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Ritz Carlton Hotel • Naples,Florida • September 9, 1998

9:00 Opening Remarks – Edward Hanlon, SWFREC, Immokalee

9:10 Free Trade Agreement of the Americas: current status and future opportunities for Florida tomato growers – John Van Sickle, IFAS, Food & Resource Dept., Gainesville, **Page 2**

9:30 Update on tomato yellow leaf curl virus – Jane Polston, Virologist, IFAS, GCREC, Bradenton, **Page 5**

9:50 *Phythophthora capsici*: New problems from an old enemy – Robert McGovern, Pathologist, IFAS, GCREC, Bradenton, **Page 9**

10:10 Update on the use of bacteriophages for control of bacterial spot – Jeff Jones, Pathologist, IFAS, GCREC, Bradenton, **Page 17**

10:30 Bacterial spec: The other bacterial disease – Ken Pernezny, Pathologist, IFAS, EREC, Belle Glade, **Page 20**

10:50 The scientific, economic, and political reality of the phaseout of methyl bromide – Joe Noling, Nematologist, IFAS, CREC, Lake Alfred and Jim Gilreath, Weed Scientist, IFAS, GCREC, Bradenton, **Page 23**

11:10 Effect of commercial bacterial and fungal microorganisms to colonize tomato roots andcontrol *Fusarium* crown and root rot under fumigated and non-fumigated conditions – Lawrence Datnoff, Pathologist and Ken Pernezny, Pathologist, IFAS, EREC, Bradenton, **Page 26**

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1:00 What's new in the industry – Industry Representatives

1:30 Agricultural labor in southwest Florida – Fritz Roka, Economist, IFAS, SWFREC **Page 34**

1:50 The food quality protection act and the Florida grower – Dan Botts, Environmental & Pest Management Division, FFVA (paper not available)

2:10 Florida automated weather network: A tool for growers – John Jackson, Ext. Agent III, IFAS, Lake County Extension Service, **Page 38**

2:30 Tomato transplant cell size effects earliness and yield – Charlie Vavrina, Horticulturist, IFAS, SWFREC, **Page 42**

2:50 Prospective releases from the University of Florida tomato breeding program – Jay Scott, Breeder, IFAS, GCREC, **Page 45**

3:10 Update on the Florida premium-quality tomato program – Steve Sargent, Postharvest Specialist, Hort. Science Dept., IFAS, Gainesville, **Page 49**

3:30 Tomato fertilization recommendations-evaluation and review – George Hochmuth, Extension Specialist, Hort. Science Dept., IFAS, Gainesville, **Page 55**

ADJOURN

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THE FREE TRADE AREA OF THE AMERICAS: CURRENT STATUS AND FUTURE OPPORTUNITIES FOR FLORIDA TOMATO GROWERS

John VanSickle

Food & Resource Economics Department, IFAS

University of Florida

P.O. Box 110240

Gainesville, Florida 32611-0240

SUMMARY

The Free Trade Area of the Americas (FTAA) is the next hurdle in trade negotiations that the administration is seeking. The IV Business Forum of the Americas held in San Jose, Costa Rica provided a forum for business leaders, public officials and other interested parties to discuss issues of concern in developing a FTAA. The Florida delegation attending those meetings was the third largest delegation behind the Brazilian and U.S. delegations. The Florida delegation was successful in having Miami named as home to the Secretariat of the FTAA for the next three years, making it the administrative headquarters for FTAA. In general, the Florida delegation was supportive of FTAA, recognizing the benefits Florida will derive as the center for business and trade in the western hemisphere when FTAA is finalized. The Florida tomato industry needs to be involved in negotiations for FTAA and develop an agenda that will allow it to benefit from the process.

While many in the agricultural community may point to the recent agenda toward free trade within a global economy as something new, the truth of the matter is that free trade has been an issue of debate for centuries. Our country was founded on the principles of free trade and economic security. Protectionism was practiced through the use of tariffs, which served as the largest source of revenue for our government in its early period. After the Civil War and up until the Great Depression, the United States operated in a more open international economy with little weight given to domestic producers and workers. The Cold War period marked a return to more protectionist policies with trade being used to promote foreign policy objectives, particularly stability and prosperity in Japan and Western Europe and economic opportunities for developing nations (Eckes, 1995).

The post-Cold War period has seen a return to promoting free trade and economic efficiency. Economic efficiency is achieved through free trade by allowing countries to capitalize on the natural resources they own and to specialize and gain from efficiencies created in the global market.

The General Agreement on Tariffs and Trade (GATT) is the international agreement under which many of the rules for international trade are established. GATT was created in 1948 and has been through 8 rounds of negotiation with 122 nations signing onto the agreement in May 1994. GATT 1994 created the World Trade Organization and the 'rules of the game' to accompany lower tariffs and market access in the global community. It serves as the larger body to which regional trade agreements must conform. There were 98 regional agreements notified under GATT 1994 about GATT dispute settlement provisions. There are currently 10 regional agreements in place in the Americas and 15 bilateral agreements. The North American Free Trade Agreement (NAFTA) has had the largest impact on Florida agriculture. NAFTA was created to lower barriers to trade between the U.S., Mexico and Canada. Sensitive industries like fresh tomatoes were given special considerations with extended phase out periods for the removal of tariffs, but those considerations were not enough to stem the increase in fresh tomato imports from Mexico. The devaluation of the peso in the first quarter of 1995 resulted in large increases in imports from Mexico. The Florida industry followed that by filing petitions with the U.S. International Trade Commission and U.S. Department of Commerce seeking relief from the increased imports. The industry was able to eventually receive relief in the form of the suspension agreement that Mexican growers signed, agreeing not to dump fresh market tomatoes on U.S. markets and also to not sell fresh market tomatoes for less than the floor price of 20.68 cents per pound.

The experiences following NAFTA have led to several reservations within the agricultural community for expanding NAFTA to other countries. NAFTA has been looked to as a model in discussions about the Free Trade Area of the Americas, partly because it is one of the few agreements that is not restricted in members that could be added to the agreement. NAFTA has no geographic boundaries within the agreement that restricts other nations from being added. The ascension of Chile to NAFTA has been proposed and discussions have been held. That discussion, however, has taken a back seat to negotiations of the Free Trade Area of the Americas (FTAA).

The FTAA is an important policy issue that faces the Florida agricultural industry. The IV Business Forum of the Americas was held in San Jose, Costa Rica from March 16 through March 20, 1998. Those meetings provided a forum for business, government and other interested parties to develop an agenda to move discussions of FTAA forward. Specific objectives of the Forum were: 1) laying out the objectives of the negotiations as they unfold; 2) developing a set of principles which provide the fundamental rules under which negotiations are to take place; 3) ranking the major issues which must be resolved according to their relevance to the discussions and 4) identifying an agenda for progress by the year 2000 that will support trade liberalization in the region.

The IV Business Forum was organized around 10 major issues. These issues ranged from market access, rules of origin and customs procedures to private sector involvement in the negotiations. Position papers were submitted to organizers of the IV Business Forum prior to the meetings in order to be included in the agenda for discussions held at the meetings. The Summit of the Americas Center at Florida International University submitted a paper (Summit of the Americas Center, 1998) that was organized in partnership with Enterprise Florida, Inc., and Florida Partnership of the Americas, Inc. Enterprise Florida is a not-for-profit government/business partnership established by the Governor of Florida to guide the development of Florida's economy. Florida Partnership of the Americas is a not-for-profit corporation dedicated to furthering hemispheric economic integration.

The paper submitted by the Summit of the Americas Center was forwarded as **Florida's** position paper on the FTAA. Its proposed purpose was to identify and expand awareness of the commercial and business implications for Florida of the movement toward creation of a FTAA and to deepen the understanding of key issues in FTAA that will affect Florida's business and public affairs communities. The paper endorsed the granting of fast-track authority to the U.S. administration in order to accelerate the FTAA process. Fast-track gives authority to the U.S. administration to negotiate trade agreements, with Congress having the opportunity only to approve or vote down the agreement. Congress may not amend trade agreements negotiated with fast-track authority.

The paper submitted by the Summit of the Americas Center focused on general issues in the key areas around which the IV Business Forum was organized. Even though Florida agriculture is an important economic sector in the Florida economy, little attention was given to the issues Florida agriculture should be concerned about in negotiating a FTAA. The Center did post a paper on their Internet site (VanSickle, 1998b) focussing on issues important to Florida agriculture.

IV BUSINESS FORUM EXPERIENCES

Enterprise Florida and the Florida Partnership of the Americas coordinated the participation of Florida delegates (Team Florida) that attended the IV Business Forum meetings. Team Florida was the largest delegation outside of Brazil and the U.S. delegation. Team Florida composed roughly 40% of the U.S. presence in Costa Rica.

Of the 85 participants from Florida who pre-registered for the IV Business Forum meetings, only 6 held formal affiliations with the agricultural community. The remaining participants represented various sectors of the Florida economy, ranging from the public sector (headed by Governor Lawton Chiles) to the tourist, banking and service sectors.

One of the key initiatives that the Florida delegation pursued was the naming of Miami as the Secretariat of the FTAA. The Secretariat will serve as the formal headquarters of the FTAA, i.e., the administrative home of the FTAA. Team Florida organized the Florida delegation with a message that Miami is the natural location for placing the Secretariat. Miami is a largely bilingual community which serves as a primary business and tourist destination for many individuals throughout the hemisphere. Team Florida publicized Florida's role as the "Business Center of the Americas" in Latin America.

Trade ministers from the participating countries met following the IV Business Forum. The purpose of their meeting was to promote the development of the FTAA process and to select a home for the Secretariat. In addition to Miami, Rio de Janeiro and Mexico City made strong bids to be named home to the Secretariat. The Trade Ministers decided to name Miami as a temporary home for the Secretariat, for a period of 3 years and to then revisit the issue.

Participants from other countries brought up the issue of the administration's inability to obtain fast-track authority as a deterrent to formal negotiations of FTAA. Most participants from the U.S. delegation agreed that fast-track authority is significant for achieving an agreement that could be ratified in the U.S., but pointed to the lack of fast-track authority in the most recent GATT negotiations until the end of the process approached as evidence that it should not slow negotiations for FTAA. Members of the U.S. administration that attended the conference expressed confidence that fast-track authority would be achieved. Several members of the Florida delegation in Costa Rica expressed confidence that Florida's congressional delegation would support fast-track authority.

Most of the Florida delegation attending the IV Business Forum was supportive of forwarding negotiations for a FTAA. As you look to economic activity within the western hemisphere, Florida stands to benefit in providing services needed to facilitate the increase in hemispheric trade expected following implementation of FTAA. Florida agriculture, however, has reason to be concerned about how it will be affected by FTAA. The subtropical environment in Florida is much like that of several countries within the FTAA that will compete in a hemispheric market. Many of Florida's products, especially horticulture, are directly competitive with products grown in other FTAA countries. Florida agriculture should be a participant in negotiations of FTAA to assure that a fair agreement is reached.

A package of initiatives could be developed that would benefit Florida agriculture and allow it to favorably compete in a FTAA. The banning of methyl bromide use in the U.S. scheduled for January 1, 2001 will have devastating consequences for the Florida tomato industry unless an economically viable alternative is developed over the next two years. Development of alternatives before that date that will allow our producers to compete appears to have slim chances at best. Most recent estimates of the impact that next best alternatives will have on Florida tomato growers are in the 10 to 20 percent range for reduction in yield. An impact of that magnitude will move a significant share of the Florida tomato industry to Mexico where pest pressures are not as intense and where there is more land to allow crop rotation practices to minimize pest pressures. The Montreal Protocol is the international agreement between member nations to control the production and use of ozone depleting substances. The international community faces a ban on methyl bromide use in 2005 in developed countries and 2015 in developing countries under rules of the Montreal Protocol. An increase in research expenditures in Florida to find better alternatives and an extension of the phase out date to 2005 are issues the Florida tomato industry should put on the negotiating table when FTAA fast-track authority is introduced again in Congress.

Other issues the Florida industry has identified as important (VanSickle, 1998a) include country of origin labeling, a child labor law to restrict imports from countries employing child labor in producing items sold in the U.S., reform of the Perishable Agricultural Commodity Act (PACA), broadening of the suspension agreement to other commodities, and increases in research and development to keep the Florida industry competitive.

CONCLUSIONS

Florida agriculture must prepare itself to be included as the FTAA negotiations move forward. The long sustained growth in economic activity within the U.S. has been credited by many to the growth in international trade throughout the world. The North American Free Trade Agreement (NAFTA) passed because of the benefits it was to provide our society. Few analysts foresaw the problems that surfaced in the winter produce industry. Florida was a lonely force in the landscape of doubters about the impact NAFTA would have on our producers. Those fears were realized when Mexico increased exports of fresh market tomatoes 53.7% in 1995. They have continued to ship large volumes of fresh market tomatoes to the U.S., exceeding the Tariff Rate Quotas included in NAFTA as safeguard measures for our producers.

Florida agriculture may become an even more lonely voice in expressing concerns about FTAA. The Florida economy will benefit from FTAA if it becomes the center of economic activity for the western hemisphere as many believe it will. That point alone makes participation in the negotiation process even more important for Florida fresh tomato growers. It also makes it important to develop as much information as possible on potential impacts FTAA may have on different commodity groups.

The FTAA can be of benefit to all of the countries in the FTAA. Agriculture is important in the process of developing the FTAA and should be given a pivotal role in its development. There are special concerns that should be given to agriculture in both the large and smaller economies of the FTAA. The private sector deserves a voice in this process as it stands to be either the winner or loser, depending on the commodity and country from which it originates.

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TOMATO YELLOW LEAF CURL VIRUS: REVIEW OF THE FIRST YEAR AND EXPECTATIONS FOR THE FUTURE

Polston, J. E.[1], McGovern, R. J.[1], and Brown, L. G.[2]

[1] University of Florida, Gulf Coast Research and Education Center, 5007 60th St. E., Bradenton, FL 34203, and [2] Florida Department of Agriculture and Consumer Services, Division of Plant Industry, 1911 S.W. 34th St., Gainesville, FL 32608.

SUMMARY

In July 1997 the first symptoms characteristic of tomato yellow leaf curl virus (TYLCV) were observed nearly simultaneously on a tomato plant from a field in Collier Co. and several tomato plants from a retail garden center in Sarasota Co. Three different techniques were used to identify the virus, and later, sequencing showed it to be nearly identical to that of TYLCV-IL found in Israel and the Dominican Republic. It is not known how TYLCV-IL entered Florida, but it is likely that it entered the U.S. in Dade Co. in late 1996 or early 1997, where it infected tomato plants in production for retail sale in at least two Dade Co. greenhouses, and was rapidly distributed via retail garden centers around the state. Infected plants were purchased by homeowners and in some cases the virus appeared to readily move from home gardens to nearby commercial nurseries and production fields. By February, TYLCV-IL had been detected in plants from all the southern tomato-producing regions. Many tomato growers around the state responded to the presence of TYLCV-IL by using management practices which helped to minimize its incidence during the 1997-98 season in most parts of Florida. Concern from several sources prompted the development of regulatory procedures to minimize the possible movement of this virus within and out of Florida and maintain confidence in the quality of Florida-produced transplants. For the future, TYLCV-IL is likely to remain of economic concern not only for tomato growers, but also for commercial and retail transplant producers of tomatoes and other crops. New cost-effective approaches that are appropriate for the various production regions of Florida need to be developed.

BACKGROUND

Tomato yellow leaf curl virus-Israel (TYLCV-IL) (family *Geminiviridae*, genus *Begomovirus*) is a whitefly-transmitted virus first described from infected tomato plants (*Lycopersicon esculentum* Mill.) in Israel almost 40 years ago (5). This virus causes economically significant losses in tomato and many years have been devoted to developing successful strategies for its management. TYLCV-IL symptoms appear several weeks after infection and include severe stunting, marked reduction in leaf size, upward curling and chlorosis of leaf margins, mottling, flower abscission, and significant yield reduction. This virus has a broad host range including both crop and weed species (5, 6, 10). TYLCV-IL is readily transmitted in a persistent manner by *Bemisia* tabaci Biotype B Genn. (a.k.a. *B. argentifolii* Bellows and Perring).

In the early 1990's, TYLCV-IL appeared in the eastern Caribbean in Cuba, the Dominican Republic and Jamaica (4, 9, 11, 12, 16). Means of introduction into Cuba and Jamaica have not been established, but in the Dominican Republic, TYLCV-IL is believed to have been introduced on infected but probably asymptomatic tomato transplants. TYLCV-IL can have a catastrophic impact on tomato production and is often associated with high levels of crop losses both in the eastern Mediterranean and the Western Hemisphere (14). Though no formal crop loss assessment studies have been conducted, an informal survey of growers in the Dominican Republic reported yield losses of up to 95% in the 1993-1994 production season (1). Management of TYLCV-IL can be difficult, often requiring significant changes in production, control strategies and yield expectations.

IDENTIFICATION OF TYLCV-IL IN FLORIDA

In July 1997, symptoms characteristic of TYLCV-IL were first seen on a tomato plant from a field in Collier County. Simultaneously, four tomato plants which had symptoms typical of TYLCV-IL were found at retail garden centers in Sarasota and Charlotte counties. Three approaches were taken in the laboratory to identify which virus was causing the symptoms; polymerase chain reaction (PCR), restriction analysis, and hybridization. All three tests indicated that TYLCV-IL was present. Later, a PCR-amplified 1300 bp fragment from one of the symptomatic plants was cloned and sequenced. This sequence was 98% identical to the TYLCV-IL sequence reported from Israel and 99% identical to an infectious clone of TYLCV-IL obtained from the Dominican Republic (13).

MOVEMENT AND DISTRIBUTION OF TYLCV-IL IN FLORIDA

In the weeks following initial detection, TYLCV-IL was detected in tomato plants from additional locations throughout Florida (Fig. 1). Though a survey of retail outlets was never made, the virus was detected in tomato plants collected from retail outlets and home gardeners who had purchased plants from retail stores in four counties: Alachua, Charlotte, Sarasota, and St. Lucie. In all but one location (Alachua Co.) these infected plants could be traced to production facilities located in Dade Co.

A visit to Dade Co. in July 1997 revealed that symptomatic plants were present in two retail tomato transplant production sites. One of these growers had seen these symptoms in tomatoes as early as March 1997, but he did not know their cause. On the same visit, TYLCV-IL infected plants were detected in an abandoned experimental tomato field in Dade Co. Other commercial tomato fields had been disced and could not be inspected. However, no characteristic symptoms of TYLCV-IL had been reported by growers or IPM scouts earlier during the spring 1997 production season.

It is likely that TYLCV entered Dade Co. sometime between the fall and spring of the 1996-97 production season. As temperatures increased, whiteflies and probably the incidence of plants infected with TYLCV-IL increased in abandoned tomato fields in February and March. It is common in Dade Co. to abandon tomato fields after harvesting and to disk under crop residue several weeks to months later. TYLCV-IL may have spread from these abandoned fields to the tomato plants in nearby greenhouses which were in production for distribution to garden centers. These tomato plants were shipped to garden centers throughout Florida until July 1997 when TYLCV-IL was detected and a quarantine issued. Two similar retail tomato production sites in Collier Co. were examined during the same time, and TYLCV-IL was not detected, though ToMoV was found at low incidence.

It is difficult to determine how TYLCV-IL entered Florida because there are several possible means of entry. Dade Co. is the southernmost county in Florida and includes the city of Miami, a major port of entry for people, plants and produce. In addition, Dade Co. is an agriculturally intense production region with ornamental plant nurseries, tropical fruit groves, and vegetable fields in close proximity. It is likely that the virus entered the U.S. through either legal or illegal means in plant material (fruit tree, vegetable or ornamental) that was infected with TYLCV-IL or infested with whiteflies carrying TYLCV-IL. The virus then quickly moved from the original source to local plants via whiteflies.

From at least March until July 1997 tomato plants infected with TYLCV-IL were distributed throughout the state via the retail trade. There is some circumstantial evidence that suggests that TYLCV-IL was able to spread at low rates from infected tomato plants in backyards and patio gardens to nearby tomato fields and greenhouses with tomato transplants for commercial production. By October 1997 TYLCV-IL had been detected in commercial tomato fields in the following counties: Broward, Collier, Dade, Hillsborough, Manatee, St. Lucie, and Palm Beach, and by February 1998 from Lee and Marion Co. TYLCV-IL-infected plants appeared in the first half of the growing season at low incidence (less than 0.1%) in all commercial tomato fields in the fall of 1997, except Dade and Palm Beach Counties. Little to no spread of TYLCV-IL within these fields was observed, due primarily to the intervention of growers and IPM scouts. Many growers applie d imidacloprid (Admire) for whitefly control at transplanting and rogued suspicious-looking plants from fields. Transplants for these fields were produced in West Central (Hillsborough, Manatee, Sarasota) and Southwest Florida (Collier, Lee) counties. In several of these counties TYLCV-IL had already been found in retail tomato plants by early fall. Very little TYLCV-IL was observed in the spring months of 1998 in these same counties.

The highest rates of infection in 1997-98 were recorded in Dade and Palm Beach counties. One field in Palm Beach Co. planted in the fall of 1997 was observed to have an incidence of 10% by the end of the season. In Dade Co. in September, TYLCV-IL was observed at 4 weeks after transplant in about 3% of the plants in one field where imidacloprid application had been delayed until several weeks after transplanting. Incidences of TYLCV-IL in Dade Co. were generally low from September through January but began to rise in February 1998 as whitefly populations increased. Incidences of infected plants were highly variable among fields, with incidences of less than 1% to 100% observed by the end of the production season in April 1998.

The situation in Dade Co. is different from the rest of the tomato-producing areas in Florida because TYLCV-IL appears to have established there. It is likely that the virus has at least one alternate host species that allows it to survive through the summer when tomatoes are not present. This is the reason that TYLCV-IL appeared so quickly in September in field tomatoes and by the rapid resurgence of TYLCV-IL in February when whitefly populations began to rise. The establishment of TYLCV-IL in Dade Co. is a concern for both tomato growers and retail plant producers. Tomato growers will have to use management practices that reduce the incidence of TYLCV-IL. The proximity of ornamental and retail vegetable transplant production facilities to commercial fields of tomatoes increases the difficulty of TYLCV-IL exclusion from transplants and ornamentals. New regulations for certification have been imposed in response to the presence of TYLCV-IL. Commercial tomato transplant producers, though not located in Dade Co., have also been affected by these regulations.

RESPONSES TO TYLCV-IL

Initial recommendations for growers and transplant producers were designed to 1) limit the spread of TYLCV-IL in Florida and 2) to limit the spread to other locations in the U.S. Immediately after TYLCV-IL was identified in Florida, an inspection of Dade Co. transplant production facilities was conducted. Symptoms of TYLCV-IL were observed and infection was later confirmed in two production facilities which produced tomato transplants for retail outlets. A quarantine on shipments of tomato plants out of Dade Co. was immediately issued by the Florida Department of Agriculture and Consumer Services, Division of Plant Industry (FDACS/DPI). This quarantine was maintained based on subsequent findings of TYLCV-IL infected plants, and lasted until mid-September 1997. In addition, consumers were reached through county extension personnel and an appeal was made through local television news programs and newspapers instructing homeowners in TYLCV-IL recognition and proper disposal of infected plants. Commercial tomato transplant producers, tomato growers, extension personnel, state and university officials and members of the vegetable industry were informed of the presence of TYLCV-IL through five meetings held around the state which were completed approximately one month after the initial discovery of the virus. Transplant producers were encouraged to apply imidacloprid to all tomato transplants in production at that time. Growers were encouraged to apply imidacloprid at planting to all tomato plants in the fall production season, and to continue to scrupulously manage whiteflies for the entire season. Scouting of fields and roguing of suspicious-looking plants were recommended. IPM scouts and growers were encouraged to send samples of rogued plants to University of Florida Disease Clinics for confirmation of TYLCV-IL infection.

There was an excellent response by the tomato industry to these recommendations, with many growers applying imidacloprid, rouging and sending suspicious-looking plants to diagnostic clinics during the fall season. Infected plants were found by several growers at low incidence in fall production fields in all the Florida tomato committee districts. Grower cooperation was the most important component of managing TYLCV-IL this first year. Growers were so successful that very little TYLCV-IL was observed in the spring season in most of Florida (with the exception of Dade Co.).

TYLCV AND TRANSPLANTS

There is a concern by growers, regulatory personnel, and others that TYLCV-IL could be moved out of Florida on vegetable and ornamental transplants. This concern is based on the history of TYLCV-IL in the Dominican Republic and the rapid movement of TYLCV-IL in Florida in 1997 (14). The probability of movement can be greatly reduced through intervention. Management of both whiteflies and virus in the area of the transplant production facilites will reduce the chances of movement of TYLCV-IL out of the area via transplants. In addition, the population of whiteflies and the distribution of TYLCV-IL infected plants does not appear to be uniform throughout the year, so during certain periods the probability of movement will be greater than other times (17, Polston unpublished).

In October, 1997 a meeting of the USDA/APHIS/PPQ New Pest Advisory Group and the Southern Plant Board was held in Orlando, FL to review FDACS/DPI's protocol for out-of-state movement of tomato transplants from areas where TYLCV-IL had been detected. This involved three plant species reported as hosts of TYLCV-IL in the eastern Mediterranean, tomato, tobacco (*Nicotiana tabacum L.*) and lisianthus (*Eustoma grandiflorum* (Raf.) Shinn.), (5, 6, 10). From this meeting came a Tomato, Tobacco and Lisianthus

Compliance Agreement (PI-275) and a Tomato/Tobacco Plant Certificate (PI-237). Out-of-state shipments of tomato, tobacco and lisianthus are now regulated by the PI-237 certificate (based on Chapter 581 of the Florida Statutes). This requires a zero tolerance for B. tabaci, based on twice-weekly inspections of transplants to be certified. Another change was a requirement for exclusion of whiteflies (either chemically or physically) from the transplant production house.

DISCUSSION AND CONCLUSIONS

TYLCV-IL, a virus endemic to the eastern Mediterranean and more recently the eastern Caribbean, was found in Florida in mid 1997. It was rapidly distributed throughout the state on infected tomatoes produced for the garden center trade in greenhouses in Dade Co. In some case it appeared that the virus was able to move at low rates from infected plants which had been purchased by homeowners to nearby commercial nurseries and production fields. Rapid and widespread action by the commercial tomato industry including the application of a systemic insecticide and the roguing of symptomatic plants, probably reduced the spread of this virus in fields in almost all of the tomato-producing areas of Florida. However, it appears that TYLCV-IL has established in Dade Co. It is likely that re-introductions of TYLCV-IL may occur annually from Dade Co. to other areas of Florida, since a significant portion of the tomato and ornamental plants for garden centers are produced in Dade Co.

Transplants appear to play a role in the spread of geminiviruses in the Western Hemisphere. TYLCV was introduced into the Dominican Republic in transplants from Israel; several Mexican tomato geminiviruses have been spread throughout Mexico presumably on transplants; tomato mottle virus (ToMoV), which has been recognized in Florida since 1989, has been reported in other parts of the southeastern United States (1994), Puerto Rico (1995) and Mexico (Yucatan)(1996) in production regions where tomato transplants originated in Florida (3, 7, 8, 15). ToMoV introductions resulted in epidemics that lasted for only a limited time in the southeastern U.S. and in Puerto Rico. (The fate of ToMoV in Mexico is not known at this time.) It is important to recognize that the introduction of ToMoV into these other areas occurred following seasons in which incidences of ToMoV and viruliferous whiteflies were relatively high in the tomato fields near where tomato transplants were produced.

In addition to spread by transplants, there are probably other mechanisms by which geminiviruses can be moved over long distances. The appearance of bean golden mosaic virus (BGMV) in Dade Co. in the fall of 1994 has never been explained (2). Like TYLCV-IL, BGMV reduces yields and has become a concern for bean producers in Dade Co.

Several steps have been taken to reassure out-of-state transplant customers, maintain confidence in transplants produced in Florida, and minimize the movement of TYLCV out of Dade Co. The Division of Plant Industry has been carefully monitoring Dade Co. production facilities for the presence of both TYLCV-IL and whiteflies since July 1997. Regulatory changes have been made such that certified transplants will have a very remote chance of acting as sources of TYLCV-IL. Effective whitefly management in the field to minimize the size of the whitefly population exposed to TYLCV-IL in combination with the use of certified transplants will aid greatly in limiting the spread of this virus to other locations.

THE LONG TERM OUTLOOK

The experiences of the past year make it clear that TYLCV has become established in at least one county in Florida. It is too soon to know if the virus has or will establish in other parts of the state. However, the dynamic nature of agriculture in Dade Co. makes it likely that the virus will not be contained there, and will be re-introduced periodically to other parts of the state especially during those seasons when whitefly populations are high. It has also become clear that TYLCV-IL is a concern not just for tomato growers, but for commercial and retail transplant producers of tomatoes and other crops. This virus is not likely to disappear, and we can expect to deal with it for some time. The characteristics of this virus: its potentially devastation to tomato yields, its highly efficient transmission by whiteflies, and its extensive host range, make it a pathogen that cannot be managed successfully by traditional tactics alone, as has been the case in Israel for many years. New cost-effective approaches that are appropriate for the various production regions of Florida will have to be developed.

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Figure 2. *Lycopersicon esculentum* 'Better Bush Improved' infected with tomato yellow leaf curl virus which was purchased at a retail garden center, Sarasota, FL. in July 1997.

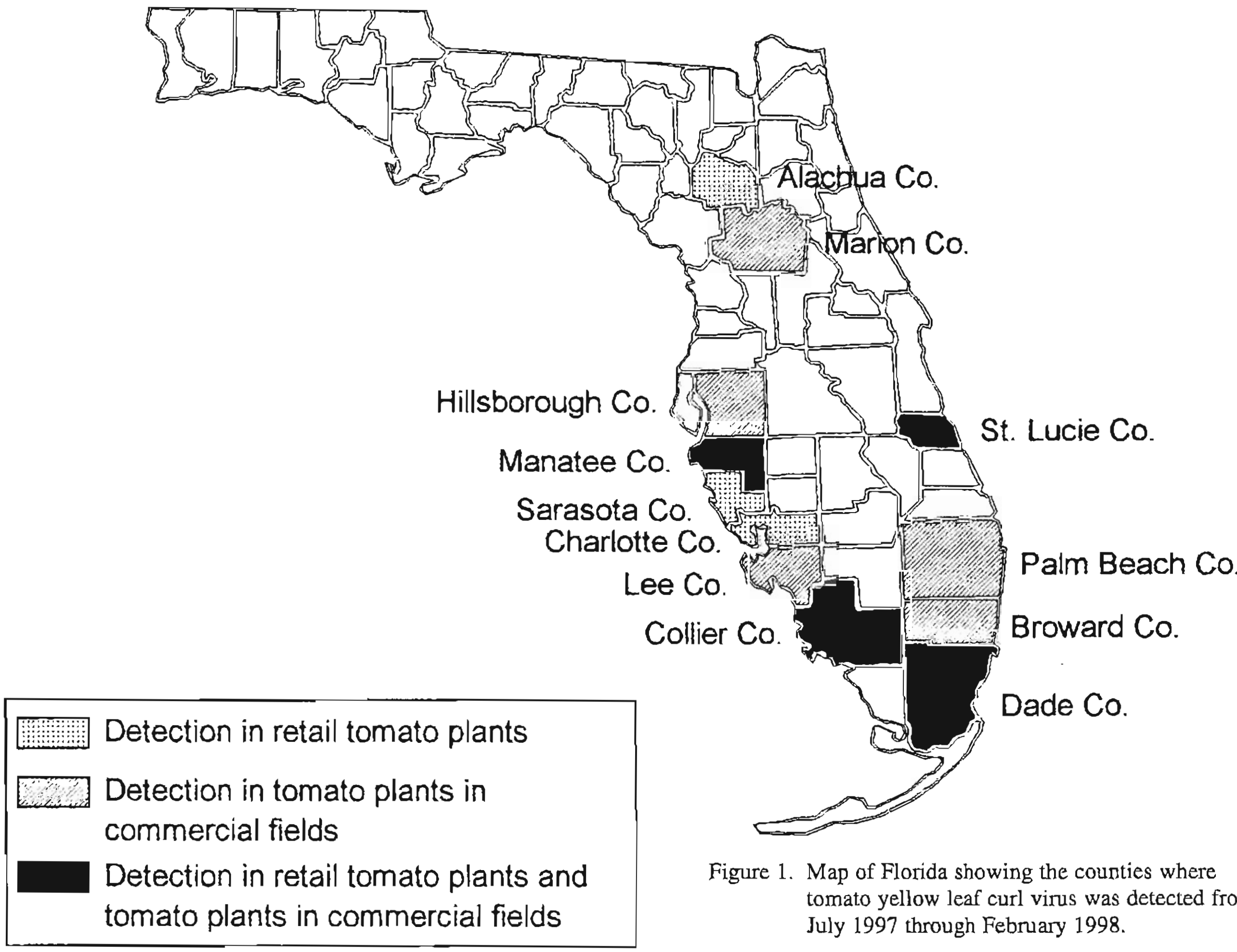

Figure 1. Map of Florida showing the counties where tomato yellow leaf curl virus was detected from July 1997 through February 1998.

PHYTOPHTHORA CAPSICI: NEW PROBLEMS FROM AN OLD ENEMY

R. J. McGovern[1], P. D. Roberts[2], T. A. Kucharek[3], and P. R. Gilreath[4]

[1] University of Florida, Gulf Coast Research and Education Center, Bradenton, FL 34203; [2]Southwest Florida Research and Education Center, Immokalee, FL, 34142; [3]Plant Pathology Department, Gainesville, FL, 32611; [4] Manatee County Cooperative Extension Office, Palmetto, FL, 34221

SUMMARY

Severe epidemics of *Phytophthora* blight caused by the fungus *Phytophthora capsici* occurred in Southwest and West-Central Florida during February through April in 1998. These outbreaks were unprecedented because of the diversity of vegetable crops affected and magnitude of losses incurred. Plant losses coincided with excessive rainfall and flooded field conditions which were common during this period. Disease incidences (percentage of diseased or dead plants) were obtained in late April via field surveys and grower estimates from Collier, Hendry, and Lee counties in Southwest Florida, and Manatee county in West-Central Florida. Phytophthora blight incidence ranged from 3-60% in cantaloupes, 0-42% in cucumbers, 16-25% in eggplants, 3-36% in bell and specialty peppers, 29-100% in squash, 2-25% in tomato, and 0-80% in watermelon. Significant plant mortality in cantaloupe, watermelon, and tomato was observed for the first time in the state. *P. capsici* was also detected in tomato and pepper volunteers, and these may provide sources of the fungus for new epidemics.

PHYTOPHTHORA CAPSICI

Phytophthora capsici causes rapid blighting of leaves and leaves, fruit, root, and stem rot, and/or wilt in many hosts including cantaloupe, chayote, cucumber, honeydew melon, macadamia, pumpkin, papaya, pepper, summer squash, tomato, and watermelon (Farr et al., 1989; McGovern et al., 1993; Sherf & MacNab, 1986). The fungus survives in and on seed and host plant debris in the soil. It is spread by spores through wind and water, in infected transplants, and by means of contaminated soil, equipment, and shoes. Plentiful surface moisture is required by its motile spores (zoospores) to reach and invade host tissue. Therefore, diseases caused by *P. capsici* are most severe during warm (75-90° F), wet weather, and in low, water-logged parts of fields. Excessive rainfall coupled with standing water create ideal conditions for epidemics caused by *P. capsici*; cumulative rainfall appears to be the primary determinant for Phytophthora blight outbreaks. (Bowers, *et al*, 1990; Ristaino, 1991). The fungus has been reported to cause major epidemics in diverse crops in many locations (Central and South America, Europe, Asia, and many states in the United States) because of the rapidity of pathogen reproduction and spread during favorable wet weather (Sherf and MacNab, 1986).

EARLY *P. CAPSICI* EPIDEMICS IN FLORIDA

Although blight in pepper caused by *P. capsici* was recorded in Florida as early as 1931 in the Homestead area (Weber, 1932), it did not become a major problem for commercial growers until it appeared in pepper plantings in Palm Beach County in the spring of 1982. Plants less than one foot tall were especially susceptible and entire fields of young peppers were commonly destroyed. The disease appeared to be less severe in older plantings but still reached 100% in some fields. Typical symptoms of *P. capsici* in pepper included foliar blight, fruit rot and a very characteristic stem rot at the soil line (Figure 1). Phytophthora blight was also observed in eggplant and summer squash in the same county, but losses were lower than those seen in pepper. During subsequent seasons outbreaks of *P. capsici* in pepper in Palm Beach County resulted in extensive losses. Sporadic outbreaks of Phytophthora blight also occurred on cucurbits in Dade County, but *P. capsici* was not commonly detected in other vegetable production areas in Florida prior to 1993.

P. CAPSICI EPIDEMICS, 1992-1997

Significant losses from *P. capsici* in summer squash and watermelon were observed for the first time in Southwest, West-Central, and Central Florida in 1993. These Phytophthora blight outbreaks were preceded and accompanied by a period of excessive rainfall, which undoubtedly increased disease incidence and severity. Plant mortality exceeding 90% occurred during April and May, 1993 in six summer squash production fields in Southwest and West-Central Florida (Collier, Hillsborough, and Manatee counties). [Blight symptoms had also been observed in summer squash in south Florida as early as December, 1992 (Broward County) and as late as April, 1993 (Dade County)].

Damage to watermelon by *P. capsici* during this period was primarily in the form of fruit rot. Fruit rot incidences exceeding 90% occurred in five watermelon fields in Southwest, West-Central, and Central Florida (Charlotte, Collier, Hillsborough, and Polk counties) during mid April through early June, 1993. All stages of watermelon fruit appeared to be susceptible. Initial fruit rot symptoms of *P. capsici* in watermelon (irregular brown lesions which become round to oval) may resemble those of bacterial fruit blotch. Lesions caused by the fungus enlarge radially, have water-soaked margins, and become covered by grayish fungal growth (Figure 2). Symptoms were more commonly observed on, but not limited to, areas of fruit coming in contact with the soil. Spread of *P. capsici* between watermelons in the packing house also occurred. During the epidemics of 1993 foliar symptoms of *P. capsici* in watermelon were primarily limited to water-soaked blotches in young leaves, which dried and turned brown, and dieback in a limited number of shoot tips. Similar foliar symptoms were observed in cantaloupe. No significant losses in cantaloupe production due to Phytophthora blight were reported, and plant mortality in either cantaloupe or watermelon was not observed.

By the spring of 1994, Phytophthora fruit rot of watermelon was widespread throughout the state and occurred as far north as Madison County, which borders on Georgia, where *P. capsici* has also become a major problem. From 1994 through 1997 sporadic, localized outbreaks Phytophthora blight reoccurred in all cucubit crops in Florida and Georgia during periods with excessive rainfall and at waterlogged sites. The first significant outbreaks of Phytophthora blight in pepper outside of Palm Beach County were detected in two commercial plantings in Hendry County (Southwest Florida) during 1995 following abnormally high precipitation. *P. capsici* infection resulted in 1-2% losses in one 30 acre pepper field and 5-10% in another 60 acre field.

Because resistance or insensitivity to Ridomil (Metalaxyl) had been reported in other Phytophthora species (Kadish and Cohen, 1988; Chang and Ko, 1990) and demonstrated in laboratory experiments with *P. capsici* (Bower and Coffey, 1985), we evaluated this capacity in field isolates of the fungus from Florida. Twelve isolates of *P. capsici* obtained during this period from cantaloupe, squash, and watermelon from 12 fields in six counties were screened for resistance to the fungicide Ridomil 2E by comparing their growth on corn meal agar amended with metalaxyl at 6.0 g/ml to growth on the nonamended medium. This in vitro assay was conducted twice. Sensitivity to metalaxyl varied significantly among these isolates (Figure 3). Using the criterion developed in screening for resistance to metalaxyl in Phytophthora infestans (growth at 5 g/ml greater than 40% of the control) (Goodwin *et al.*, 1996), five of the twelve *P. capsici* isolates could be considered resistant to metalaxyl. Resistance to mefenoxam (the active ingredient and metalaxyl replacement in fungicides such as Ridomil Gold) has recently been reported in isolates of *P. capsici* from North Carolina and New Jersey (Parra and Ristaino, 1998).

PHYTOPHTHORA BLIGHT EPIDEMICS, SPRING 1997

Severe outbreaks of Phytophthora blight in Southwest and West-Central Florida which adversely affected all major vegetable crops including cantaloupe, cucumber, eggplant, pepper, squash, tomato, and watermelon occurred from February through April 1997. As with previous *P. capsici* epidemics in the state, the most recent outbreaks were driven by excessive soil moisture and warmer than usual temperatures, caused, in this case, by the prevailing "El Nino" weather pattern.

Symptoms of *P. capsici* in eggplant, pepper, and squash (stem rot at the soil line, foliar blight, and fruit rot) and the fruit rot observed in watermelon were identical to symptoms seen in previous epidemics. However, significant plant mortality in tomato, canteloupe, and watermelon was observed for the first time. Stem rot at and slightly above the soil line occurred in tomato transplants shortly after setting in the field and up until 3 to 4 weeks following transplanting (Figure 4). Prior to the outbreaks seen in Florida, symptoms of *P. capsici* in tomato had been limited to root and fruit rot. (Farr *et al.*, 1989; Kreutzer *et al.*, 1940). Cantaloupe and watermelon plants of all ages also succumbed, including those that had set fruit. As with tomatoes, attack by P. capsici in these plants primarily occurred at the soil line and was rapidly followed by wilting and death.

We conducted a survey of vegetable fields in Collier, Hendry, and Lee counties in Southwest Florida, and Manatee county in West-Central Florida to document the losses caused by Phytophthora blight. The survey protocol consisted of recording the percentage of diseased and dead or missing plants among 40 plants in each of five randomly-selected rows per field (200 plants/field). The great majority of fields surveyed were selected because of the presence of *P. capsici*. Occassionally adajacent fields with no apparent disease symptoms were also surveyed. Additonal information on the impact of Phytophthora blight was obtained through a written questionnaire sent to vegetable growers in Southwest Florida and through informal grower contacts.The presence of *P. capsici* in surveyed fields was confirmed by morphological examination of isolates from representative plant samples following culture on a Phytophthora-selectivemedium (Kannwischer and Mitchel, 1978).

Phytophthora blight incidence was high in all crops and ranged from 3-60% in cantaloupe, 0-42% in cucumber, 16-25% in eggplant, 3-36% in bell and specialty pepper, 29-100% in squash, 2-25% in tomato, and 0-80% in watermelon (Table 1). In general, there appears to be close agreement between survey and grower estimates of Phytophthora blight incidence. Similar losses occurred in Dade and Palm Beach Counties (M. L. Lamberts, K. D. Shuler, personal communications).

P. capsici was consistently detected in symptomatic plant samples from surveyed fields. In addition, the fungus was also recovered from tomato and pepper volunteers at the same sites and these may provide an important source of inoculum for future epidemics.

PRELIMINARY FUNGICIDE EVALUATIONS

Evaluations of the efficacy of labeled and nonlabeled commercial fungicides and experimental materials in reducing P. capsici were conducted at the Southwest Florida Research and Education Center (SWFREC) in Immokalee and the Gulf Coast Research and Education Center (GCREC) in Bradenton. The trial at SWFREC used naturally-occurring inoculum of *P. capsici* to test the effectiveness of weekly applications of Ridomil Gold Bravo (mefenoxam + Chlorothalonil) rotated with Actiguard, an experimental compound alone and rotated with Actiguard, and two rates of Quadris (Azoxystrobin) on Phytophthora blight in watermelon cv. Regency grown in raised beds. The blight epidemic in nontreated plants was rapid with 50% mortality occurring within a week of initial infection. All fungicides significantly reduced the final severity of disease and its rate of spread (Figure 5).

The fungicide evaluation at GCREC used summer squash cv. Goldie grown in pots on raised beds to evaluate weekly applications of Acrobat MZ (dimethomorph + mancozeb), Ridomil MZ (mefenoxam + mancozeb), Manzate (mancozeb), Quadris (azoxystrobin), Aliette (fosetyl-al), Tatoo (propamocarb), Curzate (cymoxanil), and Actiguard. Curzate was applied 24 hours after hypothetical inoculation had occurred. Inoculum sources for the experiment were provided by plants infected with a mixture of *P. capsici* isolates placed between each block of controls and fungicide-treated plants. Plants were watered by means of overhead irrigation from 8:00 to 9:00 PM to achieve splash dispersal of *P. capsici* spores similar to that observed in the field. The progress of Phytophthora blight was rapid, with 100% mortality occurring in controls within 17 days. Curzate, Ridomil MZ, and Tatoo significantly decreased mortality, and the latter two fungicides also reduced the progress of Phytophthora blight (Figure 6).

MANAGEMENT OF PHYTOPHTHORA BLIGHT

Vegetable growers throughout Florida can expect reoccurring problems from Phytophthora blight during warm, wet seasons , and whenever saturated soil conditions are prevalent. Management practices for Phytophthora blight must integrate a number factors including the following actions:

* Use pathogen-free seed and transplants.
* Avoid planting in poorly drained areas and improve drainage where possible
* Manage water properly.
* Eliminate volunteer crop plants and weeds .
* Use a preplant fumigant.
* Rogue infected plants and fruit when disease incidence is low. Allow plants to dry before removal. Workers should disinfest hands and shoes following handling infected plants.
* Decontaminate equipment before moving between infested and noninfested fields.
* Thoroughly cull infected fruit to prevent spread in the packing house and in during shipment.
* Use effective, labeled fungicides preventively.

FUTURE PROSPECTS

Phytophthora blight epidemics which have increased in severity over the last 5 years indicate that this disease can be a major limiting factor for production of most major vegetable crops in Florida. The incidence and severity of the disease in upcoming seasons will depend on conducive environmental conditions, residual *P. capsici* levels, the prevalence of fungicide-resistant isolates, and the availability of effective fungicides.

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Fig. 1. Stem rot of pepper at the soil line caused by *P. capsici*

Fig. 2. Watermelon fruit rot caused by *P. capsici*

Fig. 4. Stem blight in tomato caused by *P. capsici*

Fig. 3

Effect of Metalaxyl (6.0 µg/ml) on Growth of *Phytophthora capsici* from Cucurbits -1993

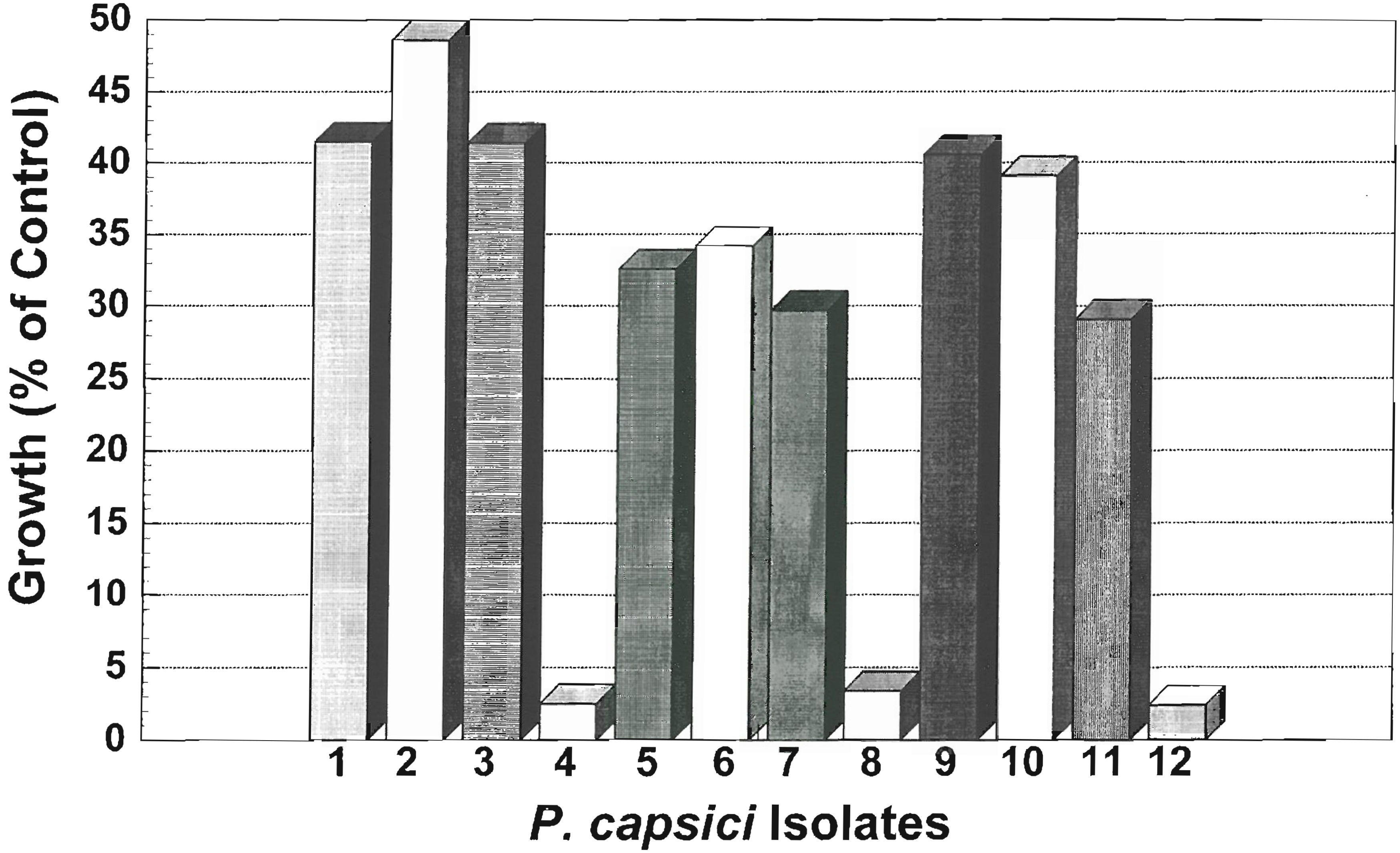


Table1. Survey of *Phytophthora capsici* Incidence in Vegetable Crops in West-Central and Southwest Florida - Spring, 1998[1]

Crop	Phytophthora Incidence (%)	Acres planted	County
Cantaloupe	5.0*[2]	30	Collier
"	6.0	15	"
"	22.0	25	"
"	3.0	24	Hendry
"	12.8	20	Lee
"	10.0	15	"
"	60.0*	75	Manatee
Cucumber	34.5	11	"
"	41.2	66	"
"	22.0	15	"
"	0.0	15	"
"	0.0	15	"
"	2.5	10	"
Eggplant	16.6	10	Collier
"	25*	20	Hendry
"	20.5	5	Manatee
Pepper (Bell)	3.0*	20	Hendry
"	27.5	3.5	Manatee
"	36.5	20	"
"	30.5	10	"
"	30.5	15	"
"	5.5	8.0	"
"	10.0	1.0	"

Crop	Phytophthora Incidence (%)	Acres Planted	County
Pepper (Cubanelle)	20*	8.0	Hendry
Pepper (Habanero)	10.0*	1.0	"
Pepper (Jalapeno)	10*	10	"
"	5*	8.0	"
"	31.5	5.0	Manatee
Summer Squash	29.0	20	"
"	30.0	20	"
"	100	90	"
"	100*	20	"
Tomato	1.5	3.0	"
"	2.2	3.0	"
"	31.0	5.0	"
"	8.5	10	"
"	10.0*	100	"
"	25.0	43	"
Watermelon	48.4	50	Collier
"	0.0*	100	Hendry
"	22.5	30	Lee
"	80.0	20	"
"	49.0	25	"
"	4.3	14	Manatee
"	0.0	10	"
"	35.5	30	"
"	21.0	23	"
"	25*	100	"

[1]Based on a survey of 200 plants per field (40 plants in each of five randomly selected rows).

[2]Grower estimates are indicated by (*)

Fig. 5.

Effect of Fungicides on Phytophthora Blight Severity in Watermelon cv. Regency

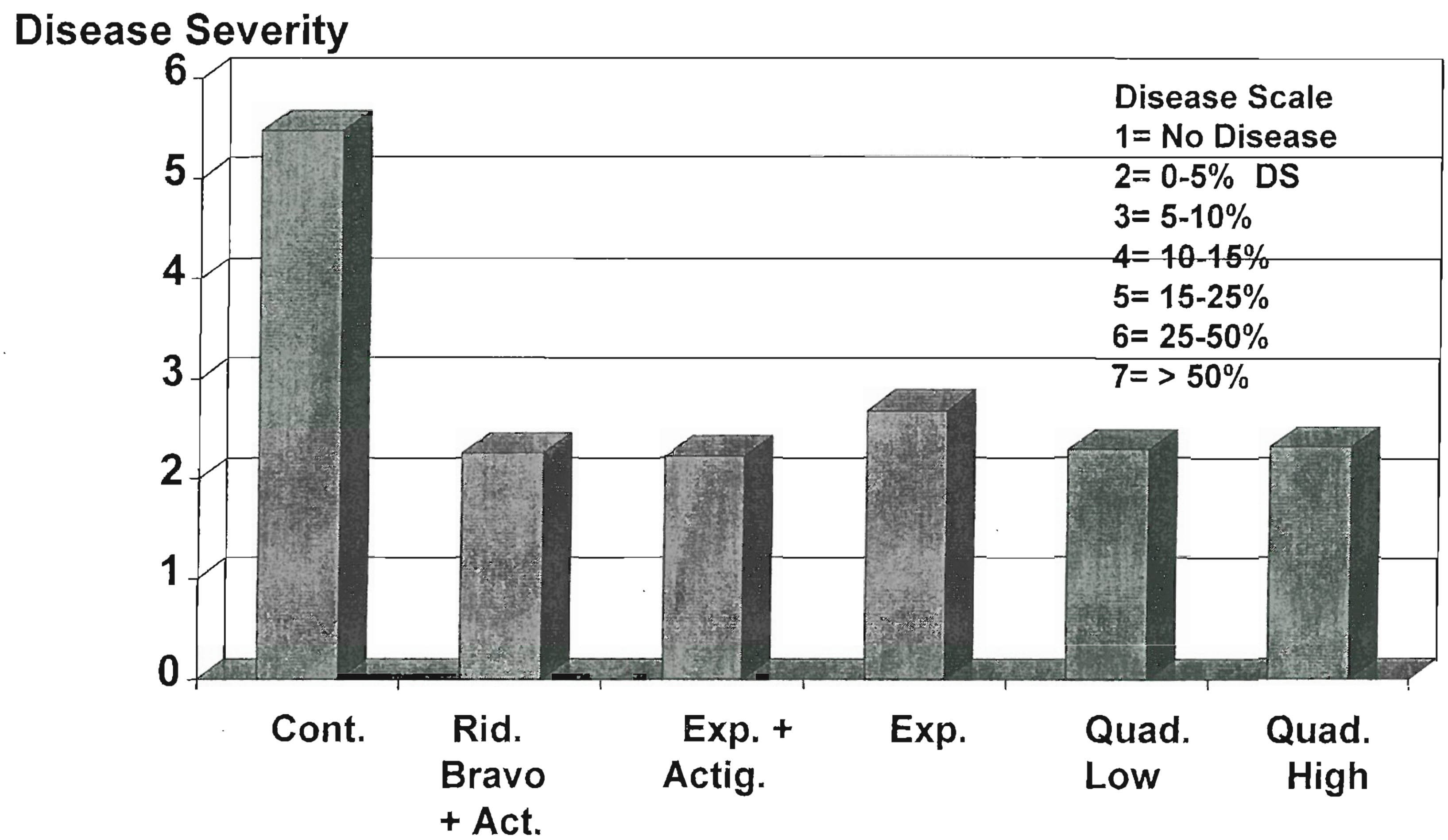
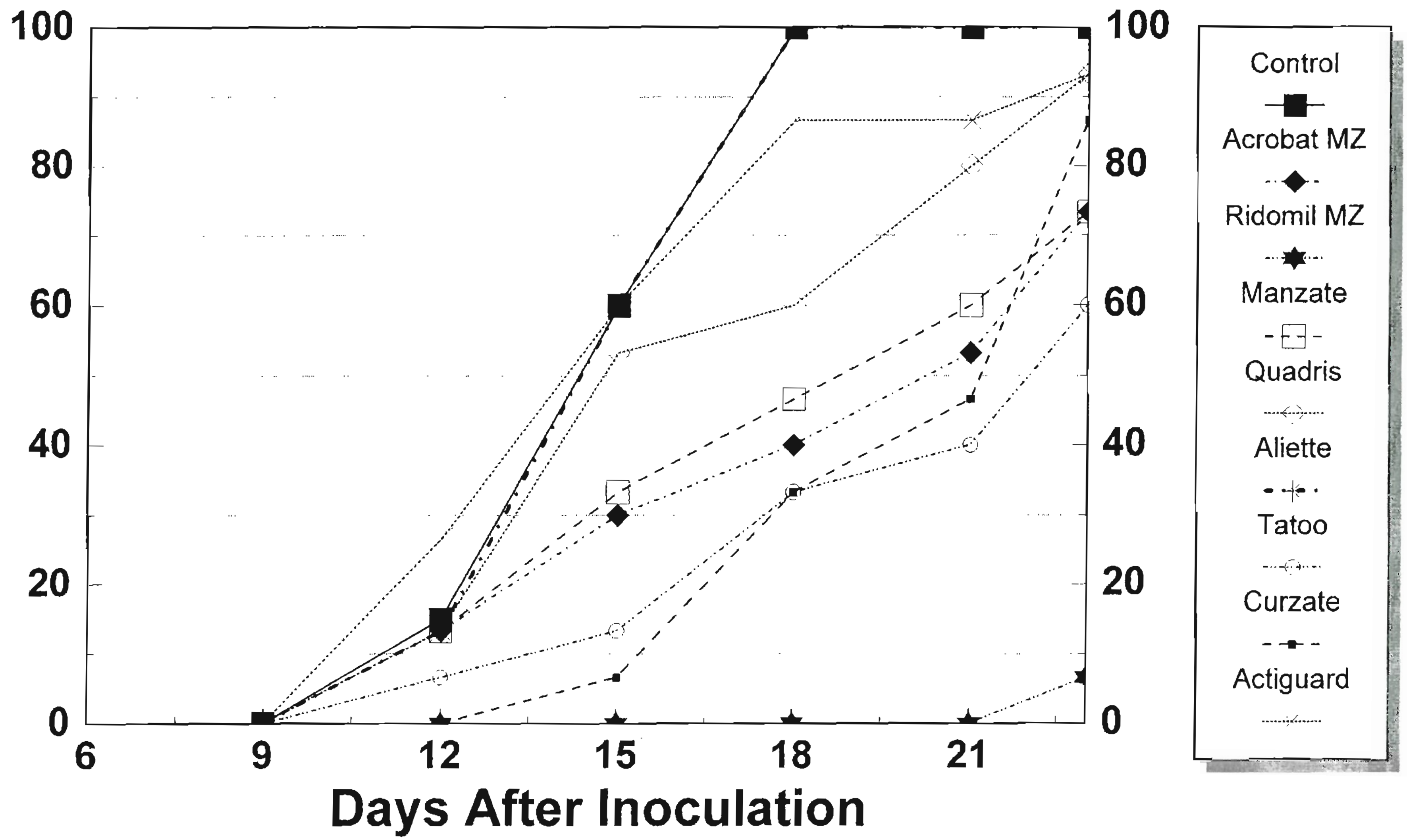


Fig. 6.

Effect of Fungicides on Phytophthora Blight in Summer Squash cv. Goldie



CONTROL OF BACTERIAL SPOT ON TOMATO IN THE GREENHOUSE AND FIELD WITH BACTERIOPHAGES

J. B. Jones[1]*, G. C. Somodi[1], L. E. Jackson[2], B. K. Harbaugh[1] and J. E. Flaherty[1]

[1]University of Florida, Gulf Coast Research and Education Center, 5007 60th St. E., Bradenton, FL 34203; [2]AgriPhi, Inc., 160 North Main, Logan, UT 84321.

**Current address: Department of Plant Pathology, University of Florida, Gainesville, 342611.*

Bacterial spot of tomato, incited by *Xanthomonas campestris* pv. *vesicatoria* (Xcv), is devastating to tomato production in Florida when weather conditions are optimal. In the fall crop, growers often apply a copper-mancozeb tank mix two or more times per week in an attempt to control this disease. However, control is difficult when weather conditions are optimal for disease development. Furthermore, control is hampered by the presence of copper-tolerant strains and the endemic nature of the pathogen in Florida.

As a result of control being difficult, other strategies such as biological control have been investigated. In biological control, organisms can be used which are inhibitory or lethal to the target pest. Bacteriophages are viruses that infect bacteria. They have been proposed as potential biological control agents for bacterial plant pathogens. During the past year, as a result of funding from the Florida Tomato Committee and the USDA-SBIR, we determined that tomato transplants, which had been treated daily with irrigation water containing the bacteriophage specific to the bacterial spot pathogen, had a low percent (<10%) infection as compared to high percent (>60%) on tomato transplants which received weekly applications of a copper bactericide.

Although significant control of the bacterial spot organism by bacteriophages has been demonstrated in the greenhouse, it is essential to demonstrate the efficacy of these agents under field conditions. We present data from a fall 1997 study to demonstrate the efficacy of bacteriophages for bacterial spot control starting in the greenhouse and extending into the field.

MATERIALS AND METHODS

Greenhouse experiment. 'Sunbeam' tomato seedings were transplanted to Speedling flats and placed in the greenhouse. The following treatments were initiated: (1) seedlings received overhead irrigation with water alone; (2), seedlings received overhead irrigation with water and were sprayed every 5 days with copper-mancozeb; and (3), seedlings were irrigated with water containing a mixture of phages specific against T1 and T3 strains. For research studies, overhead irrigation (a common irrigation practice for transplant production) was simulated by applying water evenly to the seedlings by gently misting over the seedlings using a Solo Back-Pack sprayer (Origin). The final concentration of phage was 107 pfu/ml. Phages were used in all irrigations of phage treated seedlings. The flats were set up in a randomized complete block and consisted of four replications. One week after initiating treatments, the center plant in each flat was inoculated by infiltrating a suspension of approximately 108 CFU/ml of a mixture of T1 and T3 strains with a hypodermic needle. All bacterial strains used were copper resistant. The bactericide, copper hydroxide, was applied in combination with mancozeb. The seedlings were grown in preparation for planting in the field. Prior to transplanting to the field, disease incidence was assessed in each flat.

Field Experiment. The transplants were set in the field in a randomized complete block. Transplants for each block were taken from the Speedling flats in the greenhouse. Each replicate of a transplant treatment from the greenhouse was set into each of the following field treatments: (A) no foliar spray; (B), copper-mancozeb applied every 4-5 days; and (C), bacteriophage mixture applied 2-3 times per week between 5 and 6:30 AM.

Disease severity ratings were made three times during the season and then the area under the disease progress curve (AUDPC) was determined for each plot. Plant vigor ratings were made twice prior to harvesting fruit and was assessed by determining the overall vigor of the plant based on disease severity and epinasty associated with the plant. Yield determinations were made by harvesting mature green, pinks and ripe fruit. Ten plants per plot were picked. The center row was picked in all but one plot. Plants with virus or other problems were eliminated and substitutions were made. The fruit were graded according to size and then weighed. All data were subjected to ANOVA analyses. Significance of the main factors and interactions were determined by ANOVA. Differences between means were determined by Duncan's Multiple Range Test.

RESULTS

Greenhouse experiment. The copper-mancozeb and bacteriophage treatments significantly reduced the incidence of bacterial spot on seedlings compared to the control (Table1). However, the copper-mancozeb and bacteriophage treatments did not differ significantly from each other.

Field experiment. Field treatments consisting of copper-mancozeb or bacteriophage had significantly lower disease ratings than the control (Table 2). The greenhouse treatments had no affect on the field AUDPC values (data not shown).

Vigor ratings were made on 3 October and 15 October following a significant rain event in late September. Plants in the bacteriophage treated plots had significantly higher plant vigor ratings than those in the copper-mancozeb or control treatments (Table 3). This was an indication that bacteriophage treated plots had significantly greater plant vigor. Vigor ratings were unaffected by the greenhouse treatments (data not shown).

The greenhouse treatments had some affects on yield parameters. Plants in plots, which were planted with bacteriophage treated transplants, had significantly greater numbers and weight of extra large fruit than the control (Table 4). Transplants receiving copper-mancozeb in the greenhouse were not significantly different from either of the other two treatments. Plants in field plots, which received bacteriophage, had significantly greater number and weight of extra large fruit than plants receiving the copper-mancozeb or no bactericide (Table 5). This accounted for a 25 percent yield increase in plots receiving the bacteriophage treatment as compared to plots receiving the copper-mancozeb treatment.

SUMMARY

The use of bacteriophages for controlling bacterial spot of tomato appears very promising. In comparison to plants in the control plots, plants treated with bacteriophages specific for the bacterial spot organism had reduced incidence of bacterial spot in the greenhouse and reduced disease severity in the field and increased plant vigor. Furthermore, their use in comparison to the control and copper treatments resulted in increased plant vigor and increase in extra large fruit number and weight.

Table 1. Effect of greenhouse treatments on incidence of bacterial spot on seedlings in Speedling flats

Treatment	Bacterial Spot Incidence (%)
Control	40.5 a[z]
Copper-mancozeb	5.5 b
Bacteriophage	0.9 b

[z]Values in a column followed by the same letter are not significantly different according to Duncan's multiple range test (p=0.05).

Table 2. Effect of field treatments on bacterial spot disease severity (AUDPC)

Treatment	AUDPC
Control	113.6 a[z]
Copper-mancozeb	94.4 b
Bacteriophage	93.7 b

[z]Values in a column followed by the same letter are not significantly different according to Duncan's multiple range test (p=0.05).

Table 3. Effect of field treatment on field vigor rating

Treatment	Vigor Rating I[z]	Vigor Rating II
Control	2.8 b[y]	3.6 b
Copper-mancozeb	1.6 a	2.7 a
Bacteriophage	4.5 c	4.7 c

[z]0=Sparse plant canopy, necrotic leaf spots on most of the leaves on each plant, severe epinasty of new growth. 7= Uniform plant canopy, few or no necrotic leaf spots on most of the leaves on each plant, lack of epinasty of new growth.

[y]Values in a column followed by the same letter are not significantly different according to Duncan's multiple range test (p=0.05).

Table 4. The effect of greenhouse treatment on yield in the field

Trt	Xlgno[z]	Xlgwt (lbs)	Lgno	Lgwt (lbs)	Medno	Medwt (lbs)
Water	115 B[y]	47 B	63 A	20 A	30 A	7 A
Copper-mancozeb	131 AB	56 AB	69 A	22 A	27 A	7 A
Phage	143 A	60 A	71 A	22 A	27 A	7 A

[z]Xlgno=total number of extra large size fruit; Xlgwt= total weight of extra large size fruit; Lgno=total number of large size fruit; Lgwt=total weight of large size fruit; Medno= total number of medium size fruit; Medwt=total weight of medium size fruit.
[y]Values in a column followed by the same letter are not significantly different according to Duncan's multiple range test (p=0.05).

Table 5. The effect of field treatment on yield in the field

Trt	Xlgno[z]	Xlgwt (lbs)	Lgno	Lgwt (lbs)	Medno	Medwt (lbs)
Water	126 B[y]	53 B	67 A	21 A	32 A	8 A
Copper-mancozeb	119 B	49 B	65 A	20 A	25 A	6 A
Phage	143 A	61 A	72 A	23 A	27 A	7 A

[z]Xlgno=total number of extra large size fruit; Xlgwt= total weight of extra large size fruit; Lgno=total number of large size fruit; Lgwt=total weight of large size fruit; Medno= total number of medium size fruit; Medwt=total weight of medium size fruit.
[y]Values in a column followed by the same letter are not sign ificantly different according to Duncan's multiple range test (p=0.05).

BACTERIAL SPECK OF TOMATO: THE OTHER BACTERIAL DISEASE

Ken Pernezny
Everglades Research and Education Center, IFAS, University of Florida, Belle Glade, FL

Nearly every year, bacterial spot, caused by *Xanthomonas campestris pv. vesicatoria,* is widespread in Florida tomato fields, often causing significant yield and quality losses. Occasionally however, bacterial speck, caused by *Pseudomonas syringae pv. tomato,* can be a significant factor in production. Such an outbreak occurred in the cool, wet winter of 1977-78. Another outbreak of considerable note occurred during the 1997-98 season in southern Florida. Therefore, it is timely to discuss the symptoms and epidemiology of this disease.

SYMPTOMS

Bacterial speck is best differentiated from its cousin, bacterial spot, based on fruit symptoms. Speck lesions on green fruit are black, somewhat shiny, and sunken. The depressed nature of these fruit lesions is best seen by observing them tangentially, rather than directly from above. Many appear to be surrounded by a darker green halo. They never really appear scabby as do bacterial spot lesions. When fruit ripen, speck lesions look like small, black, superficial flecks.

Leaf lesions, on the other hand, can be virtually impossible to distinguish from bacterial spot in the field. Speck leaf lesions are usually small, greasy-looking, black spots. Even small ones are often surrounded by a prominent, chlorotic halo. Lesions on stems and petioles are elongated ovals, with the long axis of the oval parallel to the long axis of the shoot tissue.

Bacterial speck will give a good "streaming test". Suspected lesions can be cut through several times with a razor blade, mounted in water on a glass slide, and observed with dark background under either a dissecting or compound microscope. Samples that show a milky substance oozing from cut edges are positive for a bacterial pathogen. However, this test does not tell you which particular bacterium is involved. Identification of the organism as *P. s. pv. tomato* requires isolation and identification of the bacterium on agar plates. This may require a week to 10 days at a plant disease clinic. We have had some success recovering and differentiating the speck pathogen on a semi-selective medium (Pohronezny *et al*, 1979).

EPIDEMIOLOGY

Bacterial speck is a cool, wet weather disease. Inspection of weather data for 1977-78 compared with long-term averages revealed that the winter of 1977-78 was substantially cooler and wetter than normal. In 1997-98, rainfall amounts were much higher than normal (Fig. 1). However, temperatures were close to the 69 year averages (Fig. 2). These observations may lead us to conclude that moisture is more critical to development of bacterial speck in Florida tomatoes than is temperature.

Infection occurs through wounds and natural openings (e.g., stomates). Many of the storms of the 1997-98 season were associated with high winds. Sandblasting of foliage and fruit may very well have been associated with this outbreak of bacterial speck. Spread of the pathogen occurs by means typical for bacterial pathogens: splashing water and mechanical transfer. The driving rains of the 1997-98 season were no doubt a big factor in the widespread movement of *P. s. pv. tomato.*

Only very small fruit are likely to be infected by *P. s. pv. tomato* (Getz *et al,*1983). Once fruit become larger, young lesions expand and become visible. Fruit larger than 3.5 cm in diameter never become infected.

MANAGEMENT

Bacterial speck is difficult to control, once established in the field. Little information is available on susceptibility of Florida strains to copper. One might speculate that the strains would likely be fairly sensitive to copper, because *P. s. pv. tomato* is much less common than *X. c. pv. vesicatoria* and therefore would have less selective pressure for tolerance. However, in the Czech and Slovak Republics of East-central Europe, tolerance to copper was quite high, despite infrequent use of copper in production fields (Perneznyet al, 1995). If seed are an important source of inoculum, it may be that the copper tolerance is more reflective of spray practices in the areas where tomato seed are produced. This could lead to the introduction of copper-tolerant strains into production fields in Florida and other areas of the world.

We can guard against mechanical spread of this pathogen by minimizing activity in fields when plants are wet. It is best to disinfect hands of workers (and scouts) at least between fields.

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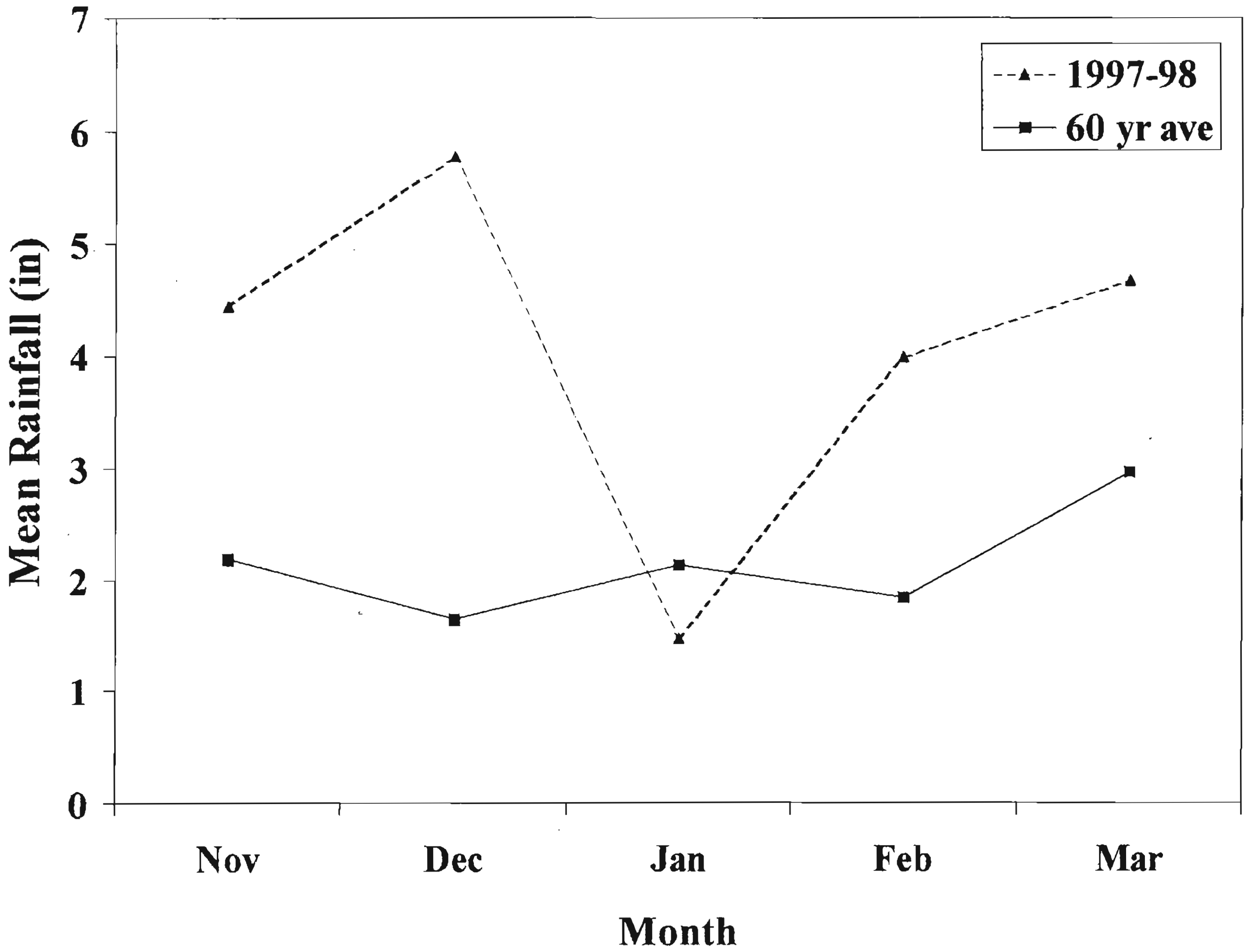
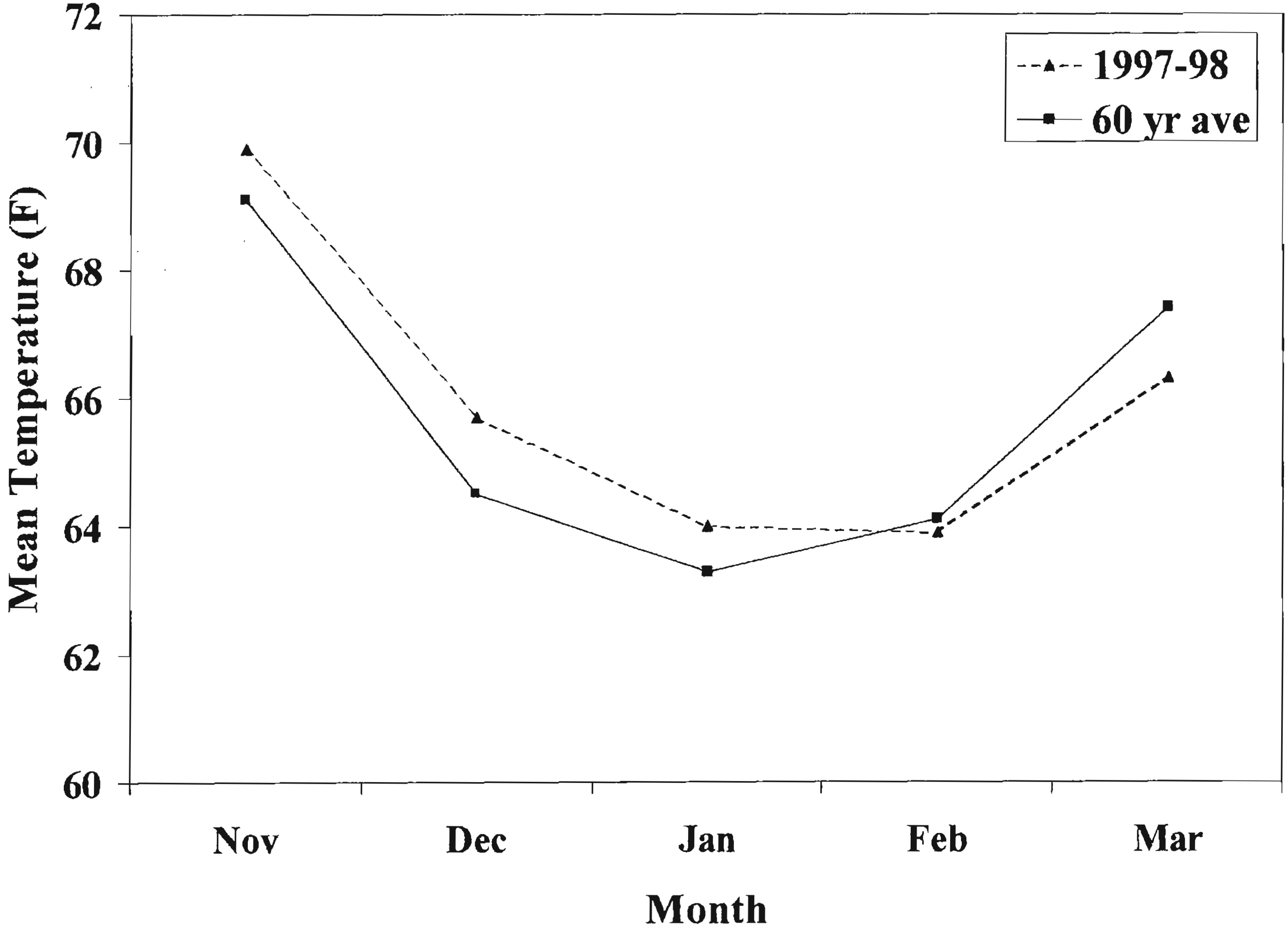
Fig. 1.



Mean Rainfall (in)
7
6
5
4
3
2
1
0
1997-98
60 yr ave
Nov
Dec
Jan
Feb
Mar
Month

Fig. 2.


72
70
68
66
64
62
60
Mean Temperature (F)
1997-98
60 yr ave
Nov
Dec
Jan
Feb
Mar
Month

THE SCIENTIFIC, ECONOMIC AND POLITICAL REALITY OF THE PHASEOUT OF METHYL BROMIDE

Joseph. W. Noling
University of Florida, IFAS,
Citrus Research & Education Center, Lake Alfred, FL
and
James P. Gilreath
University of Florida, IFAS,
Gulf Coast Research & Education Center,
Bradenton, FL

Methyl bromide is probably the single most important pest management tool used in Florida today, and it plays a critical role in maintaining Florida in a highly competitive position within most of our high value production systems. The basic problem we face as scientists involves defining just how critical the chemical is, identifying economically acceptable alternatives, and then determining the extent to which agricultural industries will change (if any) once methyl bromide is phased out and producers are forced to rely on alternatives in an increasingly competitive global marketplace.

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 control. At the same time, however, the phaseout of methyl bromide has led to the development of a new "zoo" of supposed replacement compounds and alternatives, and concurrent with this, a series of new challenges since each of these must be scientifically and economically evaluated. In past years, research reports and presentations on methyl bromide alternatives research efforts have been a continuing feature of the Florida Tomato Institute. This year, our intent is to step back and provide more of an overview of statewide research efforts and anticipated impacts and to look at not only the scientific status of alternatives but also to provide a view of the economic and political aspects of current affairs involving the phase-out of methyl bromide.

SCIENCE

Since 1993, when methyl bromide was added to the class I category of ozone depleting substances and a phaseout date of 2001 established under the Clean Air Act, a considerable amount of research has been conducted on a international basis, as well as by University of Florida scientists. In Florida, the principal research objective has been to identify and evaluate alternatives to methyl bromide which minimize agricultural impacts. Results of much of this work has been presented as annual updates at these meetings. In general, the results of these Florida studies shows that no single, equivalent replacement (chemical or nonchemical) currently exists which exactly matches the broad spectrum efficacy of methyl bromide. A summary of chemical alternatives research shows that a combination of different fumigants (1,3 Dichloropropene and Chloropicrin; Telone C-17®) and a separate, but complementary herbicide treatment (Tillam®) will be required to achieve satisfactory soilborne pest control and tomato yield. However, in reality, it is not clear at this time whether this treatment regime will survive the environmental scrutiny of our regulatory agencies or ultimately be adopted by growers due to the significantly increased needs for personnel protective equipment required for all workers in the field during application. Current labeling of Tillam® excludes use in hand transplanted tomatoes and there is some question as to whether the use of a planter of the type used in Florida constitutes mechanical or hand transplanting. Telone C-17® presently requires the use of a spray suit, rubber gloves, boots, and a full face respirator by all personnel in the field at the time of application. Although efforts are underway to address both of these restrictions with the manufacturers and the U.S.E.P.A., the current label restrictions would severely limit their usage in Florida tomato production.

The breadth and focus of the methyl bromide alternatives research program in Florida is not limited exclusively to evaluation of chemical combination treatment regimes. The program also encompasses an evaluation of a diversity of nonchemical tactics. Since 1993, an ever expanding list of nonchemical alternatives has been evaluated in field research and demonstration trials. Some of the nonchemical alternatives evaluated include:

1)Cover crops
2)Organic Amendments
3)Biological Control Agents
4)Crop Rotation (Strip Tillage)
5)Super Heated Water and Steam
6)Paper and Plastic Mulch Technologies and Emissions Reduction
7)Pest Resistant Crop Varieties
8)Solarization / Biofumigation
9)Natural Product Pesticides
10)Supplemental Fertilization
11)Fallowing

In general, the results from some of these nonchemical studies have been encouraging, but, in most cases, should be construed as incomplete from a soil pest control or crop yield enhancement perspective. Many of these nonchemical tactics are not only marginally effective (at this time) or show activity against a single target pest, but also impractical, cost prohibitive, or have requirements for specialized equipment and operators. In addition, none of the nonchemical tactics should be considered stand alone replacement strategies for methyl bromide soil fumigation at this time. As a result, new field studies evaluating combinations of tactics have been proposed or are in progress to establish cumulative impacts on soilborne pest control and crop yields. However, the lack of sufficient research funding and the proximity of the currently defined phaseout date of January 1, 2001 should be considered major obstacles to evaluation, development, and implementation of many of these proposed nonchemical alternatives.

It is also important to recognize that research within Florida has been principally confined to tomato and only recently expanded to include strawberry. Moreover, a host of other crops currently dependent on methyl bromide still requires a considerable amount of discovery type research. These crops include for example: pepper, eggplant, cucurbits, cut flowers, caladiums, other ornamentals and turf. In addition, multi-year studies have not been performed to determine whether crop yields under high pest pressures, and diverse geographical / environmental conditions, can be achieved consistently with the alternatives. This is of particular concern since the long history of methyl bromide use mitigates recurring pest problems. As pointed out previously, research efforts evaluating many of the nonchemical alternatives are in a very preliminary stage, and have not been studied in sufficient detail at multiple locations to accurately predict either short or long term impacts. In reality, a considerable amount of critical research remains to be done in a very short time to be of any practical benefit to Florida growers at the time of the proposed phaseout.

The international scientific community also periodically assesses the "state-of-the-science" on ozone depletion and alternatives research. Every three to four years, a written document presenting the consensus view of the scientific big picture is produced under the auspices of the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) . For example, the latest Scientific Assessment of Ozone Depletion, conducted in 1998, indicated that the role of the chemical methyl bromide as an ozone-depleting substance is less than previously estimated. For example, the current best estimate of the ozone depletion potential (ODP) for methyl bromide is 0.4, as compared to an ODP of 0.6 estimated in the previous assessment.

It is important to recognize that amendments or adjustments in global and national environmental policy issues are directly linked to the release of these updated global assessments and that the results of this latest assessment could have significant impact towards future U.S. policy decisions regarding the methyl bromide phaseout schedule. However, at this time, the U.S. Clean Air Act still dictates the elimination of any substance with a ODP greater than 0.2 within 7 years of its designation as such (1994), and methyl bromide is still listed as such. Modification of the Clean Air Act is somewhat of a possibility, but it is a political issue and agriculture has much less impact on politics today than it did 50 years ago. Even if the Clean Air Act is amended, the U.S.A. is still bound by an international agreement (Montreal Protocol) to suspend use of methyl bromide by 2005.

ECONOMIC

Given that most of the alternative pest control tactics are not as effective as methyl bromide and often have higher costs associated with them, some discussion of statewide economic impacts is warranted. For example, in 1994, the costs to growers, local economies, and consumers resulting from the suspension of methyl bromide for soil fumigation purposes alone was estimated to be at least $ 1 billion annually. While we've made progress with alternative pest control strategies, and impacts are not as great as originally estimated in 1994, they are still expected to be very significant (currently believed to be in the neighborhood of $400 million). A considerable amount of research still remains before we can say whether various agricultural industries within Florida can compete and will survive within the international marketplace without methyl bromide.

In addition to the efforts of Dr. John Vansickle, the United States Department of Agriculture (USDA) Economic Research Service (ERS) has intensified efforts during the past year to develop economic models which characterize costs and potential impacts for adoption of proposed alternatives to methyl bromide for soilborne pest control for all Florida crops which now rely on methyl bromide. All models rely upon a type of spreadsheet and best guesstimate approach. The biggest concern that agricultural scientists have with these economic models involve the inability to crystallize treatment response and production variability with the alternatives. In all reality, it is not possible at this time to provide accurate model estimates since long term studies have not been performed showing that yield responses under high pest pressures can be achieved consistently. As indicated previously, research efforts evaluating nonchemical alternatives are in a very preliminary stage, and for many, there remain very serious concerns regarding potential merits and negative short and long term economic impacts. Of more apparent concern to USDA economists appears to be the extent to which Florida growers can accept (by adoption of alternatives to methyl bromide) higher production costs and lower cropping system productivity and the extent to which planted acreage will shrink or disappear completely if the alternatives do not perform as claimed.

Further, the consequences to the current double cropping systems do not appear to be a key feature of many of the economic models under development. It is often the profit from the second crop, benefiting from residual pest control properties of the initial methyl bromide treatment, that economically sustains the overall production system. In essence, expenses must be shared across crops. If the alternatives remove double cropping opportunity, then costs increase dramatically for single crops and we lose competitiveness. Besides farm level impacts, these industries are very important to state and local economies, and significant multiplier effects are expected to spill over into the other areas of the private sector.

In all reality, the apparent key to the economic stability of Florida cropping systems will likely be contingent upon impacts of alternative strategies on marginal costs and returns to production, particularly when one considers further removal of international trade barriers and increased market competition. Most, if not all, economic forecasts indicate that in today's highly competitive markets, particularly with that of Mexico, small changes in the price of production inputs can and will have a major effect on the viability of the total farm operation. Two states will bear the economic brunt of the phaseout, Florida and California, and that the big winner is Mexico where tomato production is expected to increase dramatically when methyl bromide is phased out in 2001.

POLITICAL

On September 17, 1997 at the Ninth Meeting of the Parties to the Montreal Protocol (an international treaty developed to protect the earth from detrimental effects of ozone depletion), a number of significant decisions were made with regard to global controls on methyl bromide. The most important of which regarded the differential phase out schedules for developed and developing countries summarized below:

For Developed (industrialized) Countries:

- •25% reduction in methyl bromide use in 1999
- •50% reduction in methyl bromide use in 2001
- •70% reduction in methyl bromide use in 2003
- •100% reduction in methyl bromide use in 2005

For Developing (non-industrialized) Countries:

- •20% reduction in methyl bromide use in 2005
- •100% reduction in methyl bromide use in 2015

Florida tomato growers should recognize that as a member nation of the Montreal Protocol, the U.S. is obligated to implement a 25% use reduction in 1999, when and if the new amendments to the treaty are ratified by the U.S. and other member countries.

More recently, legislation (Miller Bill: H.R. 2609) developed and supported by representatives from Florida and California was introduced to the 105th session of the U.S. Congress. The Miller Bill effectively proposes to change and delay the methyl bromide phase out schedule in the United States. In brief, the legislation states that American farmers should have the same tools as foreign competitors (level playing field concept) and requires the Administration to implement controls on methyl bromide in the U.S. which are no more stringent than required of any other party to the Montreal Protocol. On June 10, 1998 a U.S. House Agriculture Subcommittee on Forestry, Resource Conservation, and Research hearing was held to review the phase-out of methyl bromide, probable economic impacts, and status of alternatives research. In general, the hearing served as a forum for debate of what constitutes a technically feasible and economically viable alternative to methyl bromide for all of its current uses, and the extent to which we can rely on any of these tactics as short or long term pest control solutions after the phaseout of methyl bromide. Senator Bob Graham also submitted a written statement as testimony to this hearing emphasizing the need to focus efforts at the congressional level towards accelerating the statewide research program strategy to insure that all actions are taken in the next 2 years that could possibly lead to progress in identifying economically viable alternatives to methyl bromide.

CONCLUSION

As pest control specialists with the University of Florida, we continue to hear from those who propose the existence of many "technically feasible and economically viable alternatives to methyl bromide". These claims, for the most part we believe, are predicated on a mere 'pittance' of research, or research performed outside of Florida which ultimately may have little or no application or transferability within Florida. At the same time, however, it is clear that under the specific conditions of some tests, alternative research has produced some encouraging results. However, long term applicability of many of these alternatives has not been demonstrated, particularly in Florida with its unique soils, and subtropical environmental conditions conducive for weed growth, pest outbreak, and crop damage.

Every currently proposed alternative, at their present stage of research and development, comes with certain constraints or incompatibilities which affect the technological feasibility or, more importantly, the economic viability of the proposed alternative. The adoption of these alternatives will all involve trade-offs of one sort or another, and can have tremendous future impacts to Florida agriculture. In addition and contrary to persistent claim, the extent to which we can rely on any of these tactics as short or long term solutions in the absence of methyl bromide has not been scientifically, statistically, or practically established.

We cannot over emphasize the difficulty of providing simple descriptions of the viabilities of the alternatives, as the appropriateness of a given alternative or alternative IPM system is very dependent on a variety of interrelated factors, such as climate, market, pest level and presence, land, labor, and resource input availability, soil type and conditions, to name but a few. The complex interaction of these factors requires choice of best alternatives to be developed on a field by field basis. At present it is not possible to provide the level of detail required to make this analysis or formulate a prescription for all crop production systems currently using methyl bromide. And as such it is erroneous to conclude, until more comprehensively evaluations are made, that an alternative is both technically feasible and economically viable.

Since little or no information exists on which to base the effectiveness of alternative pest management systems for all of the various crops and producing regions in Florida, new research efforts are critical and must be initiated immediately to take advantage of the few planting cycles remaining. Contingency plans and strategies must also be researched given the likelihood that some of the alternatives developed now may not be available for the future. Without additional information, recommendations to growers clearly will not be established or well defined. To facilitate the search for economically / environmentally viable alternatives and to expand grower awareness of these pending problems, broader participation and greater support of ongoing field research efforts is urgently required. It should also be recognized that in all reality, additional research and extension funds would help alleviate some, but probably not all, of the problems, uncertainties, and risks which will face Florida farmers after the methyl bromide phaseout.

EFFECT OF BACTERIAL AND FUNGAL MICROORGANISMS TO COLONIZE TOMATO ROOTS, IMPROVE TRANSPLANT GROWTH AND CONTROL FUSARIUM CROWN AND ROOT ROT

L. E. Datnoff and K. L. Pernezny
University of Florida, Everglades Research and Education Center, Belle Glade, FL 33430

INTRODUCTION

One of the most serious soilborne diseases limiting tomato production in southern Florida is Fusarium crown and root rot (FCRR) caused by *Fusarium oxysporum f. sp. radicis- lycopersici* (Jones *et al.*, 1990; McGovern *et al.*, 1993b). FCRR has been increasing in Florida over the last several years (Jones *et al.*, 1991; McGovern *et al.*, 1993b) and commercial yields have been reported to be reduced by 15 percent (Jones *et al.*, 1991).

Several disease management strategies have been employed for trying to control FCRR in the greenhouse and field (McGovern *et al.*, 1993b; Javris, 1988; Rowe and Farley, 1981). Fumigation with methyl bromide/chloropicrin has provided good but incomplete control of this disease in the field. Since the Montreal Protocol has established methyl bromide as an ozone-depleting substance, it will be removed from use by January 1, 2001 (Hayes, 1994). Although fungicides such as benomyl or captafol have been demonstrated to be somewhat effective, captafol is no longer labeled for usage. Host resistance to *F. oxysporum f. sp. radicis-lycopersici* is limited in commercially acceptable tomato cultivars (McGovern *et al.*, 1993a).

Research has demonstrated that biological control of FCRR has been successful in some instances. Caron *et al.* (1985 and 1986) decreased FCRR with *Glomus intraradices*. Sivan and Chet (1993) used *Trichoderma harzianum* in combination with soil sterilization and reduced rates of methyl bromide to obtain significant control of FCRR in the field. Datnoff et al. (1994; 1995) demonstrated that using selective commercial microorganisms such as *T. harzianum and G. intraradices* alone or in combination were effective for controlling FCRR.

Because of the upcoming loss of methyl bromide and the potential for biological control, the purpose of this study was to further evaluate commercial bacterial and fungal microorganisms for root colonization of greenhouse-grown tomatoes and determine if these microorganisms are effective in promoting plant growth, yield and controlling FCRR under fumigated and non-fumigated field conditions.

MATERIALS AND METHODS

Metro potting mix #350 was amended with a bacterial strain (Gustafson). *Trichoderma harzianum* (RootShield™, Bioworks, Inc.) or *Gliocladium virens* (SoilGard™ 12 G, ThermoTrilogy) also were amended into the mix at 1 x 10^6 cfu/cell. These fungal and bacterial microorganisms were either added alone or in combination. The amended soil mix was dispensed into container flats #242. 'Sunny' tomato seeds were planted and grown in the greenhouse for four or five weeks. Plants were fertilized with Peter's 20-10-20 N-P-K at a ratio of 1:100 (15.2 g/l) applied by using a rate dispenser (Dosatron International, Clearwater, FL).

Four to five weeks before transplanting to the field, data were collected on fresh and dry weights of shoots and roots, heights and number of petioles, and stem caliper measurements at soil line. Populations (cfu/g fresh root weight) of the bacterial and fungal microorganisms also were determined before transplanting using semi-selective media (Elad *et al.*, 1981).

Experiments were established in commercial tomato fields with a known previous history of FCRR in 1996 and 1997. The experiment was a factorial design with four replications. Main plot was either non-fumigated or fumigated with methyl bromide. The subplot consisted of the following treatments: *T. harzianum* + bacterial strain, *T. harzianum*, bacterial strain and an untreated control in 1996. In 1997, the main plots were the same but the subplot consisted of the following treatments: *G. virens* + bacterial strain, *G. virens*, bacterial strain and an untreated control.

Fusarium crown and root rot of tomato which appears at or after the first harvest was evaluated after harvesting for disease incidence and severity using a rating scale of 0 to 3 where 0=no disease and 3=50 to 100% internal necrosis of root system 10 to 15 cm up the stem from the crown (Datnoff *et al.*, 1995). The mean percentage of severity for each numerical rating was used for estimating the differences between treatments. Fruit number and weights also were used to measure response of plants. Fruits were harvested when approximately 5 to 10% of the fruits were pink, and the fruits were sized and graded according to the USDA standard of large to extra-large fruit, diameter greater than or equal to 6.27 cm. Data were subjected to ANOVA and the means were tested for significant differences using the Protected Fisher's Least Significant Difference. Arcsine-transformation were used if appropriate.

RESULTS

Effect on transplant growth in 1996: *Trichoderma harzianum* alone, the bacterial strain alone or both microorganisms in combination significantly ($P \leq 0.05$) increased stem caliper, height, fresh and dry shoot weight, and leaf area of the four week old tomato transplants over the control (Table 1). Only *T. harzianum* increased fresh ($P=0.08$) and dry ($P \leq 0.05$) root weight over the control. The combination of both microorganisms together had the greatest affect on leaf area.

Effect on root populations in 1996: Root colonization (cfu/g root tissue) of tomato transplants by the bacterial strain was very similar in value whether heated or non-heated before plating onto a semi-selective medium (Table 2). Populations of the bacterial strain alone were similar to the combination of the bacterial strain + *T. harizanum*. Populations of *T. harizanum* were 15% greater alone in comparison to T. harizanum and the bacterial strain. All controls contained either the bacterial strain or *T. harizanum* but were at populations well below the treatments. It is possible that the controls were contaminated by dispersal of inoculum during watering.

Effect on tomato yields in 1996: Differences were not observed in the first harvest for large or small fruit weight and large or small fruit number between the bacterial and fungal microorganisms and the control whether non-fumigated or fumigated with methyl bromide (Tables 3 and 4). Yields in the non-fumigated plots were much lower in comparison to the fumigated plots because of a heavy infestation of root knot nematode (Table 4 and 5). It was interesting to note, however, that the number and weight of large to extra-large fruit in the first harvest increased between 22 to 44 % and 31 to 48%, respectively, for the bacterial and fungal microorganisms over the control in the fumigated plots. The total weights and numbers of fruit in this first harvest increased similarly. Differences were not observed between treatments in the non-fumigated or fumigated with methyl bromide plots in the second harvest (data not shown).

Effect on FCRR in 1996: The bacterial strain alone or in combination with *T. harzianum* significantly reduced the incidence (P=0.09) and severity (P=0.05) of FCRR under fumigated conditions (Table 5). There also was a 13.3% decrease in FCRR for *T. harzianum* but this treatment was not significantly different from the control. Although some FCRR was apparent, the results in the nonfumigated plots were very difficult to assess since there was a heavy infestation of root knot nematode. Among all treatments the ratings were 4.2 to 5.0, where 5=100% of the roots infected by root knot nematode. In addition, other pathogens such as *Rhizoctonia solani* and *Pythium aphandermatium* were found infecting the roots and crowns, too.

Effect on transplant growth in 1997: *Gliocladium virens* alone or in combination with the bacterial strain significantly ($P \leq 0.05$) increased leaf area, fresh shoot weight, height and petiole number over the control (Table 6). However, *G. virens* alone and the bacterial strain alone significantly increased dry shoot and root weight.

Effect on root populations in 1997: Colonization of the roots (cfu/g fresh root weight) by the bacterial strain or *G. virens* whether alone or in combination was extremely high (Table 7). Populations of the bacterial strain alone were greater by 20% in comparison to the bacterial strain in combination with *G. virens*. However, populations of *G. virens* alone was 72% greater in comparison to the *G. virens* in combination with the bacterial strain.

Effect on tomato yields in 1997: Both the bacterial strain alone and the non-treated control under non-fumigated conditions were significantly lower for number and weight of large fruit in comparison to all the other treatments (Table 8). The total number and total weight of large fruit were significantly lower for the non-fumigated control and non-fumigated bacterial strain alone in comparison to the fumigated control. This same trend was true for total fruit number and weight, too. Differences between all treatments were not detected for number and weight of small fruit. The number and weight of large fruit and the number and weight for total fruit for *G. virens* alone and in combination with the bacterial strain under non-fumigated conditions were not significantly different from the fumigated control.

Effect on FCRR in 1997: Disease incidence for FCRR ranged from 40 to 75% in the field fumigated with methyl bromide and from 70 to 90% in the non-fumigated field (Table 9). Severity was relatively low in both the fumigated (3.0 to 20.6%) and non-fumigated plots (5 to 11.2%). Only the bacterial strain alone in the fumigated plots significantly reduced FCRR in comparison to the control.

DISCUSSION

An important characteristic necessary for the acceptance and effectiveness of microorganisms for biological control is their ability to survive in foreign environments as well as successfully colonize plant roots during the required protection period against plant pathogens (Nemec *et al.*, 1996). By incorporating microorganisms into pasteurized plant mixes before seeding, these biocontrol microorganisms have a minimal level of competition from other microorganisms. Consequently, the planting mix environment was very favorable for the high level of root colonization (greater than 1 x 10^6 cfu/g fresh root tissue) achieved by the bacterial strain and fungi used in this study. In addition, *G. virens* and *T. harzianum* also were compatible with this bacterial strain and vice versa because of the high level of root colonization by these microorganisms.

Another potentially important feature of using microorganisms for biocontrol is their influence on transplant growth and development. The bacterial strain, *G. virens* and *T. harzianum* alone and in combination strongly influenced height, leaf area, root and shoot weight and stem caliper in the first four to five weeks of growth. If microorganisms are a good candidate for promoting a more vigorous tomato transplant as demonstrated in this study, this could be of potential interest to many tomato growers who would like to transplant into the field at selected time intervals or into the field earlier.

The high level of root colonization by the bacterial strain appeared to be effective enough in the field to significantly reduce the incidence and severity of FCRR under fumigated conditions in both years. Although *T. harzianum* did not significantly reduce FCRR in the field, the 13% reduction observed is similar to other studies that have been conducted using this fungus (Datnoff *et al.*, 1995; Nemec et al., 1996). Although *G. virens* did not reduce FCRR in this study, the relatively low disease severity level of FCRR in the field or other environmental factors probably accounts for this lack of consistent significance.

Effectiveness of microorganisms used for biocontrol to reduce a disease such as FCRR should translate into increased plant yield. Reduction of FCRR by the use of *T. harzianum* and G. intraradices had improved tomato yields between 4 to 25%, although not significantly (Datnoff *et al.*, 1994). Similar observations were made in 1996, the number and weight of large to extra-large fruit in the first harvest increased between 22 to 44 % and 31 to 48%, respectively, for the bacterial strain and *T. harzianum* over the control in the fumigated plots. In addition, these microorganisms may be able to maintain yields under non-fumigated conditions equal to those fumigated by methyl bromide. The number and weight of large fruit and the number and weight for total fruit for *G. virens* alone and in combination with the bacterial strain under non-fumigated conditions were not significantly different from the fumigated control.

These studies help to support the selected use of microorganisms used for biocontrol to reduce a root disease such as FCRR. The concept of adding a biological control agent alone or in combination into a planting mix at seeding is an efficient, inexpensive means to provide a more vigorous transplant with disease protection when it is transplanted to the field (Nemec *et al*, 1996). In addition, these microorganisms may enhance transplant growth that could potentially lead to improved yields. These microorganisms can be used in conjunction with other alternative IPM practices or chemicals for methyl bromide. However, these results demonstrate the difficulty in obtaining significantly reliable differences among these microorganisms for biological control under field conditions. This lack of reproducibility is not unexpected as commonly an organism used for biological control is taken from one environment and expected to act in another to which it is not adapted (Whipps, 1992). In addition, these organisms are subjected to the rigors of fluctuating environmental conditions that can influence performance. Biological control agents are always compared with existing chemical controls and often are inferior on grounds of efficacy, i. e. chemicals generally work irrespective of environment or inoculum potential. Consequently, research in biological control needs to be extended because of these reasons, and site and seasonal variations.

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Table 1. Influence of biological treatments on different plant growth parameters of five week old tomato transplants ("SUNNY") in 1996.

Treatment	Stem Diameter (mm)	Height (cm)	Shoot Weight (g) Fresh	Shoot Weight (g) Dry	Root Weight (g) Fresh	Root Weight (g) Dry	Leaf Area (cm^2)
Trichoderma harzianum + Bacterial Strain	3.0 a	15.1 a	1.04 a	0.07 a	0.25 ab	0.04 b	22.7 a
Trichoderma harzianum	3.0 a	14.1 a	0.89 ab	0.08 a	0.31 a	0.06 a	17.9 b
Bacterial Strain	2.8 a	14.1 a	0.79 b	0.02 c	0.18 b	0.03 b	18.4 b
Control	2.2 b	10.7 b	0.58 c	0.04 b	0.17 b	0.02 b	14.2 c

Table 2. Populations of bacterial strain and *Trichoderma harizanum* on the roots of five week old tomato transplants ('SUNNY') in 1996.

Treatments	Bacterial Strain (cfu/g root)	*Trichoderma harzianum* (cfu/g root)
Trichoderma harzianum + Bacterial Strain	1.2×10^7	5.8×10^5
Trichoderma harzianum	———	6.8×10^5
Bacterial Strain	1.1×10^7	———
Control	2.2×10^3	2.6×10^5

Table 3. Influence of biologicals on fruit development of first harvest of tomatoes ("SUNNY") in a fumigated field with methyl bromide in 1996.

Treatments	Number (#/4 plants)		Weight (kg/4 plants)		TW*	TN*
	Large Fruit	Small Fruit	Large Fruit	Small Fruit		
***Trichoderma harzianum* + Bacterial Strain**	36.2 a	9.5 a	5.5 a	0.9 a	6.4 a	45.6 a
Trichoderma harzianum	42.5 a	10.0 a	6.2 a	0.9 a	7.0 a	52.5 a
Bacterial Strain	38.3 a	9.3 a	6.1 a	1.1 a	7.2 a	47.6 a
Control	29.5 a	9.0 a	4.2 a	0.8 a	4.9 a	38.5 a

TW=Total Weight of large and small fruit.
TN=Total Number of large and small fruit.

Table 4. Influence of biologicals on fruit development of first harvest of tomatoes ("SUNNY") in non-fumigated field in 1996.

Treatments	Number (#/4 plants)		Weight (kg/4 plants)		TW*	TN*
	Large Fruit	Small Fruit	Large Fruit	Small Fruit		
***Trichoderma harzianum* + Bacterial Strain**	18.6 a	22.6 a	2.2 a	1.6 a	3.8 a	41.3 a
Trichoderma harzianum	18.0 a	21.6 a	1.9 a	1.5 a	3.4 a	39.6 a
Bacterial Strain	25.3 a	18.0 a	3.1 a	1.3 a	4.4 a	43.3 a
Control	18.3 a	21.0 a	2.2 a	1.6 a	3.7 a	39.3 a

*TW=Total Weight of large and small fruit.
*TN=Total Number of large and small fruit.

Table 5. Influence of biologicals on incidence and severity of *Fusarium* crown and root rot in a non-fumigated and fumigated methyl bromide field in 1996.

Treatments	Fumigated		Non-fumigated*	
	Incidence	Severity**	Incidence	Severity**
***Trichoderma harzianum* + Bacterial Strain**	26.6 b	0.86 b (5.1)	100 a	1.14 a (10.2)
Trichoderma harzianum	43.3 ab	0.98 ab (10.3)	100 a	1.18 a (12.6)
Bacterial Strain	23.3 b	0.85 b (5.4)	86.6 ab	1.10 a (09.8)
Control	56.6 a	1.08 a (15.0)	100 a	1.14 a (10.2)

*Nonfumigated treatments were heavily infested with root knot nematode. Using a rating scale of 0 to 5, where 0= no galls and 5≥ 100% of the roots are infected, the ratings ranged between 4.2 to 5.0 among all the treatments. Although symptoms like FCRR were observed, other pathogens such as *Rhizoctonia solani* and *Pythium aphandermatium* were found infecting the roots and crowns.
**Arcsine-transformed data of percentage of disease severity, numbers in parentheses represent actual mean percentages of disease severity.

Table 6. Influence of biologicals on different plant growth parameters of four week old tomato ('Sunny') transplants in 1997.

Treatments	Stem Caliper (cm)	Leaf Area (cm^2)	Shoot Weight (g) Fresh	Shoot Weight (g) Dry	Root Weight (g) Fresh	Root Weight (g) Dry	Height (cm)	Petiole Number
Control	2.46 ab	17.6 de	0.82 cd	0.056 cd	0.121 abc	0.056 cd	12.5 de	4.5 cd
Bacterial Strain (BS)	2.45 b	18.4 cde	0.91 bc	0.073 ab	0.141 a	0.073 ab	13.4 cd	4.7 abcd
Gliocladium virens (GV)	2.69 a	25.5 a	1.21 a	0.078 a	0.122 ab	0.078 a	17.9 a	5.2 a
GV + BS	2.51 ab	25.8 a	1.13 a	0.064 bc	0.122 ab	0.064 bc	15.7 b	5.1 ab

Table 7. Populations of bacterial strain and *Gliocladium virens* on the roots of four week old tomato transplants in 1997.

Treatments	Bacterial Strain (cfu/g fresh root)	*Gliocladium virens* (cfu/g fresh root)
Control	-	-
Bacterial Strain (BS)	5.68×10^7	-
B S	1.41×10^8	-
Gliocladium virens (GV)	-	1.06×10^7
GV + BS	1.15×10^7	7.63×10^6

Table 8. Influence of biologicals on fruit development of tomatoes ('Sunny') harvested in 1997.

Treatments*	Number (#/4 plants) Large Fruit	Number (#/4 plants) Small Fruit	Weight (kg/4 plants) Large Fruit	Weight (kg/4 plants) Small Fruit	Total Fruit Number (#/4 plants)	Total Fruit Weight (kg/4 plants)
FUMIGATED						
Control	40.0 a	24.2 a	7.6 a	3.0 a	64.2 a	10.7 a
Bacterial Strain (BS)	38.2 ab	20.0 a	7.5 ab	2.5 a	58.2 ab	10.1 ab
Gliocladium virens (GV)	38.5 ab	17.5 a	7.6 a	2.1 a	56.0 abc	9.8 ab
GV + BS	42.0 a	13.2 a	8.1 a	1.6 a	55.2 abc	9.6 ab
NON-FUMIGATED						
Control	21.8 c	23.5 a	4.2 c	2.7 a	45.2 cde	7.0 cd
Bacterial Strain (BS)	19.2 c	20.8 a	3.6 c	2.4 a	40.0 e	6.1 d
Gliocladium virens (GV)	36.8 ab	15.0 a	7.4 ab	1.8 a	51.8 bcd	9.2 ab
GV + BS	37.5 ab	14.8 a	7.4 ab	1.9 a	52.2 bcd	9.3 ab

Table 9. Influence of biologicals on severity and incidence of Fusarium crown and root rot of tomatoes ('Sunny') in a methyl bromide fumigated and non-fumigated field in 1997.

Treatments	% Disease Severity*	% Disease Incidence
FUMIGATED		
Control	2.8 ab (10.6)	65.0 ab
Bacterial Strain (BS)	1.5 c (3.0)	40.0 b
Gliocladium virens (GV)	3.7 a (19.1)	75.0 a
GV + BS	3.7 a (20.6)	65.0 ab
NON-FUMIGATED		
Control	2.9 ab (10.1)	85.0 a
Bacterial Strain (BS)	3.2 ab (11.2)	90.0 a
Gliocladium virens (GV)	2.1 bc (5.0)	70.0 ab
GV + BS	2.6 abc (7.8)	85.0 a

*Arcine-transformed data of percentage of disease severity, number in parenthesis represent actual mean percentages of disease severity.

ESTIMATING THE DEMAND AND AVAILABILITY OF SEASONAL AGRICULTURAL LABOR IN THE SOUTHWEST FLORIDA TOMATO INDUSTRY

Fritz M. Roka
Southwest Florida Research and Education Center
IFAS, University of Florida
Immokalee, FL

The Florida tomato industry depends on a sizable number of seasonal farmworkers. Unlike the citrus industry which employs seasonal farmworkers primarily during harvest periods, the tomato industry utilizes farmworkers throughout the season, from the time beds are prepared to the post-harvest clean up. University of Florida crop budgets estimate more than 114 man-hours are required to lay plastic, transplant, stake, tie and prune one acre of tomatoes. This work is done primarily by seasonal farmworkers and does not include the labor hours of tractor drivers and farm managers. Seasonal farmworkers are also important during harvest. Between 70 and 90 additional man-hours are required to harvest 1,400 (25 pound) cartons, approximately the production from one acre. Labor payments to seasonal farmworkers ($1,762 per acre) account for one third of the combined operating and harvest costs ($5,151 per acre). When fixed costs, packing and other selling costs are added, 15% of all costs ($11,720 per acre) are paid to seasonal farmworkers (Smith and Taylor).

Documenting the number of farmworkers and monitoring changes in the size and composition of the work force has become an important issue. In recent years, Florida's citrus and vegetable growers have expressed concern over the future availability of seasonal farmworkers. Industry officials fear that tighter immigration policies and a robust U.S. economy will reduce and divert the supply of potential farmworkers to a point where agricultural operations will be adversely affected. Growers and their industry associations are considering several options, such as grower provided housing and federal H-2A programs, to insure a reliable supply of future farmworkers.

Critical to these efforts are estimates of the industry's labor requirement and the number of available farmworkers. Developing these estimates has proved to be an elusive task. A high percentage of seasonal farmworkers migrate in and out of producing areas, making accurate census counts difficult, if not impossible to complete. Further, a significant number of farmworkers move among employers during the season. Therefore, counting workers on the basis of annual W-2 forms would inflate the overall count by the number of workers who receive multiple W-2 forms. Finally, the presence of a significant number of illegal aliens complicates any counting process.

The purpose of this paper is to explain a feasible method to estimate farmworker numbers at specific times of the year. The technique depends on three points of information – total production, worker productivity, and typical work week schedules. Results reported in this paper pertain to the tomato industry in southwest Florida[1] and reflect findings from employer and farmworker surveys initiated during the 1997/98 production season.

More than 40% of Florida's tomato acreage is in southwest Florida (Tomato Committee Report). During the 1997/98 production season, more than 14,000 acres of tomatoes in southwest Florida were planted. Based on the crop budget information presented above, more than 2.5 million man-hours of seasonal farm labor were required to grow and harvest the 1997/98 southwest Florida tomato crop. The total hours were spread unevenly across a season that started in early August and ended in early spring. Demand for tomato farmworkers is expected to track with planted acreage, starting slowly in August, escalating during the fall months, reaching a peak between November and February before tapering downward during the spring of the year.

A procedure for estimating farmworker numbers begins by selecting a reference day. Since many farmworkers shift among agricultural operations, restricting the reference period to one day eliminates the likelihood of counting one person more than once. During the 1997/98 season, January 6th was selected as the reference day[2] on which to base a farmworker count. Such an estimate would reflect the demand for farmworkers during peak production.

Table 1 provides the information and key assumptions used to estimate the number of seasonal farmworkers employed in the southwest Florida tomato industry. The first step outlines field tasks and estimates the acreage by task. The Florida Agricultural Statistic Service publishes weekly reports documenting tomato acreage in southwest Florida at various stages of production. For the week ending January 10th, 7,256 acres were being harvested and another 5,437 acres were at various growing stages. Assuming vegetable operations work six days a week, daily labor requirements would be based on harvesting 1,206 acres and 906 acres that were either planted, staked, or tied.

From employer interviews, average worker productivity rates were determined. For instance, one worker can transplant one-half acre of tomato seedlings per day. Therefore, an estimate of 66 workers were required to transplant 33 acres per day. Using similar logic, an estimated 1,460 farmworkers were employed by tomato growers in southwest Florida on January 6th to do field cultural tasks (Table 1).

Estimating harvest workers depended on two assumptions. First, per acre tomato production averaged 1,400 (25 pound) cartons. Second, the total harvest was distributed as 70% first pick, 20% second pick, and 10% third pick. Employer payroll records indicated that a typical worker picks slightly more than 19 cartons per hour and harvests six hours per day. Therefore, in one day an average worker picks 115 cartons. The evidence suggested that a worker's productivity remained constant between first, second and third harvests. Table 2 combines harvest acreage, yield and worker productivity to estimate that on January 6th, 3,985 farmworkers were employed harvesting tomatoes.

The total estimate of tomato farmworkers, 5,445 (Table 1), represents the number of farmworkers employed by tomato growers on January 6th. This value should be interpreted as an estimate of average daily industry demand during the peak period of the season. The supply of farmworkers, or the number of farmworkers available and willing to work, is a different value and more complex to determine. Supply of farmworkers depends on worker preferences, the prevailing wage rates, general working conditions, and competing employment opportunities. Information about all these factors were not available. However, more than 120 vegetable farmworkers were interviewed and asked about their work week schedules. On average, a typical vegetable farmworker worked 31 hours per week. Assuming a vegetable operation could employ one person 48 hours per week (six days times eight hours per day), the 31 hours of a typical vegetable farmworker represents 0.646 of a full time position. In other words, more than ten tomato workers are employed for every seven positions. Dividing 5,445 positions by 0.646 provides an estimate of the overall farmworker supply, or 8,431 people.

Demographic characteristics of seasonal farmworkers have an important bearing on future labor supplies. More than 90% of the vegetable workers interviewed in southwest Florida indicated that they are migrant farmworkers. Between August and October, 89% of the migrant farmworkers arrive in southwest Florida with September accounting for 55% of migrant farmworker arrivals. Their residency in southwest Florida lasts until late spring when ninety-four percent of the migrant farmworkers leave the region in either May or June. The high percentage of migrant farmworkers creates imposes a greater degree of uncertainty that farmworkers will return next season.

SUMMARY

At the peak of the southwest Florida tomato season, more than 8,400 farmworkers are employed in either field or harvesting crews. While some attempt was made to adjust for underemployment of farmworkers, the estimate of 8,400 workers more closely represents the demand for labor services by tomato growers.

[1]Southwest Florida includes Collier, Hendry, Lee, Glades and Charlotte counties. More than 90% of the tomato acerage is in Collier, Hendry and Lee counties.

[2]Selection of the reference date depended not only on vegetable production, but also on the peak harvest of the early season citrus crop.

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Table 1: Southwest Florida tomato acreage by field task and estimation of required farmworker numbers for January 6, 1998.

Production Stage	Task	Southwest Florida tomato acreage inventory: [1/] Jan 4 -10, 1998	Average daily acreage [2/]	Worker productivity rates [3/]	Number of farmworkers as of Jan. 6, 1998
		ac	ac	ac / worker-day	number of workers
pre-fruit	transplant	200	33	0.5	66
pre-fruit	stake	1,673	279	0.5	558
pre-fruit	1st prune	1,673	279	1.5	186
pre-fruit	1st tie	1,673	279	1.5	186
pre-fruit	2nd prune	1,200	200	1.5	133
pre-fruit	2nd tie	1,200	200	1.5	133
fruit set	3rd tie	957	160	2.0	80
pre-harvest	4th tie	1,407	235	2.0	118
	Growing acreage	**5,437**		**Field workers**	**1,460**
1st harvest	1st pick	1,579	263	4/	
2nd harvest	2nd pick	2,913	486	4/	
3rd harvest	3rd pick	2,764	461	4/	
	Harvest acreage	**7,256**		**Harvest workers**	**3,985**
complete	clean-up	421	70		
	Total Acreage	**13,114**		**Tomato farmworkers [5/]**	**5,445**

Notes:

1/ Acreage based on FASS Tomato Report No.18 indicating tomato acreage inventory in southwest Florida as of January 10, 1998. A total of 3,073 acres were in "pre-fruit set" category.

2/ Daily acreage based on assumption of six day work week and total acres evenly distributed across work days.

3/ Worker productivity rates based on conversations with several southwest Florida growers.

4/ See Table 2 for estimation of harvest workers.

5/ This number is an estimate of workers employed on January 6th by southwest Florida tomato growers.

Table 2: Estimation of farmworkers engaged in tomato harvest on January 6, 1998.

Harvest number	Jan 6th acreage 1/	Yield 2/	Harvested cartons	Worker productivity 3/	Worker count
	ac	carton/ac	cartons	carton / worker-day	number
1st	263	980	257,740	115	2,241
2nd	486	280	136,080	115	1,183
3rd	461	140	64,540	115	561
Number of Farmworkers harvesting tomatoes Jan. 6, 1998					3,985

Notes:

1/ See Table 1.

2/ One acre of tomato assumed to produce 1,400 (25 pound) cartons. Distribution of yield assumed to be 70% harvested at 1st pick, 20% harvested at 2nd pick, and 10% harvested at 3rd pick.

3/ Based on southwest Florida employer surveys (1998), an average worker picks 15 (32 pound) bucket of round tomatoes per hour and harvests six hours per day. One bucket equals 1.28 cartons.

Table 3: Demographics of seasonal farmworkers employed on southwest Florida vegetable farms.

Number of workers interviewed	121
Percent male	88%
Percent Mexican origin	89%
Percent other Hispanic origin	10%
Percent Haitian origin	1%
Percent living alone	5%
Percent living with companions	76%
Percent living with family	13%
Percent living with relative	6%
Household size of families / number of children	4 / 2
Hours worked Jan 4th - 10th ,1998	44.1 hours/week
Hours worked most recent seven days	17.5 hours/week
Average hours/week	30.8 hours/week

Source: Roka, F.M. Southwest Florida Agricultural Labor Study. 1998.

FLORIDA AUTOMATED WEATER NETWORK

PROVIDING QUALITY WEATHER DATA TO A WIDE VARIETY OF USERS

John Jackson

IFAS, University of Florida, Lake County Extension Service

INTRODUCTION

Several factors were instrumental in the establishment of the Florida Automated Weather Network (FAWN). The National Weather Service eliminated agricultural forecasts on April 1, 1996 stating they were products for a special interest group. Nine months later a major freeze hit Central and South Florida causing an estimated $300 million economic loss. Growers felt it was time to deal with a gap in weather information and through various associations formed the Agricultural Weather Task Force. The members include Florida Fruit and Vegetable Association, Florida Citrus Mutual, Florida Farm Bureau, Florida Nursery and Growers Association, Florida Department of Agriculture and Consumer Services, Senator Bob Graham's office, University of Florida Institute of Food and Agricultural Sciences (IFAS) and an independent grower.

The Task Force suggested IFAS submit an addition to its 97/98 budget to fund a comprehensive agricultural weather program that would interface the University of Florida with the National Weather Service to provide increased weather data, coordinate weather related research, and assist Florida agriculture to deal with abnormal weather events. In addition the Task Force strongly supported the privatization of agricultural weather forecasting. The legislature provided IFAS with $125,000 (half of the request). The Task Force then recommended that IFAS establish a network of automated weather stations to be located at Research and Education Centers (REC) in Central and South Florida. They strongly urged IFAS to have the network up and running by December 1, 1997 in order to provide growers with data for the winter. The Task Force felt the automated network would provide a highly visible and useful expenditure of the special appropriation. They also realized that annual funding is critical if a comprehensive agricultural weather program is to function.

LOCATIONS

The enclosed map shows the locations for the nine (9) REC's and main campus in Gainesville that have FAWN stations. In addition six (6) sites that are part of the Lake/Orange Extension network have been included to bring the total automated sites to sixteen (16). It is planned that over time other automated networks will be added to the system. The South Florida Water Management District has been of great value in the design of FAWN and has indicated they want to be a partner as has the Southwest Florida Water Management District. Immediate plans call for the addition of six(6) REC locations in North and West Florida to the system. Long term goals for FAWN include incorporating existing automated networks to generate an extensive data base.

DATA COLLECTED AND THE PROCESS

The data collected and the process used are described in accompanying the two graphics. Also provided is a schematic of the data flow from the automated sites to the end user. Currently the data is available through the University of Florida web site (http://fawn.ifas.ufl.edu) and a voice data system using conventional telephone (352/846-3100). The voice data system will be expanded to several locations in Florida to improve access to the system. A number of delivery methods will be used to provide users with the data. Hopefully commercial TV stations, the Weather Channel, and the National Weather Service radio network will have the data available during critical events.

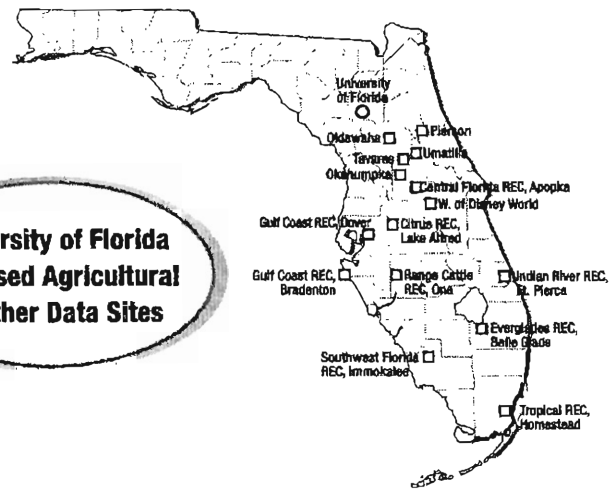
TIME FRAME

The system began operation on January 1, 1998. Currently sixteen (16) sites are providing data hourly. During 1999 plans call for the addition of six (6) more sites at REC facilities in Hastings, Live Oak, Monticello, Madison, Quincy and Jay. The data base, web site and voice data delivery system will be modified and improved. Currently funding does not allow for the necessary work needed to incorporate additional automated networks. Hopefully the 99/00 budget will address this situation.

CONCLUSION

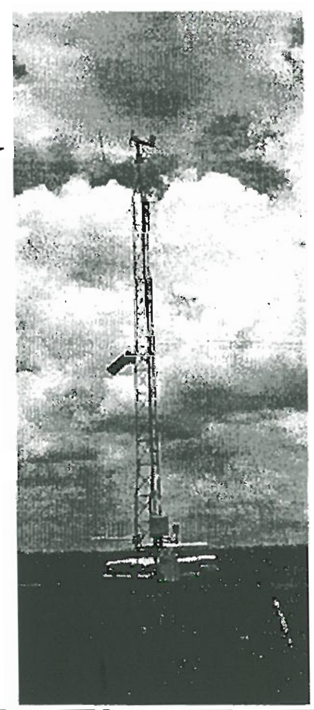
FAWN is in operation providing a wide variety of users with accurate and timely weather. An ongoing effort is needed to provide agriculture with accurate weather data that can be used in the development of models, assist forecasters, establish historical records, interact with other data bases, and much more. FAWN is just the first step, growers need to work hard to see that the complete UF/IFAS **Weather Program is implemented**.

Locations



University of Florida Proposed Agricultural Weather Data Sites

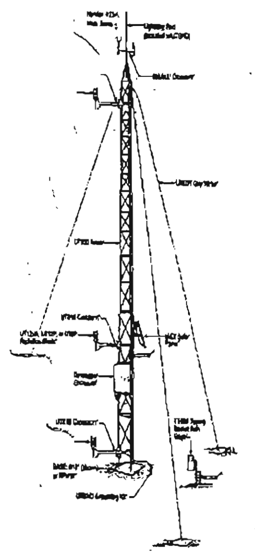
Weather Data Collected



- Temperature - 2, 6 and 30 feet
- Soil temperature - 4 inches
- Wind speed and direction
- Rainfall
- Relative humidity
- Barometric pressure
- Leaf wetness
- Total radiation

Data Collection Process

- Solar powered
- Microprocessor
  - collects data continuously
  - can store 5 days
- Downloads every 15 minutes
- Hardwire to computer at REC
- Transferred to central data base



Data Flow

End Users
Agriculture
Private Forecasters
Government

Delivery Devices
Internet - NWS Radio
Voice - Weather Channel
Extension Programs

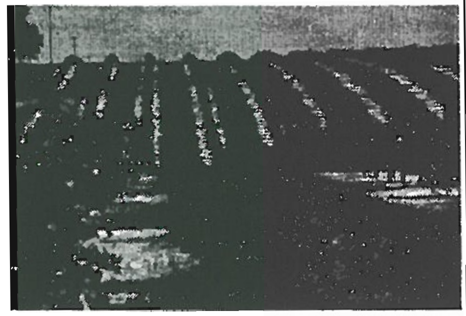
Models
Temp Forecast
Irrigation
Plant Pests

Weather Data Base
Temperature - Humidity
Wind speed and direction - Rainfall
Pressure -Radiation - Leaf wetness

UF/IFAS
Research Centers
Extension Networks

Other Networks
NWS sites
Water Management Districts
Private

Distribution of the Data



- Internet
- NWS Weather Radio
- Voice Mail
- Weather Channel
- Extension Programs
  - Lake/Orange/Volusia/Marion/Brevard/Osceola/Flagler/Seminole
  - Polk/Hillsborough
  - Highlands/Hendry/DeSota/Collier/Hardee
  - Dade

GROWTH AND YIELD OF TOMATO AS AFFECTED BY TRANSPLANT CONTAINER CELL SIZE[1]

C.S. Vavrina and Mireia Arenas
Southwest Florida Research and Education Center
IFAS, University of Florida
Immokalee, FL

SUMMARY

Tomato transplants grown commercially in a container cell size of 4.4 cm had greater dry matter accumulation at planting and 30 days after planting than plants grown in 2.5 cm cells (the industry standard.) Additionally, transplants grown commercially in a container cell size of 4.4 cm produced earlier and yielded greater than transplants grown in 2.5 cm cells. The cell size impact was more dramatic in the spring than in the fall, perhaps due to environmental complications experienced in the fall. Our recommendations at this time would be to produce tomato transplants in cells of at least 4.4 cm if economically feasible.

INTRODUCTION

Today's competitive agricultural environment demands that FL growers produce high yields of good quality fruit to meet market demand. Global market economics have been unfavorable with respect to tomato over the past several years. Therefore, when the market is favorable, growers require higher yields to compensate for the "bad" years and escalating production costs. One simple approach to augment yields may be to increase the container cell size in which the tomato transplant is grown.

As early as 1961, researchers noticed the benefits of growing vegetable transplants in larger container volumes (Peirce and Peterson, 1961). Most recently NeSmith and Duval (1997) reviewed the effect of container cell size and concluded that a reduction in container cell size increased the potential of root restriction. But root restriction alone did not account for the many conflicting results found in the literature. A grower-oriented review of cell size by Vavrina (1997) further indicated that regardless of the lack of statistical significance in some studies, there was an overwhelming trend toward earlier and greater yields with larger cells in almost all studies.

The objective of the current study was to determine the impact of container cell size on transplant growth, stand establishment, and yield of tomato in both spring and fall seasons.

MATERIALS AND METHODS

Commercially-grown tomato transplants were obtained from local greenhouses in the Immokalee, FL area. Container cell sizes are commonly referred to by the measurement of a single side. This study examined 2.5 cm (or 1 inch, 200 cells of 24 cc volume), 3.8 cm (or 1.5 inch, 150 cells of 38 cc volume) and 4.4 cm (or 1.75 inch, 128 cells of 48 cc volume) cells in styrofoam trays (Speedling Inc., Sun City, FL). 'Solimar' (Asgrow Seed, Kalamazoo, MI) was used in the fall trial (Barnett Partin Plants, Felda, FL) and 'FTE 30' (Petoseed, Saticoy, CA) was used in the spring trial (Johnson Plants, Immokalee, FL). These varieties were chosen specifically for their performance in the season in which they were grown.

Each season a seepage irrigation, methyl bromide fumigated (269 kg•ha^{-1}, broadcast), granular fertilized (220N-78P-300K kg•ha^{-1}), plastic mulched (3 mil, white in fall, black in spring), 81 cm wide bed was prepared at the Southwest FL Research and Education Center of the University of Florida in Immokalee, FL. Two weeks were allowed for fumigant action. Holes were punched in a single row, 46 cm pattern on 2 meter centers, and transplants were set on 30 Sept. 1996 and 19 Feb. 1997. Manzate and copper fungicides were applied weekly to prevent the advancement of bacterial spot. Various *Bacillus thuringiensis* were also applied to reduce worm pressure.

Six replications were set out in a randomized complete-block fashion. Data were taken on plant dry weight (at planting, and 30 and 45 days after planting [DAP]), developing fruit 45 DAP, and yield. Yield was separated into red and breaker fruit and mature-green fruit and further subdivided into medium, large, and extra-large size. Data were analyzed by ANOVA with mean separation by Fisher's Protected LSD (SAS, 1988).

RESULTS AND DISCUSSION

Early Plant Growth. Total plant top growth (stems and leaves) at planting reflected the early impact of cell size (Tables 1, 2). Each successive increase in cell size resulted in an increase in plant dry matter accumulation. This result was particularly true in fall-grown transplants where environmental conditions (high temperature and high light) were more conducive to rapid growth. Stem length in both spring and fall was within acceptable limits (i.e., less than 10 cm) by grower standards (data not shown). Peterson *et al.* (1991) also noted shoot height and biomass reduction of tomato transplants in smaller container cells.

Thirty days after planting in the fall, the benefit of greater dry matter accumulation with larger container cell size was still evident as the plants grown in larger cells established more rapidly (Tables 1, 2). Plant growth in the spring did not mimic this response. By 45 DAP, the effect of the large cell increased dry matter accumulation had dissipated, as plants appeared to achieve similar growth rates.

Fruit initiation at 45 DAP did not show an advantage with the increased cell size in the fall trial, but larger cells resulted in greater fruit loads in the spring trial (Tables 1, 2). Environmental conditions in the spring (lower light level and lower temperature) were perhaps more conducive to fruit set and hence the impact of the larger cell more apparent.

Yield Parameters. Fruit maturity (i.e., earliness) in tomato can be generally determined by red fruit production if the crop is healthy. First harvest, red fruit yield in both the fall and spring showed transplant production in the 4.4 cm cell size resulted in earlier production (Tables 1, 2). This factor may be tied directly to a "larger" plant at planting. A larger, more vigorous plant may reach maturity sooner than a smaller plant, and plants grown in the 4.4-cm cell had twice the dry weight of those grown in the 2.5-cm cell at field planting. Ruff *et al.* (1987) noted a delay in tomato fruit maturation as influenced by restricted root growth in plants grown in small and large pots.

Marketable, extra-large (XL) fruit yield was not significantly different between treatments in the fall. However, the 4.4-cm cell size plants produced more XL fruit than the 2.5-cm cell size plants in the spring. The production of XL fruit is important to the grower as XL fruit most often commands the highest price. Fruit sizing might also be considered a sign of maturity, as larger fruit tend to be on the plant for longer periods of time.

Total marketable fruit followed the same pattern as that of XL fruit. Nothing significant in overall yield was noted in the fall, but plants grown in 4.4 cm cells had higher overall yields than plants grown in 2.5 cm cells in the spring through three harvests.

These data tend to support the larger cell size benefits purported by other vegetable researchers (Csinzinsky and Shuster, 1993; Weston, 1988) and specifically tomato (Weston and Zandstra, 1989). Tomato yield and earliness of production was enhanced by larger container cell sizes in the current study. Fall trial results were less supportive of this finding, but this might have been due to a freeze that terminated the trial before a third harvest could be completed, and a late first harvest that might have obscured XL fruit production.

Though these results represent only two seasons of research, our recommendations at this time would be to produce tomato transplants in cells of at least 4.4 cm if economically feasible. The enhancement of earliness and yield may aptly cover the additional cost of production.

[1]Reprinted from FL State Hort. Soc. 110:264-265.

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Table 1. Field response of tomato transplants grown in container cells of varying size (and volume) Immokalee, FL., Fall, 1996 (all yields from 10 plants, 2 harvests).

Cell size	Top DW at planting	Top DW 30 DAP[z]	Top DW 45 DAP	Imm. fruit 42 DAP	Red fruit 1st harvest	Total XL fruit[y]	Total fruit
(cm)	(g)	(g)	(g)	(no.)	(kg)	(kg)	(kg)
2.5 x 2.5	0.075	29.5	128	6.3	27	43	70
3.8 x 3.8	0.114	34.4	129	7.3	28	41	69
4.4 x 4.4	0.154	40.8	137	6.8	32	41	70
LSD 0.05	0.023	6.5	NS	NS	3	NS	NS

[z] DAP= days after planting

[y] XL= extra large (minimum diameter > 7.3 cm)

Table 2. Field response of tomato transplants grown in container cells of varying size (and volume) Immokalee, FL., Spring, 1997 (all yields from 10 plants, 3 harvests).

Cell size	Top DW at planting	Top DW 30 DAP[z]	Top DW 45 DAP	Imm. fruit 42 DAP	Red fruit 1st harvest	Total XL fruit[y]	Total fruit
(cm)	(g)	(g)	(g)	(no.)	(kg)	(kg)	(kg)
2.5 x 2.5	0.065	27.9	157	16	0.5	28	41
3.8 x 3.8	0.081	26.0	146	24	1.1	32	48
4.4 x 4.4	0.138	38.8	192	27	5.1	36	55
LSD 0.05	0.030	NS	NS	6	0.8	7	8

[z] DAP= days after planting

[y] XL= extra large (minimum diameter > 7.3 cm)

PROSPECTIVE RELEASES FROM THE UNIVERSITY OF FLORIDA TOMATO BREEDING PROGRAM

J. W. Scott
University of Florida
Gulf Coast Research and Education Center
5007 60th St. E.
Bradenton, FL 34203

Tomato (*Lycopersicon esculentum*, Mill.) breeding at the University of Florida emphasizes development of inbred lines with characteristics that are beneficial for production in the state. As lines emerge that appear to have desirable horticultural traits, test crosses are made to evaluate their potential as parents. When these results are favorable the inbreds are considered for release and placed in replicated trials to measure marketable yield, fruit size, and various quality traits such as fruit color and firmness. Since there are numerous seed companies breeding tomatoes for Florida which are doing extensive hybridization, and since the University program is quite large, it seems that the best way to get improved breeding material to growers is by making breeding line releases to the seed industry. Then they can make the hybrids with the inbreds which will be grown by the tomato growers. Several releases are planned for 1998 or soon thereafter. One objective of this report to describe these releases.

An alternative to the mature green harvest system that might allow some Florida growers to circumvent competition from Mexico would be to use more careful handling and harvest premium tomatoes with very good flavor and color. This could be done with the development of crimson (*og* gene) varieties which have about 50% more lycopene than normal tomatoes. This idea was proposed earlier (Scott, 1996). In spring 1998 a group of crimson hybrids was tested for yield and horticultural characteristics to determine if any would be acceptable for production in Florida. A second objective of this report is to present these results.

The breeding lines for both trials were grown at Bradenton in spring 1998. Seed was sown in a greenhouse on 14 Jan., transplanted into Todd planter flats (#150) on 28 Jan. and set in the field on 5 Mar. They were grown using standard Florida tomato production practices with seepage irrigation and no pruning. Planting was in a completely randomized block design with three blocks and nine plants per plot in the breeding line trial and eight plants per plot in the crimson trial. Plants in both trials were spaced at 18 inches with 26 inches between plots. There were six beds between irrigation ditches with 5 feet between the bed centers. Fruit were harvested at the breaker stage and beyond on 3, 11, and 18 June. At each harvest the fruit were graded with a tomato grader according to industry specifications. Ten fruit per entry per block at the table ripe stage were used for measuring firmness and color using methods described in the footnotes of Tables 1 and 2.

Descriptions of the prospective releases follow:

FUSARIUM CROWN AND ROOT ROT (*Fusarium oxysporum* f. sp. *radicus-lycopersici*) RESISTANCE

Fla. 7775 has a medium sized, slightly open vine. It has jointless pedicels and fruit are medium- large, flat-round in shape, have light green shoulders, are very firm (Table 1), and have smooth shoulders and blossom scars. The fruit have the crimson (*og*) gene which results in high lycopene production and good red color. Fruit ripen well, are mild in flavor, and are mid-late season in maturity. In addition to crown rot, Fla. 7775 is also resistant to fusarium wilt (*Fusarium oxsporum* f. sp. *lycopersici*) races 1 and 2, verticillium wilt (*Verticillium albo-atrum*) race 1, and gray leafspot (*Stemphyllium solani*). Fla. 7775 has yielded and sized well in trials in 1997 (data not shown) and 1998 (Table 1). It has also performed well as a parent in several hybrids.

Fla. 7781 has a tall determinate vine. Pedicels are jointed. Fruit have a light green shoulder, are medium to large in size, are flat-round, and firm. They ripen well and have the og gene which provides deep red color and high lycopene. Shoulders are smooth, but blossom scars sometimes are rough in cool weather which caused the higher than desired cull production in spring 1998 (Table 1). For hybridization Fla. 7781 should be crossed with parents possessing nipple tip blossom scar genes to insure adequate smoothness. A hybrid with Fla. 7781 and a nipple tip parent is Fla. 7786 and it had impressive marketable yield in the spring variety trial at Bradenton (Howe and Scott, in press). Fla. 7781 has tested well in several other hybrid combinations. Flavor is fair to good. In addition to crown rot resistance Fla. 7781 is also resistant to fusarium wilt races 1 and 2 , verticillium wilt race 1, and gray leafspot.

JOINTLESS PEDICEL, HEAT-TOLERANCE

Fla. 7771 has a medium to tall vine. Fruit are medium to large, flat-round in shape with a smooth blossom scar. Firmness is only medium so it should be crossed with firm parents in hybrid combinations. Some puffiness has been seen which may contribute to the fruit softness. However, firmness was in the range of 'Sanibel' and 'Agriset 761' in spring 1998 (Table 1). External and internal color is slightly pale (Table 1). Flavor is mild and maturity is early-midseason. Fla. 7771 is the first jointless heat-tolerant tomato available with large fruit size. It has been difficult to get large fruit, heat-tolerance and few defects together in a single line. Fla. 7771 yielded well in spring 1998 where it had the highest numerical yield (Table 1), as well as in a summer trial in 1997 at Bradenton (Scott *et al.*, 1997). It has also looked good as a parent in several hybrid combinations. Furthermore, Fla 7771 should provide tomato breeders with a source of jointless heat-tolerance with which to develop improved inbreds.

BACTERIAL SPOT TOLERANCE, HEAT-TOLERANCE

The establishment of race T3 as the principal bacterial spot pathogen (*Xanthomonas campestris* pv. *vesicatoria*) in Florida has further complicated an already difficult breeding project (Jones *et al.*, 1995, Scott *et al.*, 1995b). Three heat-tolerant inbreds with some bacterial spot tolerance were tested in 1998. These were Fla. 7770, Fla. 7827, and Fla. 7824. Their tolerance is primarily to race T1 which will be of less value than race T3 tolerance at this point. The decision on release will be partly contingent on their disease reaction in some T1 inoculated trials in summer 1998. Of the three, I have the most trial information on Fla. 7770. It has yielded well in spring and summer 1997 (data not shown) and in spring 1998 (Table 1). The vine is medium to tall with good fruit cover. Fruit tend to be uniform in size and have good color and gloss. There has been some cuticle cracking which is difficult to understand given the sheen of the fruit which appears to be like that of highly tolerant varieties. Fla. 7770 might make a good parent line even if the level of bacterial spot tolerance is less than desired. It has midseason maturity and flavor is good to very good. Fla. 7827 is somewhat similar to Fla. 7770 but probably needs more testing before release so it will not be discussed further here. Fla. 7824 has some tolerance to bacterial wilt (*Ralstonia solanacearum*) as well as bacterial spot. A bacterial wilt experiment will be conducted during summer 1998 to better categorize the level of resistance. Fla. 7824 was the earliest tomato in the spring 1998 trial but the fruit size was not as large as desired (Table 1). It should be noted that the fruit size of Fla. 7824 was similar to that of Fla. 7324 the heat-tolerant parent in 'Equinox' which yielded and sized well in the same trial. Fla. 7824 has a medium-tall vine which has been very strong over several years of testing. If the bacterial wilt tolerance of Fla. 7824 is similar to that of 'Neptune' (Scott *et al.*, 1995a) then it may be released as a home garden tomato. It could still be used as a breeding line by seed companies.

HEAT-TOLERANCE

Fla. 7776 is a large fruited inbred with some heat-tolerance. It has the *n-2* nipple gene which provides good blossom scar smoothness without leaf curl (Barten *et al.* 1992). It has medium vines. Fruit are globe shaped and some have some zippering. It has good flavor on a scale from poor to excellent. Hybrids with Fla. 7776 have performed well. It may be released but more testing will probably be done first so it is unlikely in 1998. Fla. 7825 is a newer (F_5) inbred which looked impressive in 1997 summer and fall breeding plots. It has a strong, medium sized vine and fruit that are larger, firmer, smoother, and better tasting than previously released heat-tolerant inbreds from this program. However, in the spring 1998 trial the fruit size and yield were not as good as anticipated. Other selections of this line appeared better in breeding plots in the spring and one of those may lead to a future release. For now this will be one to watch.

HIGH FLAVOR, CRIMSON HYBRIDS

Results are in Table 2. The hybrids harvested were selected as the best from a larger group. Horticulturally the hybrids were comparable in yield, fruit size, and firmness to 'Equinox' and 'Agriset 761'. External color of the crimson hybrids tested were comparable to 'Equinox' and better than 'Agriset 761'. Internal color for the crimson hybrids was better than 'Equinox', which was better than 'Agriset 761'. Flavor was only rated by two people, but Fla.7859 and Fla. 7860 were rated the best in flavor. A grower also tasted these and preferred Fla. 7859. The parents of Fla. 7859 are both very good in flavor and this appears to be the prime candidate for a premium tomato of the group tested. An added feature of his hybrid is that it is resistant to fusarium wilt race 3 as well as the standard Florida variety disease resistances. Fla. 7861 and Fla. 7862 have Fla. 7781 as a parent and are fusarium crown rot resistant. Of course more testing is needed before any release can be made. Experimental amounts of seed will be available to Florida growers interested in trialing the crimson hybrids with 7000 numbers. Contact me to make arrangements to get seed.

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Table 1. Yield, fruit firmness and fruit color for tomato cultigens grown at Bradenton, Florida in Spring 1998.

Entry	Early Season Yield (lb/plant)	Early Season Fruit Size (oz)	Early Season Cull (% by wt.)	Total Season Yield (lb/plant)	Total Season Fruit Size (oz)	Total Season Cull (% by wt.)	Firmness[z] (mm deformation)	Fruit Color[y] External (a/b)	Fruit Color[y] Internal a/b
Fla. 7771	5.45 b[x]	6.5 b-d	16.7 fg	17.39 a	5.8 b-d	14.5 c	209 bc	0.47 d	0.58 e-g
Fla. 7770	4.77 bc	6.9 b	23.0 d-g	16.64 ab	5.8 b-d	16.2 bc	193 cd	0.55 bc	0.67 cd
Equinox	7.64 a	6.4 b-d	16.4 fg	16.39 a-c	5.8 b-d	16.1 bc	---	---	---
Fla. 7775	3.62 de	6.3 b-d	15.2 g	15.04 b-d	5.5 c-e	15.4 bc	136 e	0.65 a	0.79 b
Fla. 7827	7.08 a	5.7 b-e	18.9 e-g	14.57 c-e	5.4 c-e	18.2 a-c	200 b-d	0.65 a	0.75 bc
Agriset 761	3.07 de	6.8 b	36.0 a-c	13.89 d-e	5.6 b-e	25.9 ab	225 ab	0.50 cd	0.52 g
Sanibel	1.30 f	6.7 b	43.5 a	13.62 d-e	6.3 b	23.5 a-c	191 cd	0.52 b-d	0.63 d-f
Fla. 7825	3.72 de	5.1 de	23.9 c-g	13.33 d-e	5.1 ef	17.5 a-c	203 b-d	0.57 b	0.64 de
Fla. 7781	4.08 b-d	6.6 bc	37.6 ab	13.05 d-e	5.6 b-d	28.3 a	183 cd	0.58 b	0.90 a
Fla. 7824	7.16 a	5.3 c-e	19.1 e-g	12.76 d-e	4.9 ef	22.9 a-c	---	---	---
Fla. 7324	8.60 a	4.7 e	17.2 fg	12.59 e	4.5 f	21.1 a-c	238 a	0.53 bc	0.58 e-g
Fla. 7776	2.17 ef	8.6 a	33.3 a-d	12.59 e	7.1 a	20.5 a-c	181 d	0.50 cd	0.73 bc

[z]Measured with a pressure tester with a 1 kg (2.2 lb) wt. and a 1.5 cm (1.7 in.) contact plate for 5 seconds. Contact plate was placed over locules on 10 fruit per entry per block. Lower values indicate firmer fruit.

[y]Determined with a Minolta CR-300 Chroma Meter. External color taken in equatorial plane of fruit, internal color for each fruit was a composite of 3 locations including pericarp, placenta, and locule. There were 10 fruit per entry per block sampled. A greater a/b ratio indicates higher red color.

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

Table 2. Yield, fruit firmness, fruit color, and flavor for crimson tomato hybrids and control hybrids grown at Bradenton, Florida in Spring 1998.

	Early Season			Total Season				Fruit Color[y]		
Entry	Yield (lb/plant)	Fruit Size (oz)	Cull (% by wt.)	Yield (lb/plant)	Fruit Size (oz)	Cull (% by wt.)	Firmness[z] (mm deformation)	External (a/b)	Internal (a/b)	Flavor[x]
Fla. 7862	5.47 a-c[v]	8.3 a	19.3 bc	19.05 a	6.4 a	13.7 c	--	--	--	3
Fla. 7860	5.92 ab	6.2 ab	19.2 bc	16.69 ab	5.7 ab	16.5 bc	199 b	0.61 a	0.80 a	4
Equinox	6.09 a	6.1 b	10.1 c	16.53 ab	5.6 b	15.0 c	240 a	0.59 a	0.71 b	3
Agriset 761	2.74 bc	6.8 ab	27.9 b	15.16 b	6.0 ab	22.3 ab	221 ab	0.49 b	0.51 c	2.5
Fla. 7861	2.52 c	5.7 b	46.2 a	15.02 b	5.8 ab	23.4 a	205 b	0.56 a	0.79 a	3.5
E305	4.30 a-c	6.9 ab	20.8 bc	14.73 b	5.8 ab	17.4 a-c	--	--	--	3
Fla. 7859	3.43 a-c	5.9 b	16.7 bc	14.03 b	5.6 b	14.4 c	200 b	0.60 a	0.84 a	4

[z]Measured with a pressure tester with a 1 kg (2.2 lb) wt. and a 1.5 cm (1.7 in.) contact plate for 5 seconds. Contact plate was placed over locules on 10 fruit per entry per block. Lower values indicate firmer fruit.

[y]Determined with a Minolta CR-300 Chroma Meter. External color taken in equatorial plane of fruit, internal color for each fruit was a composite of 3 locations including pericarp, placenta, and locule. There were 10 fruit per entry per block sampled. A greater a/b ratio indicates higher red color.

[x]On a scale from 1 to 5 where 5 is excellent and 1 is poor, 3 is probably acceptable. Ratings by J. Scott and Jan Watson (technician).

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

IMPLEMENTING THE FLORIDA PREMIUM-QUALITY TOMATO PROGRAM

Steven A. Sargent, Fernando Maul and Charles A. Sims[2]
Horticultural Sciences Department
[2]*Food Science & Human Nutrition Department*
IFAS, University of Florida
P.O. Box 110690
Gainesville FL 32611

INTRODUCTION

Since January 1996 we have been developing information leading to a harvest/postharvest handling program which will allow Florida growers to continue using the green-tomato harvest system while shipping tomatoes with consistently high consumer acceptance. Although gassing with ethylene has served the industry well since its introduction in the 1960's, the goal of this Premium-Quality Tomato Program has been to refine these established handling procedures in order to compete in the market with tomatoes that have consistently high flavor and quality. This program has four focal points, or quality control points, which are key to the implementation process:

1. **Growing high-flavor varieties**
2. **Minimizing harvest of immature-green tomatoes by rigorous field sampling**
3. **Using gassing to sort tomatoes with the best flavor**
4. **Maintaining proper storage temperature throughout shipping and marketing**

This past year has seen significant progress in the development of information and procedures which will allow this program to be implemented. **The good news for our industry is that tomatoes picked at mature-green stage and properly ripened had excellent flavor and were equivalent in quality to tomatoes picked at pink stage or later.** These results have been consistent for carefully controlled sensory tests conducted during the past 30 months with major tomato varieties grown throughout the state.

Based on this information we present below current recommendations for the four focal points for successful implementation of a Premium-Quality Tomato Program. Growers who harvest at breaker stage or later would bypass the gassing step, concentrating on proper temperature management described in point 4.

GROWING HIGH-FLAVOR VARIETIES

The success of this program hinges upon the use of tomato varieties noted for high flavor and aroma. This is the "home-grown" flavor that consumers long for and will seek out at the supermarket. The ultimate goal of a Premium-Quality Tomato Program is to establish a differentiated product that is readily recognized by consumers as having consistently high quality. Some of these high-quality varieties may require more careful handling than the varieties bred to be "good shippers" (hard, with less flavor).

Tests were conducted this past February on several varieties grown in the West Palm Beach area. The tomatoes were harvested at light-red stage and ripened at 68°F (20°C) prior to sensory analysis. These varieties were all rated quite high for ripe aroma, sweetness and typical tomato flavor, and were rated lower for off-odor, sourness, green-flavor and off-flavor (Figures 1a and 1b). 'Solar Set' stood out by being rated highest for ripe aroma and tomato flavor while 'Mountain Pride' was rated higher for sweetness and lower in sourness.

Sensory evaluations were also made in June on red-ripe tomatoes representing three tomato types:

- a field-grown tomato, 'FL-47' (harvested in Bradenton at pink stage or green and gassed and ripened to pink stage)
- an extended shelf-life (ESL) tomato (harvested in Bradenton at light-red stage)
- a hydroponic, cluster tomato, 'Durasol' (harvested when the last tomato of the cluster reached light-red stage, and previously rated as having high flavor compared with several other greenhouse cluster varieties)

All three tomato types were rated similarly by panelists for ripe aroma, off-odor, green/grassy flavor and off-flavor (Figure 2). 'FL-47' picked at pink stage was rated highest in sweetness over the ESL and 'Durasol', while ESL and gassed 'FL-47' were rated higher in sourness than 'Durasol'. More extensive analyses are necessary to provide definitive data as to flavor and aroma differences between these very different types of tomatoes.

MINIMIZING HARVEST OF IMMATURE-GREEN TOMATOES BY RIGOROUS FIELD SAMPLING

The objective at this stage is to harvest the maximum number of tomatoes which have the potential to ripen to high flavor and color. This requires that the field block only be picked when most of the tomatoes are at maturity stages M-2, M-3 or M-4. Tomatoes must be frequently sampled from each field to determine internal maturity, since mature-green tomatoes cannot be consistently distinguished from immature-green tomatoes without slicing. (See Sargent and VanSickle, 1996 for details.)

At the 1997 Florida Tomato Institute we presented results in which trained taste panelists compared ripe tomatoes picked at light-red stage with those picked at green stage and gassed until breaker stage (Sargent, *et al.*, 1997). The panelists could detect slight differences in flavor between the tomatoes harvested almost ripe and those which required up to 3 days gassing at 68°F to reach breaker stage. However, tomatoes which required 4 or 5 days gassing had noticeably poorer flavor and off-color upon reaching red-ripe stage. Minimizing drops and other handling impacts deserves careful attention. The panelists could easily pick out tomatoes with internal bruising, and described the flavor as "bland" or "watery" when compared with unbruised tomato samples. Internal bruising can be induced with a little as a single drop from 4 inches (Sargent, *et al.*, 1992).

USING GASSING TO SORT TOMATOES WITH THE BEST FLAVOR

Sorting for proper maturity will require running the tomatoes twice over a low-impact packing line. On the day of harvest the lot would first be run over a packing line for washing, drying, sorting and possibly pre-sizing. Tomatoes at breaker stage or above would be packed that day while green tomatoes would be carefully bulk-packed for gassing at the packinghouse or shipment for gassing elsewhere. On-site gassing is preferred since previous studies have shown that delays of 7 days or more resulted in less uniform ripening within the lot (Chomchalow, 1991). Forced-air cooling has also been shown to promote uniform ripening within palletized tomatoes by rapidly raising or lowering pulp temperatures before or after ripening (M.T. Talbot, J.K. Brecht and S.A. Sargent, unpublished data).

Our studies have consistently shown that tomatoes should be gassed for a maximum of 3 days at 68°F and 85% relative humidity, which is sufficient time for all mature-green harvested tomatoes to reach breaker stage. After 3 days gassing the lot would be rerun over the packing line, color sorted and packed as premium tomatoes into the final shipping container, most likely a single or double-layer carton. There are a number of manufacturers of electronic color sorters which are capable of consistently sorting, grading and packing tomatoes, reducing costs through automation of labor-intensive tasks. Tomatoes which have not reached breaker stage after 3 days gassing, and with poorer flavor, could be returned to the gassing room for 2 more days and resorted for sale to food service accounts.

MAINTAINING PROPER STORAGE TEMPERATURE THROUGHOUT SHIPPING AND MARKETING

Successful implementation of a Premium-Quality Tomato Program doesn't stop at the packinghouse door. Over the years we have observed many instances of good temperature management as well as marginal temperature management, beginning with initial storage or gassing and continuing through shipping, repacking and retail levels. Mismanagement can occur at any of these steps during handling and distribution, reducing tomato flavor and quality. Storage of tomatoes at typical household refrigerator temperatures could be one of the greatest contributing factors to the inferior tomato flavor complaints by consumers. The "Don't Refrigerate Tomatoes" campaign promoted by the Florida Tomato Committee for many years is evidence to the importance of proper temperature management when the tomatoes leave the shippers' hands. In fact, for the Premium-Quality Tomato Program to be successful, there must be coordination between all handlers downstream. This will require contracts which specify handling times (e.g., "best if used by" dates) and active temperature monitoring of the tomatoes by all parties involved.

It has been well established that green and ripening tomatoes are extremely sensitive to temperatures below 55°F (12.5) (Hardenburg, *et al.*, 1986). Storage below this threshold temperature at any point during handling and shipping can result in chilling injury, which is characterized by uneven ripening, poor color and flavor development, and increased susceptibility to decay as the tomatoes ripen. Storage at 34°F (2°C) for 14 days was reported to cause significant changes in the concentrations of important tomato aroma volatile compounds without the appearance of chilling injury symptoms such as pitting or decay (McDonald *et al.*, 1996). However, the effects of recommended commercial storage temperatures for fresh market tomatoes on their flavor were not addressed. Storage above 75°F (24°C) also inhibits normal ripening and accelerates postharvest decay (Masarirambi, *et al.*, 1996).

This past year studies were conducted to describe the flavor and aroma changes occurring in ripe tomatoes stored for 12 days at four commonly used temperatures. Tomatoes (cv. Solimar) were harvested at light red stage (about 80% red color) in Gainesville during fall 1997 and stored at 41°F (household refrigerator temperature), 50°F (recommended for red-ripe tomatoes), 55°F (recommended for green and breaker stage tomatoes) or 68°F (optimal ripening temperature) (5, 10, 12.5, 20°C, respectively). Samples were removed from storage after 4 days, 8 days and 12 days and given to trained sensory panelists for analysis of flavor and aroma attributes typical of fresh tomatoes. Panelists rated the tomato samples for two aroma attributes (ripe tomato and off-odor) and then for five flavor attributes (tomato flavor, sweetness, sourness, green/grassy flavor and off-flavor). Responses for each attribute were indicated on an 8-inch (150-mm) unstructured line scale with low-intensity and high-intensity anchor terms on either side. These same samples were also analyzed for aroma volatiles by electronic nose and gas chromatography.

Flavor and aroma were significantly affected by two days storage at 41F (data not shown). After 4 days storage at 41°F 'Solimar' tomatoes were rated significantly lower in ripe aroma, sweetness, tomato flavor, and significantly higher in sourness than those stored at higher temperatures (Figure 3). GC analyses showed that 4 out of the 16 aroma volatile compounds quantified (hexanal, 2+3 methylbutanol, *trans*-2-heptenal and isobutylthiazole) had significantly lower concentrations in samples stored at 41°F when compared the rest of the treatments (data not shown). Significantly higher isobutylthiazole concentrations are noteworthy since this sulfurous volatile compound, unique to tomato flavor, has been previously reported to impart a "spoiled" flavor to ripe tomatoes when concentrations are higher than normal (Petro-Turza, 1987). Three important aroma compounds were found to be positively correlated with ripe aroma ratings from sensory panels. Electronic nose analysis (EN) clearly separated the tomatoes into four distinct clusters based on storage temperature with 83.7% to 100% accuracy (data not shown).

After 8 days, tomatoes held at 41°F were still rated significantly lower in ripe tomato aroma, tomato flavor and significantly higher in sourness, when compared to tomatoes stored at the higher temperatures (Figure 4). Those tomatoes stored at 68°F were rated higher in sweetness and tomato flavor, and lower in sourness. GC analysis showed 8 aroma volatile compounds (methanol, 1-penten-3-one, hexanal, 2+3 methylbutanol, *trans*-2-heptenal, isobutylthiazole, nitro- phenylethane, and geranylacetone) with significantly different concentrations between the temperature treatments (data not shown). EN analysis classified the temperature treatments into clusters with a greater separation between treatments than after 4 days storage.

By 12 days, tomatoes stored at 41°F received the lowest ratings for ripe aroma, sweetness, and tomato flavor. Those stored at 50°F or 55°F were rated significantly lower than tomatoes stored at 68°F for ripe aroma and sweetness, and significantly higher for green/grassy flavor (Figure 5). GC analysis of aroma volatile compounds identified 13 out of the 16 compounds with significant concentration changes as result of the prolonged exposure to the different temperature treatments. EN analysis classified the 12-day storage samples with the highest degree of separation when compared to the 4-day and 8-day samples, which means that differences between the aroma volatiles continued to increase during storage.

Even though, tomatoes held at the ideal ripening temperature (68°F) had higher metabolic activity (and, therefore, faster consumption of carbohydrate reserves) when compared to the other treatments, they were still rated superior to the tomatoes stored at the lower temperatures in tomato flavor, aroma and sweetness after 12 days of storage. On the other hand, samples stored at 41°F were consistently rated higher in sourness, a characteristic often related to reduced overall acceptance in tomato flavor (Petro-Turza, 1987).

These tests also revealed that soluble solids content (°Brix) and pH do not reliably describe tomato flavor. Tomatoes stored at 41°F for 4, 8 and 12 days had significantly higher soluble solids content and titratable acidity (% citric acid) than those stored at the higher temperatures, despite being rated lowest in flavor by panelists (data not shown). Apparently, aroma and flavor compounds contribute more to tomato flavor than in other crops in which soluble solids and acidity are routinely used to quantify flavor (e.g., citrus and watermelon).

SUMMARY

A number of tests have been conducted since January 1996 to determine factors which influence tomato flavor and quality using many commercial cultivars grown at several locations around Florida . Data collected using trained sensory panels, aroma volatile profiles and electronic nose sensor outputs clearly show that the green-tomato harvest system produces consistently high-quality tomatoes with excellent flavor and aroma when the tomatoes are harvested at mature-green stage, gassed with ethylene at 68°F and ripened/stored at temperatures above 55°F. Gassing green tomatoes for 3 days allows mature-green harvested tomatoes to be separated from immature-green tomatoes to allow ripening as a premium product. By paying close attention to each step in the handling process, implementation of a competitive, Premium-Quality Tomato Program is certainly possible for Florida growers and shippers.

Acknowledgments

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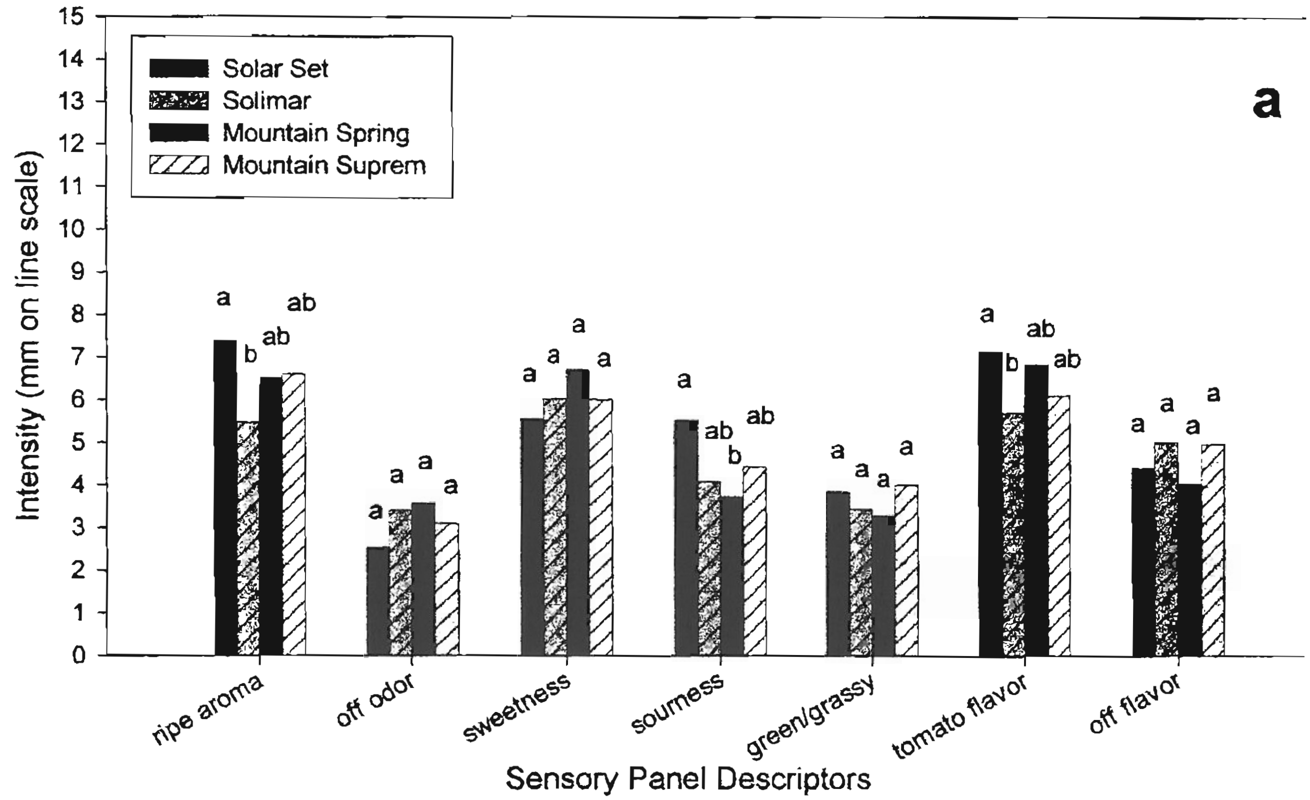


Figures 1a and 1b. Sensory panel attribute ratings for several tomato varieties at red-ripe stage. Significant differences (P=0.05) within temperature treatments for each attribute were determined for Duncan's Multiple Range Test.

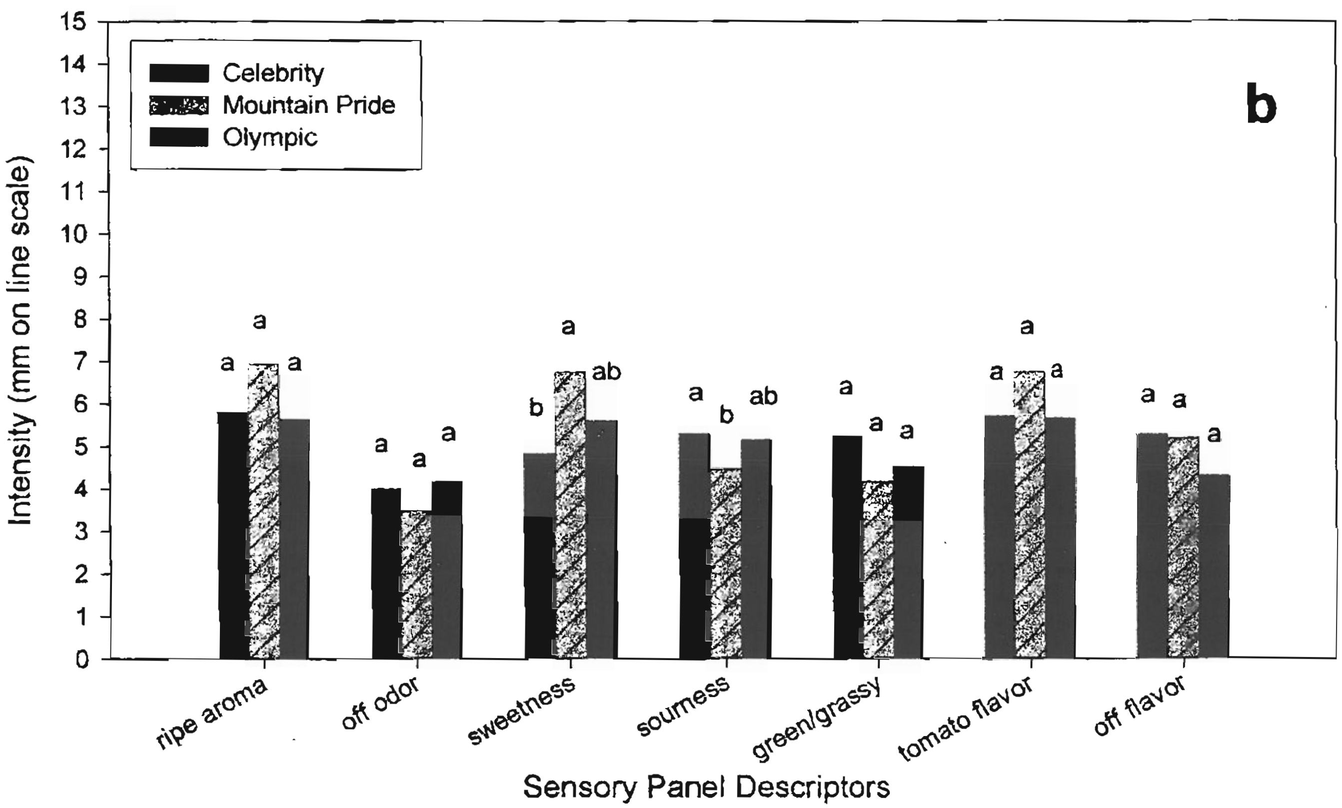


Figure 2. Sensory panel attribute ratings for standard ('FL-47'), extended shelf-life (ESL) and cluster tomato ('Durasol') types at red-ripe stage. Harvest stage for each variety is identified in the legend. Significant differences (P=0.05) within storage temperature for each attribute were determined for Duncan's Multiple Range Test

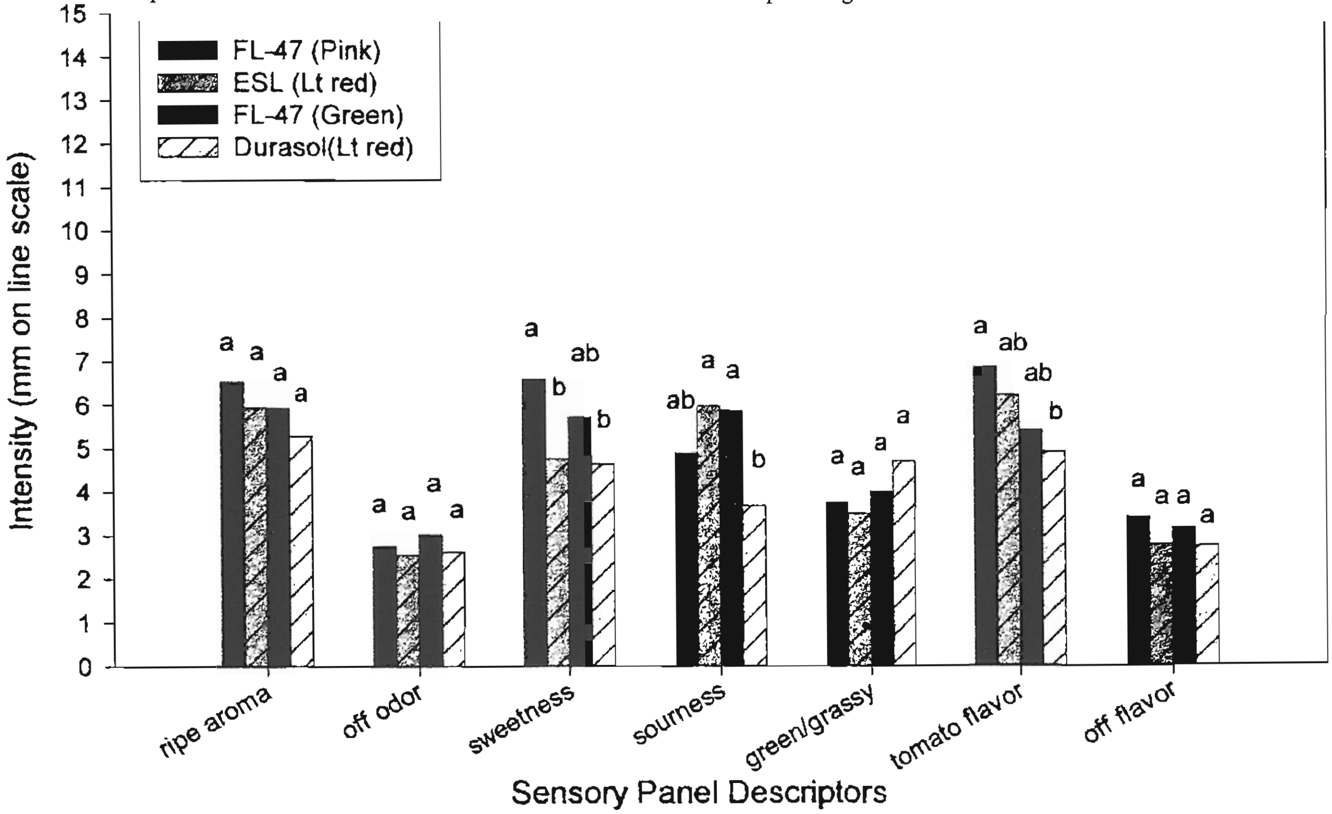


Figure 3. Sensory panel attribute ratings for ripe 'Solimar' tomatoes after 4 days storage at different temperatures. Significant differences (P=0.05) within temperature treatments for each attribute were determined for Duncan's Multiple Range Test.

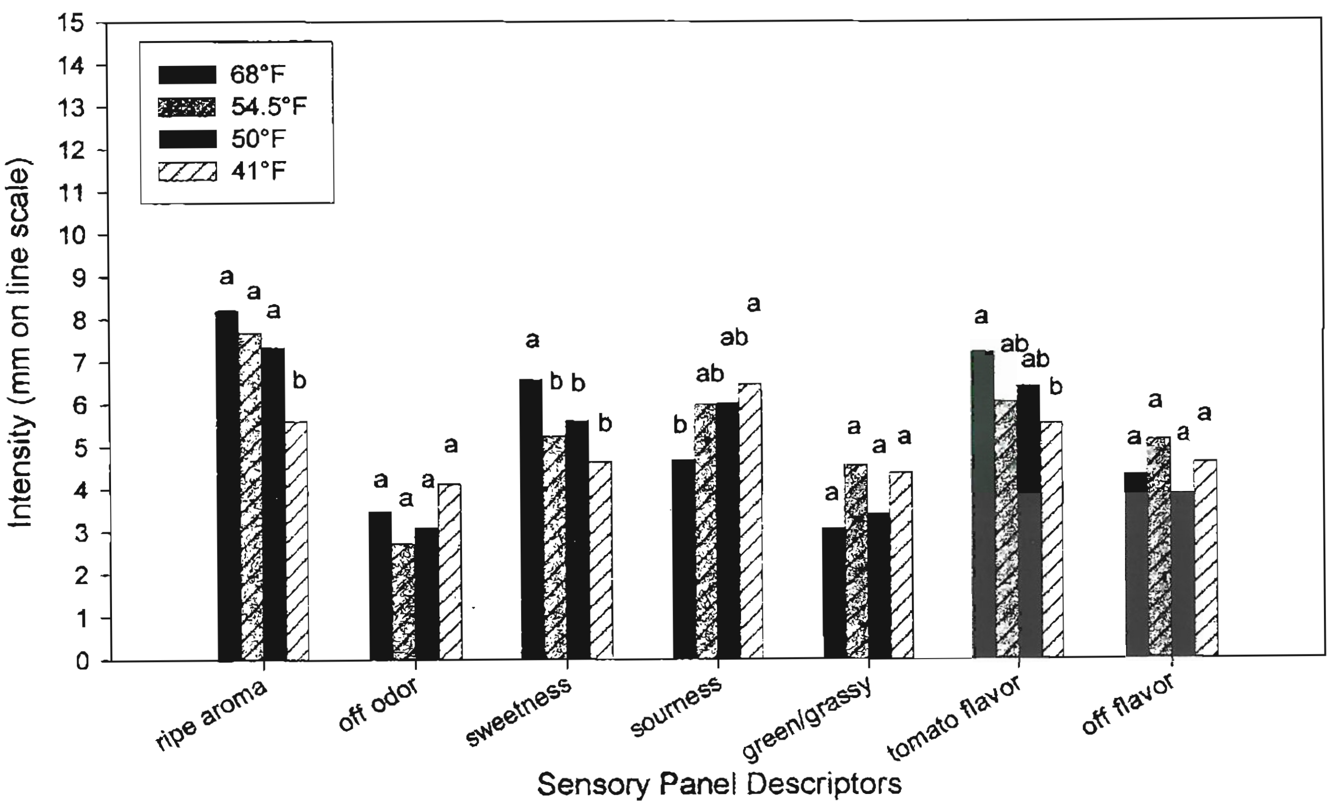


Figure 4. Sensory panel attribute ratings for ripe 'Solimar' tomatoes after 8 days storage at different temperatures. Significant differences (P=0.05) within temperature treatments for each attribute were determined for Duncan's Multiple Range Test.

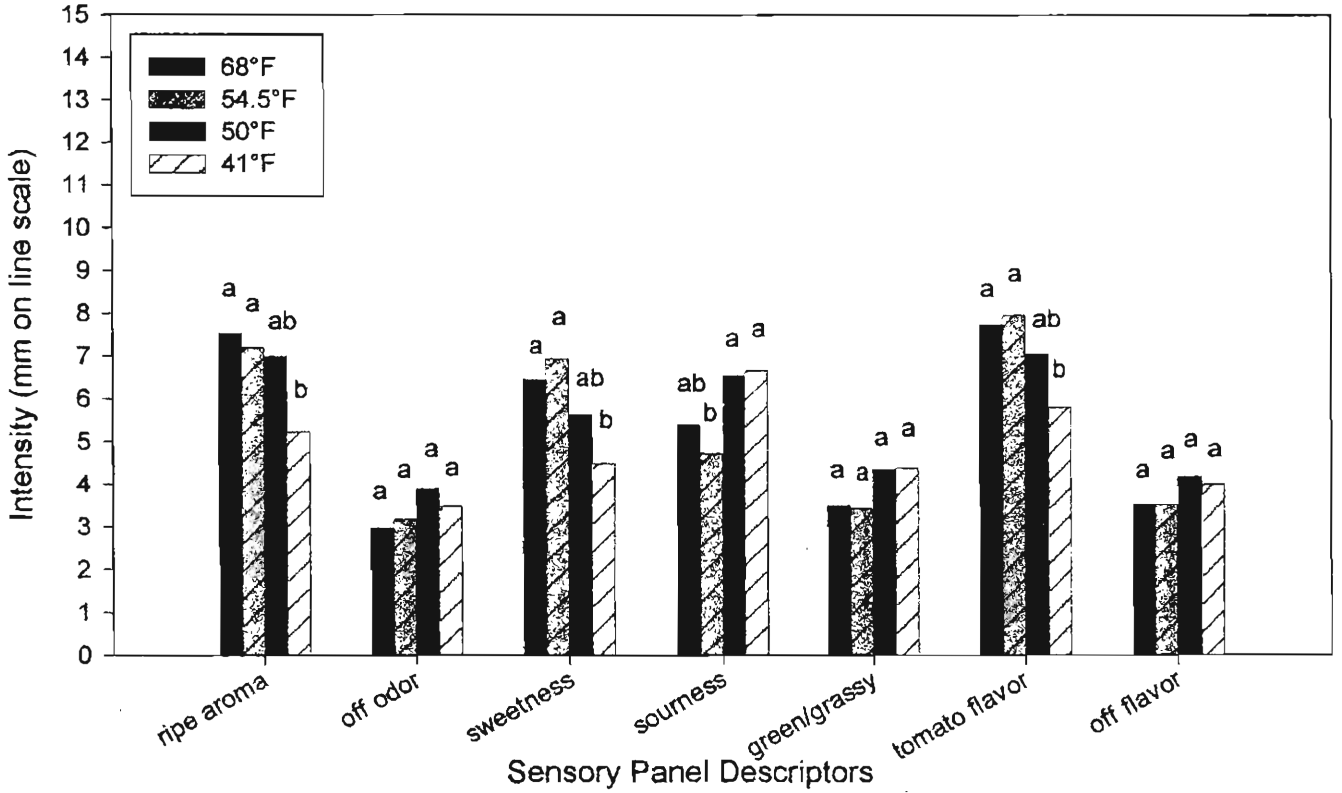
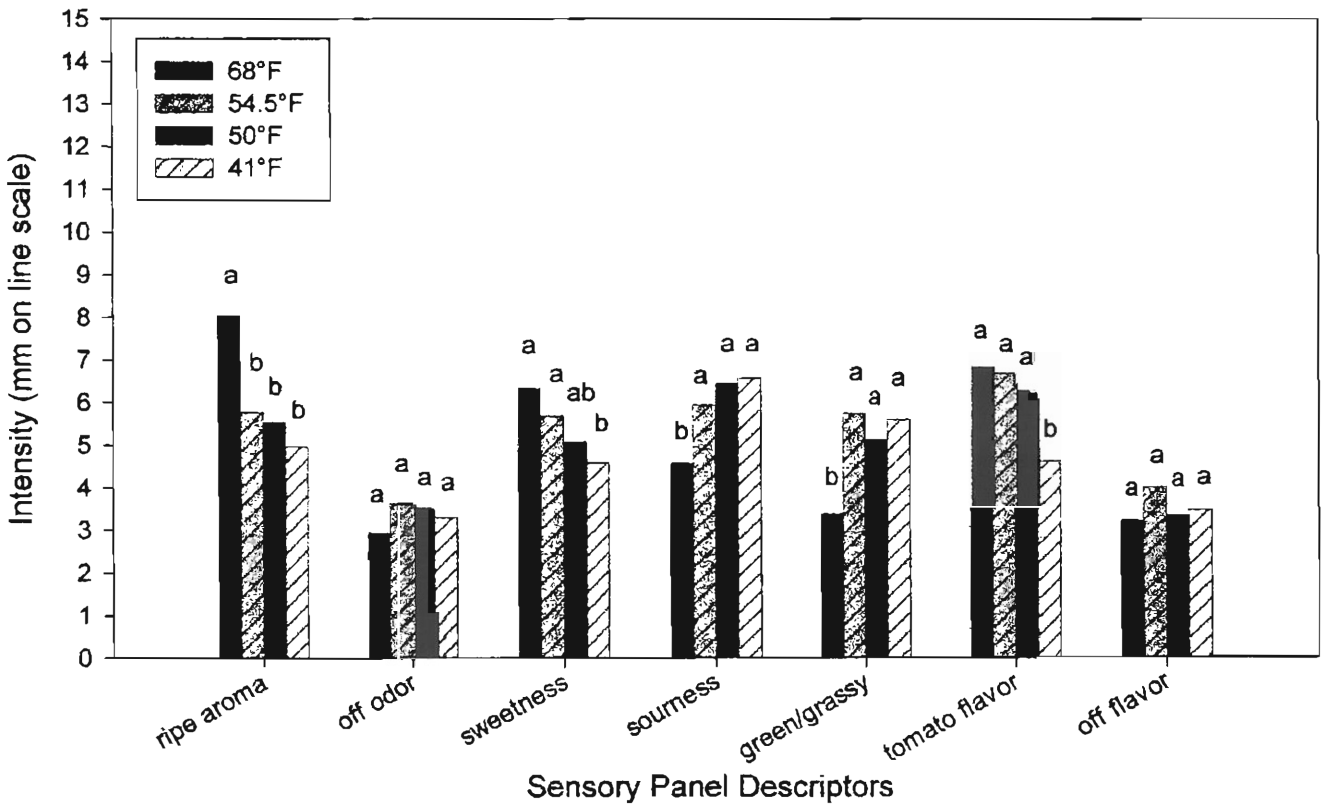


Figure 5. Sensory panel attribute ratings for ripe 'Solimar' tomatoes after 12 days storage at different temperatures. Significant differences (P=0.05) within temperature treatments for each attribute were determined for Duncan's Multiple Range Test.



A SUMMARY OF N, P, AND K RESEARCH WITH TOMATO IN FLORIDA[1]

George Hochmuth and Kim Cordasco[2]

Harvest of fresh market tomatoes in Florida for the 1995-1996 season resulted in 55,345,000 cartons (25 lb/carton) from 45,500 harvested acres (46,400 planted acres). Crop value was $440,119,000 (Fl. Dept. of Agr. and Cons. Serv., 1997). Most of the tomatoes produced in Florida were grown in the spring season (70%) with the remainder grown in the fall. Heaviest tomato production occurs in the Southwest: Bonita Springs, Immokalee, Naples, and the Palmetto-Ruskin areas produce 70% of the state's tomatoes.

State agricultural chemical usage including fertilizer use is surveyed periodically by a USDA-administered program and results are published (Fla. Agr. Stat. Serv., 1995). During the 1994 tomato crop season, N (nitrogen), P_2O_5, and K_2O were applied at an average of 310-200-540 lb/acre, rates that exceeded current IFAS nutrient recommendations for this crop (Hochmuth and Hanlon, 1995). Maximum recommended nutrient rates are 175-150-225 lb/acre N, P_2O_5, K_2O with phosphorus (P) and potassium (K) rates adjusted downward or eliminated if soils can supply some or all of these nutrients as determined by soil testing. Application of plant nutrients in excess of crop needs poses a negative environmental risk and reduces profitability.

Tomato fertilization research has been conducted in Florida for more than forty years. During this time many changes have occurred in tomato production practices including changes in cultivars, and introduction of new cultural systems such as polyethylene mulch, drip irrigation, and use of complete soil fumigants. The purpose of this publication is to summarize tomato fertilization research leading to current University of Florida recommendations for tomato fertilization and to summarize needs for refinement of recommendations and for continued research. Since nutrient and water management are linked, fertilization research will be summarized by irrigation method.

DATA SUMMARY METHOD

To compare tomato yield response to rates of fertilizer, a procedure was needed to standardize the numerous methods used for quantifying statewide yield results such as bushels, cartons, boxes, or tons/acre. In addition, responses to fertilizer can vary slightly depending on season, cultivar, and location in the state. Relative yield (RY), a calculated percentage, was chosen as the unit to express tomato yield responses to fertilization. The highest yield for each fertilizer experiment received a 100% value and other yields were expressed as a percentage of the highest yield. The actual yield in original units (25-lb cartons/acre) is presented for the yield corresponding to 100% RY. The RYs were plotted against rates of nutrient to determine how tomato yields responded to fertilizer in Florida. The RY presentation allowed data from a variety of experiments to be included in the graphical summary of yield responses to fertilization. For most studies, RYs of 95 to 100% were not significantly different.

Fertilizer rates are expressed on a per-acre basis (amount of fertilizer used on a crop growing in an area of 43,560 sq. ft.) Changes in bed spacing often lead to needed changes in fertilizer amounts. For example, to maintain the same amount of feritlizer in the bed for a crop on 6-foot bed spacing as a crop with 4-foot bed spacing would mean an increase by a factor of 1.5, in the "per acre" rate of fertilizer for the crop growing in beds spaced 4-foot on center. The important aspect is to have the same amount of fertilizer per linear bed foot. This linear bed foot system is used by the University of Florida Extension Soil Testing Laboratory to express fertilizer rates. The concept is explained by Hanlon and Hochmuth (1989) and by Hochmuth (1996). Fertilizer rate expression used in this summary and its figures are those rates presented by the various authors in their research papers. Most authors expressed rates on a per-acre basis, irrespective of variations in bed spacings among reports or experiments. Authors of a few reports chose to use the linear bed foot system to standardize fertilizer rate expressions across experiments and planting patterns. We will attempt to specify planting patterns and fertilizer rates for each experiment as far as we can determine from each report.

NITROGEN

Mixed Fertilizer Trials

Experimentation with tomato fertilization included numerous studies where mixed N-P-K fertilizers were used. Yield results from three of these studies are presented here as responses to rate changes of N fertilizer since N is the most limiting major nutrient in sandy soils. Yields from these mixed fertilizer studies, however, were not graphed with experiments where N rate was increased and P and K were applied at uniform rates for all treatments (Figure 1).

Fertilizer rate studies were a secondary aspect of two Immokalee experiments conducted in the fall of 1970 and spring of 1971 (Everett, 1971). Increased use of polyethylene mulch on several thousand south Florida tomato-production acres resulted in disposal problems estimated at $50 to $70 per acre. Residual polyethylene in the field was caught up in tillage equipment, interfered with seeding and transplanting operations, and aroused interest in biodegradable paper and polyethylene-coated paper mulches. Tan or black paper mulches (impregnated with a fungicide to retard decomposition) were un-coated or coated with 0.25 mil of polyethylene coating on one or both sides. Single side coated mulches were applied either coated side up to the sun or down on the soil. Yield results from tomatoes mulched with these biodegradable mulching materials were compared to yields from plants mulched with 1.5 mil of black polyethylene. Yields were also compared for plants fertilized with N-P_2O_5-K_2O fertilizer formulations of 130-72-157 (low), 220-72-261 (medium), or 310-72-364 (high). All treatments received 40 lb/acre N from a 5-8-8, N-P_2O_5-K_2O, fertilizer placed 3-inches to each side of the bed center and 3-inches deep. A second application of an 18-0-25, N-P_2O_5-K_2O, fertilizer was applied 9-inches to each side of bed center at rates of 500, 1000, or 1500 lb/acre. This single fertilizer sidedress application was divided into two sidedress applications for the unmulched beds. Un-staked, subsurface-irrigated plants were grown for one to three harvests. Row or water-furrow spacing was not indicated.

Mulch type and fertilizer rate did not interact significantly with either experiment. Yields did not respond to increased fertilization in these experiments where the author noted a limited, 1 to 3 pick, harvest season reduced the demand for fertilizer. Yields averaged 1227 cartons/acre over all fertilizer and mulch treatments in fall 1970. In the spring, 1971 season, yields fell slightly between the medium and high fertilizer treatments, 220 to 310 lb/acre N, from 1664 to 1536 cartons/acre (significant at 5% probability). Yields were best from plants mulched with un-coated tan paper (1464 cartons/acre) or black paper (1376 cartons/acre) in the fall, 1970. Yields from plants with all other mulch treatments were not significantly greater than yields from unmulched plants (1184 cartons/acre). Drought conditions and low temperatures in spring 1971 accentuated the benefits of mulch. Yields were significantly better (1% probability) from all mulched plants, regardless of mulch type, compared to unmulched plants. Mulched plants produced 400 to 856 cartons/acre more tomatoes than the unmulched plants with higher yields from black mulches than from tan mulches. The highest yields in this dry season resulted from tomato plants mulched with black paper (polyethylene side to the soil), 1920 cartons/acre compared to yields from unmulched plants, 1064 cartons/acre. Similar yields resulted where polyethylene-coated papers were placed coated-side up or coated-side down. Paper mulches tested well on these un-staked tomatoes largely due to the abbreviated season (3.5 months) and reduced foot and machine traffic compared to tomatoes grown with the staked cultural system.

The effects of increased rates of N and K fertilizer on yield and fruit size of polyethylene mulched, stake-grown tomatoes, were evaluated over two spring and fall seasons in Immokalee (AREC) (Everett, 1976). Beds spaced 6-feet on center received 0, 54, 108, 162, 216, 270, 324, 432, 540, or 648 lb/acre N and 0, 75, 150, 225, 300, 375, 450, 600, 750, or 900 lb/acre K_2O from NH_4NO_3 and KNO_3 (70% NO_3 - N and 30% NH_4 - N). An 18-inch fertilizer band was applied from 10% of N treatments through 324 lb/acre and 5% of treatments from 432 to 648 lb/acre. The remaining fertilizer was applied in surface bands 9-inches to each side of the plant row. Subsurface irrigation was applied in all experiments to Immokalee fine sand soils. Common N and K fertilizer rates used by area growers were cited as 350 lb/acre N and 475 lb/acre K_2O.

Marketable yield increases were only significant between 0 and 54 lb/acre N in fall 1974 (571 to 1130 cartons/acre, respectively). In spring 1975, yields were similar with or without N fertilizer, averaging 1058 cartons/acre. Heavy rains this season damaged roots and limited the crop to two harvests. Significant yield increases occurred in fall 1975 with N rates through 648 lb/acre N (2800 cartons/acre, 100% /RY) from 64% RY with 216 lb/acre N. In the spring 1976 experiment yields with 0 lb/acre N were nearly twice those of previous seasons with 0 lb/acre N. The author cited upward movement of nutrients with subsurface irrigation and the presence of a spodic soil horizon known to impede nutrient leaching. These same factors likely increased soluble salt content resulting in reduced yields with higher N rates (73% RY with 648 lb/acre N compared to 100% RY, 2734 cartons/acre, with 324 lb/acre N). Nitrogen fertilization did not affect fruit weight in any season, except with the initial N fertilization of 54 lb/acre N in the fall 1975. The author concluded that tomatoes grown on previously cropped land reached optimum yield in the range of 162 to 270 lb/acre N.

Two spring experiments were conducted on previously mulched beds, following a fall tomato crop, to test fertilizer rates and placement methods in a two crop system (Everett, 1978). Tomatoes grown in both the fall (first planting) and spring (second planting) were unstaked, single-harvest, "ground" tomatoes. Yields from the second planting were 50 to 60% lower than yields from the first planting, but estimated production costs were reduced 70 to 75% by reusing the polyethylene. Fertilizer was placed in a hole punched through the polyethylene at rates of 0, 0.5, 1.0, 2.0, or 4.0 oz per hole. Fertilizer holes were 8-inches to one side of the plant, 8-inches to both sides of the plant, or halfway between the plants (in the "drill"). Nitrogen treatments of 0, 65, 130, or 260 lb/acre (18-0-25 N-P_2O_5-K_2O fertilizer) were calculated based on 5808 plants/acre (5-foot row spacing). Fields were subsurface irrigated to maintain soil moisture at field capacity before planting the spring tomato crop (3 weeks after removing fall season plants).

Yields increased in both spring seasons with N treatments between 0 and 65 lb/acre to 90 and 94% RY each season. Yield increases with N treatments above 65 lb/acre were not significant. Optimum, 100% RYs, occurred with 260 lb/acre N (714 cartons/acre) and with 130 lb/acre N (781 cartons/acre) in each respective spring season. Fruit size increased with 130 and 260 lb/acre N in the first season and increased only with 65 lb/acre N in the second season. Fertilizer placement did not effect yield or fruit size in either experiment season.

NITROGEN

Overhead Irrigation

Although fertilizer leaching losses were reduced with polyethylene mulching on overhead-irrigated fields, researchers found that soluble salt injury reduced yields with all of the fertilizer applied before mulching (Locascio *et al.*, 1984). Researchers in a 1980 spring trial on Sparr sand sought to avoid this early plant fertilizer injury yet apply sufficient N for the late-season demand of fruit set and development. Four preplant N sources, KNO_3 - Ca(NO_3)$_2$, NH_4NO_3, sulfur-coated urea (SCU), or isobutyliene diurea (IBDU) were applied broadcast and incorporated preplant in single N-source treatments or paired with another for sixteen treatments, each applied at 200 lb/acre N. Prepared beds were spaced four feet apart.

Yield was highest with IBDU combined with KNO_3 - Ca(NO_3)$_2$ in a 2 to 1 ratio (3177 cartons/acre). Similar yields resulted with all combinations of IBDU or SCU and KNO_3 - Ca(NO_3)$_2$. Intermediate yields resulted with CR - N sources (IBDU or SCU applied singly) and lowest yields resulted with soluble N sources (NH_4NO_3 or KNO_3 - Ca(NO_3)$_2$) applied singly. Intermediate to low yields resulted with all combinations of NH_4NO_3 with other N sources, likely due to soluble salt effects of NH_4NO_3 on early plant growth. Researchers concluded that the N release rate of IBDU was superior to SCU, based on optimum tomato yields, and that yields with CR - N sources were highest only when combined with soluble N sources.

The effect on tomato yields of mulch, N source, and irrigation method (overhead or drip) were evaluated for tomatoes grown on Plummer sand, spring 1981 (Sweeney *et al.*, 1987). Nitrogen sources were a 50:50 mix of NH_4NO_3 and SCU or 100% NH_4NO_3. Mulched and overhead-irrigated tomatoes received 100% of the N and K preplant. Unmulched and overhead-irrigated tomatoes received 50% of the N and K preplant/incorporated and 50% sidedressed in two equal applications. Drip-irrigated tomatoes received 50% of N and K preplant and 50% through the drip line. Plant N recovery was measured by a ^{15}N-labeled NH_4NO_3, which was applied 100% preplant or in the split N treatment as either the 50% preplant applied N or the 50% fertigated N. Rates of N, P_2O_5, and K_2O were 200 - 230 - 220 lb/acre, respectively, for beds spaced 4 foot on center.

Irrigation method did not affect marketable fruit yields of tomato. Polyethylene mulch, however, increased marketable fruit yields 25% (2445 cartons/acre) over unmulched plants (1842 cartons/acre). Likewise, mulch use enhanced N recovery by vegetative plant tissues which extracted 30% of the applied preplant N compared to

12 to 14% N recovery with the unmulched plants, averaged over irrigation methods. Nitrogen recovery in the fruit was not affected by mulch or irrigation method. Researchers found that less fertilizer N was needed when mineralized N from soil organic matter was present. Plant, fruits, and vegetative tissues recovered 30 to 60 lb/acre N of soil N and an additional 110 to 150 lb/acre N from the 200 lb/acre of applied N. Marketable yields, in this study, were affected by N source. Twenty-one percent more fruits were harvested from plants fertilized with NH4NO3 (2400 cartons/acre) than plants fertilized with 50:50, NH_4NO_3 : SCU (1884 cartons/acre).

Unaccounted-for N amounted to 10 lb/acre N from mulched and overhead-irrigated beds. Researchers found that much more N was unaccounted for and presumed leached from drip-irrigated mulched or unmulched beds and from overhead-irrigated unmulched beds averaging 93 lb/acre of unaccounted-for N. Heavy leaching losses from drip-irrigated beds occurred despite seasonal water use of 7 inches as compared to 16 inches of applied water with overhead-irrigation. All tomatoes received 21 inches of rainfall, eight of which were moderate rainfall events (1 to 2 inches each).

Subsurface Irrigation

Starter fertilizer was applied at 20, 30, and 40 lb/acre N in Manatee County, Fall 1988; in Palm Beach County, Winter 1988-1989; and in Manatee County, spring 1989, respectively (Hochmuth *et al.*, 1989). The starter fertilizer was supplemented with banded NH_4NO_3, KNO_3, and $Ca(NO_3)_2$. Nitrogen rates, calculated on the basis of a 6-foot bed center for the Manatee studies, were applied in bands and the beds were mulched with polyethylene. Water table height was continually measured by a water stage recorder.

Fall, 1988 yields at Manatee County for a three-harvest season were lower than yields at the winter and spring sites. Yields were not significantly different with total (starter plus band-placed fertilizer) N rates from 160 to 280 lb/acre. A 98% RY (752 cartons/acre, based on 13 foot row spacing) was achieved with 160 lb/acre N. Large fruit made up only 16% of the total marketable yield in this Fall season of high rainfall. The yield with the grower fertilizer rate of 366 lb/acre N was 15% lower than with the reduced N rates (160 to 280 lb/acre N). At first flower sampling, leaf N concentrations were all high. Leaf N concentrations remained high through early harvest increasing linearly as N rate increased.

In a winter, 1988-1989, planting in Palm Beach County, fertilizer rates and yields were based on beds spaced on 5.5 foot centers. Increasing N rates from 160 to 280 lb/acre had no effect on yield. High yield occurred with 160 lb/acre N, 100% RY (1153 cartons/acre). Leaf N concentrations at all sampling dates were high and not different with increasing N rates. Large fruit accounted for 20% of the total marketable yield.

Spring, 1989 yields at Manatee County, with a two-harvest season, were based on 3,350 LBF (13-foot row spacing). A 99% RY (1308 cartons/acre) occurred with 180 lb/acre N and was not significantly improved with N rates of 240 and 300 lb/acre. Yields with the grower N rate of 402 lb/acre did not exceed yields with 180 lb/acre N. Leaf N concentrations were adequate and not different with increasing N rates. Large fruit comprised 61% of the total marketable yield. This season was marked by early drought that dropped the water table 36 inches below the bed on four occasions. Fertilizer containing 30-110-60 lb/acre N, P_2O_5, K_2O was broadcast preplant on Oldsmar sand (0.62% organic matter) at Boynton Beach in the fall 1988 (Shuler *et al.*, 1989). Additional fertilizers from: KNO_3, $Ca(NO_3)_2$, and NH_4NO_3 were applied in double bands resulting in total N rates of 160, 220, or 280 lb/acre. These rates were tested against the grower program of 336 lb/acre N and 672 lb/acre K_2O. Beds were 5.25 feet wide, mulched with black polyethylene, and planted with 'Sunny' tomatoes. Water levels were monitored using a water table recorder.

The greatest yield response occurred with 160 lb/acre N, 100% RY (1922 cartons/acre). Yields dropped to 90 and 87% RY with 220 and 280 lb/acre N, respectively and to 91% RY with the grower fertilization program. Leaf N concentrations were high and not different through all growth stages with all N rates.

Low organic matter, 0.6%, Myakka sand fields in Boca Raton were planted in fall 1990 with 'Sunny' tomatoes (Shuler *et al.*, 1991). Nitrogen rates of 160 and 220 lb/acre were compared to the grower rate of 328 lb/acre N (502 lb/acre K_2O). Beds were spaced 5 feet apart and fertilizer rates and yields were expresssed on 5 foot bed spacing. Preplant fertilizer, 48-160-40 lb/acre N, P_2O_5, K_2O, was broadcast and covered with black polyethylene mulch. The remaining N was applied in double bands 20 inches apart. Nitrogen sources were KNO_3, $Ca(NO_3)_2$, and NH_4NO_3 .

Yield response was greatest with 160 lb/acre N providing 100% RY (1597 cartons/acre). Relative yield dropped 5% with 220 lb/acre N. The grower yield was 92% of maximum. Leaf N concentrations through early fruit set ranged from 4.6 to 5.7%, higher than the adequate range of 2.5 to 4.0% (Hochmuth *et al.*, 1991b). Nitrogen concentrations in leaves were not different through early fruit set with all N rates including the higher grower N rate. At harvest, leaf N concentrations fell to adequate levels with all N rates. Large fruit accounted for 20% of total marketable yield. Incidence of graywall increased from 150 and 195 cartons/acre with N rates between 160 and 220 lb/acre (significant at 5% probability).

Three N rates of 120, 180, and 240 lb/acre were tested at Boynton Beach, fall-winter 1991-1992 (Shuler *et al.*, 1992). Beds were spaced 5 feet apart and fertilizer rates and yields were expressed on 5 foot bed spacing. Broadcast fertilizer containing 40-200-40 lb/acre N, P_2O_5, K_2O was applied in a 12-inch center band before bed shaping. White-on-black polyethylene mulch was pulled back for application of additional double-band fertilizer treatments of 80, 140, or 200 lb/acre N for total N rates of 120, 180, or 240 lb/acre.

Added N above 120 lb/acre had no significant effect on yield or fruit quality of 'Sunny' tomato. Plants with all N rates yielded 29 to 31% number-one grade large fruit. Equivalent yields were produced with 120 and 180 lb/acre N, 1638 and 1642 (100% RY) cartons/acre, respectively. Leaf N-concentrations were well above the adequate concentration of 4.0% at first flower and at early fruit set with concentrations greater than 6.0% and 5.0% measured at each stage. Graywall affected 10% or less of the fruit and did not increase with N rate.

Tomatoes in four of the subsurface-irrigated trials reached maximum yields with 160 lb/acre N, while in two other trials, yields were maximized with 120 and 180 lb/acre N. In all trials, yields were maximized with N very near the current IFAS recommended 175 lb/acre N for tomato (Hochmuth and Hanlon, 1995). Increasing N above 175 lb/acre rarely increased yields or fruit quality. Leaf tissue sampling showed that tomato generally absorbed N at higher than adequate level. Increased N did not consistently increase incidence of graywall in 'Sunny' tomatoes.

Drip Irrigation

At the Gulf Coast Research and Education Center, yield responses to four N rates were tested over three growing seasons: fall 1983, spring 1984, and fall 1984 (Csizinszky *et al.*, 1988). Nitrogen derived from NH_4 -N (30%) and NO_3 - N (70%) was applied, together with K, thirty percent incorporated preplant and 70% injected over the fourteen-week growing season. Polyethylene mulch was used, black in the spring and white in the fall seasons on beds spaced 4.5 feet on center. The fields were irrigated three times daily, 68% of total water requirements in early afternoon, and 16% each at early morning and late afternoon. Nutrient injection increased linearly through the fourteen-week season with heaviest fertilization in the last five weeks.

Marketable yields did not differ among N rates of 150, 300, 450, and 600 lb/acre in two fall seasons, 1983-1984. One hundred percent RY occurred with 300 and 450 lb/acre N (1221 and 1665 cartons/acre in 1983 and 1984, respectively). In the spring 1984 season, higher fertilizer rates reduced RY to 68% of the highest yield with 150 lb/acre N (1050 cartons/acre) (Csizinszky *et al.*, 1988). Leaf N concentrations measured at spring harvest 1984 increased with added N from an adequate level with 150 lb/acre N, 2.74%, to 3.62% with 600 lb/acre N. Adequate leaf N concentrations for the harvest period are between 2.0 and 3.0% (Hochmuth et al., 1991b).

Work with drip irrigation at the North Florida Research and Education Center, Quincy (Rhoads *et al.*, 1988) was designed to test yield responses to N rates ranging from 0 to 200 lb/acre on the same field over spring 1983, 1984, and 1986 planting seasons. Beds were spaced 6 feet apart and soil moisture was monitored with tensiometers, placed 6 inches from the plant and 6 inches deep. A soybean crop grown in 1982 left sufficient residual N to return a total tomato yield 99% RY (2640 cartons/acre) with 60 lb/acre N fertilizer for the first crop season. Total yields responded similarly to N rates from 60 to 180 lb/acre in 1984. Slight responses occurred with 120 lb/acre N this season resulting in 98% RY (2570 cartons/acre). Yields were similarly unaffected by changes in N source between NH_4NO_3 and $Ca(NO_3)_2$ or between preplant N application and split N applications; 40% preplant and 60% injected. In 1986, total tomato yields increased with N rates through 200 lb/acre (2850 cartons/acre, 100% RY) and were also unaffected by preplant or injected fertilizer treatments.

Two N rates and two tensiometer settings, -10 and -15 centibars, were evaluated on sandy, flatwood soils over three seasons for effects on drip and subsurface-irrigated tomato production at the Gulf Coast Research and Education Center in Bradenton (Clark et al., 1989). Total N rates of 200 and 300 lb/acre were applied to subsurface irrigated fields. Nitrogen applied with drip irrigation was applied in graduated weekly amounts from a 4-0-8 (N - P_2O_5 - K_2O) solution which resulted in differing cumulative N rates each year. The total drip-applied N rates in fall 1987 were 210 and 311 lb/acre N, 202 and 289 lb/acre N in spring 1988, and 176 and 266 lb/acre N in fall 1988. Fruits were harvested three times each season, except the fall 1988 season which was abbreviated to two harvests by a tropical storm. Beds were polyethylene mulched and spaced on 6-foot-centers each season.

Tomato yields were not affected by fertilizer rate or by irrigation method (-10 centibar drip or subsurface irrigation) in fall 1987 or spring 1988 trials resulting in average yields of 1724 and 2557 cartons/acre each year. Lower yields, 1306 cartons/acre, occurred with the 300 lb/acre N, subsurface-irrigated treatment (fall 1988) compared to 1585 cartons/acre with 266 lb of drip-applied N/acre irrigated to -10 centibars of soil moisture. Average yields with 202 and 289 lb/acre N and the drier -15 centibars drip-irrigated treatment were lower, 2360 cartons/acre, compared to 2570 cartons/acre average yields with the wetter -10 centibar drip irrigation treatment (spring 1988). With the drier irrigation treatment this season, large-size fruit yields were reduced to 78% of large fruit yields with the -10 centibar and subsurface irrigated treatments averaged over both N rates. Soil moisture had no effect on marketable fruit or large-size fruit yields in either the fall of 1987 or 1988. Plants with all treatments had high concentrations of N in most recently matured whole leaves, taken at first flower and early fruit set and leaf tissue N concentrations remained adequate thereafter. All tomato plants initially received 400,000 gallons per acre of subsurface-applied water to raise the water table and establish the transplants. For the remainder of the trial, drip or subsurface irrigation was applied as specified. The total drip-applied water was one-third of the total subsurface-applied water.

Using whole plant plus fruit analysis for N and K, drip-irrigated tomatoes were found more efficient in N utilization than the subsurface-irrigated tomato crop (spring 1988). At -15 centibars and 202 lb/acre N, 220 lb/acre N was removed from the soil. The subsurface-irrigated crop removed 163 lb/acre N with 200 lb/acre of applied N and removed 173 lb/acre N with 300 lb/acre of applied N (Clark *et al.*, 1989). Drip irrigation proved to efficiently provide irrigation water and nutrients while maintaining high yields.

Limited research results on fertigated tomato grown on Rockdale soils prompted a Dade County Fall/Winter 1996 study (Carranza *et al.*, 1996). Nitrogen and K were applied in a 4 x 4 factorial experiment. Nitrogen from NH_4NO_3 was applied, 20% preplant and 80% injected, as recommended in the Vegetable Production Guide for Florida (Hochmuth and Maynard, 1996). Bed spacing was not indicated in this study. High yields resulted with 150 lb/acre N, 99% RY (1901 cartons/acre). Yield nearly doubled with 75 lb/acre N (94% RY) compared to yield with the check (zero N) treatment. No significant yield advantage occurred with 225 lb/acre N (100% RY).

Incidence of graywall and blotchy ripening (BR) in tomato, considered to be K deficiency disorders (Hochmuth *et al.*, 1994a), were also studied at this site. Increasing K from 0 to 150 lb/acre K_2O had no effect on graywall or BER on this Dade county soil that tested medium-high in K. Nitrogen rate, however, had a positive effect on graywall incidence. Graywall incidence, averaged over both tested cultivars increased with N rates from 0 to 225 lb/acre (7 to 34 cartons). 'Agriset 761' had a 40% higher incidence of graywall than 'Sunny'.

Petiole sap nitrate concentrations were positively correlated with optimum tomato yields in South Florida subsurface-irrigated trials and optimum sap nitrate and K ranges were published (Hochmuth, 1994). Researchers at the North Florida Research and Education Center, Quincy designed spring and fall 1995 experiments to test these petiole-sap nitrate levels against optimum tomato yields on a drip-irrigated North Florida site (Rhoads *et al.*, 1996). In the spring, N was applied either 100% preplant-incorporated or 40% preplant-incorporated with 10% injected six times between 3 and 13 weeks from transplanting. All N was applied preplant in the fall. Five N rates: 0, 60, 120, 180, and 240 lb/acre were applied from NH_4NO_3 in both seasons. The beds were spaced 6-feet apart and mulched with black polyethylene in the spring and white in the fall.

Battery-operated ion-specific meters provided instant sap-nitrate analysis and results were comparable to the South Florida standards derived with colorimetric procedures (Rhoads *et al.*, 1996). Tomato yields were highly correlated with petiole-sap nitrate concentrations for the period of 4 to 10 weeks after planting. Ten weeks after transplanting, applied N fertilizer ceased to affect yield response in either spring or fall planting seasons. Researchers concluded that field ion meters were effective mid-season monitors of tomato N needs. Yields with preplant-applied fertilizers were not different above 120 lb/acre N in spring and above 60 lb/acre N in fall trials. Reduced fall yields (1280 carton/acre) in the presence of N pointed to other factors such as poor fruit set due to high day/night temperatures that limited tomato yield. Authors noted that tomato yields would likely respond to N rates nearer the recommended rate of 175 lb/acre during a cooler fall. The highest yielding plants were grown with 180 lb/acre N applied 40% preplant and the remainder injected (2268 cartons/acre). These yields were 7% higher than yields of plants with 100% preplant-applied fertilizer with the same N rate.

A lack of experiments with fall-grown tomato in North Florida prompted 1995 and 1997 experiments in Gadsen County (Rhoads, 1997). Particular attention was given to petiole sap NO_3 - N concentrations measured with Cardy ion meters. Nitrogen was applied 100% preplant from NH_4NO_3 at N rates of 0, 60, 120, 180, and 240 lb/acre. Bed spacing was not indicated in this study. High temperatures in fall 1995 were suspected of limiting yield response (due to poor fruit set) to applied N that season. Significant yield increases occurred in both seasons between 0 and 60 lb/acre N with 95 and 96% RY (1260 and 1996 cartons/acre, respectively) occurring at the 60 lb/acre N rate. Yield increases to 100% RY with 180 lb/acre N (1332 cartons/acre) and 120 lb/acre N (2082 cartons/acre), in each respective season, were insignificant. Comparison of petiole sap NO_3 - N concentrations averaged over both seasons confirmed a range of N sufficiency concentrations in plants grown with 60 lb/acre N (low) to 120 lb/acre N (high). An adequate N rate for fall grown tomato was given as 120 lb/acre. Researchers suggested that N fertilization efficiency may be improved by application of 40 lb/acre N at preplant and 15 lb/acre N injected weekly from weeks 5 through 8. The weekly injected N rate may be adjusted to meet petiole sap N sufficiency concentrations monitored through week ten.

Findings in spring 1993 (Quincy) and spring 1994 (Gainesville) also indicated that petiole sap-N concentrations at mid-season correlated with yield (Locascio *et al.*, 1997b). Beds, spaced 6-feet apart, were mulched with polyethylene and irrigated when soil water tension reached -10 centibars. The total applied N was 175 lb/acre at both sites. Yields were 16% higher when 60% of the N and K fertilizers were injected than when all were applied preplant (1328 cartons/acre) at Gainesville. Tomato yields in the Quincy trials were either unaffected by application method or had 16% higher yields with all preplant applied fertilizer than with split-applied N (1738 cartons/acre).

Yield responses to the time of N and K application, either preplant only or preplant with fertigation, were dependent upon soil type. Less yield response resulted with fertigated N on heavier soils, such as Orangeburg loamy sands in Quincy, compared to the lighter Arredondo fine sands in Gainesville. Earlier research supported this finding (Locascio *et al.*, 1989). Yields averaged over 1984 and 1985 on Arredondo fine sands resulted in increased late-season extra large and large fruit yields (489 and 360 cartons/acre, respectively) with 60% drip applied N and K compared to yield response with all preplant applied N and K (300 and 293 cartons/acre, respectively). Researchers noted that drip-applied nutrients extended the season of large fruit harvest by maintaining plant nutrient concentrations late in the season. Results of this experiment were repeated in 1988 at Gainesville (Locascio and Smajstrla, 1989). When 60% of the applied N and K were fertigated, yields of extra-large fruits were 40% higher than extra-large fruit yields where N and K were applied 100% preplant. Yields of large and total marketable fruits were also 10% higher with the same fertigated treatment compared to 100% preplant applied fertilizer. When percentages of fertigated N and K were increased above 50% to 75 and 100%, yields declined linearly (2473, 2459, and 2060 cartons/acre, respectively) in other Arredondo fine sand fertigation research (Dangler and Locascio, 1990). Average yields from 1984 and 1985 seasons resulted in higher yields of medium-size early fruit, mid-season large fruit, and total season large fruit with 50% fertigated N and K (or N).

Experimentation with fertigation continued in Gainesville on Millhopper fine sand soil in the spring of 1996 (Locascio *et al.*, 1996). Two-foot wide beds were prepared on six foot centers and 40% of the total applied N was broadcast on the bed surface, tilled, and mulched with polyethylene. 'Agriset 761' tomato transplants were set March 14 and fertigation began April 3. Equal amounts of N were applied each week through ten weeks of fertigation. Total N (NH_4NO_3) rates were 120, 180, 240, or 300 lb/acre. Drip irrigation was applied to maintain soil moisture at -10 centibars by tensiometer with one overhead irrigation for freeze protection. Marketable yields responded quadratically to increasing N rates leveling off above 180 lb/acre N with 240, and 300 lb/acre N. Respective RYs for these N rates were 88, 98, and 100% RY (2270 cartons/acre). Leaf tissue N concentrations were adequate (2.5 - 4.0%) above 180 lb/acre N (> 2.7%).

Numerous drip-irrigation trials, summarized above, were treated with soluble N sources applied at preplant or at preplant and fertigated throughout the crop season. Tomato yields generally maximized at or near the current recommended 175 lb/acre N rate. Researchers, field-testing a polymer-coated fertilizer (Meister fertilizer; Helena Chem. Co., Memphis, TN), hoped to improve the efficiency of N fertilizer on tomato (Hochmuth, 1997). Trials were conducted on Arredondo fine sands near Gainesville, spring 1997, on raised two-foot wide beds placed on four-foot centers (N rate calculations and expressions were based on six-foot bed centers). The polymer-coated, 19 N - 5 P_2O_5 - 14 K_2O, fertilizer was compared to soluble N and K sources (NH_4NO_3 and KCl). Fertilizers applied to the bed surface were broadcast and tilled or applied in a four-inch off-center band and pressed into the soil. All beds were mulched with black polyethylene, planted with 'Agriset 761' tomato, and drip-irrigated to -10 centibars soil moisture.

Interactions occurred in the first, third, and overall season harvests affecting marketable fruit yields, all fruit grades initially, and then extra large and large fruit yields only. Yields of early fruit from all fruit grades increased when soluble fertilizers were applied broadcast and when polymer-coated fertilizer was placed in bands (yields averaged over all applied N rates). Total marketable yields and yields of large-fruit also increased with the same fertilizer placement methods. Nitrogen rate increases with the polymer-coated material resulted in higher early yields, more extra large, large, and total marketable fruits with increasing N rates from 75 to 175 lb/acre N at the third harvest. With the soluble N source, yields decreased slightly with higher N rates. Overall, plants fertilized with the polymer-coated fertilizer produced 40 to 50% more fruits than soluble N fertilized plants (3326 over 1859 cartons/acre, respectively) and resulted in significantly higher yields, 80%, 86%, and 100% RY (3326 cartons/acre) with N rates of 75, 125, and 175 lb/acre N. Yields well above the state average yields of 1216 cartons/acre (1996) were likely due to increased plant density with plant rows spaced four instead of the standard six feet on center.

Cull fruit yields were similar with both fertilizers and were not changed by fertilizer placement or rate.

Overfertilization with N has been measured in terms of reduced yield but, recent findings tie high rates of N application (>175 lb/acre) with increased populations of western flower thrips (Funderburk *et al.*, 1997). As a vector of the disease, tomato spotted wilt virus, increased western flower thrips populations resulted in higher disease incidence in Quincy grown tomatoes (1996 and 1997). Plants were fertilized with 190 or 275 lb/acre N, mulched with black or silver plastic, and drip-irrigated. Beds were spaced 6-feet apart. Pesticides were not applied to thrips or their natural predators. Tests on the effect of N rates (0, 60, 120, 180, and 240 lb/acre) on flower N concentration, amino acid quality, flower number, and plant size were also conducted in 1997.

In 1996, adult thrips populations were generally lowest on silver-mulched beds fertilized with the recommended N rate. Occurrence of tomato spotted wilt virus, measured in 1997, was lowest, 23.6%, on silver-mulched beds fertilized with the recommended N rate (30% disease occurrence with the higher N rate). Disease occurrence was highest, 46.9%, where black plastic was applied to beds fertilized with the higher N rate (40% disease occurrence with the recommended N rate). As a simple disease control measure, researchers recommended use of silver mulch with the recommended N rate. Analysis of flower tissue was not completed for the study, but, analysis of plant sepal tissue revealed higher protein concentrations in the sepals of plants fertilized with excess N. Although thrips are commonly seen clustered on tomato plant sepals, researchers advised additional study to confirm an association. In general, increased N fertilization significantly increased plant size and flower number in both seasons without a subsequent yield increase.

In fourteen of the fifteen tomato fertilization trials summarized above, optimum yields resulted with N rates between 60 and 200 lb/acre N. Residual N from a previous soybean crop was responsible for high yield response with only 60 lb/acre N. Yields only occasionally increased with N rates above 200 lb/acre and, in one trial, RY fell to 68% with 600 lb/acre N compared to 100% RY with 150 lb/acre N. Slightly more large fruits were reported at one location with 300 lb/acre N. Split N applications (20 to 40% preplant and the remainder injected) increased tomato yields 7 and 16% in two trials, reduced yields 14% in a third trial, and did not differ from yields with all preplant applied N in four other trials. Split N application proved most effective on some sandy soils in Gainesville and least effective on Orangeburg loamy sands in Quincy. Excessive N fertilization (to 240 lb/acre) was found to increase incidence of the disease tomato spotted wilt virus. Researchers found that populations of the western flower thrips, the vector for this virus, were increased where plants were fertilized with excess N.

Field use of the Cardy ion meter to monitor petiole-sap nitrate concentrations proved a reliable and quick mid-season (4 to 10 weeks from transplant) method of assessing petiole nitrate concentrations. Controlled-release polymer-coated fertilizer at 175 lb/acre N proved superior to broadcast or banded soluble N sources resulting in high yields with one preplant band application. The practice of drip irrigation reduced water usage to one-third of the total water used with comparable subsurface-irrigated tomatoes.

NITROGEN SUMMARY

Tomato yields in 75% of all experiments did not increase with N rates above the recommended rate of 175 lb/acre (indicated by the dashed line in Figure 1). Nitrogen rates below 175 lb/acre were not evaluated in three experiments that optimized above 175 lb/acre N (Clark *et al.*, 1989). Among these experiments, yields were not significantly different with N rates from 200 to 300 lb/acre. Yield data from one experiment indicated a clear negative response with N above the recommended rate (Csizinszky, *et al.*, 1988). Yield responses to N were similar for tomatoes grown with subsurface or drip irrigation. Water savings with drip-irrigated tomato, however, provided optimum yields with one-third of the water applied by subsurface irrigation and up to one-half of the water applied by overhead irrigation. Researchers found that despite the significantly lower water rates used with mulched and drip-irrigated tomato, N leaching losses accounted for 47% of the applied N compared to 5% of the applied N with mulched and overhead irrigated beds. On mulched, overhead-irrigated tomato trials, yields were highest with IBDU in combination with KNO_3 - $Ca(NO_3)_2$ where all fertilizers were applied preplant. Soluble salt injury resulted in these trials where preplant NH_4NO_3 was applied alone or in combination with CR - N sources.

Response of tomato to fertigated N was related to soil type. Tomato yields were 16% higher with 175 lb/acre N (40% preplant applied, 60% fertigated) on Arredondo sands in Gainesville compared to yields on loamy soils of the Florida panhandle. When yields responded to higher than the recommended N rate on sandy soils nutrient leaching was suspected. Incidence of graywall in 'Sunny' tomato was not consistently affected by N application, however, when affected, high rates of N increased graywall incidence. Incidence of the disease, tomato spotted wilt virus, was also found to increase with excess N application to 275 lb/acre. Incidence of the disease was tied to higher populations of the disease vector, the western flower thrips, where plants were fertilized with the higher N rate.

PHOSPHORUS AND POTASSIUM

Soil Testing

Knowledge of soil nutrient levels, particularly P and K, before planting is the starting point to analysis of tomato response to varying rates of applied nutrient. Using the Mehlich-1 (M-1) extractant to determine preplant soil nutrient concentrations provides information so research results may be reviewed for degree of support of existing fertilization recommendations established by M-1.

Mehlich-1 extractant indices (expressed as ppm soil-extracted nutrient) are classified as very low, low, medium, high, and very high, and a crop specific fertilizer recommendation is made from that classification (Hochmuth *et al.*, 1995). The M-1 solution became the accepted extractant standard in 1979 at the University of Florida. Previous to M-1, ammonium acetate and water extractants were used. Indices recorded from these methods cannot be equated with M-1 indices or fertilizer recommendation rates but review of these studies presents a profile of tomato response to fertilizer under varying conditions. Water management practices, fertilizer sources and application methods, and the effect of mulch in the nutrient management system, will also be summarized.

PHOSPHORUS

Soil pH on an Immokalee fine sand was 4.7, and hydrated lime was applied in October 1961 at rates of 500, 2,000, and 5,000 lb/acre (Hortenstine and Stall, 1962). Subplots 40 x 14 foot, with 78 subplots per acre, were treated with 100, 300, and 910 lb/acre P_2O_5 in November and N, K_2O, and Mg were applied through the growing season at respective rates of 220, 250, and 80 lb/acre. Irrigation method, mulch use, or research location, were not specified.

Calcium present in hydrated lime increased individual tomato fruit weight while P increased vegetation, flowering, and fruit set. Soils with high lime treatments and low P (100 lb/acre P_2O_5) resulted in plants with P deficiency symptoms. The reverse application of low lime, (500 lb/acre) and high P_2O_5, (910 lb/acre) resulted in nutrient toxicity symptoms expressed as leaf roll. Higher P rates also simultaneously resulted in lower pH, reduced nitrification by microorganisms, and immobilization of Ca in the soil. Adequate rates of lime and P for this soil were 5,000 lb/acre lime and 300 lb/acre P_2O_5. These combined rates brought soil pH to near 6.5, recommended for tomato, with soil samples taken in December and April of 6.2 and 6.3, respectively. Marketable yield with 300 lb/acre P2O5 was 88% RY, (360 cartons/acre, based on 115 lb/subplot and 78 subplots/acre, bed spacing not indicated). An additional 600 lb/acre of P_2O_5 increased the RY to 100%, but was not cost effective.

Tomato response to added P on acidic, poorly drained Immokalee sand was studied over three winter seasons near Immokalee (Rhue and Everett, 1987). Lime and P were needed to raise the pH from 5.0 to 6.5 and supplement the very low (9 ppm) M-1 extracted soil P. Typical beds were arranged six feet apart, mulched with black polyethylene, and subsurface irrigated with the water table kept 16 inches below the bed surface. Dolomitic lime was applied annually in November at 0, 2,000, and 4,000 lb/acre (0, 1, and 2 times the amount required to reach 6.5 pH). Concentrated superphosphate (CSP) was broadcast and incorporated in January 1982 at 0, 250, 500, and 750 lb/acre P_2O_5 (150 lb/acre was recommended for this site) with starter applications of N and K_2O of 25 and 40 lb/acre. Double bands of 180 lb/acre N and 250 lb/acre K_2O were applied last to the bed shoulders. The same N and K fertilizer treatments were used in 1983 and 1984 except P application was reduced to 0 or 40 lb/acre P_2O_5 (CSP) broadcast.

Tomato yields on unlimed soils were not different with 0 or 250 lb/acre applied P_2O_5 but, declined 35% with 500 lb/acre P_2O_5 (1600 cartons/acre). Two probabilities were cited for reduced yields, the first was nutrient toxicity with excess P and the second related to decreasing leaf Mg concentrations with increases in P rate on unlimed soils. Limed soil had significantly more extractable P, but soils did not retain increased P concentrations into the next growing season. The first season, when 0, 250, 500, and 750 lb/acre P_2O_5 had been incorporated preplant, M-1 soil extractable P taken at harvest was high. Phosphorus concentrations were low in samples taken before fertilization in 1983 and became very low in 1984. Leaching of P was likely on these very sandy, unlimed soils, as well as on sandy limed soils with successive annual P applications. Phosphorus under these conditions is managed as a mobile nutrient and researchers recommended seasonal P applications not to exceed crop uptake to prevent leaching losses. High yield occurred in the first trial year (1982) with 2,000 lb/acre lime and with 250 lb/acre P_2O_5, 100% RY (3,070 cartons/acre). An additional 40 lb/acre P_2O_5 applied in 1983 and 1984 increased yields 10% (1830 and 2,000 cartons/acre respectively) above yields with 0 lb/acre P_2O_5.

Repeated annual applications of P on neutral pH 'EauGallie' fine sand at the Gulf Coast Research Center in Bradenton increased soil P concentrations (Clark *et al.*, 1989). Soil pH remained at or near 7.0 in this three-season study and represented typical production soils in west-central and southwest Florida. Concentrated superphosphate with micronutrients was broadcast uniformly at 375 lb/acre P_2O_5 each season: fall 1987, spring and fall 1988. Successive tomato crops failed to deplete soil P concentrations, rather soil P concentrations (M-1 extracted at preplant) increased from low to high concentrations over the three seasons. Yield responses to increased soil P concentrations were not evaluated. Previously cropped soil with near neutral pH often retains sufficient P so that P fertilization is not needed. IFAS recommends withholding P fertilizer when soils test high for P. On soils that test low for P, application of 120 lb/acre P_2O_5 is recommended and 100 lb/acre P_2O_5 for medium P soils.

Authors of research conducted in Boynton Beach, 1994-1995 fall/winter, concluded that excess applied P did not enhance tomato yields (Shuler and Hochmuth, 1995). Mehlich-1 soil indices of 222 ppm P for the soil at this site exceeded the 60 ppm needed for a very high soil P interpretation. Response to P was not predicted for this site but: 0, 50, 100, 150 lb/acre P_2O_5, and the grower rate of 200 lb/acre P_2O_5 were applied to test yield response to excess P. Phosphorus treatments combined with micronutrients, 39 lb/acre N, and 50 lb/acre K_2O were broadcast in a 12 to 18 inch band and incorporated at bed formation. Grower N and K_2O rates were applied in double bands at 306 and 600 lb/acre, respectively. Single beds, 5 x 24 feet, were mulched with black polyethylene, planted with 'Solimar' transplants, and subsurface irrigated.

Total marketable yield was not affected by added P through 200 lb/acre P_2O_5. The yield average over all P rates was 2600 cartons/acre. High temperatures and tropical storm 'Gordon' claimed 10% of the plants in the first four weeks followed by conducive growing conditions for the remainder of the season. Phosphorus concentrations from whole leaf tissue samples were high at early fruit set and adequate through harvest with all P rates. Soil P concentrations increased through 444 ppm with P fertilization to 200 lb/acre P_2O_5 at the early soil sampling. Soil P concentration remained unchanged through the season with the zero P treatment. Soil Zn concentrations decreased 40% with added P.

Further testing of tomato yield response in the presence of excess P occurred on Millhopper fine sands near Gainesville (Locascio *et al.*, 1996). Soils at this spring 1996 trial tested very high (92 ppm) in M-1 soil-extracted P and additional P was not recommended. Beds two-foot wide and six feet on center received broadcast applications of N, P (CSP), and K which were incorporated, mulched in black polyethylene, and drip-irrigated to maintain soil moisture at -10 centibars by tensiometer. Phosphorus was applied at 0 or 160 lb/acre P_2O_5. Soil P concentrations were higher (1% level) through June 17 where P had been applied. Although marketable fruit yields were not affected by higher soil P concentrations, plant growth at the May 17 whole-plant sampling had accelerated. Larger plants at this sampling contained 13% more P (significant at 1%) in whole plant analysis than plants grown with zero added P.

PHOSPHORUS SUMMARY

Cited research indicated that successive seasonal applications of P, at rates above M-1 recommendations, accumulates in most soils but provides no yield advantage. In the presence of excess soil P, mid-season plant growth was accelerated over plants grown on high P soils without added P. Plants grown with excess P also contained 13% more P by whole plant analysis but did not yield more fruit.

On acidic soils, P did not accumulate and P leaching occurred. Application of P should not exceed crop uptake on coarse sandy soils to prevent possible interim leaching losses between crop seasons. Phosphorus application on acidic, unlimed soils causes nutrient toxicity symptoms in tomato as well as restricting Ca, Mg, and N availability from the soil solution. On limed, very low M-1 tested P soils, up to 250 lb/acre P_2O_5 acre were needed for maximum yield. More research is needed to better relate required P fertilization with the M-1 soil test index.

POTASSIUM

Subsurface Irrigation

A fall/winter 1988-1989 trial conducted in Boynton Beach evaluated response of tomato to four K_2O rates of 80, 160, 240, and 440 lb/acre and the grower rate of 672 lb/acre K_2O (Shuler *et al.*, 1989). Fertilizers were derived from KNO_3, $Ca(NO_3)_2$, and NH_4NO_3. Soil tested very low (16 ppm) in extracted K using M-1 extractant and 160 lb/acre K_2O was the recommended rate in 1989 for very low K soils (Hochmuth and Hanlon, 1989; Kidder *et al.*, 1989). A starter fertilizer with 60 lb/acre K_2O was broadcast and the remaining K was double banded to equal the total rates listed above. Single beds were 5.25 x 23.8 feet and contained 12 to 13 plants. Subsurface water levels were monitored with a water table recorder.

Total marketable yield increased linearly with increases in K_2O through 240 lb/acre, 100% RY (2160 cartons/acre). Yield declined 24% with grower N and K_2O rates of 336 and 672 lb/acre. Leaf K concentrations at first flower and early fruit were adequate with 240 lb/acre K_2O, but deficient at first flower with 160 lb/acre K_2O. Leaves with all experimental K rates were considered K deficient at first harvest with leaf K concentrations less than 2.0% (Hochmuth *et al.*, 1991b). Soil had returned to very low M-1 potassium levels after harvest and researchers noted that removal of mulch and plant material allowed residual soil K to leach. Band fertilization with 672 lb/acre K_2O resulted in residual K (76 ppm) in the band at the end of the season. The yield response of subsurface-irrigated tomato to higher K rates in this study and others (Locascio *et al.*, 1997) led to a K rate revision for very low K soils from the 1989 standard recommendation of 160 lb/acre K_2O (Kidder *et al.*, 1989) to 225 lb/acre K_2O (Hochmuth and Hanlon, 1995).

Starter K_2O was applied to commercial fields at rates of 40, 60, and 80 lb/acre in Manatee (fall), Palm Beach (winter), and Manatee (spring), respectively (Hochmuth et al., 1991a). Subsurface irrigation was managed by the grower on polyethylene-mulched fields. Experimental rates of K_2O were applied in shoulder bands at varying rates depending on the specific experiment. Fertilizer sources were as follows: KNO_3, $Ca(NO_3)_2$, NH_4NO_3, and K_2SO_4. 'Sunny' transplants were used for all trials.

Tomato yields were not different with all experimental K rates during the warm fall (1988) and spring (1989) seasons at Manatee County. High RYs were 98, 100, and 97% with 80, 160, and 240 lb/acre K_2O (1988) and 96, 100, and 99% with 120, 200, and 280 lb/acre K_2O (1989). High yields were 748 and 1326 cartons/acre (13-foot row spacing, K rates calculated on 6-foot bed centers) with 160 and 200 lb/acre K_2O applied each year. Acceptable yields occurred with the 1989 recommendation for very low and low K soils, 160 lb/acre K_2O (fall 1988), and 130 lb/acre K_2O (spring 1989), respectively. Satisfactory leaf K concentrations above the adequate range occurred with all K rates during these seasons. In the cooler winter season in Palm Beach County, 1988-1989, tomato yields responded linearly to added K through the 240 lb/acre K_2O rate, 100% RY (2,160 cartons/acre). Leaf K concentrations were deficient for lesser K rates, 80 and 160 lb/acre K_2O, during this winter sampling. The 1989 recommendation of 160 lb/acre K_2O for very low K soils (16 ppm), was insufficient. Winter yields requiring 240 lb/acre K_2O responded near the revised recommendation (Hochmuth and Hanlon, 1995) of 225 lb/acre K_2O. Higher grower K rates used over all three seasons, 530, 625, and 393 lb/acre K_2O resulted in yields 15% lower, equal to, and slightly greater than yields with 240 lb/acre K_2O for fall, winter, and spring trials, respectively.

A fall/winter 1991 experiment in Boynton Beach evaluated marketable yield response to three reduced N rates, four reduced K rates, and the grower rates of 652 lb/acre K_2O, and 346 lb/acre N (Hochmuth et al., 1992; Shuler et al., 1992). Mehlich-1 extracted K was low, 20 ppm, and 130 lb/acre K_2O were recommended based on 1989 standards (Kidder *et al.*, 1989). All treatments consisted of 40-200-40 lb/acre N-P_2O_5-K_2O preplant broadcast fertilizer. The remaining K_2O was double banded for total K_2O rates of 80, 160, 240, and 320 lb/acre. Beds were spaced 5-feet on center with fertilizer calculations based on this spacing. Beds were mulched with white-on-black polyethylene and 'Sunny' tomatoes were harvested three times.

High, 100% RY, (1770 cartons/acre) occurred with 240 lb/acre K_2O with a 94% RY with 160 lb/acre K_2O, in a quadratic response to applied K. This yield response exceeded the 130 lb/acre K_2O 1989 recommendation and supported the higher 1995 recommendation of 150 lb/acre K_2O for low K soils. Yields did not increase with 320 lb/acre K_2O, nor were they different with the commercial rate of 652 lb/acre K_2O (1907 cartons/acre). Extra-large fruit yields increased 45% with 160 lb/acre K2O over the 80 lb/acre K_2O rate and leveled off thereafter. Adequate leaf K concentrations did not increase significantly with K rate at first flower, but increased linearly at early fruit set. Soil samples taken through the fertilizer band after harvest resulted in high concentrations of M-1 extracted K, 490 ppm from the 612 lb/acre banded K_2O and 221, 93, 37, and 19 ppm from the reduced K rates 280, 200, 120, and 40 lb/acre banded K_2O, respectively. Increasing K rates from 80 to 320 lb/acre K_2O did not significantly affect incidence of graywall and BR.

A winter 1991-1992 trial in Boca Raton, tested reduced rates of soluble and controlled-release (CR) K sources against a commercial fertilizer treatment (Shuler, 1992). Mehlich-1 soil test revealed very low levels of soil K (4 ppm) and 160 lb/acre K_2O was recommended in 1989. All treatments consisted of 40-20-60 lb/acre N, P_2O_5, K_2O broadcast preplant with remaining treatments double banded for total K_2O rates of 180 and 260 lb/acre (160 lb/acre N). The grower applied 300 lb/acre K_2O, using broadcast and band placement, with 200 lb/acre N. Single-bed plots were 5.5 x 21.8 feet with eight 'Mountain Pride' tomato plants per bed. Beds were covered with silver-topped polyethylene mulch.

Following five harvests, marketable yield response was not different with any K rate or K source. Yield response to soluble K sources was slightly higher with 180 lb/acre K_2O, 100% RY (1745 cartons/acre) and lower with 260 lb/acre K_2O, 89% RY. When half of the band applied K_2O was from a CR source, equally high yields (1828 cartons/acre) were produced with 180 lb/acre K_2O. Large fruit accounted for 48% of this yield while other treatments resulted in 43% large fruit (Shuler, 1992). Tomato yield response to the grower rate resulted in 1870 cartons/acre, likely responding to the 200 lb applied N with that treatment as opposed to the 160 lb/acre N applied with the experimental K rates. IFAS increased the N recommendation for tomato in 1995 from 160 to 175 lb/acre N (Hochmuth and Hanlon, 1995; Kidder *et al.*, 1989). Leaf tissue K concentration was adequate with all treatments sampled at mature green fruit. Tissue K concentration was the same for plants receiving all soluble K fertilizer and plants receiving half soluble and half CR forms of K. Soil samples taken through the fertilizer band after harvest had 409 ppm K with the commercial application of 300 lb/acre K_2O (200 lb/acre banded). Lesser banded amounts, 120 and 160 lb/acre soluble K_2O returned 55 and 89 ppm M-1 K in the fertilizer band.

Graywall and BR incidence decreased with higher K_2O rates, 52 to 20 cartons/acre as K_2O increased from 180 to 260 lb/acre K_2O, consistent with the theory that these disorders are related to K deficiency. When K was reduced to 180 lb/acre K_2O but, half in CR form, fewer cartons of graywall and BR fruit were harvested, 17 cartons/acre (Shuler, 1992). Reduced graywall and BR with CR fertilizer was probably due to more consistent availability of K. Similar leaf N and K concentrations indicated factors in addition to K were involved in these disorders.

Three Bradenton trials, two spring and one fall, and one West Palm Beach winter trial evaluated the effects of K source and rate on subsurface-irrigated, polyethylene-mulched tomato (Locascio *et al.*, 1994; Locascio et al., 1997a). The bed spacing for each experiment was not cited.

Neither the 1989 recommendation of 130 lb/acre K_2O, nor the 1995 recommendation of 150 lb/acre K_2O optimized yields for M-1 low K (25 and 26 ppm) soils in Bradenton spring trials, 1991 and 1992. Yields increased linearly in spring 1991 and increased quadratically in 1992 leveling off above 240 lb/acre K_2O, 93% RY (2535 cartons/acre). One hundred percent RY occurred at both trials with 325 lb/acre K_2O. Researchers cited the inefficiency of banded K fertilizers when post-harvest M-1 soil tests revealed large amounts of residual K_2O in the band (all of the N and K_2O were applied in two bands on the bed shoulder). Despite the higher yield demand for K, tomato leaf K concentrations measured in leaves taken at mid-season (spring 1992) were adequate with even the lowest K rate of 80 lb/acre K_2O. In research with pepper (Hochmuth et al., 1994b), band placement was also found the least effective placement method with subsurface-irrigation.

Plants growing in a M-1 very low K (15 ppm) soil in Bradenton, fall 1992, produced 100% RY (3200 cartons/acre) with 240 lb/acre K_2O. The maximum yield exceeded the 160 lb/acre K_2O rate recommended in 1989 and was nearer the 225 lb/acre K_2O rate recommended in 1995. Yields increased quadratically through 0, 80, and 160 lb/acre K_2O, maximizing with 240 lb/acre K_2O, and declining to 93% RY with 325 lb/acre K_2O. Band placement of K_2O was used in this trial. Mid-season leaf concentrations were adequate with all K rates, increasing linearly with K_2O treatments from 80 to 320 lb/acre. Yields varied less than 3% with K sources, KCl, K_2SO_4, or KNO_3 at two of the three Bradenton trials but, in the spring of 1992 marketable fruit yield increased 19% with KNO_3.

In West Palm Beach, winter 1990-1991, 80 lb/acre K_2O was broadcast preplant and the remainder was banded on the bed shoulders for total K_2O rates of 80, 160, 240, 320 and 400 lb/acre (Locascio *et al.*, 1997a; Shuler *et al.*, 1991). The bed spacing was not indicated in this experiment. Yields responded quadratically to increasing K rates leveling off with 320 lb K_2O/acre, 100% RY (1850 cartons/acre). Yields optimized above the 1989 recommended rate of 160 lb/acre K_2O for this very low (12 ppm) K soil and above the 1995 recommended rate of 225 lb/acre K_2O. Leaf K concentrations at mid-season were adequate above 240 lb/acre K_2O, but deficient with 80 and 160 lb/acre. A dry period between October 15 through December 20 (2.0 inches of rain) was cited for the inefficient utilization of banded K fertilizer which resultied in the higher-than-expected fertilizer demand. Significant amounts of K remained in the fertilizer band after harvest , ranging from 34 to 674 ppm with treatments of 80 to 502 lb/acre K_2O (post-harvest M-1 soil samples).

In eight of twelve subsurface irrigated experiments, yield was maximized at or below 240 lb/acre K_2O. Shoulder band applications of N and K_2O were used in all experiments and yields responded similarly to 0 through 80 lb/acre K_2O broadcast preplant. Poor absorption of band-applied K by tomato was apparent in some instances when leaf K concentrations were deficient despite high amounts of residual K extracted through the fertilizer band post harvest. Low absorption of band-applied K was exaggerated by dry weather and fluctuations in soil water conditions. Higher grower K_2O rates up to 672 lb/acre caused yields to drop 15 to 25% or show no increase over lower fertilization rates. Equivalent yields resulted with all K sources including KCl, K_2SO_4, KNO_3, soluble sources, or half soluble: half CR sources. Graywall incidence decreased 9% (not significant) with K_2O increases up to 320 lb/acre.

Drip Irrigation

In studies in Quincy, Gainesville, and Live Oak, the effects of K rate and source on drip-irrigated 'Sunny' tomato were evaluated in spring seasons 1986, 1990, and 1991 (Locascio *et al.*, 1994; Locascio *et al.*, 1997a). Micronutrient mix was broadcast preplant at 40 lb/acre with all of the K fertilizer (either 215 or 430 lb/acre K_2O). Soil beds at all sites were mulched with black polyethylene (bed spacing was not indicated).

Medium M-1 K concentrations of 60 and 50 ppm, were reported in the spring 1986 at Gainesville and Quincy, respectively and 100 lb/acre K_2O was recommended. Yield responses to 215 and 430 lb/acre K_2O were similar at both sites. Relative yields with 215 lb/acre K_2O were 99% (2,970 cartons/acre) at Quincy and 95% (2,070 cartons/acre) at Gainesville. Yields were also similar with both KCl and K_2SO_4 potassium sources. Leaf K concentration was adequate in the Gainesville study, data were not presented for Quincy.

Two additional Quincy studies were conducted in spring 1990 and 1991 where the soil M-1 potassium indices were medium (37 ppm), and low (34 ppm). All of the K fertilizer was broadcast preplant. Yield in 1990 was maximized within the medium recommendation of 100 lb/acre K_2O with non-significant yield increases above 80 lb/acre K_2O (97% RY) (2590 cartons/acre). Likewise in 1991, yield peaked with 160 lb/acre K_2O, 100% RY (1660 cartons/acre), near the recommended rate of 150 lb/acre K_2O for low M-1 K soils. With K rates of 240 and 325 lb/acre K_2O, yields declined 8 and 12%, respectively. There were no significant differences in yield responses to K supplied from either KNO_3, KCl, or K_2SO_4 at either location.

A fifth study at Live Oak, spring 1990, was conducted on a soil testing 54 ppm for K and 100 lb/acre K_2O was recommended (Locascio et al., 1994; Locascio et al., 1997a). Yield increased through 160 lb/acre K_2O (2175 cartons/acre, 97% RY) and was unaffected by additional K_2O at 240 or 325 lb/acre. The recommended K rate at this site would have been insufficient for maximum production. Yield response was not affected by K sources KNO_3, KCl, or K_2SO_4.

Research in Dade County was aimed at determining N and K fertigation rates for the rockland soils and evaluating N and K effects on graywall incidence (Carranza et al., 1996). Graywall and other ripening disorders are often associated by growers with low K fertilization. Graywall is a particular concern in commercial fields as yield losses to graywall of 10 to 20% are common with occasional losses greater than 50%.

A factorial experiment was used with four N rates and four K rates from NH_4NO_3 and KCl, in a fall/winter 1995-1996 season (Carranza *et al.*, 1996). Twenty percent of the fertilizer was applied and incorporated preplant and the remainder was injected through a drip irrigation line. Bed spacing was not indicated. Fertilizer injection graduated from 7 lb/acre/week N or K_2O through 14 lb/week after the fourth week in the season. Tensiometers were used to monitor soil moisture.

Soil samples sent to the IFAS Analytical Research Laboratory (ARL) resulted in medium to high K interpretations using the AB-DTPA soil analysis method (Soltanpour and Schwab, 1977). No yield response to applied K was anticipated and subsequent yield data confirmed no response to increased K (Carranza *et al.*, 1996). The largest yield occurred with 50 lb/acre K_2O, 100% RY (1743 cartons/acre) and the yield was 83% with zero lb/acre K_2O. Leaf tissue analysis results were not reported. Leaf petiole sap K^+ concentrations averaged 3300 ppm just below the 3500 to 4000 ppm recommended concentration (Hochmuth, 1994) at first flower. Potassium concentrations were adequate for the remaining three sample stages, but did not increase appreciably with K rates above the 50 lb/acre K_2O rate throughout the sampling periods. Low K fertilization was not a factor in graywall incidence on this medium to high K soil, contrary to earlier mentioned observations on causes of graywall. Additional K_2O at rates above 50 lb/acre had no effect on total marketable yield or graywall incidence.

The M-1 recommended K rate for drip-irrigated tomato was supported by high yields in three of five statewide studies. The recommended rate (100 lb/acre K_2O) was not evaluated at two of these three trials, higher rates (215 and 430 lb/acre K_2O) were applied instead. At the third trial, yields maximized above the recommended rate. Increases in K above the recommended rate did not generally increase yields, in one season, yields fell 12% with 325 lb/acre K_2O. Potassium absorption as measured by petiole sap testing indicated K concentrations did not increase with excess K application. Higher than recommended rates of K were not utilized by tomato for optimum growth or yield. Potassium sources, KCl, K_2SO_4, or KNO_3 did not affect yield response at any drip-irrigated site.

POTASSIUM SUMMARY

Potassium rate recommendations from 1989 consistently failed to optimize yields in 15 of the 18 trials reported above. Tomato yields responded near the new 1995 recommended K rate, based on M-1 soil test indices, in 70% of the trials documented above. Four subsurface-irrigated trials and one drip-irrigated trial accounted for the remaining 30% of trials that required greater K amounts for optimum yields. Winter conditions likely reduced absorption of applied K in two of the subsurface trials but, of greater significance were the large amounts of residual K fertilizer found in the band post-harvest. Band application of K fertilizer has proven the least efficient K application method with other vegetables. Based on results from these K trials, the recommended maximum K rate was increased in 1995 from 160 to 225 lb/acre K_2O. Yield data is graphed in Figure 2 where the dashed line indicates the maximum IFAS recommended K rate for soils very low in M-1 K (225 lb/acre K_2O). Revised recommendations were from 160 to 225 lb/acre K_2O and from 130 to 150 lb/acre K_2O, for respective very low and low M-1 tested K soils (Kidder and Hochmuth., 1989; Hochmuth and Hanlon, 1995), based on some of the above summarized work. Where symbols overlap (figure 2), yield data confirm high yields of 94 to 100% RY to the left of the dashed line or with 240 lb/acre K_2O, (near 225 lb/acre K_2O). Potassium sources KCl, K_2SO_4, and KNO_3, had no effect on yields of drip or subsurface-irrigated tomatoes in all trials except one where tomato yields increased 19% with the KNO_3 treatment.

SUMMARY

Applied fertilizers used in Florida tomato production averaged 310-200-540 lb/acre N - P_2O_5 - K_2O as surveyed by the Florida Agriculture Statistics Service for 1994 (Fla. Agr. Stat. Serv., 1995). These actual applied rates exceed IFAS current maximum recommendations of 175-150-225 lb/acre N, P_2O_5, K_2O, found through experiment to meet tomato requirements for high yields based on soils with very low P and K concentrations (Hochmuth and Hanlon, 1995). Mehlich-1 soil tests often result in low, medium, high, and very high indices of residual soil P and K and IFAS recommendations are further adjusted downward based on nutrient concentrations present in the soil. Assuming soils tested statewide were very low in P and K, 1994 applied fertilizers were 25 and 60% above the recommended rate for these nutrients and 45% above the recommendation for N fertilizer. Lower rates of applied fertilizer would reduce fertilizer costs $6,000,000 without sacrificing yields (fertilizer costs: $305/acre. Smith and Taylor, 1996). When no additional P and K are required on soils high and very high in these nutrients, fertilizer costs and environmental impact could be reduced further.

Determination of the most yield-responsive fertilizer rate for tomato, improving fertilizer- plant efficiency, and reducing nutrient leaching losses have dominated research. Use of polyethylene mulched beds, coated fertilizers (polymer, resin, and sulfur-coating), split fertilizer applications, and restricted water application have focused on fertilizer application timed to plant needs without the N losses associated with excessive water and fertilizer application. In these studies, most tomato yields responded to applied fertilizer N up to 175 lb/acre N, with slightly less nutrient required with tomatoes grown on loamy soils compared to sandy soils.

The objective of increasing fertilizer efficiency was found in these studies to be partially accomplished by avoiding inefficient fertilizer placement methods, particularly band placement of K fertilizer. Other means of increasing fertilizer efficiency include following calibrated soil test recommendations, managing irrigation in an optimal manner, and applying some of the N and K through the drip irrigation system.

Additional research is needed to improve the efficiency of the fertilizer-soil-plant system. Although drip irrigation has reduced water use by one-third to one-half of the water used in subsurface and overhead-irrigated fields, N and K remain of greatest concern as potentially leached fertilizer elements, even with this low water-use irrigation method. Research is needed with CR - N and K sources, where a preplant only fertilizer application could reduce N leaching losses, reduce management costs associated with split fertilizer application and fertigation, and provide a sustained nutrient source.

As CR fertilizer sources are developed, experimentation will be needed to determine their effectiveness with specific crops. Improvement remains possible with fertilizer sources that adjust to seasonal growing conditions, spring, fall, and winter crop periods where temperatures, soil microbial activity, and plant growth rate change. Where soil N retention is poor, increasing organic matter content with cover cropping or otherwise, is known to increase N mineralization and decrease the need for applied fertilizer N. Studies also are needed on optimal timing of N application with drip irrigation systems and on the fate of N in the soil system as it relates to N and irrigation management. Large-scale demonstrations on commercial farms of recommended nutrient management programs are also needed.

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2. George Hochmuth, professor, and Kim Cordasco, technical writer, Horticultural Sciences Department, CooperativeExtension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611

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Fig. 1. Relative Yield of Tomatoes for Experiments, Years, and Seasons as a Function of Added N

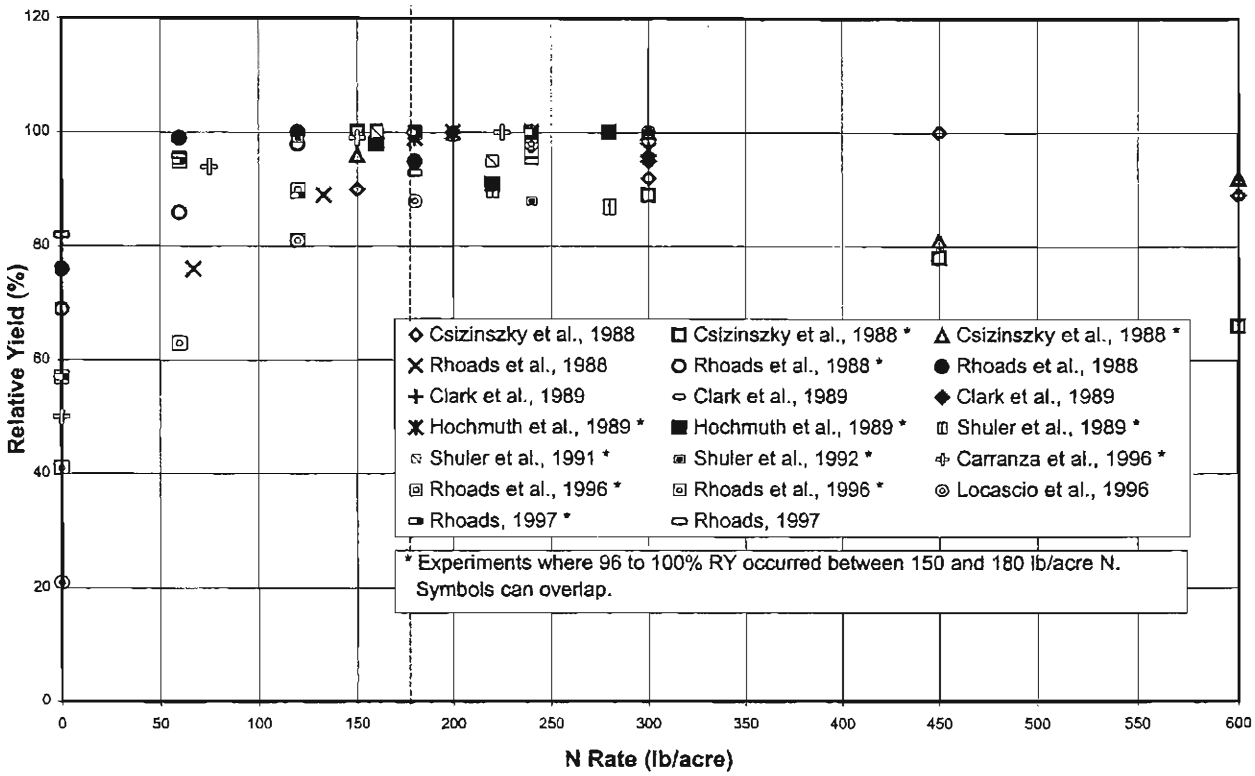
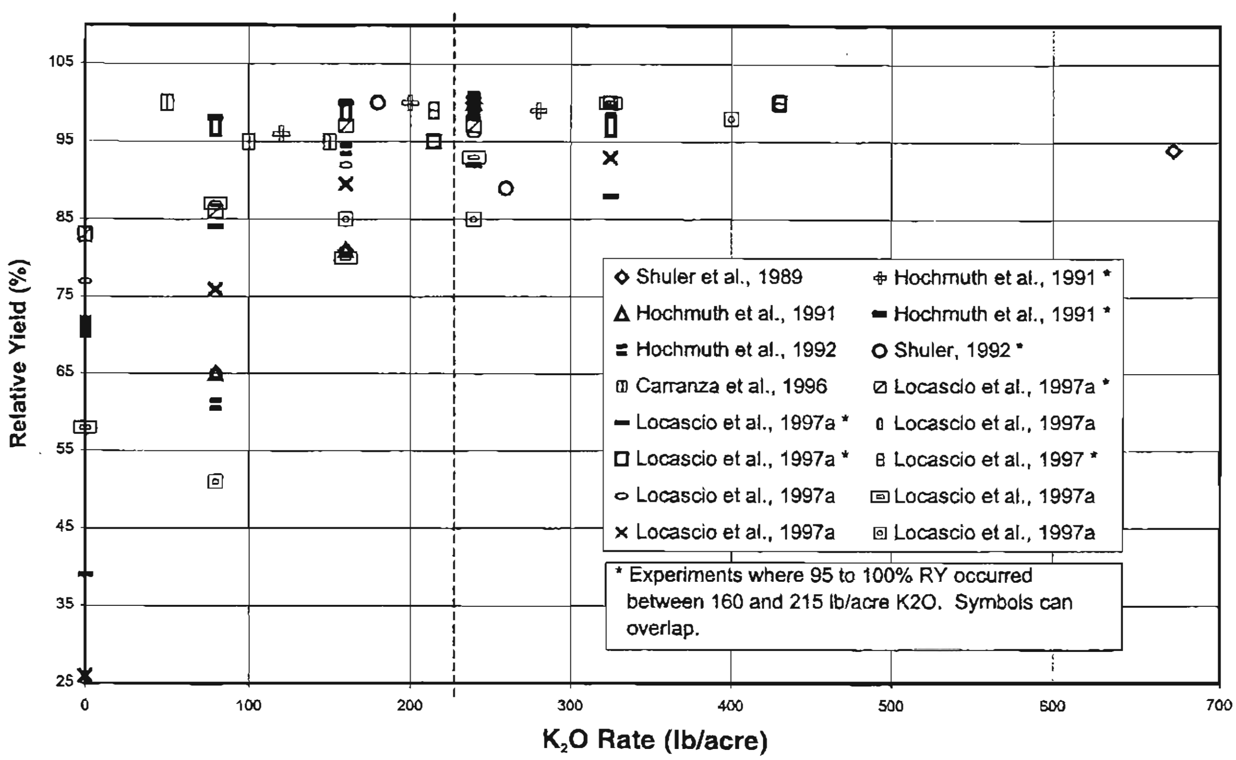


Fig. 2. Relative Yield of Tomatoes for Experiments, Years, and Seasons as a Function of Added K_2O



APPENDIX
TOMATO CONTROL GUIDE

Tomato Varieties in Florida, D.N. Maynard
Tomato Fertilizer Management, G.J. Hochmuch
Nematicides Registered for Use on Florida Tomato, J.W. Noling
Chemical Insect Control in Tomatoes, Dr. Freddie Johnson
Chemicals for Foliar Disease Control in Tomatoes, Tom Kucharek
Weed Control in Tomato, W.M. Stall and J.P. Gilreath

TOMATO VARIETIES FOR FLORIDA

D. N. Maynard
University of Florida
Bradenton, FL
and
S. M. Olson
University of Florida
Quincy, FL

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 acreage. 'Agriset 761' was grown on 22% of the acreage in Florida in the 1997-98 season - down somewhat from the 35% planted the previous season and only about half of that planted in 1995-96. 'Agriset 761' was grown on about 32% of the acreage in southwest Florida, 25% of the acreage on the east coast, and 12% in west central Florida.

'Florida 47' had over 15% of the states acreage - a tremendous increase over the previous year when it was first made available. It was grown on about 32% of the Dade County acreage and had substantial plantings in other areas.

'Solimar', 'Sunbeam', and BHN varieties each had about 11% of the state's acreage. 'Solimar' was mostly grown on the east coast, 'Sunbeam' was most popular in west central Florida, and BHN was grown extensively in southwest Florida.

'Solar Set' was grown on about 7% of the state's acreage - down from 12% the previous year. 'Sanibel' acreage was at about 6% of the Florida acreage in 1997-98. 'Sunpride' and 'Floraset' each had about 3% and 'Sunny', 'Sun Leaper', and XPH 10035 each had about 1% of the states 1997-98 tomato acreage. Several other varieties and experimental lines were grown on less than 1% of the Florida 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; Tropical Research and Education Center; Homestead; and North Florida Research and Education Center, Quincy for the Spring 1997 season are shown in Table 1. High total yields and large fruit size were produced by NC 32-2, FE 10, 'Leading Lady' and PSR 888994 at Homestead; and FT 4012 at Quincy. Not all entries were grown at each location.

Table 1. Summary of University of Florida tomato variety trial results. Spring 1997.

Location	Variety	Total Yield (ctn/acre)	Variety	Large Fruit Size (oz)
Bradenton	Equinox	2808	Affirm	7.2
	Flavor More 223	2685	Merced	6.8
	Florida 7699	2611	Sunpride	6.5
	Florida 7658	2557	FL 47	6.5
	Affirm	2530[1]	STM 5206	6.4[2]
Homestead	NC 32-2	1225	NC 32-2	9.6
	FE 10	1182	FE 10	8.8
	PSR 891994	1121	Leading Lady	8.0
	PSR 888994	1096	PSR 888994	7.8
	Leading Lady	1075[3]	PSR 67396	7.5[4]
Quincy	XPH 10069	2677	SRT 6657	9.8
	FT 4012	2665	FT 4012	9.0
	XPH 10091	2656	FT 3260	8.9
	SRT 6633	2644	STM 5206	8.7
	Agriset 761	2606[5]	PSR 842694	8.6[6]

[1]Thirteen other entries had yields similar to Affirm.
[2]Eight other entries had fruit weight similar to STM 5206.
[3]Eleven other entries had yields similar to Leading Lady.
[4]Seven other entries had fruit weights similar to PSR 67396.
[5]Fourteen other entries had yields similar to Agriset 761.
[6]Four other entries had fruit weights similar to PSR 842694.

Seed Sources:

Agrisales: Agriset 761, Equinox
Asgrow: FL 47, Sunpride, XPH 10091, XPH 10069
Ferry-Morse: Flavor More 223
Frontier: FE 10
NC State Univ.: 32-2
Novartis: FT 3260, FT 4012, Merced
Petoseed: PSR 67396, PSR 842694, PSR 888994, PSR 891994

Sakata: Affirm, STM 5206
Sunseeds: Leading Lady, SRT 6633, SRT 6657
University of Florida: Florida 7658, Florida 7699

Summary results listing outstanding entries in order from trials at the University of Florida's Gulf Coast Research and Education Center, Bradenton; Palm Beach County Extension Service; 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 'Sanibel' and XPH 10091 at Bradenton; 'Florida 47', 'FTE 30', 'Sunbeam', and 'Suncrest' at Palm Beach County; 'Agriset 761', Florida 7791, Florida 7792, 'Solar Set', and 'Sunny' at Ft. Pierce; and XPH 10091 at Quincy. 'Equinox' produced high yields at three of four locations and Florida 7791, 'Sanibel', 'Solar Set', and XPH 10091 at two locations. Florida 7792 and XPH 10091 produced large fruit at two of the four locations. As in the spring trials, not all entries were included at all locations.

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

Table 2. Summary of University of Florida tomato variety trial results. Fall 1997.

Location	Variety	Total Yield (ctn/acre)	Variety	Large Fruit Size (oz)
Bradenton	Sanibel	1430	XPH 10091	6.7
	Florida 7791	1396	HMX 2824	6.5
	XPH 10091	1390	Sanibel	6.3
	Solar Set	1371	Florida 7792	6.3
	Equinox	1368[1]	XTM 6217[2]	6.3
Boynton Beach	FTE 30	2385	Sunbeam	6.5
	Sunbeam	2253	FTE 30	6.4
	Equinox	2157	FL 47	6.3
	Suncrest	2127	SRT 6629	6.1
	FL 47	2126	Suncrest	5.9
			STM 5206	5.9
Ft. Pierce	Agriset 761	2609	Sunny	6.6
	Solar Set	2342	Agriset 761	6.5
	Florida 7792	2340	Florida 7792	6.2
	Sunny	2333	Florida 7791	6.1
	Florida 7791[3]	2329	Solar Set[4]	5.8
Quincy	Equinox	2844	Merced	7.7
	Florida 7696	2802	XPH 10091	7.4
	Florida 7763	2789	XPH 10035	7.3
	XPH 10091	2701	FL 47	7.3
	Sanibel[5]	2695	P3260[6]	7.2

[1]Nine other entries had yields similar to Equinox.
[2]Thirteen other entries had fruit weight similar to XTM 6217
[3]Two other entries had yields similar to Florida 7791
[4]Three other entries had fruit weight similar to Solar Set
[5]Six other entries had yields similar to Sanibel
[6]Six other entries had fruit weight similar to P3260

Seed Sources:

Agrisales: Agriset 761, Equinox
Asgrow: Florida 47, Solar Set, Sunbeam, Sunny, XPH 10035, XPH 10091
Harris Moran: HMX 2824
Novartis: Merced, P3260, Suncrest
Petoseed: FTE 30, Sanibel
Sakata: STM 5206, XTM 6217
Sunseeds: SRT 6629
University of Florida: Florida 7696, Florida 7763, Florida 7791, Florida 7792

TOMATO VARIETIES FOR COMMERCIAL PRODUCTION

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

LARGE FRUITED VARIETIES

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

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. (Novartis).

Equinox. An early determinate, heat-tolerant jointed hybrid. Fruit are flattened globe-shaped with green uniform shoulders. Smoother blossom scar than 'Solar Set' enhances cool-season production. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), and gray leaf spot. (Agrisales).

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

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

Leading Lady. A midseason, determinate, jointed hybrid. Uniform green, firm fruit. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), Alternaria stem canker, gray leaf spot. For trial. (Sunseeds).

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

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

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

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

Suncrest. Early midseason, determinate hybrid. Fruit are green-shouldered and deep oblate to globe shaped. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), tobacco mosaic virus, and nematodes (some species). Tolerant: gray wall and gray leaf spot. (Novartis).

Sun Leaper. A determinate, early midseason, heat-tolerant hybrid. Fruit are uniform green and flattened-globe to deep-oblate shaped. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), tobacco mosaic virus, nematode, and gray leaf spot. (Novartis).

PLUM TYPE VARIETIES

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

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

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

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

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

CHERRY TYPE VARIETIES

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

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

REFERENCE

Maynard, D. N. (ed.). 1998. Vegetable variety trial results in Florida for 1997. Fla. Agr. Expt. Sta. Circ. S-396.

TOMATO FERTILIZER MANAGEMENT

G. J. Hochmuth
Horticultural Sciences Department
University of Florida

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

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

		Nutrient Requirements	Supplemental Applications[1]	
Soil	Number of expected harvests	lbs/A[2] N-P_2O_5-K_2O	lbs/A N-P_2O_5-K_2O	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

[1]Sidedressing to replenish nitrogen and potassium can be accomplished by the use of a liquid fertilizer injection wheel.
[2]Approximately 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 K_2O were applied through the drip system. Some growers find this method helpful where they have had problems with soluble-salt burn. This approach would be most likely to work on soils with relatively high organic matter and some residual potassium. However, it is important to begin with rather high rates of N and K_2O to ensure young transplants are established quickly. In most 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-P_2O_5-K_2O. About 30 to 50 percent of the total applied nitrogen should be in the nitrate form for soil treated with multi-purpose fumigants and for plantings in cool soil 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 K_2O are applied, then there should be no concern for the K source or its associated salt index.

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

Growers with drip irrigation can obtain faster analyses for N or K by using a plant sap quick test. Several kits have been calibrated for Florida tomatoes (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 K_2O injection for mulched tomato on soils testing low in K.

Crop development		**Injection (lb/A/day)**[z]	
stage	weeks	N	K_2O
1	2	1.0	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

[z]Total nutrients applied are 175 lb N and 225 lb K_2O 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)].

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

continued

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

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

[z]MRM=Most recently matured leaf.

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

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

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

1. If treated area is tarped, dosage may be reduced by 33%.
2. The manufacturer of Telone II 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 1, 1998 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

UNIVERSITY OF FLORIDA
Cooperative Extension Service
Institute of Food and Agricultural Sciences

Insect Control in Tomatoes[1]

Freddie Johnson[2]

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 ½ 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

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2. Freddie Johnson, professor of Entomology, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
oil (Sun Spray)	98.8%	1-2 gal/100 gal H_2O	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_2O	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
Bacillus thuringiensis	See individual brand labels		---
chlorpyrifos (Lorsban) (except cherry tomatoes)	50 W	2 lb	14
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) (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.			
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

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
endosulfan			2 - field and greenhouse
(Phaser, Thiodan)	3 EC	2/3 - 1 1/3 qt	1
(Thirethrin)	2.9 L	1 qt	
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
Bacillus thuringiensis	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			2 - field and greenhouse
(Phaser, Thiodan)	3 EC	1 - 1 1/3 qt	1
(Thirethrin)	2.9 L	1 ½ qt	
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	
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)	2S, 2L (EC)	1 1/2 pt	up to day of harvest
(Sniper)	2 E	1 ½ pt	
	50 PVA	3/4 lb	
Bacillus thuringiensis subsp. *tenebrionis* (Novodor)	see individual labels	see individual labels	0
	80S	2/3 - 1 1/4 lb	
carbaryl (Sevin)			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

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
endosulfan			2 - field and greenhouse
(Phaser, Thiodan)	3 EC	2/3 - 1 1/3 qt	1
(Thirethrin)	2.9 L	1 qt	
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
imidacloprid (Provado)	1.6 EC	3.75 oz	0 - foliar
(Admire)	2.0 EC	16 - 24 oz (soil use)	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)	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.			
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)	5% L	2/3 gal	0
(Rotacide)	EC	1 gal	
CORN EARWORMS (See also: Tomato Fruitworms)			
azinphosmethyl (Guthion)	2S, 2L (EC)	3 - 6 pts	up to day of harvest for 3 pt or less(1½ lb or less); 14 for 3+ pt (1½ +)
(Sniper)	2 E	3 - 6 pts	
	50 PVA	1 ½ - 3 lb	
Bacillus thuringiensis	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)	2 S, 2 L(EC)	1 ½ - 2 pts	up to day of harvest
(Sniper)	2 E	1 ½ - 2 pts	
	50 PVA	3/4 - 1 lb	
(banded cucumber beetle)			
carbaryl (Adios)	13 B	½ - 3/4 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
Bacillus thuringiensis	See individual brand labels		0
carbaryl (Sevin)	80S (WP)	2 1/2 lb	0

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
	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)	2S, 2L (EC)	1 1/2 - 2 pt	0
(Sniper)	2 E	1 ½ - 2 pt	
	50 PVA	3/4 - 1 lb	
diazinon AG500 (vinegar fly)	4 EC	1/2 - 1 1/2 pt	1
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)	2S, 2L (EC)	2 - 3 pt	up to day of harvest
(Sniper)	2 E	2 - 3 pts	
	50 PVA	1 - 1 ½ lb	
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

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
	FLEA BEETLES		
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 (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
	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 +)
Bacillus thuringiensis	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

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
cyhalothrin (Karate, Warrior)	1 EC	1.92 - 3.20 oz	5 - caution, see label
endosulfan			2 - field and greenhouse
(Phaser, Thiodan)	3 EC	2/3 - 1 1/3 qts	1
(Thirethrin)	2.9 L	1 - 2 qts	
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)	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.			
LACE BUGS			
carbaryl (Sevin)	80S (WP)	1 1/2 - 2 1/2 lb	0
LEAFHOPPERS			
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	
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.			
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)	2S, 2L (EC)	1 1/2 - 2 pt	up to day of harvest
(Sniper)	2 E	1 ½ - 2 pt	
	50 PVA	3/4 - 1 lb	
cyfluthrin (Baythroid)	2 EC	1.6 - 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
cryomazine (Trigard)	75%	1/6 lb	7
diazinon AG500 (dipterous leafminer)	4 EC	½ pt	1
	50 WP	1/2 lb	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 *Liriomyza trifolii*)	2 EC	2 - 4 pt	1
permethrin (Ambush)	2 EC	3.2 - 12.8 oz	up to day of harvest
permethrin (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.			
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
Bacillus thuringiensis	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
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

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
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
SALTMARSH CATERPILLARS			
Bacillus thuringiensis	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
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	

Table 1. Chemical Insect Control in Tomatoes

Insecticide	Formulation	Formulation Rate/Acre	Min Days to 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.			
SOWBUGS			
carbaryl (Sevin)	5 B	20 - 40 lb	0
STINKBUGS			
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
(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 (Phaser, Thiodan) (Thirethirn)	 3 EC 2.9 L	 1 - 1 1/3 qt 1 ½ - 2 qt	2 - field and greenhouse 1
pyrethrins + rotenone (Pyrellin)	EC	1 - 2 pts	0
THRIPS			
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
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_2O	0
TOMATO FRUITWORMS (CORN EARWORM)			
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 pt 3 - 6 pt 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 +)
Bacillus thuringiensis	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
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
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	½ - 1 1/2 pt	7
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.			
TOMATO PINWORM			
abamectin (Agri-Mek)	0.15 EC	16 oz	7
azinphosmethyl (Guthion) (Sniper)	2S, 2L (EC) 2 E 50 PVA	3 - 6 pt 3 - 6 pt 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 +)
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	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) (fresh fruit only)	4 EC	1/2 - 1 1/2 pt	7
methomyl (Lannate LV)	2.4 EC	1.5 - 3 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.			
Pheromones (NoMate TPW Spiral) (NoMate TPW Fiber)	The product funtions by disrupting mating communications of adult moths. Read label carefully.		See label
TUBERWORMS			
azinphosmethyl (Guthion) (Sniper)	2S, 2L (EC) 2 E 50 PVA	2 1/4 - 3 pt 2 1/4 - 3 pt 1 1/8 - 1 ½ lb	0 0 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

Disease Management for Tomato

Tom Kucharek, Pl. Path. University of Florida/IFAS

Chemical	Maximum Rate/Acre/		Minimum Days to Harvest	Pertinent Diseases	Select Remarks
	Application	Crop			
**For best possible chemical control of bacterial spot, a copper fungicide must be tank-mixed with a maneb or mancozeb fungicide.					
Ridomil Gold EC Ridomil WSP	2 pts/trtd acre 2 lbs	12 pts/trtd acre 6 lbs/trtd acre		Pythium diseases	See label for use at and after planting.
Kocide 101, Blue Shield or Champion WP's	4 lbs		2	Bacterial spot	
Kocide LF, Cuproxat or Champion FL's	5 ⅓ pts		2	Bacterial spot	
Kocide 606	3 qts		2	Bacterial spot	
Champ	2 ⅔ pts		2	Bacterial spot	
Basicop or Basic Copper 53	4 lbs		2	Bacterial spot	
Oxycop WP	6 lbs		2	Bacterial spot	
Microsperse C.O.C. 53WP	4 lbs		2	Bacterial spot	
Manex 4F	2.4 qts	16.8 qts	5	Early and late blight, Gray leaf spot, Bacterial spot[1]	Field and Greenhouse use
Kocide or Blueshield DF's	4 lbs		2	Bacterial spot	
Maneb 80 WP	3 lbs	21 lbs	5	Same as Manex FL	Field and Greenhouse use
Dithane F45 FL	2.4 pts	16.8 qts	5	Same as Manex FL	
Dithane, Penncozeb or Manzate 200 DF's	3 lbs	21 lbs	5	Same as Manex FL	
Bravo 720, Terranil 6L or Echo 720	3 pts		2	Early and late blight, Gray leaf spot, Target spot	Use higher rates at fruit set and lower rates before fruit set.
Maneb 75DF	3 lbs	22.4 lbs	5	Same as Manex FL	
Terranil 90DF or Echo 90 DF	2.3 lbs		2	Early and late blight, Gray leaf spot, Target spot	Use higher rates at fruit set and lower rates before fruit set.
Bravo W75	3 lbs		1	Early and late blight, Gray leaf spot, Target spot	

Disease Management for Tomato

Chemical	Maximum Rate/Acre/		Minimum Days to Harvest	Pertinent Diseases	Select Remarks
	Application	Crop			
Bravo 500, Chloronil 500, Terranil 4L, Evade, Supanil, Echo 500, or Agronil FL's	4 pts		2	Early and late blight, Gray leaf spot, Target spot	Use higher rates at fruit set and lower rates before fruit set.
Ridomil Bravo 81W	3 lbs		2	Early and late blight, Gray leaf spot, Target spot	Limit is 4 appl/crop
Ridomil MZ58WP[2] Ridomil MZ72WP[2]	2 lbs 2.5 lbs	8 lbs 7.5 lbs	5 5	Late blight Late blight	Limit is 4 appl/crop 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 and Late blights Gray leaf spot	
JMS Stylet Oil	3 qts		NTL	Potato Virus Y, Tobacco Etch Virus	See label for specific info on appl. technique (e.g. use of 400 psi spray pressure)
Ridomil/Copper 70W	2.5 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 and Late blights, Gray leafspot, Target spot, Botrytis, Rhizoctonia fruit rot	Use higher rates at fruit set.
Bravo Weather Stik	3 pts		2	Same as Bravo Ultrex	Use higher rates at fruit set
Quadris 2.08 FL	6.2 fl oz	37.2 fl oz	7	Early blight, late blight, sclerotinia	Do not make more than 2 sequential appl. with Quadris. Limit is 6 appl.

Disease Management for Tomato

Chemical	Maximum Rate/Acre/		Minimum Days to Harvest	Pertinent Diseases	Select Remarks
	Application	Crop			
Botran 75W	1 lb	4 lbs	10	Botrytis	Greenhouse tomato only. Limit is 4 applications. Seedlings or newly set transplants may be injured.
Exotherm Termil	1 can/1000 sq. ft.		2	Botrytis, Leaf mold, Late & Early blights, Gray leafspot	Greenhouse use only. Allow can to remain overnight and then ventilate. Do not use when greenhouse temperature is above 75F.

[1]When tank mixed with a copper fungicide.

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

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

UNIVERSITY OF FLORIDA

Cooperative Extension Service
Institute of Food and Agricultural Sciences

Fact Sheet HS-200
August 1998

Weed Control in Tomato[1]

William M. Stall and James P. Gilreath[2]

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: August 1998. Please visit the FAIRS Website at **http://hammock.ifas.ufl.edu**.

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

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

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

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

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

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.

<table>
<tr><th rowspan="2">Herbicide</th><th rowspan="2">Labelled Crops</th><th rowspan="2">Time of Application to Crop</th><th colspan="2">Rate (lbs. AI./Acre)</th></tr>
<tr><th>Miineral</th><th>Muck</th></tr>
<tr><td>Clethodem
(Select 2 EC)</td><td>Tomatoes</td><td>Postemergence</td><td>0.9-.125</td><td>—</td></tr>
<tr><td colspan="5">Remarks: Postemergence control of actively growing annual grasses. Apply at 6-8 fl oz/acre. Use high rate under heavy grass pressure and/or when grasses are at maximum height. Always use a crop oil concentrate at 1% v/v in the finished spray volume. Do not apply within 20 days of tomato harvest.</td></tr>
<tr><td>Diquat (Diquat H/A)</td><td>Tomato Vine Burndown</td><td>After final harvest</td><td>0.375</td><td>—</td></tr>
<tr><td colspan="5">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.</td></tr>
<tr><td>Diquat dibromide (Diquat)</td><td>Tomato</td><td>Pretransplant Postemergence directed-shielded in row middles</td><td>0.5</td><td>—</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>MCDS (Enquik)</td><td>Tomatoes</td><td>Postemergence directed/shielded in row middle</td><td>5 - 8 gals.</td><td>---</td></tr>
<tr><td colspan="5">Remarks: Controls many emerged broadleaf weeds. Weak on grasses. Apply 5 to 8 gallons of Enquik in 20 to 50 gallons of total spray volume per treated acre. A non-ionic surfactant should be added at 1 to 2 pints per 100 gallons. Enquik is severely corrosive to nylon. Non-nylon plastic and 316-L stainless steel are recommended for application equipment. Read the precautionary statements before use. Follow all restrictions on the label.</td></tr>
<tr><td>Metribuzin
(Sencor DF) (Sencor 4)
(Lexone DF)</td><td>Tomatoes</td><td>Postemergence
Posttransplanting after establishment</td><td>0.25 - 0.5</td><td>—</td></tr>
<tr><td colspan="5">Remarks: Controls small emerged weeds after transplants are established direct-seeded plants reach 5 to 6 true leaf stage. Apply in single or multiple applications with a minimum of 14 days between treatments and a maximum of 1.0 lb ai/acre within a crop season. Avoid applications for 3 days following cool, wet or cloudy weather to reduce possible crop injury.</td></tr>
<tr><td>Metribuzin
(Sencor DF) (Sencor 4)
(Lexone DF)</td><td>Tomatoes</td><td>Directed spray in row middles</td><td>0.25 - 1.0</td><td>—</td></tr>
<tr><td colspan="5">Remarks: Apply in single or multiple applications with a minimum of 14 days between treatments and maximum of 1.0 lb ai/acre within crop season. Avoid applications for 3 days following cool, wet or cloudy weather to reduce possible crop injury. Label states control of many annual grasses and broadleaf weeds including, lambsquarter, fall panicum, amaranthus sp., Florida pusley, common ragweed, sicklepod, and spotted spurge.</td></tr>
<tr><td>Napropamid
(Devrinol 50WP)
(Devrinol 50DF)
(Devrinol 2E)</td><td>Tomatoes</td><td>Preplant incorporated</td><td>1.0 - 2.0</td><td>—</td></tr>
<tr><td colspan="5">Remarks: Apply to well worked soil that is dry enough to permit thorough incorporation to a depth of 1 to 2 inches. Incorporate same day as applied. For direct-seeded or transplanted tomatoes.</td></tr>
</table>

Table 1. Chemical weed controls: tomatoes.

Herbicide	Labelled Crops	Time of Application to Crop	Rate (lbs. Al./Acre)	
			Miineral	Muck
Napropamid (Devrinol 2E) (Devrinol 50WP)	Tomatoes	Surface treatment	2.0	---
Remarks: Controls germinating annuals. Apply to bed tops after bedding but before plastic application. Rainfall or overhead-irrigate sufficient to wet soil 1 inch in depth should follow treatment within 24 hours. May be applied to row middles between mulched beds. A special Local Needs 24(c) Label for Florida. Label states control of weeds including Texas panicum, pigweed, purslane, Florida pusley, and signalgrass.				
Paraquat (Gramoxone Extra)	Tomatoes	Premergence; Pretransplant	0.62 - 0.94	---
Remarks: Controls emerged weeds. Use a non-ionic spreader and thoroughly wet weed foliage.				
Paraquat (Gramoxone Extra)	Tomatoes	Post directed spray in row middle	0.47	---
Remarks: Controls emerged weeds. Direct spray over emerged weeds 1 to 6 inches tall in row middles between mulched beds. Use a non-ionic spreader. Use low pressure and shields to control drift. Do not apply more than 3 times per season.				
Pebulate (Tillam 6E)	Tomato	Pretransplant Incorporated	4	---
		Directed	6	---
Remarks: Do not use on seeded tomatoes. Apply pretransplant incorporated to mechanical transplanted tomatoes. Do not hand transplant. Consult label for incorporation methods recommended. May be applied post transplanting as a directed spray to clean cultivated soil. There is a 8 day PHI. Product is volatile and not persistent in soil. Susceptible weeds germinating late in the season may not be controlled. Do not use hot caps or row covers after application.				
Pelargonic Acid (Scythe)	Fruiting Vegetable (tomato)	Preplant Preemergence Directed-Shielded	3-10% v/v	---
Remarks: Product is a contact, nonselective, foliar applied herbicide. There is no residual control. May be tank mixed with several soil residual compounds. Consult the label for rates. Has a greenhouse and growth structure label.				
Sethoxydim (Poast)	Tomatoes	Postemergence	0.188 - 0.28	---
Remarks: Controls actively growing grass weeds. A total of 4½ pts. product per acre may be applied in one season. Do not apply within 20 days of harvest. Apply in 5 to 20 gallons of water adding 2 pts. of oil concentrate per acre. Unsatisfactory results may occur if applied to grasses under stress. Use 0.188 lb ai (1 pt.) to seedling grasses and up to 0.28 lb ai (1½ pts.) to perennial grasses emerging from rhizomes etc. Consult label for grass species and growth stage for best control.				
Trifluralin (Treflan 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.				

NOTES

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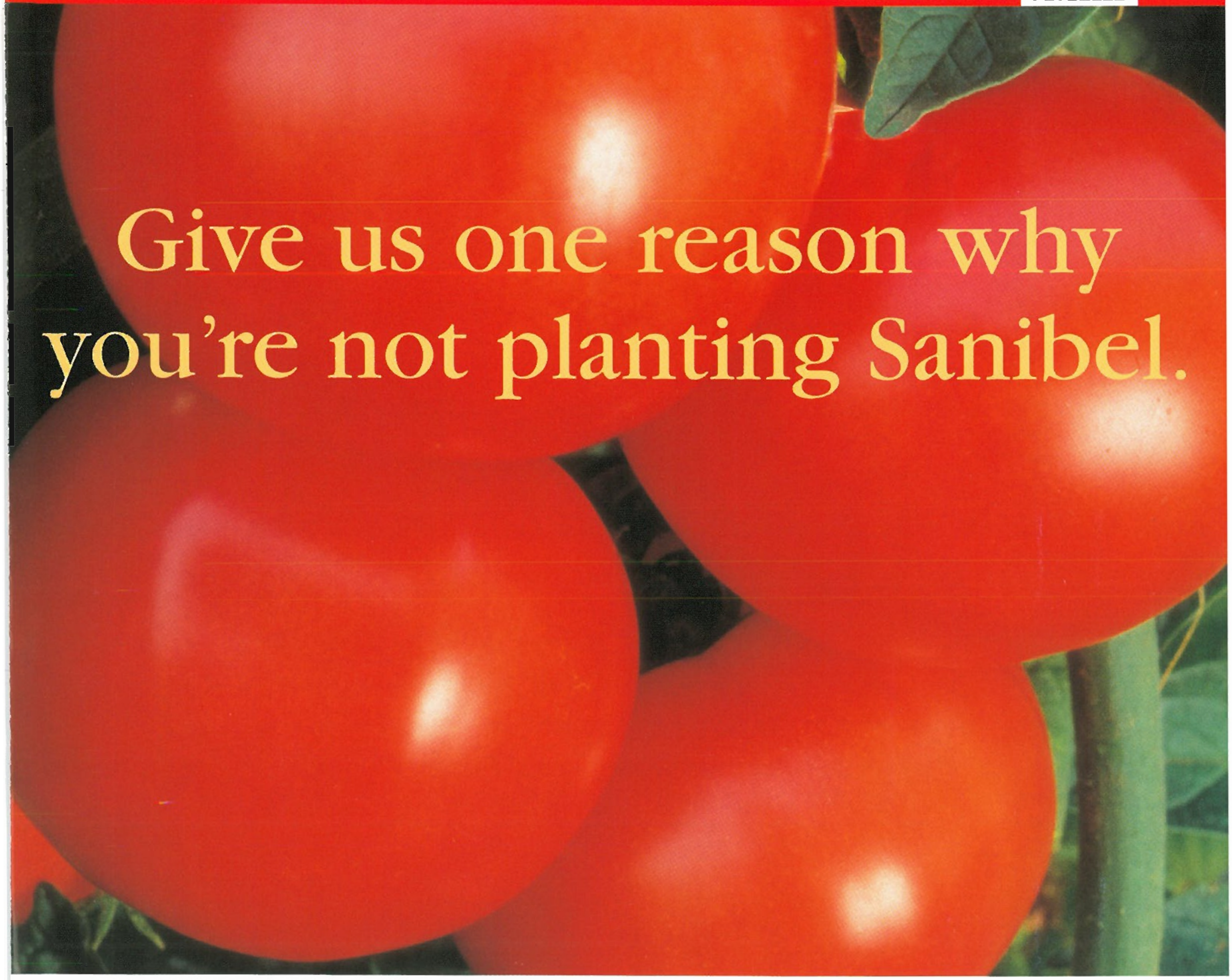

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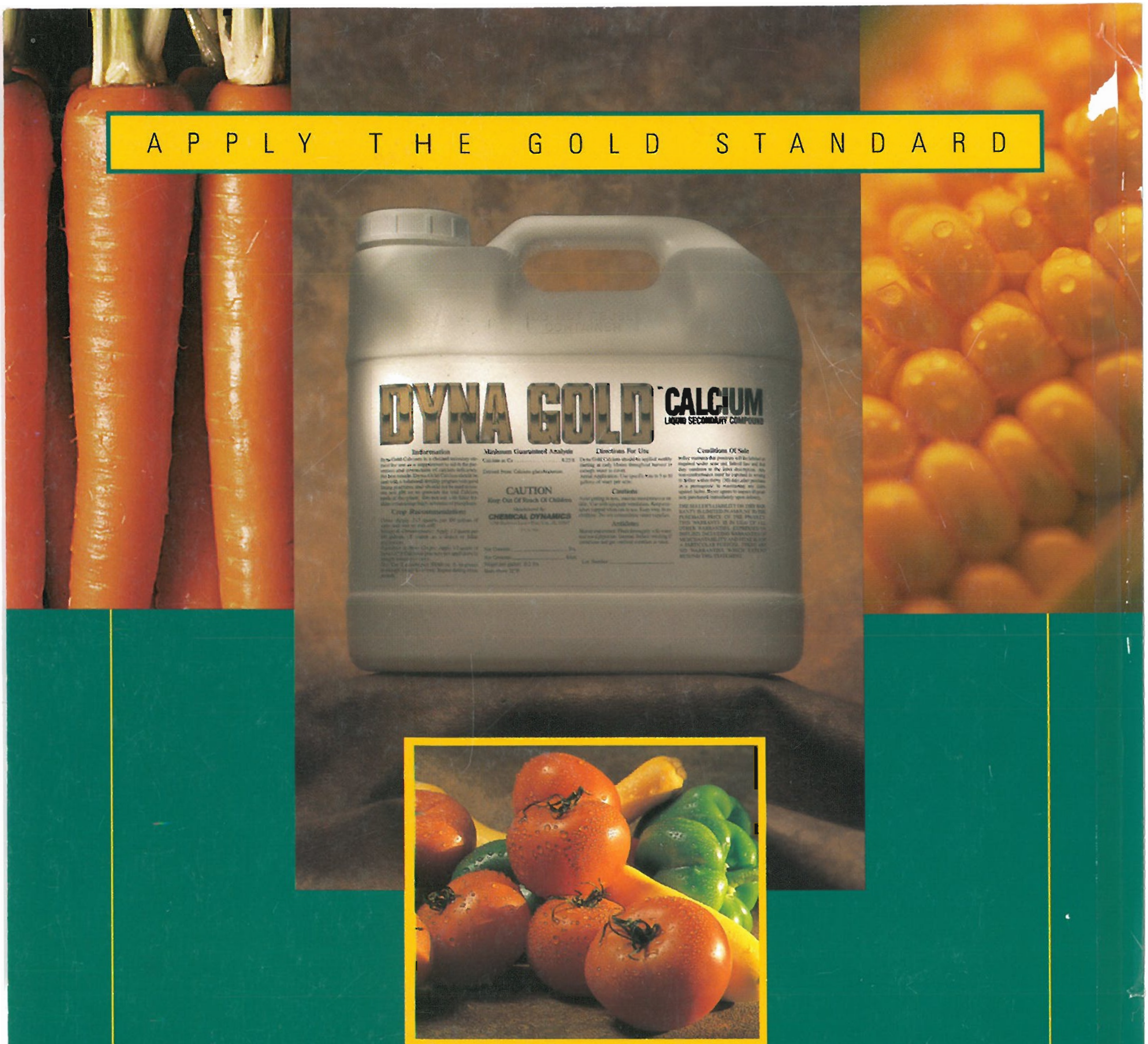

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