA extractable P in rockdale and marl soils. Each data point represents the mean of four replications.

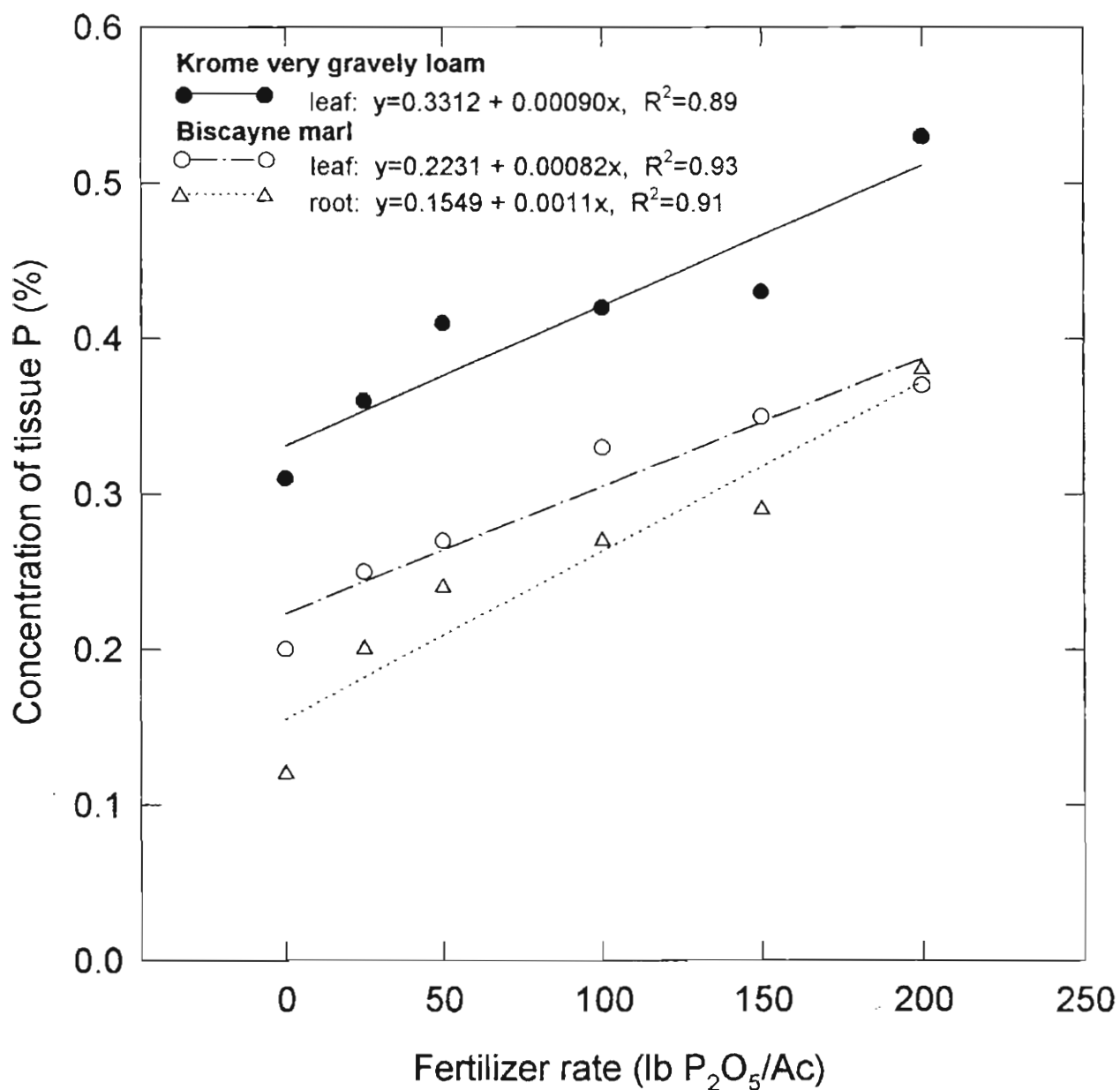


Fig. 2. Effects of phosphorus fertilizer rates on concentrations of tissue P of tomato in rockdale and marl soils. Each data point represents the mean of four replications.

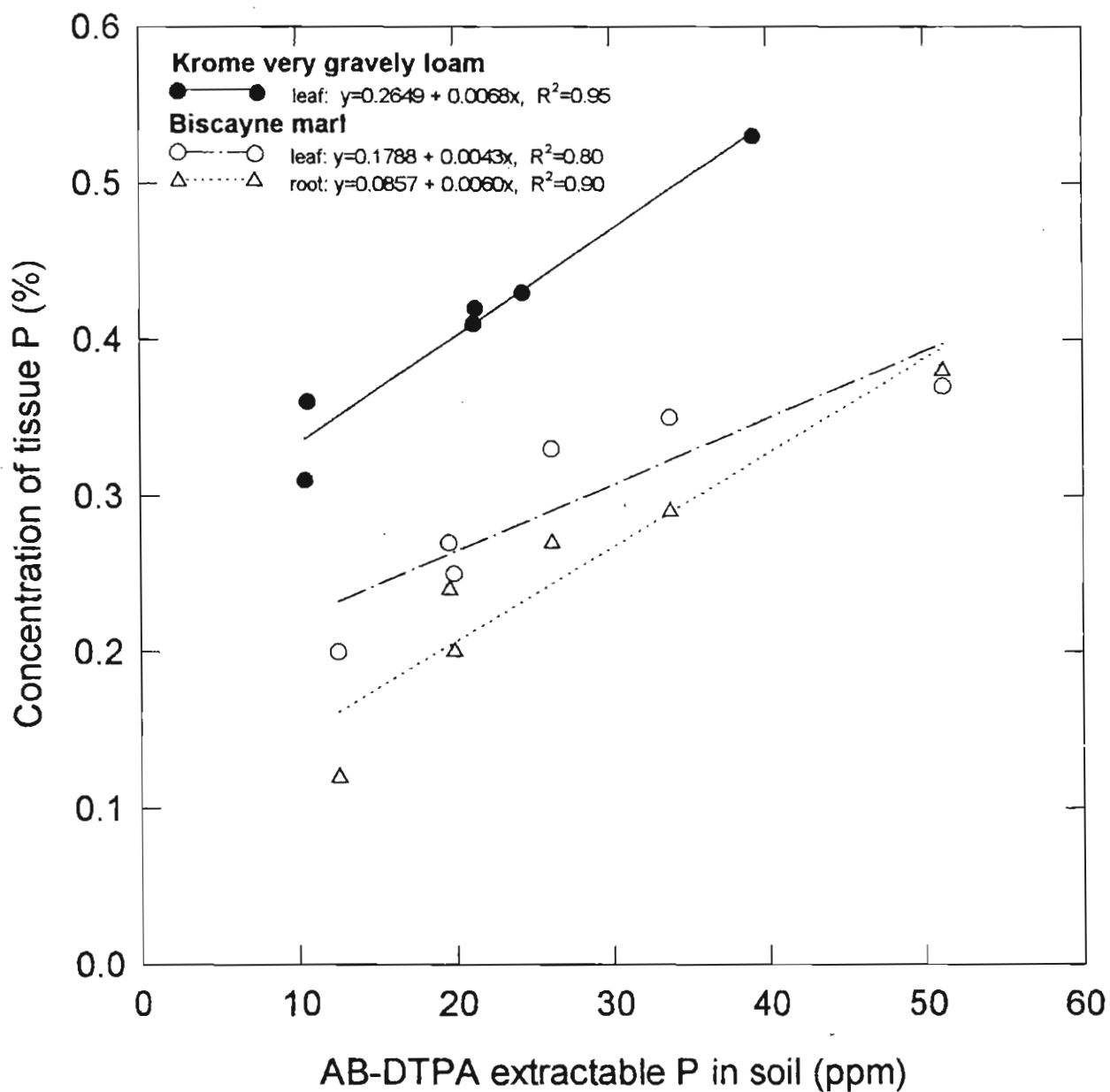


Fig. 3. Relationship between P concentrations of leaf and root and AB-DTPA extractable P in rockdale and marl soils. Each data point represents the mean of four replications.

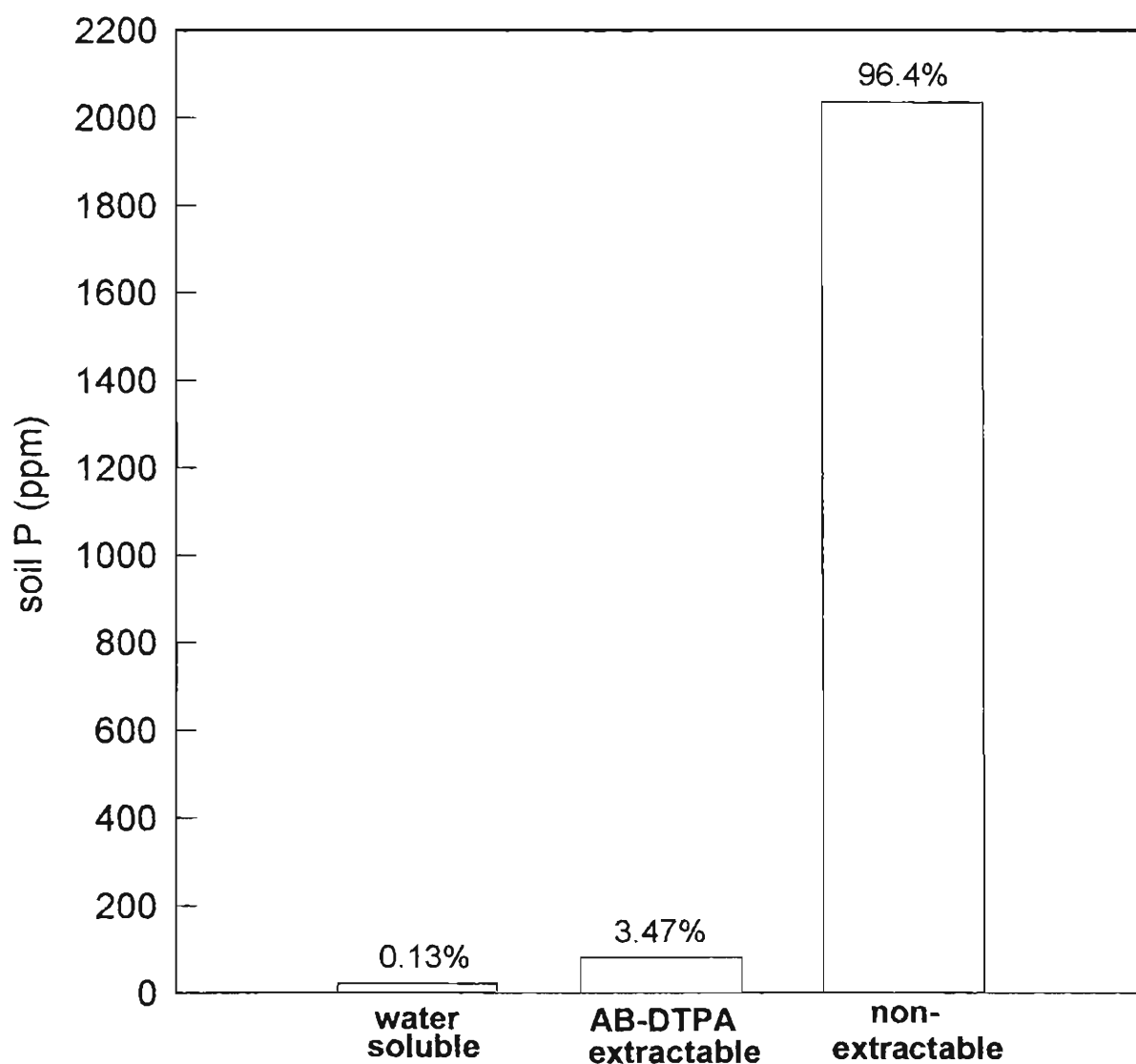


Fig. 4 Concentrations and percentage of water soluble, AB-DTPA extractable and nonextractable phosphorus in 15 soil samples collected in vegetable fields and tropical fruit groves in Dade County.

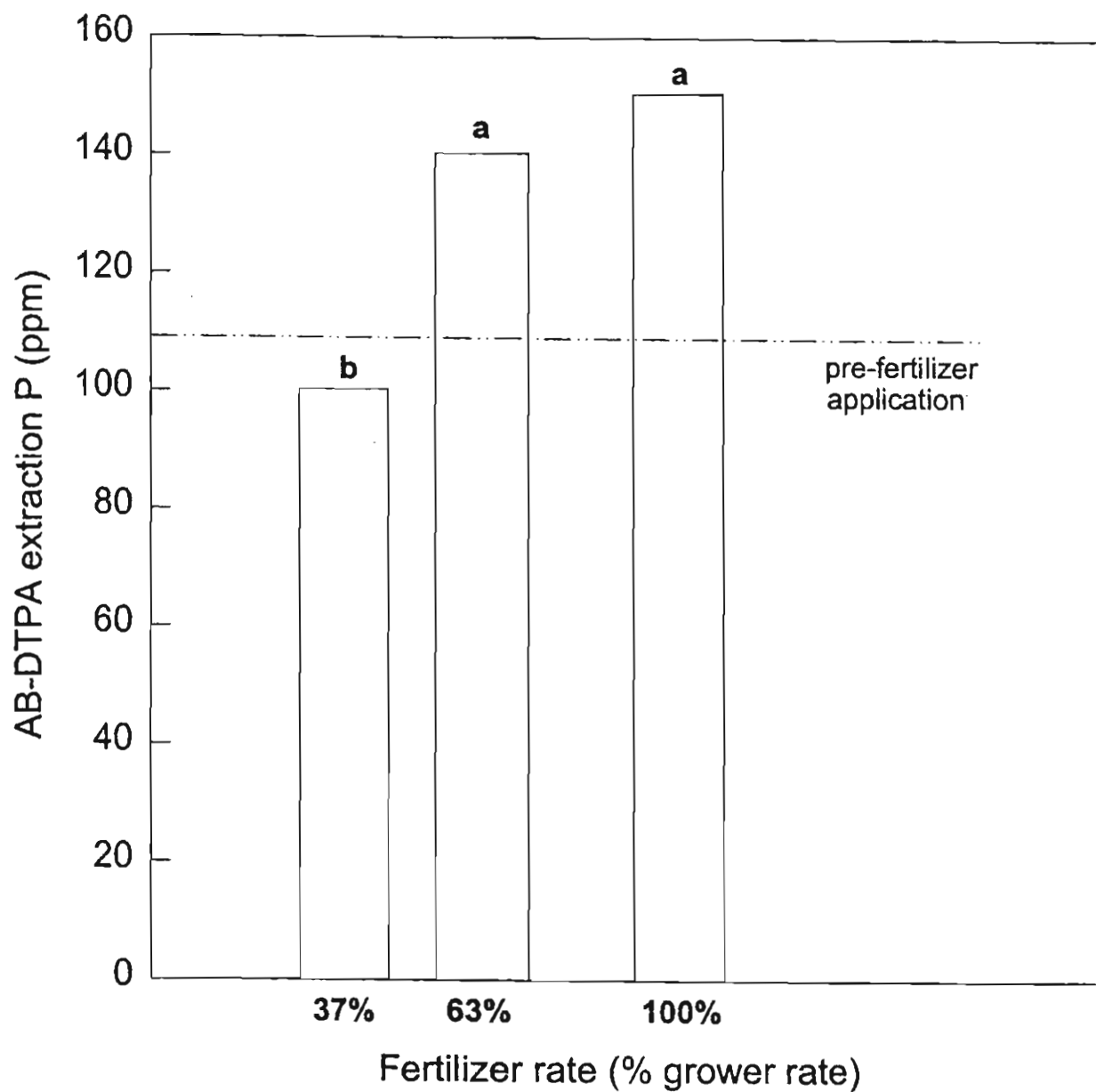


Fig. 5. AB-DTPA extraction P from fields of a Krome very gravely loam soil sampled prior to and 15 weeks after fertilizer application.

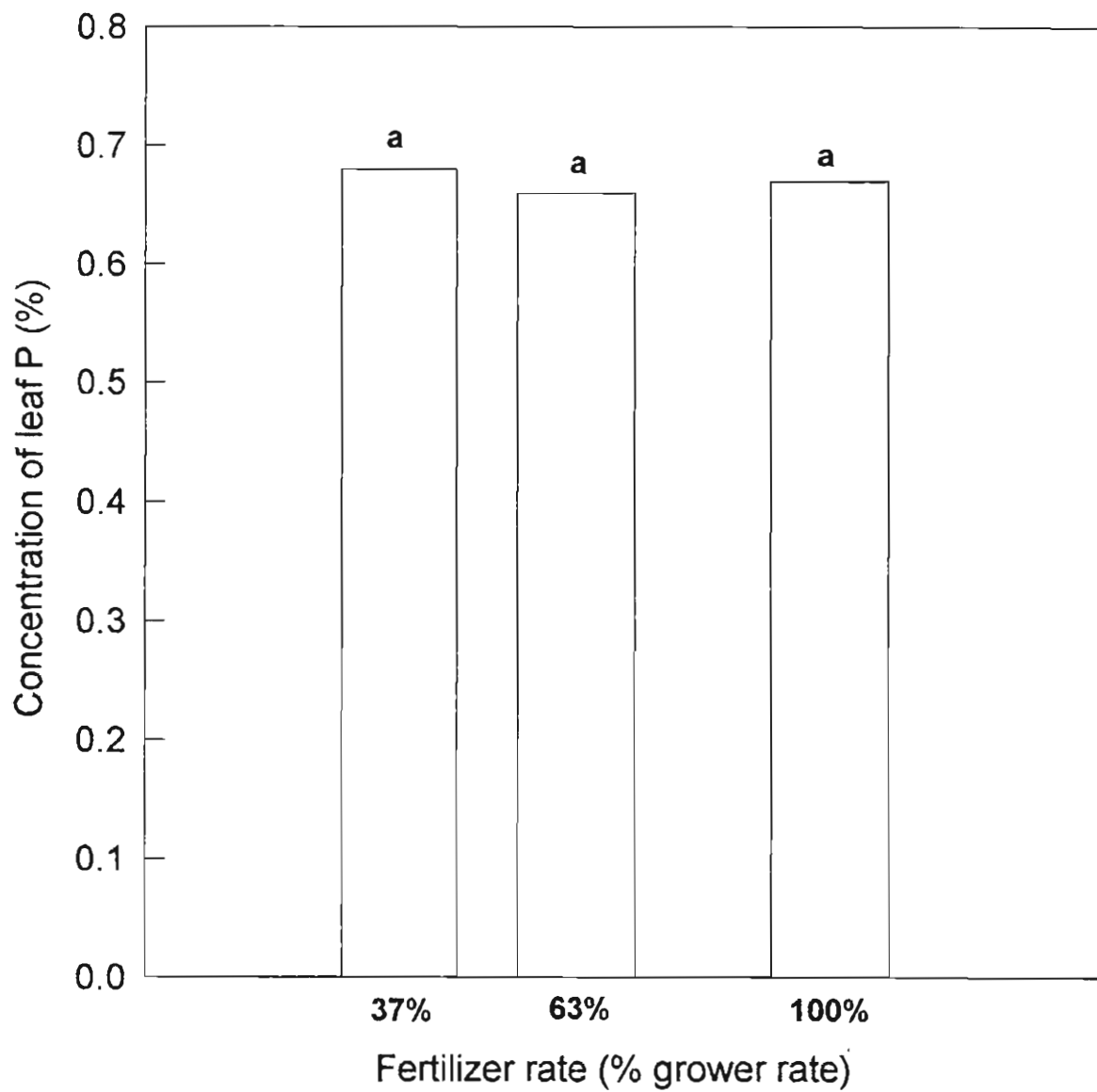


Fig. 6. Effects of phosphorus fertilizer rates applied to soil on leaf P concentrations.

APPENDIX

TOMATO CONTROL GUIDES

Tomato Varieties in Florida, D.N. Maynard

Tomato Fertilizer Management, G.J. Hochmuth

Chemical Insect Control in Tomatoes, Dr. Freddie Johnson

Chemicals for Foliar Disease Control in Tomatoes, Tom Kucharek

Nematicides Registered for Use on Florida Tomato, J.W. Noling

Weed Control in Tomato, W. M. Stall and J. P. Gilreath

TOMATO VARIETIES FOR FLORIDA

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

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

***Yield** - The variety selected should have the potential to produce crops at least equivalent to varieties already grown. The average yield in Florida is currently about 1300 25-pound cartons per acre. The potential yield of varieties in use should be much higher than average.

***Disease Resistance** - Varieties selected for use in Florida must have resistance to Fusarium wilt, race 1 and race 2; Verticillium wilt (race 1); gray leaf spot; and some tolerance to bacterial soft rot. Available resistance to other diseases may be important in certain situations.

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

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

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

CURRENT VARIETY SITUATION

Many tomato varieties are grown commercially in Florida, but only a few represent most of the acreages.

'Agrisat 761' was grown on 35% of the acreage in Florida in the 1996-97 season - down somewhat from the 41% planted the previous season. 'Agrisat 761' was grown on 49% of the acreage in southwest Florida, 24% of the acreage in west central Florida, and was the predominant variety in north Florida.

'Solar Set' had over 12% of the state acreage, about the same as in 1995-96. It was the most popular variety in Dade County, and had significant acreage on the East Coast, in Palmetto-Ruskin, and in north Florida.

All BHN varieties combined accounted for about 12% of the state's acreage which was almost double what was planted in 1995-96. About 20% of the southwest Florida crop was planted with BHN material.

'Sunbeam' and 'Solimar' each had about 10% of the state acreage. 'Sunny' was the most widely planted variety in Florida for many years, but only accounted for about 3% of the acreage in 1996-97.

'Florasette' was grown on about 4% of the acreage; and 'Bonita', 'Merced', 'Cobia', and 'Olympic' were grown on 1 or 2% of the Florida tomato acreage. Several other varieties and experimental lines were grown on less than 1% of the state acreage.

TOMATO VARIETY TRIAL RESULTS

Summary results listing the five highest yielding and the five largest fruited varieties from trials conducted at the University of Florida's Gulf Coast Research and Education Center, Bradenton; Indian River Research & Education Center, Ft. Pierce; and North Florida Research & Education Center, Quincy for the Spring 1996 season are shown in Table 1. High total yields and large fruit size were produced by FT 3260, HMX 2824, and 'Sunpride' at Bradenton; by 'Merced', 'Agrisat 761', and Florida 7578 at Ft. Pierce; by 'Majesty' and RXT 4012 at Quincy. Florida 7699 produced high yields at two of the three locations. 'Sunbeam' produced large fruit at all three locations. It should be noted that the same entries were not included in all trials.

Summary results listing outstanding entries in order from trials at the University of Florida's Gulf Coast Research & Education Center, Bradenton; the Indian River Research and Education Center, Ft. Pierce; and the North Florida Research and Education Center, Quincy for the fall 1996 season are shown in Table 2. High total yields and large fruit size were produced by XPH 10047 at Bradenton; by 'Bonita', 'Merced', 'Solar Set' and 'Equinox' at Ft. Pierce; and by FT 4012 and 'Equinox' at Quincy. High yields were produced in all three locations by 'Equinox' and by 'Agrisat 761' in two of three locations. 'Merced' produced large fruit size at all locations. As in the spring trial, not all entries were included at all locations. For spring and fall trials combined, high yields and/or large fruit size were achieved by 'Equinox' and 'Merced' seven times and 'Agrisat 761' four times.

Table 1. Summary of University of Florida tomato variety trial results. Spring 1996.

Location		Total Yield (ctn/acre)		Large Fruit Size (oz)
Bradenton (1)	FT 3260	2490	FT 3260	6.7
	HMX 2824	2396	HMX 2824	6.7
	Florida 7699	2396	Merced	6.2
	Flavor More 215	2374	Florida 7658	6.1 ¹
	Sunpride	2218 ¹	Sanibel	6.1
			Sunpride	6.1
Ft. Pierce (4)	Merced	2990	Sunbeam	7.7
	Bonita	2988	Merced	7.5
	Agrisat 761	2983	Florida 7658	7.5
	Equinox	2870	Agrisat 761	7.3
	Florida 7578	2771 ³	Florida 7578	7.2 ⁴
Quincy (3)	RXT 4010	2775	SR 3119	8.7
	Majesty	2611	RXT 4012	8.2
	RXT 4012	2508	Majesty	7.8
	Colonial	2429	Equinox	7.8
	Florida 7699	2417 ⁵	Sunbeam	7.7 ⁶

¹15 other entries had yields similar to those of 'Sunpride'.

²5 entries besides those listed had similar fruit weight.

³No significant yield difference.

⁴3 other entries had fruit weight similar to Florida 7578.

⁵17 other entries had yields similar to Florida 7699.

⁶11 other entries had fruit weight similar to 'Sunbeam'.

Seed Sources:

Agrisales: Agrisat 761, Equinox
Asgrow: Majesty, Sunbeam, Sunpride
Ferry-Morse: Flavor More 215
Harris Moran: HMX 2824
Potosseed: Colonial, Sanibel
Rogers: Bonita, Merced, FT 3260,
RXT 4010, RXT 4012
Sunseeds: SR 3119
University of Florida: Florida 7528
Florida 7678, Florida 7699

Table 2. Summary of University of Florida tomato variety trial results. Fall 1996.

Location		Total Yield (ctn/acre)		Large Fruit Size (oz)
Bradenton (2)	XPH 10047	2981	Affirm	6.2
	Agrisat 761	2915	Merced	5.9
	Equinox	2850	XPH 10047	5.8
	Florida 7658	2840	XPH 10035	5.7
	FT 4029	2800 ¹	Spica	5.5 ²
Ft. Pierce (4)	Bonita	3893	Merced	7.4
	Merced	3561	Bonita	6.9
	Agrisat 761	3458	Solar Set	6.6
	Solar Set	3441	Equinox	6.6
	Equinox	3427 ³	Florida 7713	6.6 ⁴
Quincy (3)	Florida 7514	1851	FT 4012	8.3
	PS 8432	1755	XPH 10035	8.0
	FT 4012	1666	Merced	7.9
	Equinox	1286	Equinox	7.3 ⁶
	Florida 7578	1231 ⁵	Solar Set	7.3
			Sunre 6631	7.3
			Sanibel	7.3

¹17 other entries has yields similar to FT 4029.

²14 entries besides those listed had similar fruit weight.

³5 other entries had yields similar to 'Equinox'.

⁴15 other entries had similar fruit weight.

⁵15 other entries had yields similar to Florida 7578.

⁶10 other entries had fruit weight similar to those listed.

Seed Sources:

Agrisales: Agrisat 761, Equinox
Asgrow: Solar Set, XPH 10035, 10047
Dachmoldt: Spica
Potosseed: PS 8432, Sanibel
Rogers: Bonita, Merced, FT 4012, FT4029
Sakata: Affirm
Sunseeds: Sunre 6631
University of Florida: Florida 7514, Florida
7578, Florida 7658, Florida 7713

TOMATO VARIETIES FOR COMMERCIAL PRODUCTION

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

Agriset 761. An early 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.

Bonita. A midseason, jointless hybrid. Fruit are globe-shaped and green-shouldered. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), gray leaf spot.

Equinox. A determinate, jointed, heat-tolerant hybrid that also performs well in the spring. Fruit are flattened globe-shaped with light-green shoulders. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), and gray leaf spot.

Merced. Early, deep-globe shaped, green-shouldered fruit are produced on determinate vines. Jointed hybrid. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), gray leaf spot, tobacco mosaic virus.

Olympic. A mid-season determinate, jointed hybrid. Fruit are deep oblate with green shoulders. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), Alternaria stem canker, and gray leaf spot.

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

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

Sunbeam. Early mid-season, deep-globe shaped, jointed, 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.

Sunny. A midseason, jointed, determinate, hybrid. Fruit are large, flat-globular in shape, and are green-shouldered. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), Alternaria stem canker, gray leaf spot.

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TOMATO FERTILIZER MANAGEMENT

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

The crop nutrient requirements of nitrogen, phosphorus, and potassium (designated in fertilizers as N-P₂O₅-K₂O) Table 1 represent the optimum amounts of these nutrients needed for maximum production (8).

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

LIMING

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

Calcium and magnesium levels should be corrected according to the soil test. If both elements are low and lime is needed, 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 would be indicative of adequate soil-Ca. On limestone soils, add 30-40 pounds per acre of magnesium in the basic fertilizer mix. It is best to apply lime several months prior to planting. However, if time is short, it is better to apply lime any time before planting than not to apply it at all. Where the pH does not need modification, but magnesium is low, apply magnesium sulfate or potassium-magnesium sulfate with the fertilizer.

BLOSSOM-END ROT

At certain times, growers have problems with blossom-end-rot, especially on the first one or two fruit clusters. Blossom-end rot (BER) is basically a Ca deficiency but is often more related to water stress than to Ca concentrations in the soil. This is because Ca movement in the plant is with the water stream. Anything that impairs the ability of the plant to obtain water will increase the risk of BER. These factors include damaged roots from flooding or mechanical damage, clogged drip emitters, inadequate water applications, and alternating dry-wet periods. Other causes include high fertilizer rates, especially potassium and nitrogen. High fertilizer increases the salt content and osmotic potential in the soil reducing the ability of roots to obtain water. Excessive N encourages excessive vegetative growth reducing the proportion of Ca that is deposited in the fruit.

There should be adequate Ca in the soil if the double-acid index is 300 to 350 ppm, or above. In these cases, added gypsum (calcium sulfate) is unlikely to reduce BER. Foliar sprays of Ca are unlikely to reduce BER because Ca does not move out of the leaves to the fruit. Foliar-applied Ca stays on the leaf from where it more likely will wash during a rain.

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

MICRONUTRIENTS

For virgin, sandy soils, or sandy soils where a proven need exists, a general guide for fertilization is the addition of micronutrients (in pounds per acre) manganese -3, copper -2, iron -5, zinc -2, boron -2, and molybdenum -0.02. Micronutrients may be supplied from oxides or sulfates. Growers using micronutrient-containing fungicides need to consider these sources when calculating fertilizer micronutrient needs. More information on micronutrient use is available (2, 5, 9).

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

Soil	Number of expected harvests	Nutrient Requirements		Supplemental Applications ¹
		lbs/A ² N-P ₂ O ₅ -K ₂ O	lbs/A N-P ₂ O ₅ -K ₂ O	Number of Applications
Mineral	2-3	175-150-225	30-0-20	0-2
Rockdale	2-3	150-200-200	30-0-20	0-2

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

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

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 or tomatoes, consult the Commercial Vegetable Fertilization Guide, Circular 225-C (2).

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 new fertilizing equipment, such as 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 requirement and all of the phosphorus and micronutrients. Starter fertilizer can be broadcast over the entire area prior to bedding and then incorporated. During bedding, the fertilizer will be gathered into the bed area. An alternative is to use a "modified broadcast" technique for systems with wide bed spacings. Use of modified broadcast or banding techniques can increase phosphorus and micronutrient efficiencies, especially on alkaline soils.
3. Formation of beds, incorporation of herbicide, and application of mole cricket bait.
4. Application of remaining fertilizer. The remaining 80 to 90 percent of the nitrogen and potassium is placed in narrow bands 9 to 10 inches to each side of the plant row in furrows. The fertilizer should be placed deep enough in the grooves for it to be in contact with moist bed soil. Bed presses are modified to provide the groove. Only water-soluble nutrient sources should be used for the banded fertilizer. A mixture of potassium nitrate (or potassium sulfate or potassium chloride), calcium nitrate, and ammonium nitrate has proven successful.

5. Fumigation, pressing of beds, and mulching. This should be done in one operation, if possible. Be sure that the mulching machine seals the edges of the mulch adequately with soil to prevent fumigant escape.

There is equipment that will do most of the operations in steps 4 and 5 above in one pass over the field. More information on fertilization of mulched crops is available (1, 10).

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

Mulched Culture With Overhead Irrigation

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

Mulched Production With Drip Irrigation

Where drip irrigation is used, drip tape or tubes should be laid 1 to 2 inches below the bed soil surface prior to mulching. This placement helps protect tubes from mice and cricket damage. The drip system is an excellent tool with which to fertilize the crop. Where drip irrigation is used, before planting apply all phosphorus and micronutrients, and 20 percent to 40 percent of total nitrogen and potassium prior to mulching. Use the lower percentage (20 percent) on seep-irrigated tomatoes. Apply the remaining nitrogen and potassium through the drip system in increments as the crop develops.

Successful crops have resulted where the total amounts of N and K₂O were applied through the drip system. Some growers find this method helpful where they have had problems with soluble-salt burn. This approach would be most likely to work on soils with relatively high organic matter and some residual potassium. However, it is important to begin with rather high rates of N and K₂O to ensure young transplants are established quickly. In most other situations, some preplant N and K fertilizer are needed.

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

Additional nutrients can be supplied through drip irrigation if deficiencies occur during the growing season. Be careful not to apply excessive amounts of water with the fertilizer because severe leaching can occur. Tensiometers can be used to help monitor soil moisture and guide the application of water. More detail on drip-irrigation management for fertilization is available (6).

Sources Of N-P₂O₅-K₂O

About 30 to 50 percent of the total applied nitrogen should be in the nitrate form for soil treated with multi-purpose fumigants and for plantings in cool soil temperature.

Slow-release nitrogen sources may be used to supply a portion of the nitrogen requirement. One-third of the total required nitrogen can be supplied from sulfur-coated urea (SCU), isobutylidene diurea (IBDU), or polymer-coated fertilizers incorporated in the bed. Nitrogen from natural organics and most slow-release materials should be considered ammoniacal nitrogen when calculating the amount of ammoniacal nitrogen.

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

Recent research has shown that all sources of potassium can be used

for tomatoes. Potassium sulfate, sodium-potassium nitrate, potassium nitrate, potassium chloride, monopotassium phosphate, and potassium-magnesium sulfate are all good K sources. If the soil test predicted amounts of K₂O are applied, then there should be no concern for the K source or its associated salt index.

Tissue Analysis

Analysis of tomato leaves for mineral nutrient content can help guide a fertilizer management program or assist in diagnosis of a suspected nutrient deficiency. Tissue nutrient norms are presented in Table 3. Growers with drip irrigation can obtain faster analyses for N or K by using a plant sap quick test. Several kits have been calibrated for Florida tomatoes (3, 4). Interpretation of these kits is provided in Table 4. More information is available on plant analysis (7).

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

Crop development stage	weeks	Injection (lb/A/day)*	
		N	K ₂ O
1	2	1.0	1.5
2	2	1.5	2.0
3	7	2.5	3.0
4	1	1.5	2.0
5	1	1.0	1.5

Total nutrients applied are 175 lb N and 225 lb K₂O per acre (7260 linear bed feet). These injection programs assume no N or K preplant. If 20% of N and K are applied preplant in the bed, then first two week's of injection can be reduced or omitted.

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

%																ppm							
Tomato	MRM ² 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	0.3	3.0	1.0	0.3	0.3	40	30	25	20	5	0.2								
				5.0	0.6	5.0	2.0	0.5	0.8	100	100	40	40	15	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	0.2	2.5	1.0	0.3	0.3	40	30	25	20	5	0.2								
				4.0	0.4	4.0	2.0	0.5	0.8	100	100	40	40	15	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	0.2	2.5	1.0	0.25	0.3	40	30	20	20	5	0.2								
				4.0	0.4	4.0	2.0	0.5	0.6	100	100	40	40	10	0.6								
			High	>4.0	0.4	4.0	2.0	0.5	0.6	100	100	40	40	10	0.6								
			Toxic (>)													250							

continued

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

			%						ppm						
			N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo	
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	0.2	2.0	1.0	0.25	0.3	40	30	20	20	5	0.2
				3.5	0.4	4.0	2.0	0.5	0.6	100	100	40	40	10	0.6
	MRM leaf	During harvest period	High	>3.5	0.4	4.0	2.0	0.5	0.6	100	100	40	40	10	0.6
			Deficient	<2.0	0.2	1.5	1.0	0.25	0.3	40	30	20	20	5	0.2
			Adequate range	2.0	0.2	1.5	1.0	0.25	0.3	40	30	20	20	5	0.2
3.0	0.4	2.5		2.0	0.5	0.6	100	100	40	40	10	0.6			
			High	>3.0	0.4	2.5	2.0	0.5	0.6	100	100	40	40	10	0.6

²MRM=Most recently matured leaf.

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

Stage of growth	Sap concentration (ppm)	
	NO ₃ -N	K
First buds	1000-1200	3500-4000
First open flowers	600-800	3500-4000
Fruits one-inch diameter	400-600	3000-3500
Fruits two-inch diameter	400-600	3000-3500
First harvest	300-400	2500-3000
Second harvest	200-400	2000-2500

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Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
ANTS			
carbaryl (Sevin)	5 B	20 - 40 lb	0
pyrethrins + piperonyl butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0
APHIDS			
aliphatic petroleum (JMS Stylet Oil)	97.6% EC	see label	see label
azinphosmethyl (Guthion) (Sniper)	2S, 2L (EC) 2 E 50 PVA	2 - 3 pt 2 - 3 pt 1 - 1 1/2 lb	up to day of harvest
cyfluthrin (Baythroid)	2 EC	1.6 - 2.8 oz	0
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84 oz	5 - caution, see label
diazinon AG500	4 EC	1/2 pt	1
dimethoate (Cygon)	4 EC	1/2 - 1 pt	7
disulfoton (Di-Syston)	8 E	1 - 3 pts	30
endosulfan (Phaser, Thiodan) (Thirethrin)	3 EC 2.9 L	2/3 - 1 1/3 qt 1 qt	2 - field & greenhouse 1
esfenvalerate (Asana XL) (potato aphid)	0.66 EC	5.8 - 9.6 fl oz	1
imidacloprid (Provado) (Admire)	1.6 EC 2.0 EC	3.75 oz 16 - 24 oz (soil use)	0 - foliar 21 - soil
lindane (Prentox)	1.63 EC	20 oz/100 gal water	apply before fruit forms
malathion	5 EC	1 1/2 - 2 pts	1
methamidophos (Monitor)	4 EC	1/2 - 1 1/2 pt	7
methomyl (Lannate LV)	2.4 EC	1 1/2 - 3 pt	1
oil (Sun Spray)	98.8%	1-2 gal/100 gal H ₂ O	1
Note: Sun Spray oil can cause phytotoxic (plant) burns if used during periods of prolonged high temperature and high relative humidity. Do not spray plants under moisture stress. Do not use in combination with or immediately before or after spraying with dimethoate (Cygon) or fungicides such as Captan, Folpet, Dyrene, Karathane, Morestan, sulfur, or any product containing sulfur. Use with Bravo is not recommended.			
oxamyl (Vydate L)	2 L	2 - 4 pts	1
pyrethrins + piperonyl butoxide (Pyrenone) (green peach aphid)	66% L (EC)	2 - 12 oz per 100 gal	0
pyrethrins + rotenone (Pyrellin)	EC	1 - 2 pts	0
rotenone (Rotacide)	EC	1 gal	0
soap, insecticidal (M-Pede)	49% EC	1-2 gal/100 gal H ₂ O	0
ARMYWORMS			
(See also: Beet, Fall, Southern, and Yellow-striped Armyworm)			
azadirachtin (Neemix)	0.25%	2.5 pts/100 gal water 150 - 300 gal/acre	1
<i>Bacillus thuringiensis</i>	See individual brand labels		---
chlorpyrifos (Lorsban) (except cherry tomatoes)	50 W	2 lb	14

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
ARMYWORMS (cont.)			
diazinon AG500 (fall and southern armyworm)	4 EC	3/4 - 1 pt	1
esfenvalerate (Asana XL) (beet, Southern, Western yellow-striped)	0.66 EC	5.8 - 9.6 fl oz	1
malathion	5 EC	1 1/2 - 2 pt	1
methomyl (Lannate LV)	2.4 EC	3/4 - 1 1/2 pt	1
methyl parathion	4 EC	1 - 3 pt	15
pyrethrins + piperonyl butoxide (Pyrenone)	66% L (EC)	2 - 12 oz per 100 gal	0
rotenone (Rotacide)	EC	1 gal	0
BEET ARMYWORMS (See also: Armyworms)			
cyfluthrin (Baythroid)	2 EC	2.8 oz	0
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84	5 - caution, see label
esfenvalerate (Asana XL) (aids in control)	0.66 EC	5.8 - 9.6 fl oz	1
methomyl (Lannate LV)	2.4 EC	1.5 - 3 pts	1
permethrin (Ambush)	2 EC	3.2 - 12.8 oz	up to day of
(Pounce)	3.2 EC	2 - 8 oz	harvest
Note: Permethrin (Ambush, Pounce) only for Florida use where final market is for fresh tomatoes. Do not use on cherry tomatoes or any variety used to produce fruit less than 1" (one inch) in diameter. Permethrin can be applied by air or ground. Use sufficient water to obtain uniform coverage. Do not apply more than 1.2 lbs. active ingredient per acre per season which is equivalent to 76.8 ozs. of Ambush 2 EC or 48 ozs. of Pounce 3.2 EC.			
BANDED CUCUMBER BEETLES			
azinphosmethyl (Guthion)	2S, 2L (EC)	1 1/2 - 2 pt	0
diazinon AG500	4 EC	3/4 - 1 pt	1
BLISTER BEETLES			
cryolite (Kryocide)	96 WP	15 - 30 lb	wash fruit
endosulfan (Phaser, Thiodan)	3 EC	2/3 - 1 1/3 qt	2 - field and greenhouse
(Thirethrin)	2.9 L	1 qt	1
methoxychlor	4 L	1 - 3 qt	1 - 1 3/4 qt; 7 - 1 3/4+ qt
CABBAGE LOOPERS (See also: Loopers)			
azadirachtin (Neemix)	0.25%	2.5 pts/100 gal water 150 - 300 gal/acre	1
<i>Bacillus thuringiensis</i>	See individual brand labels.		0
cryolite (Kryocide)	96 WP	15 - 30 lb	wash fruit
cyfluthrin (Baythroid)	2 EC	2.8 oz	0
cyhalothrin (Karate, Warrior)	1 EC	1.92 - 3.20 oz	5 - caution, see label
endosulfan (Phaser, Thiodan)	3 EC	1 - 1 1/3 qt	2 - field and greenhouse
(Thirethrin)	2.9 L	1 1/2 qt	1
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
malathion	5 EC	1 1/2 - 2 pt	1
methomyl (Lannate LV)	2.4 EC	3/4 - 1 1/2 pt	1
permethrin (Ambush)	2 EC	3.2 - 12.8 oz	up to day of harvest
(Pounce)	3.2 EC	2 - 8 oz	

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
CABBAGE LOOPERS (cont.)			
Note: Permethrin (Ambush, Pounce) only for Florida use where final market is for fresh tomatoes. Do not use on cherry tomatoes or any variety used to produce fruit less than 1" (one inch) in diameter. Permethrin can be applied by air or ground. Use sufficient water to obtain uniform coverage. Do not apply more than 1.2 lbs. active ingredient per acre per season which is equivalent to 76.8 ozs. of Ambush 2 EC or 48 ozs. of Pounce 3.2 EC.			
pyrethrins + piperonyl butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0
rotenone (Rotacide)	EC	1 gal	0
COLORADO POTATO BEETLES			
abamectin (Agrimek)	.15 EC	8-16 oz	7
azadirachtin (Neemix)	0.25%	2.5 pts/100 gal water 150 - 300 gal/acre	1
azinphosmethyl (Guthion) (Sniper)	2S, 2L (EC) 2 E 50 PVA	1 1/2 pt 1 1/2 pt 3/4 lb	up to day of harvest
<i>Bacillus thuringiensis</i> subsp. <i>tenebrionis</i> (Novodor)	see individual labels	see individual labels	0
carbaryl (Sevin)	80S	2/3 - 1 1/4 lb	0
cyfluthrin (Baythroid)	2 EC	1.6 - 2.8 oz	0
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84 oz	5 - caution, see label
cyromazine (Trigard) (suppression)	75%	1/6 pt	7
disulfoton (Di-Syston) (early season reduction)	8 E	1 - 3 pts	30
endosulfan (Phaser, Thiodan)	3 EC	2/3 - 1 1/3 qt	2 - field and greenhouse
(Thirethrin)	2.9 L	1 qt	1
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
imidacloprid (Provado) (Admire)	1.6 EC 2.0 EC	3.75 oz 16 - 24 oz (soil use)	0 - foliar 21 - soil
methoxychlor	4 L	1 - 3 qt	1 - 1 3/4 qt; 7 - 1 3/4+ qt
oxamyl (Vydate L)	2 EC	2 - 4 pts	1
permethrin (Ambush) (Pounce)	2 EC 3.2 EC	3.2 - 12.8 oz 2 - 8 oz	up to day of harvest
Note: Permethrin (Ambush, Pounce) only for Florida use where final market is for fresh tomatoes. Do not use on cherry tomatoes or any variety used to produce fruit less than 1" (one inch) in diameter. Permethrin can be applied by air or ground. Use sufficient water to obtain uniform coverage. Do not apply more than 1.2 lbs. active ingredient per acre per season which is equivalent to 76.8 ozs. of Ambush 2 EC or 48 ozs. of Pounce 3.2 EC.			
pyrethrins + piperonyl butoxide (Pyrenone)	66% L (EC)	2 - 12 oz per 100 gal	0
pyrethrins + rotenone (Pyrellin)	EC	1 1/2 - 2 pts	0
rotenone (Rotenox) (Rotacide)	5% L EC	2/3 gal 1 gal	0
CORN EARWORMS			
(See also: Tomato Fruitworms)			
azinphosmethyl (Guthion) (Sniper)	2S, 2L (EC) 2 E 50 PVA	3 - 6 pts 3 - 6 pts 1 1/2 - 3 lb	up to day of harvest for 3 pt or less (1 1/2 lb or less); 14 for 3+ pt (1 1/2+)

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
CORN EARWORMS (cont.)			
<i>Bacillus thuringiensis</i>	See individual brand labels		0
pyrethrins + piperonyl butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0
CRICKETS			
carbaryl (Sevin)	5 B	20 - 40 lb	0
pyrethrins + piperonyl butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0
rotenone (Rotacide)	EC	1 gal	0
CUCUMBER BEETLE (See also: Banded Cucumber Beetle)			
azinphosmethyl (Guthion) (Sniper)	2 S, 2 L (EC) 2 E 50 PVA	1 ½ - 2 pts 1 ½ - 2 pts ¾ - 1 lb	up to day of harvest
(banded cucumber beetle)			
carbaryl (Adios)	13 B	½ - ¾ lb	0
pyrethrins + piperonyl butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0
pyrethrins + rotenone (Pyrellin)	EC	1 1/2 - 2 pts	0
rotenone (Rotacide)	EC	1 gal	0
CUTWORMS			
azadirachtin (Neemix)	0.25%	2.5 pts/100 gal water 150 - 300 gal/acre	1
<i>Bacillus thuringiensis</i>	See individual brand labels		0
carbaryl (Sevin)	80S (WP)	2 1/2 lb	0
	5 B	20 - 40 lb	0
cyfluthrin (Baythroid)	2 EC	2.8 oz	0
cyhalothrin (Karate, Warrior)	1 EC	1.92 - 3.20 oz	5 - caution, see label
diazinon	14 G	14 - 28 lb	preplant
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
malathion	5 EC	1 1/2 - 2 pt	1
methomyl (Lannate LV) (variegated cutworm)	2.4 EC	1 1/2 pt	1
permethrin (granulate cutworm)			
(Ambush)	2 EC	3.2 - 12.8 oz	up to day of harvest
(Pounce)	3.2 EC	2 - 8 oz	
Note: Permethrin (Ambush, Pounce) only for Florida use where final market is for fresh tomatoes. Do not use on cherry tomatoes or any variety used to produce fruit less than 1" (one inch) in diameter. Permethrin can be applied by air or ground. Use sufficient water to obtain uniform coverage. Do not apply more than 1.2 lbs. active ingredient per acre per season which is equivalent to 76.8 ozs. of Ambush 2 EC or 48 ozs. of Pounce 3.2 EC.			
rotenone (Rotacide)	EC	1 gal	0
DARKLING BEETLES			
carbaryl (Sevin)	5 B	20 - 40 lb	0
DROSOPHILAS (FRUIT FLIES, VINEGAR FLIES)			
azinphosmethyl (Guthion) (Sniper)	2S, 2L (EC) 2 E 50 PVA	1 1/2 - 2 pt 1 ½ - 2 pt ¾ - 1 lb	0
diazinon AG500 (vinegar fly)	4 EC	1/2 - 1 1/2 pt	1

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
DROSOPHILAS (FRUIT FLIES, VINEGAR FLIES (cont.))			
malathion	5 EC	1 1/2 - 2 pts	1
pyrethrins + piperonyl butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0
rotenone (Rotacide) (fruit fly)	EC	1 gal	0
EUROPEAN CORN BORERS			
azinphosmethyl (Guthion) (Sniper)	2S, 2L (EC) 2 E 50 PVA	2 - 3 pt 2 - 3 pts 1 - 1 1/2 lb	up to day of harvest
carbaryl (Sevin)	80S (WP)	1 1/2 - 2 1/2 lb	0
cyfluthrin (Baythroid)	2 EC	1.6 - 2.8 oz	0
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84 oz	5 - caution, see label
pyrethrins + rotenone (Pyrellin)	EC	1 1/2 - 2 pts	0
FALL ARMYWORMS (See also: Armyworms)			
carbaryl (Sevin)	80S (WP)	1 1/2 - 2 1/2 lb	0
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84 oz	5 - caution, see label
diazinon AG500	4 EC	3/4 - 1 pt	1
methomyl (Lannate LV)	2.4 EC	1 1/2 pt	1
methoxychlor	4 L	1 - 3 qt	1 - 1 3/4 qt; 7 - 1 3/4+ qt
FLEA BEETLES			
azinphosmethyl (Guthion) (Sniper)	2S, 2L (EC) 2 E 50 PVA	2 - 3 pt 2 - 3 pt 1 - 1 1/2 lb	up to day of harvest
carbaryl (Sevin)	80S (WP)	2/3 - 1 1/4 lb	0
cryolite (Kryocide)	96 WP	15 - 30 lb	wash fruit
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84 oz	5 - caution, see label
disulfoton (Di-Syston)	8 E	1 - 3 pts	30
endosulfan (Phaser, Thiodan) (Thirethrin)	3 EC 2.9 L	2/3 - 1 1/3 qt 1 qt	2 - field and greenhouse 1
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
imidacloprid (Admire)	2.0 EC	16 - 24 oz (soil use)	21 - soil
methyl parathion	4 EC	1 - 3 pt	15
methoxychlor	4 L	1 - 3 qt	1 - 1 3/4 qt; 7 - 1 3/4+ qt
pyrethrins + piperonyl butoxide (Pyrenone)	66% L (EC)	2 - 12 oz per 100 gal	0
pyrethrins + rotenone (Pyrellin)	EC	1 1/2 - 2 pts	0
rotenone (Rotacide)	EC	1 gal	0
FLEAHOPPERS			
malathion (Cythion)	5 EC	1 1/2 - 2 pts	1
pyrethrins + rotenone (Pyrellin)	EC	1 - 2 pts	0
GARDEN SYMPHYLANS (SYMPHYLANS)			
fonofos (Dyfonate)	10 G	20 lb	preplant, broadcast
diazinon AG500	4 EC	10 qt	preplant, broadcast

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
GRASSHOPPERS			
azinphosmethyl (Guthion) (Sniper)	2S, 2L (EC) 2 E 50 PVA	2 - 3 pt 2 - 3 pts 1 - 1 ½ lb	up to day of harvest
carbaryl (Sevin)	5 B 80 S	20 - 40 lb 2/3 - 1 7/8 lbs	0
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84 oz	5 - caution, see label
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
rotenone (Rotacide)	EC	1 gal	0
HORNWORMS (TOMATO HORNWORM, TOBACCO HORNWORM)			
azadirachtin (Neemix)	0.25%	2.5 pts/100 gal water 150 - 300 gal/acre	1
azinphosmethyl (Guthion) (Sniper)	2S, 2L (EC) 2 E 50 PVA	3 - 6 pts 3 - 6 pts 1 ½ - 3 lb	up to day of harvest for 3 pt or less (1 ½ lb or less); 14 for 3+ pt (1 ½ lb +)
<i>Bacillus thuringiensis</i>	See individual brand labels.		0
carbaryl (Sevin) (tomato hornworm)	80S (WP)	1 1/2 - 2 1/2 lb	0
cryolite (Kryocide)	96 WP	15 - 30 lb	wash fruit
cyfluthrin (Baythroid)	2 EC	1.6 - 2.8 oz	0
cyhalothrin (Karate, Warrior)	1 EC	1.92 - 3.20 oz	5 - caution, see label
endosulfan (Phaser, Thiodan) (Thirethrin)	3 EC 2.9 L	2/3 - 1 1/3 qts 1 - 2 qts	2 - field and greenhouse 1
esfenvalerate (Asana XL)(tomato hornworm, tobacco hornworm)	0.66 EC	2.9 - 5.8 fl oz	1
methomyl (Lannate LV)	2.4 EC	1.5 - 3 pt	1
permethrin (Ambush) (Pounce)	2 EC 3.2 EC	3.2 - 12.8 oz 2 - 8 oz	up to day of harvest
Note: Permethrin (Ambush, Pounce) only for Florida use where final market is for fresh tomatoes. Do not use on cherry tomatoes or any variety used to produce fruit less than 1" (one inch) in diameter. Permethrin can be applied by air or ground. Use sufficient water to obtain uniform coverage. Do not apply more than 1.2 lbs. active ingredient per acre per season which is equivalent to 76.8 ozs. of Ambush 2 EC or 48 ozs. of Pounce 3.2 EC.			
LACE BUGS			
carbaryl (Sevin)	80S (WP)	1 1/2 - 2 1/2 lb	0
LEAFHOPPERS			
azinphosmethyl (Guthion) (Sniper)	2S, 2L (EC) 2 E 50 PVA	2 - 3 pt 2 - 3 pt 1 - 1 ½ lb	up to day of harvest
carbaryl (Sevin)	80S	2/3 - 1 1/4 lb	0
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84 oz	5 - caution, see label
dimethoate (Cygon)	4 EC	1/2 - 1 pt	7
disulfoton (Di-Syston)	8 E	1 - 3 pts	30
methoxychlor	4 L	1 - 3 qt	1 - 1 3/4 qt; 7 - 1 3/4+ qt
methyl parathion	4 EC	1 - 3 pt	15
oil (Sun Spray)	98.8%	1 - 2 gal/100 gal water	1
Note: Sun Spray oil can cause phytotoxic (plant) burns if used during periods of prolonged high temperature and high relative humidity. Do not spray plants under moisture stress. Do not use in combination with or immediately before or after spraying with dimethoate (Cygon) or fungicides such as Captan, Folpet, Dyrene, Karathane, Morestan, sulfur or any product containing sulfur. It is not recommended to be used with Bravo.			

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
LEAFHOPPERS (cont.)			
pyrethrins + piperonyl butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0
pyrethrins + rotenone (Pyrellin)	EC	1 1/2 - 2 pts	0
rotenone (Rotacide)	EC	1 gal	0
soap, insecticidal (M-Pede)	49% EC	1 - 2 gal/100 gal water	0
LEAFMINERS			
abamectin (Agri-Mek)	0.15 EC	8 - 16 oz	7
azadirachtin (Neemix)	0.25%	2.5 pts/100 gal water 150 - 300 oz	1
azinphosmethyl (Guthion) (Sniper)	2S, 2L (EC) 2 E 50 PVA	1 1/2 - 2 pt 1 1/2 - 2 pt 3/4 - 1 lb	up to day of harvest
cyfluthrin (Baythroid)	2 EC	1.6 - 2.8 oz	0
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84 oz	5 - caution, see label
cryomazine (Trigard)	75%	1/6 lb	7
diazinon AG500 (dipterous leafminer)	4 EC 50 WP	1/2 pt 1/2 lb	1 1
dimethoate (Cygon)	4 EC	1/2 - 1 pt	7
disulfoton (Di-Syston)	8 E	1 - 3 pts	30
esfenvalerate (Asana XL)	0.66 EC	9.6 oz	1
malathion (serpentine)	5 EC	1 1/2 - 2 pt	1
methamidophos (Monitor) adults (fresh fruit only)	4 EC	1/2 - 1 1/2 pt	7
oil (Sun Spray)	98.8%	1 - 2 gal/100 gal water	1
Note: Sun Spray oil can cause phytotoxic (plant) burns if used during periods of prolonged high temperature and high relative humidity. Do not spray plants under moisture stress. Do not use in combination with or immediately before or after spraying with dimethoate (Cygon) or fungicides such as Captan, Folpet, Dyrene, Karathane, Morestan, sulfur or any product containing sulfur. It is not recommended to be used with Bravo.			
oxamyl (Vydate L) (serpentine leafminers except <i>Liriomyza trifolii</i>)	2 EC	2 - 4 pt	1
permethrin (Ambush) (Pounce)	2 EC 3.2 EC	3.2 - 12.8 oz 2 - 8 oz	up to day of harvest
Note: Permethrin (Ambush, Pounce) only for Florida use where final market is for fresh tomatoes. Do not use on cherry tomatoes or any variety used to produce fruit less than 1" (one inch) in diameter. Permethrin can be applied by air or ground. Use sufficient water to obtain uniform coverage. Do not apply more than 1.2 lbs. active ingredient per acre per season which is equivalent to 76.8 ozs. of Ambush 2 EC or 48 ozs. of Pounce 3.2 EC.			
pyrethrins + rotenone (Pyrellin)	EC	1 - 2 pts	0
rotenone (Rotacide)	EC	1 gal	0
LOOPERS (See also: Cabbage Looper)			
azadirachtin (Neemix)	0.25%	2.5 pts/100 gal water 150 - 300 gal/acre	1
<i>Bacillus thuringiensis</i>	See individual brand labels		---
methomyl (Lannate LV)	2.4 EC	1.5 - 3 pt	1
pyrethrins + rotenone (Pyrellin)	EC	1 - 2 pts	0
MEALY BUGS			
malathion (Cythion)	5 EC	1 1/2 - 2 pts	1

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
MITES			
MITES (GENERAL):			
dicofol (Kelthane) (Pacific, tropical, two-spotted, tomato russet)	MF (4 EC)	3/4 - 1 1/2 pt	2
disulfoton (Di-Syston)	8 E	1 - 3 pts	30
malathion (Cythion)	5 EC	1 1/2 - 2 pts	1
methyl parathion	4 EC	1 - 3 pt	15
pyrethrins + rotenone (Pyrellin)	EC	1 - 2 pts	0
TOMATO RUSSET MITE:			
abamectin (Agri-Mek)	0.15 EC	8 - 16 oz	7
dicofol (Kelthane)	MF- 4 EC	3/4 - 1 1/2 pts	2
endosulfan			
(Phaser, Thiodan)	3 EC	1 1/3 qt	2
(Thirethrin)	2.9 L	2 qt	1
malathion	5 EC	1 1/2 - 2 pts	1
oil (Sun Spray)	98.8%	1 - 2 gal/100 gal water	1
Note: Sun Spray oil can cause phytotoxic (plant) burns if used during periods of prolonged high temperature and high relative humidity. Do not spray plants under moisture stress. Do not use in combination with or immediately before or after spraying with dimethoate (Cygon) or fungicides such as Captan, Folpet, Dyrene, Karathane, Morestan, sulfur or any product containing sulfur. It is not recommended to be used with Bravo.			
pyrethrins + rotenone (Pyrellin)	EC	1 - 2 pts	0
soap, insecticidal (M-Pede)	49% EC	1 - 2 gal/100 gal water	0
sulfur	see individual brand labels		---
SPIDER MITE:			
abamectin (Agri-Mek)	0.15 EC	8 - 16 oz	7
dicofol (Kelthane)	MF- 4 EC	3/4 - 1 1/2 pts	2
malathion	5 EC	1 1/2 pt per 100 gal	1
MOLE CRICKETS			
diazinon	14 G	7 lb	preplant
	AG500	1 qt	preplant, broadcast
PLANT BUGS			
carbaryl (Sevin) (tarnished plant bug)	80S (WP)	1 1/2 - 2 1/2 lb	0
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84 oz	5 - caution, see label
pyrethrins + rotenone (Pyrellin)	EC	1 - 2 pts	0
soap, insecticidal (M-Pede)	49% EC	1 - 2 gal/100 gal water	0
PSYLLIDS			
azadirachtin (Neemix)	0.25%	2.5 pts/100 gal water 150 - 300 gal/acre	1
methyl parathion	4 EC	1 - 3 pt	15
pyrethrins + piperonyl butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0
rotenone (Rotacide)	EC	1 gal	0
SALT MARSH CATERPILLARS			
<i>Bacillus thuringiensis</i>	See individual brand labels		0
SOUTHERN ARMYWORMS (See also: Armyworms)			
cyfluthrin (Baythroid)	2 EC	2.8 oz	0
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84 oz	5 - caution, see label

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
SOUTHERN ARMYWORMS (cont.)			
diazinon AG500	4 EC	3/4 - 1 pt	1
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
methomyl (Lannate LV)	2.4 EC	1.5 - 3 pt	1
permethrin (Ambush)	2 EC	3.2 - 12.8 oz	up to day of harvest
(Pounce)	3.2 EC	2 - 8 oz	
Note: Permethrin (Ambush, Pounce) only for Florida use where final market is for fresh tomatoes. Do not use on cherry tomatoes or any variety used to produce fruit less than 1" (one inch) in diameter. Permethrin can be applied by air or ground. Use sufficient water to obtain uniform coverage. Do not apply more than 1.2 lbs. active ingredient per acre per season which is equivalent to 76.8 ozs. of Ambush 2 EC or 48 ozs. of Pounce 3.2 EC.			
SOWBUGS			
carbaryl (Sevin)	5 B	20 - 40 lb	0
STINKBUGS			
azinphosmethyl (Guthion)	2S, 2L (EC)	1 ½ - 2 pt	up to day of harvest
(Sniper)	2 E	1 ½ - 2 pt	
	50 PVA	3/4 - 1 lb	
(green stinkbugs)			
carbaryl (Sevin) (suppression)	80S (WP)	1 1/2 - 2 1/2 lb	0
cyfluthrin (Baythroid)	2 EC	1.6 - 2.8 EC	0
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84 oz	5 - caution, see label
endosulfan			2 - field and greenhouse
(Phaser, Thiodan)	3 EC	1 - 1 1/3 qt	1
(Thirethrin)	2.9 L	1 ½ - 2 qt	
pyrethrins + rotenone (Pyrellin)	EC	1 - 2 pts	0
THRIPS			
azinphosmethyl (Guthion)	2S, 2L (EC)	2 - 3 pt	up to day of harvest
(Sniper)	2 E	2 - 3 pt	
	50 PVA	1 - 1 ½ lb	
imidacloprid (Admire)	2.0 EC	16 - 24 oz (soil use)	21 - soil
malathion (Cythion)	5 EC	1 1/2 - 2 pts	1
oil (Sun Spray)	98.8%	1 - 2 gal/100 gal water	1
Note: Sun Spray oil can cause phytotoxic (plant) burns if used during periods of prolonged high temperature and high relative humidity. Do not spray plants under moisture stress. Do not use in combination with or immediately before or after spraying with dimethoate (Cygon) or fungicides such as Captan, Folpet, Dyrene, Karathane, Morestan, sulfur or any product containing sulfur. It is not recommended to be used with Bravo.			
pyrethrins + piperonyl butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0
pyrethrins + rotenone (Pyrellin)	EC	1 - 2 pts	0
soap, insecticidal (M-Pede)	49% EC	1 - 2 gal/100 gal H ₂ O	0
TOMATO FRUITWORMS (CORN EARWORM)			
azadirachtin (Neemix)	0.25%	2.5 pts/100 gal water 150 - 300 gal/acre	1
azinphosmethyl (Guthion)	2S, 2L (EC)	3 - 6 pt	up to day of harvest for 3 pt or less (1 ½ lb or less); 14 for 3+ pt (1 ½ lb +)
(Sniper)	2 E	3 - 6 pt	
	50 PVA	1 ½ - 3 lb	
<i>Bacillus thuringiensis</i>	See individual brand labels		0
carbaryl (Sevin)	80S (WP)	1 1/2 - 2 1/2 lb	0
chlorpyrifos (Lorsban) (except cherry tomatoes)	50 W	2 lb	14
cryolite (Kryocide)	96 WP	15 - 30 lb	wash fruit
cyfluthrin (Baythroid)	2 EC	1.6 - 2.8 oz	0

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
TOMATO FRUITWORMS (CORN EARWORM) cont.			
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84 oz	5 - caution, see label
endosulfan (Phaser, Thiodan)	3 EC	1 1/3 qt	2
(Thirethrin)	2.9 L	2 qt	1
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
fenpropathrin (Danitol)	2.4 EC	10 2/3 oz	3
methamidophos (Monitor)	4 EC	1/2 - 1 1/2 pt	7
methomyl (Lannate LV)	2.4 EC	1.5 - 3 pt	1
permethrin (Ambush)	2 EC	3.2 - 12.8 oz	up to day of
(Pounce)	3.2 EC	2 - 8 oz	harvest
Note: Permethrin (Ambush, Pounce) only for Florida use where final market is for fresh tomatoes. Do not use on cherry tomatoes or any variety used to produce fruit less than 1" (one inch) in diameter. Permethrin can be applied by air or ground. Use sufficient water to obtain uniform coverage. Do not apply more than 1.2 lbs. active ingredient per acre per season which is equivalent to 76.8 ozs. of Ambush 2 EC or 48 ozs. of Pounce 3.2 EC.			
TOMATO PINWORM			
abamectin (Agri-Mek)	0.15 EC	16 oz	7
azinphosmethyl (Guthion)	2S, 2L (EC)	3 - 6 pt	up to day of harvest for 3 pt or
(Sniper)	2 E	3 - 6 pt	less (1 1/2 lb or less); 14 for 3+
	50 PVA	1 1/2 - 3 lb	pt (1 1/2 lb +)
carbaryl (Sevin)	80S (WP)	1 1/2 - 2 1/2 lb	0
chlorpyrifos (Lorsban)	50 W	2 lb	14
(except cherry tomatoes)			
cryolite (Kryocide)	96 WP	15 - 30 lb	wash fruit
cyfluthrin (Baythroid)	2 EC	2.8 oz	0
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84 oz	5 - caution, see label
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
methamidophos (Monitor)	4 EC	1/2 - 1 1/2 pt	7
(fresh fruit only)			
methomyl (Lannate LV)	2.4 EC	1.5 - 3 pts	1
permethrin (Ambush)	2 EC	3.2 - 12.8 oz	up to day of harvest
(Pounce)	3.2 EC	2 - 8 oz	
Note: Permethrin (Ambush, Pounce) only for Florida use where final market is for fresh tomatoes. Do not use on cherry tomatoes or any variety used to produce fruit less than 1" (one inch) in diameter. Permethrin can be applied by air or ground. Use sufficient water to obtain uniform coverage. Do not apply more than 1.2 lbs. active ingredient per acre per season which is equivalent to 76.8 ozs. of Ambush 2 EC or 48 ozs. of Pounce 3.2 EC.			
Pheromones (NoMate TPW Spiral)	The product functions by disrupting mating		See label
(NoMate TPW Fiber)	communications of adult moths. Read label carefully.		
TUBERWORMS			
azinphosmethyl (Guthion)	2S, 2L (EC)	2 1/4 - 3 pt	0
(Sniper)	2 E	2 1/4 - 3 pt	0
	50 PVA	1 1/8 - 1 1/2 lb	0
VEGETABLE WEEVIL			
pyrethrins + rotenone (Pyrellin)	EC	1 1/2 - 2 pts	0
WHITEFLIES			
azadirachtin (Neemix)	0.25%	2.5 pts/100 gal water 150 - 300 gal/acre	1

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
WHITEFLIES (cont)			
azinphosmethyl (Guthion) (Sniper)	2S, 2L (EC) 2 E 50 PVA	1 ½ - 2 pt 1 ½ - 2 pt 3/4 - 1 lb	up to day of harvest
chlorpyrifos (Lorsban) (except cherry tomatoes)	50 W	2 lbs	14
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84 oz	5 - caution, see label
endosulfan (Phaser, Thiodan)	3 EC	1 1/3 qts	2 - field and greenhouse
(Thirethrin)	2.9 L	1 qt/100 gal (use 100-200 gal/A)	1
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
imidacloprid (Provado) (Admire)	1.6 EC 2.0 EC	3.75 oz 16 - 24 oz (soil use)	0 - foliar 21 - soil
malathion (Cythion)	5 EC	1 1/2 - 2 pts	1
methamidophos (Monitor) (apply in tank mix with pyrethroids)	4 EC	1 1/2 - 2 pts	7 - see label
oil (Sun Spray)	98.8%	1 - 2 gal/100 gal water	1
Note: Sun Spray oil can cause phytotoxic (plant) burns if used during periods of prolonged high temperature and high relative humidity. Do not spray plants under moisture stress. Do not use in combination with or immediately before or after spraying with dimethoate (Cygon) or fungicides such as Captan, Folpet, Dyrene, Karathane, Morestan, sulfur or any product containing sulfur. It is not recommended to be used with Bravo.			
permethrin (ambush)	25W	3.2 - 12.8 oz	0-Ambush 7-Monitor Apply as a tank mix with Monitor 4, ground spray only.
pyrethrins + piperonyl butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0
pyrethrins + rotenone (Pyrellin)	EC	1 - 2 pts	0
soap, insecticidal (M-Pede)	49% EC	1 - 2 gal/100 gal H ₂ O	0
WIREWORMS			
diazinon	14 G 4 EC	21 - 28 lb 3 - 4 qt	preplant preplant, broadcast
dichloropropene (Telone)	II, C-17	see labels	---
YELLOW-STRIPED ARMYWORMS (See also: Armyworms)			
azinphosmethyl (Guthion) (Sniper)	2L, 2S (EC) 2 E 50 PVA	3 - 6 pt 3 - 6 pt 1 ½ - 3 lb	up to day of harvest for 3 pts (1 ½ lb); 14 - 3+ pts (1 ½ + lb)
cyhalothrin (Karate, Warrior)	1 EC	2.56 - 3.84 oz	5 - caution, see label
endosulfan (Phaser, Thiodan)	3 EC	1 1/3 qt	2 - field and greenhouse
(Thirethrin)	2.9 L	2 qt	1
esfenvalerate (Asana XL) (Western Yellow Striped)	0.66 EC	5.8 - 9.12 oz	1
fenpropathrin (Danitol)	2.4 EC	10 2/3 oz	3

Chemicals for Foliar Disease Control in Tomatoes
Tom Kucharek

Crop	Chemical	Maximum Rate/Acre/ Application	Crop	Min. Days to Harvest	Pertinent Diseases	Select Remarks
Tomato	**For best possible chemical control of bacterial spot, a copper fungicide must be tank-mixed with a maneb or mancozeb fungicide.					
	Ridomil Gold EC, or Ridomil Gold WSP	2 pts/trtd acre 2 lbs/trtd acre	3 pts/trtd acre 3 lbs/trtd acre		Pythium diseases	See label for use at & after planting.
	Nu-Cop, Kocide 101, Blue Shield, KOP Hydroxide or Champion 77WPs	4 lbs.		2	Bacterial spot	3 lbs. maximum for Nu-Cop
	Blue Shield 3L, Nu-Cop, Kocide LF, Cuproxat, Champion or KOP Hydroxide, 3-lb Copper Flowable FLs	5 1/4 pts.		2	Bacterial spot	
	Kocide 2000 54DF	3 lbs.		2	Bacterial spot	
	Champ FL	2 3/4 pts.		2	Bacterial spot	
	Basicop or Basic Copper 53 WPs	4 lbs.		1	Bacterial spot	
	Oxycop or KOP Oxy-85 WPs	6 lbs.		1	Bacterial spot	
	Microspore C.O.C. 53WP	4 lbs.		2	Bacterial spot	
	Manex 4F	2.4 qts.	16.8 qts.	5	Early & late blight, Gray leaf spot, Bacterial spot ¹	Field & Greenhouse use
	Dithane or Penncoze 75 DFs	3 lbs.	22.4		Same as Manex	
	Nu-Cop, Kocide or Blueshield DFs	4 lbs.		2	Bacterial spot	
	Maneb 80 WP	3 lbs	21 lbs.	5	Same as Manex 4F	Field & Greenhouse use
	Dithane F 45 FL	2.4 pts.	16.8 qts.	5	Same as Manex 4F	
	Dithane M-45, Penncoze 80WP, Manzate 200 DF or Dithane WSP	3 lbs.	21 lbs.	5	Same as Manex 4F	
	Bravo 720, Teranil 6L ⁴ , Echo 720, Ensign 720, Amigo 720, Chloronil 720 or Supanil 720	3 pts.		2	Early & late blight, Gray leaf spot, Target spot	Use higher rates at fruit set & lower rates before fruit set.
	Maneb 75DF	3 lbs.	22.4 lbs.	5	Same as Manex 4F	
	Terranil 90DF or Echo 90DF	2.3 lbs.		2	Early & late blight, Gray leaf spot, Target spot	Use higher rates at fruit set & lower rates before fruit set.

Crop	Chemical	Maximum Rate/Acre/ Application	Crop	Min. Days to Harvest	Pertinent Diseases	Select Remarks
Tomato (cont'd)	Bravo 500, Echo 500, Agronil, or GK Chloro Gold	4 pts.		2	Early & late blight, Gray leaf spot, Target spot	Use higher rates at fruit set & lower rates before fruit set.
	Ridomil Bravo 81W	3 lbs.		14	Early & late blight, Gray leaf spot, Target spot	Limit is 4 appl/crop
	Ridomil MZ72WP ²	2.5 lbs.	7.5 lbs.	5	Late blight	Limit is 3 appl/crop
	Benlate 50WP	1 lb.		1	Leaf mold, Botrytis, Sclerotinia	
	Bravo CM	6 lbs.		5	Bacterial spot, Bacterial speck, Target spot, Early & Late blights, Gray leaf spot	
	JMS Stylet Oil	3 qts.		N.T.	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	2.5 lbs. ³		14	Late blight	Limit is 3 appl/crop
	Sulfur			1	Powdery mildew	Not yet found in field- produced tomatoes in Florida.
	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.		2	Early & Late blights, Gray leafspot, Target spot, Botrytis, Rhizoctonia fruit rot	Use higher rates at fruit set.

Crop	Chemical	Maximum Rate/Acre/ Application Crop	Min. Days to Harvest	Pertinent Diseases	Select Remarks
Tomatoes (cont'd)	Botran 75W	1 lb. 4 lbs.	10	Botrytis	Greenhouse tomato only. Limit is 4 applications. Seedlings or newly set transplants may be injured.
	Exotherm Termil	1 can/1000 sq.ft.	2	Botrytis, Leaf mold, Late & Early blights, Gray leafspot	Greenhouse use only. Allow can to remain overnight & then ventilate. Do not use when greenhouse temperature is above 75F
	Mankocide 61.1 DF	5.3 lbs. 112 lbs.	5	Bacterial spot Bacterial speck Late blight Early blight Gray leaf spot	
	Basic Copper Sulfate 98WP	4 lbs.		Bacterial spot	Reenter when sprays are dried
	KOP 300 FL	1/2 gal.	12 hrs.	Bacterial spot	
	Copper FF	1/2 gal.	Dried spray	Bacterial spot	

¹When tank mixed with a copper fungicide

²Do not exceed limits of mancozeb active ingredient as indicated for Dithane, Penncozeb, Manex or Manzate 200.

³Maximum crop is 3.0 lbs. a.i. of metalaxyl from Ridomil/copper, Ridomil MZ 58 & Ridomil Bravo 81W.

⁴Do not tank mix with Copper Count N.

NEMATOCIDES REGISTERED FOR USE ON FLORIDA TOMATO

Row Application (6' row spacing - 36" bed) ⁴					
Product	Broadcast (Rate)	Recommended Chisel Spacing	Chisels (per Row)	Rate/Acre	Rate/1000 Ft/Chisel
FUMIGANT NEMATOCIDES					
Methyl Bromide ³					
98-2	240-400 lb	12"	3	120-200 lbs	5.5 - 9.2 lb
80-20	225-350 lb	12"	3	112-175 lbs	5.1 - 8.0 lb
75-25	240-375 lb	12"	3	120-187 lbs	5.5-8.6 lb
70-30	300-350 lb	12"	3	150-175 lbs	6.9 - 8.0 lb
67-33	225-375 lb	12"	3	112-187 lbs	5.1 - 8.6 lb
57-43	350-375 lb	12"	3	175-187 lbs	3.3 - 8.6 lb
50-50	340-400 lb	12"	3	175-250 lbs	3.3 - 9.2 lb
Chloropicrin ¹	300-500 lb	12"	3	150-250 lbs	6.9 - 11.5 lb
Telone II ²	9-18 gal	12"	3	4.5-9.0 gal	26 - 53 fl oz
Telone C17	10.8-17.1 gal	12"	3	5.4-8.5 gal	31.8-50.2 fl oz
Vapam	50-75 gal	5"	6	25 - 37.5 gal	56 - 111 fl oz
NON-FUMIGANT NEMATOCIDES					
Vydate L - treat soil before or at planting with any other appropriate nematocide or a Vydate transplant water drench followed by Vydate foliar sprays at 7-14 day intervals through the season; do not apply within 7 days of harvest; refer to directions in appropriate "state labels", which must be in the hand of the user when applying pesticides under state registrations.					

¹ If treated area is tarped, dosage may be reduced by 33%.

² The manufacturer of Telone II and Telone C-17 has restricted use only on soils that have a relatively shallow hard pan or soil layer restrictive to downward water movement (such as a spodic horizon) within six feet of the ground surface and are capable of supporting seepage irrigation regardless of irrigation method employed. Consult manufacturers label for other use restrictions which might apply.

³ Use of methyl bromide for agricultural soil fumigation is scheduled for phaseout Jan 1, 2001.

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 8, 1997 as a reference for the commercial Florida tomato grower. The mentioning of a chemical or proprietary product in this publication does not constitute a written recommendation or an endorsement for its use by the University of Florida, Institute of Food and Agricultural Sciences, and does not imply its approval to the exclusion of other products that may be suitable. Products mentioned in this publication are subject to changing Environmental Protection Agency (EPA) rules, regulations, and restrictions. Additional products may become available or approved for use.

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



Weed Control in Tomato¹

William M. Stall and James P. Gilreath²

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

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

equipment parking areas, well and pump areas, fence rows and associated perimeter areas, and ditches.

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

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

1. This document is Fact Sheet HS-200, one of a series of the Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Publication date: July, 1997. Please visit the FAIRS Website at <http://hammock.ifas.ufl.edu>.
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The use of trade names in this publication is solely for the purpose of providing specific information. It is not a guarantee or warranty of the products named, and does not signify that they are approved to the exclusion of others of suitable composition.

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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 than others and herbicide labels may specify a minimum active ingredient rate for the adjuvant in the spray mix. Before selecting an adjuvant, refer to the herbicide label to determine the adjuvant specifications.

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

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

Table 1. Chemical weed controls: tomatoes.

Herbicide	Labelled Crops	Time of Application to Crop	Rate (lbs. AI./Acre)	
			Mineral	Muck
DCPA (Dacthal W-75)	Established Tomatoes	Posttransplanting after crop establishment (non-mulched)	6.0 - 8.0	---
		Mulched row middles after crop establishment	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 (Diquat H/A)	Tomato Vine Burndown	After final harvest	0.375	---
Remarks: Special Local Needs (24c) label for use for burndown of tomato vines after final harvest. Applications of 1.5 pts. material per acre in 60 to 120 gals. of water is labelled. Add 16 to 32 ozs. of Valent X-77 spreader per 100 gals. of spray mix. Thorough coverage of vines is required to insure maximum burndown.				
Diquat dibromide (Diquat)	Tomato	Pretransplant Postemergence directed-shielded in row middles	0.5	---
Remarks: Diquat can be applied as a post-directed application to row middles either prior to transplanting or as a post-directed hooded spray application to row middles when transplants are well established. Apply 1 qt of Diquat in 20-50 gallons of water per treated acre when weeds are 2-4 inches in height. Do not exceed 25 psi spray pressure. A maximum of 2 applications can be made during the growing season. Add 2 pts non-ionic surfactant per 100 gals spray mix. Diquat will be inactivated if muddy or dirty water is used in spray mix. A 30 day PHI is in effect. Label is a special local needs label for Florida only.				
MCDS (Enquik)	Tomatoes	Postemergence directed/shielded in row middle	5 - 8 gals.	---
Remarks: Controls many emerged broadleaf weeds. Weak on grasses. Apply 5 to 8 gallons of Enquik in 20 to 50 gallons of total spray volume per treated acre. A non-ionic surfactant should be added at 1 to 2 pints per 100 gallons. Enquik is severely corrosive to nylon. Non-nylon plastic and 316-L stainless steel are recommended for application equipment. Read the precautionary statements before use. Follow all restrictions on the label.				
Metribuzin (Sencor DF) (Lexone DF)	Tomatoes	Postemergence Posttransplanting after establishment	0.25 - 0.5	---
Remarks: Controls small emerged weeds after transplants are established direct-seeded plants reach 5 to 6 true leaf stage. Apply in single or multiple applications with a minimum of 14 days between treatments and a maximum of 1.0 lb ai/acre within a crop season. Avoid applications for 3 days following cool, wet or cloudy weather to reduce possible crop injury.				
Metribuzin (Sencor DF) (Lexone DF)	Tomatoes	Directed spray in row middles	0.25 - 1.0	---
Remarks: Apply in single or multiple applications with a minimum of 14 days between treatments and maximum of 1.0 lb ai/acre within crop season. Avoid applications for 3 days following cool, wet or cloudy weather to reduce possible crop injury. Label states control of many annual grasses and broadleaf weeds including, lambsquarter, fall panicum, <i>amaranthus</i> sp., Florida pusley, common ragweed, sicklepod, and spotted spurge.				
Napropamid (Devrinol 50WP) (Devrinol 50DF) (Devrinol 2E)	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 2E) (Devrinol 50WP)	Tomatoes	Surface treatment	2.0	---

Table 1. Chemical weed controls: tomatoes.

Herbicide	Labelled Crops	Time of Application to Crop	Rate (lbs. AI./Acre)	
			Mineral	Muck
Remarks: Controls germinating annuals. Apply to bed tops after bedding but before plastic application. Rainfall or overhead-irrigate sufficient to wet soil 1 inch in depth should follow treatment within 24 hours. May be applied to row middles between mulched beds. A special Local Needs 24(c) Label for Florida. Label states control of weeds including Texas panicum, pigweed, purslane, Florida pusley, and signalgrass.				
Paraquat (Gramoxone Extra)	Tomatoes	Premergence; Pretransplant	0.62 - 0.94	---
Remarks: Controls emerged weeds. Use a non-ionic spreader and thoroughly wet weed foliage.				
Paraquat (Gramoxone Extra)	Tomatoes	Post directed spray in row middle	0.47	---
Remarks: Controls emerged weeds. Direct spray over emerged weeds 1 to 6 inches tall in row middles between mulched beds. Use a non-ionic spreader. Use low pressure and shields to control drift. Do not apply more than 3 times per season.				
Sethoxydim (Poast)	Tomatoes	Postemergence	0.188 - 0.28	---
Remarks: Controls actively growing grass weeds. A total of 4½ pts. product per acre may be applied in one season. Do not apply within 20 days of harvest. Apply in 5 to 20 gallons of water adding 2 pts. of oil concentrate per acre. Unsatisfactory results may occur if applied to grasses under stress. Use 0.188 lb ai (1 pt.) to seedling grasses and up to 0.28 lb ai (1½ pts.) to perennial grasses emerging from rhizomes etc. Consult label for grass species and growth stage for best control.				
Trifluralin (Treflan EC) (Treflan MTF) (Treflan 5) (Treflan TR-10) (Tri-4) (Trilin)	Tomatoes (except Dade County)	Pretransplant incorporated	0.75 - 1.0	---
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 EC) (Treflan MTF) (Treflan 5) (Treflan TR-10) (Tri-4) (Trilin)	Direct-Seeded tomatoes (except Dade County)	Post directed	0.75 - 1.0	---
Remarks: For direct-seeded tomatoes, apply at blocking or thinning as a directed spray to the soil between the rows and incorporate.				

NEMATOCIDES REGISTERED FOR USE ON FLORIDA TOMATO

Row Application (6' row spacing - 36" bed) ⁴					
Product	Broadcast (Rate)	Recommended Chisel Spacing	Chisels (per Row)	Rate/Acre	Rate/1000 Ft/Chisel
FUMIGANT NEMATOCIDES					
Methyl Bromide ³					
98-2	240-400 lb	12"	3	120-200 lbs	5.5 - 9.2 lb
80-20	225-350 lb	12"	3	112-175 lbs	5.1 - 8.0 lb
75-25	240-375 lb	12"	3	120-187 lbs	5.5-8.6 lb
70-30	300-350 lb	12"	3	150-175 lbs	6.9 - 8.0 lb
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57-43	350-375 lb	12"	3	175-187 lbs	3.3 - 8.6 lb
50-50	340-400 lb	12"	3	175-250 lbs	3.3 - 9.2 lb
Chloropicrin ¹	300-500 lb	12"	3	150-250 lbs	6.9 - 11.5 lb
Telone II ²	9-18 gal	12"	3	4.5-9.0 gal	26 - 53 fl oz
Telone C17	10.8-17.1 gal	12"	3	5.4-8.5 gal	31.8-50.2 fl oz
Vapam	50-75 gal	5"	6	25 - 37.5 gal	56 - 111 fl oz
NON-FUMIGANT NEMATOCIDES					
Vydate L - treat soil before or at planting with any other appropriate nematicide or a Vydate transplant water drench followed by Vydate foliar sprays at 7-14 day intervals through the season; do not apply within 7 days of harvest; refer to directions in appropriate "state labels", which must be in the hand of the user when applying pesticides under state registrations.					

¹. If treated area is tarped, dosage may be reduced by 33%.

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

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Sanibel	Mid	6-8 oz.	Deep oblate	Light green	Determinate	Large	Asc, F-1, F-2, N, St, V-1	Extra firm, jointless, productive

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