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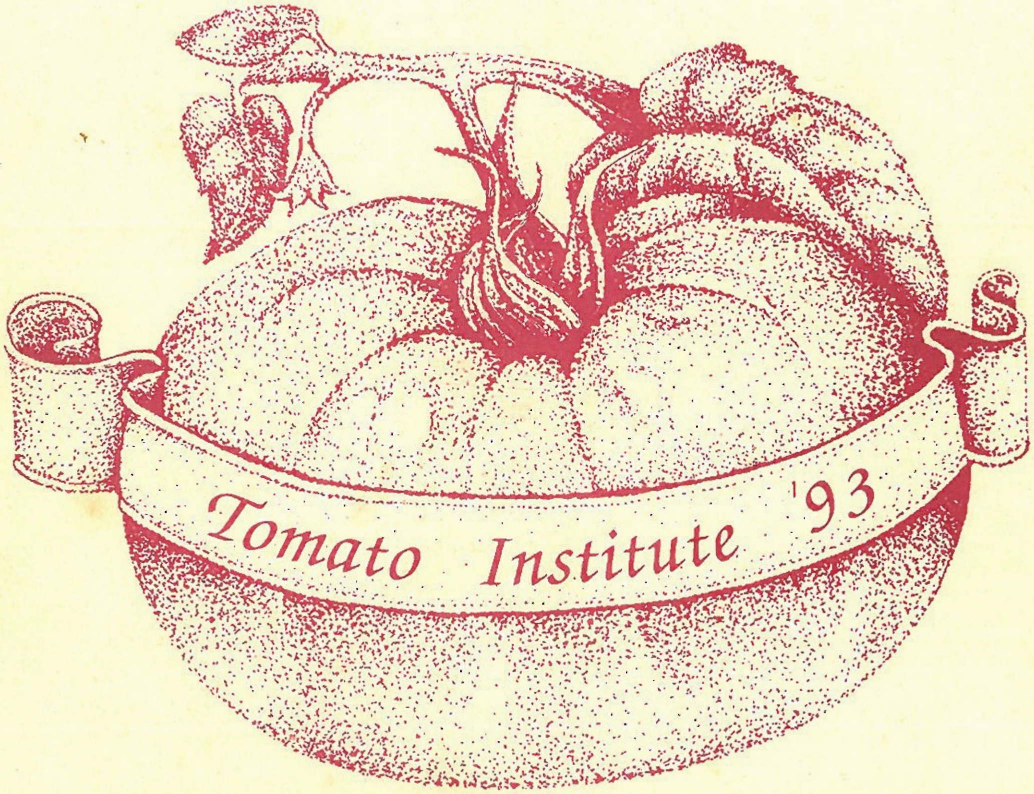

edited by C.S. Vavrina

University of Florida
Horticultural Sciences Department
Institute of Food and Agricultural Sciences

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WATER USE RESTRICTIONS AND ACREAGE REDUCTIONS

D. Manson
Carey, O'Malley, Whitaker, & Lins
Tampa, FL

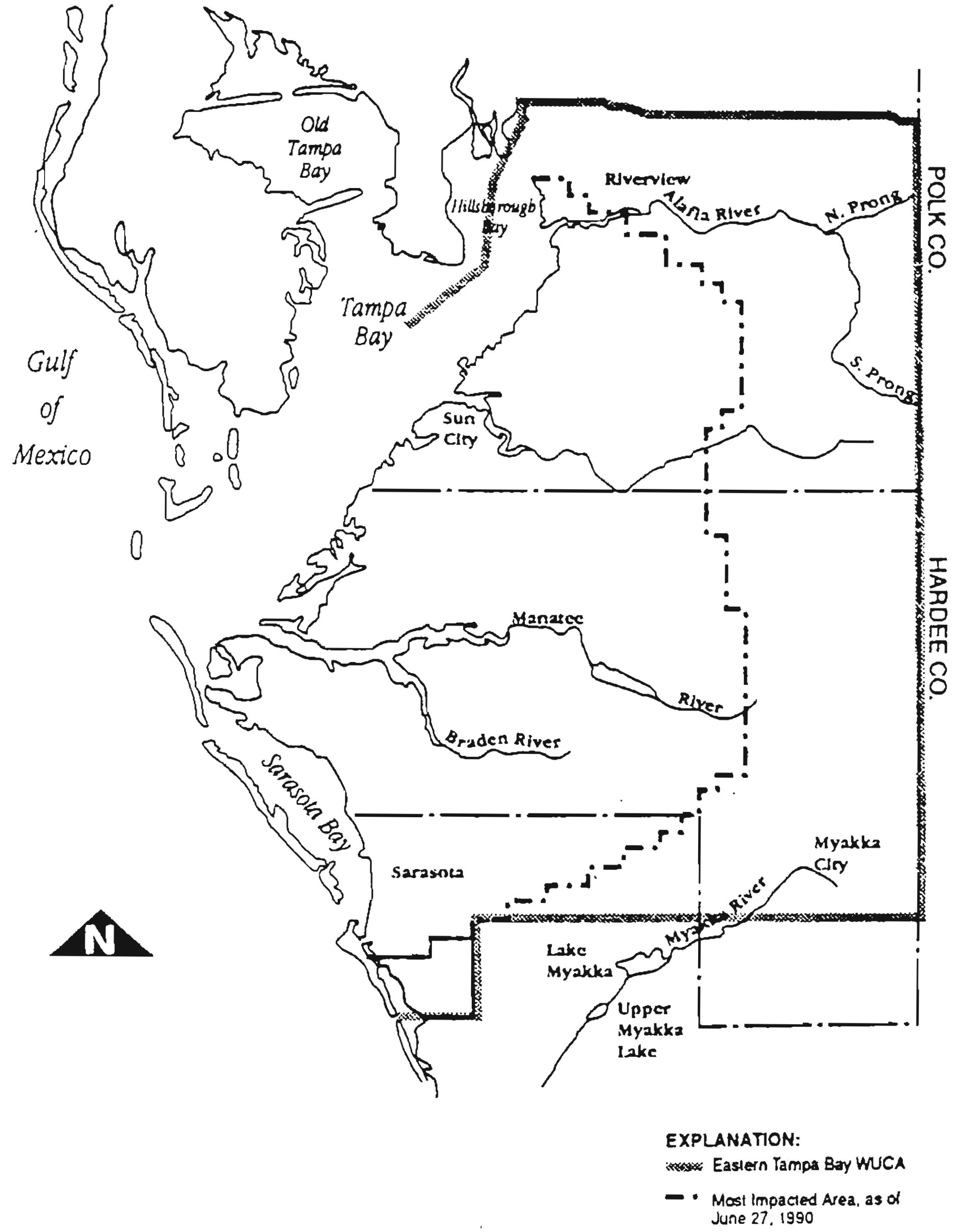
As population grows in the State of Florida, the demands on its water resources continue to increase. This is evidenced by the Everglades controversy in the South Florida Water Management District (SFWMD) over water quality and water quantities supplied to a natural system, the St. Johns River Water Management District (SJRWMD) controversy between the fern growers and nearby residential populations and the ongoing controversy in the Southwest Florida Water Management District over water resource demands. All of these controversies result from a change in the state's demographic characteristics. As the state has converted from an agriculturally-based economy to a tourist-based economy, the urban population has continued to swell. This urban population has settled mainly on the coastlines with the exception of the Orlando metropolitan area. Historically, this growth have driven agricultural inland which has coincided with a greater availability of water resource. However, as these residential populations continue to expand to areas near or adjacent to agricultural operations, the conflict between the two activities has grown.

As the Everglades controversy seems to be drawing to a close, it is obvious that agricultural interest will disproportionately share the cost in the resolution of controversies between agricultural interest and urban populations over the impact of the Everglades natural ecological system. In the same way, the Southwest Florida Water Management District's Southern Water Use Caution Area (SWUCA) process can been seen to lead to a familiar conflict between urban and agricultural interests.

In 1989, SWFWMD identified a problem in the area and created the Eastern Tampa Bay Water Use Caution Area (ETBWUCA) and instituted a water use moratorium within the Most Impacted Area (MIA) in the region of vegetable production of southern Hillsborough and Manatee Counties. This designation had been instituted due to SWFWMD concerns over regional declines in water levels in an area surrounding this highly concentrated vegetable production area. (See Graphic 1) After the designation of the ETBWUCA in 1989, the District was to perform a comprehensive study of water quality and water availability and water usage within the ETBWUCA.

After nearly four years, SWFWMD released the Eastern

Figure 7.2-2
Eastern Tampa Bay WUCA



GRAPHIC 1

Tampa Bay Water Resource Assessment Project in March 1993, concluding that seawater intrusion is the current limiting constraint to groundwater development in the ETBWUCA.

The Southwest Florida Water Management District has generated a report that alleges that saltwater intrusion along the coasts of Hillsborough, Manatee and Sarasota counties has caused a significant deterioration in water quality in the coastal and near coastal areas. The data utilized by the SWFWMD and its methods of analysis have been challenged as inconclusive. See Review of Chloride Concentration Data from Selection Wells Located in the Eastern Tampa Bay Water Use Caution Area prepared for West Coast Regional Water Supply Authority, July 1993.

Based on this water quality survey, which has been questioned, the District contracted to have a solute transport model constructed to predict and estimate the movement of the saltwater interface in this area over time. Then by connecting this solute transport model to a generalized groundwater model, the District felt that it would be able to simulate different pumpage and allocation strategies to determine the "safe yield" within the ETBWUCA. The safe yield has never formally been determined or set by the SWFWMD's Governing Board. At its October meeting, a Governing Board member simply stated that "Our definition of safe yield is there ain't gonna be no more intrusion of saltwater." (Tr. of 10/26/92 public hearing of SWFWMD Gov. Bd., p. 79) There was never a formal motion made, nor a formal policy adopted by the Governing Board to define the parameters of "safe yield" which would ultimately determine the range of available water in the system.

In an attempt to follow this Governing Board concern, the SWFWMD staff selected a number of pumpage scenarios based on a trial and error process to determine which scenario would not cause any further movement of the saltwater interface. Although it is difficult to determine, it seems from the reports and evidence from a technical session given by the District on its modelling, the District has selected a scenario and proposed a 25% reduction in groundwater use within the ETBWUCA.

The SWFWMD modelling runs simulate the SWFWMD's estimate of pumpage for the drought year 1989. By assuming the worst case scenario of a drought year with maximum vegetable acreage planted, the District found that within 50 years at this usage, the saltwater interface may move within a range of 1/4 mile to as much as 2 miles further inland. This interface would move at different rates through different areas of the coast, more slowly in the northern sections of the ETBWUCA and more quickly in the southern areas. Utilizing this modelling scenario, the District staff has stated that the ETBWUCA has a "safe yield" of 150 million gallons per day (mgd). The District estimated pumpage for 1989 was approximately 214 mgd. (See Graphic 2)

Eastern Tampa Bay WRAP

	1989 Estimated Ground Water Use	1992 Permitted Ground Water Use
Agriculture	164	330
Public Supply	33	54
Mining	9	21
Industrial	7	30
Other	1	3
Totals	**214**	**438**

GRAPHIC 2

In the early process of the SWUCA, the District proposed a 50 mgd cutback in actual use of water within the ETBWUCA. The realization must be made that public supply will continue to grow throughout the period and cannot practically cut back on any of its groundwater withdrawals without new sources of water from surface water or reverse osmosis facilities or other costly sources.

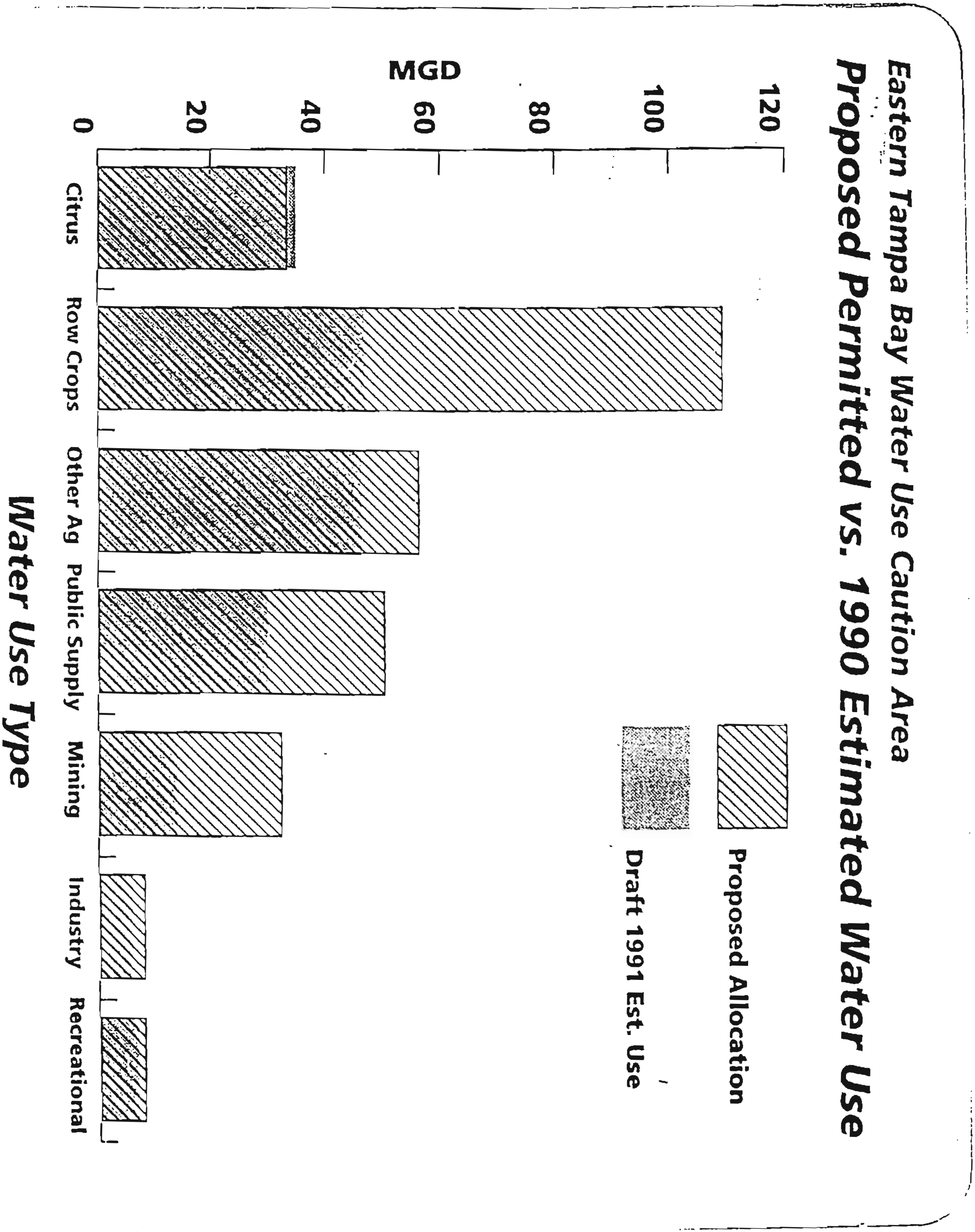
By far, the largest user of groundwater in the ETBWUCA is vegetable farmers. (See Graphic 3) Since most citrus groves have already converted to micro-jet irrigation within this area, the water savings from further efficiencies would not be significant. Therefore, the obvious target for cutbacks in water use would be a seasonal vegetable industry that has not converted to what the District feels is the most efficient irrigation systems. This alternative would mean a cutback in vegetable acreage, specifically water intensive crops such as tomatoes and peppers of as much as 40% in order to reach the targeted safe yield of 150 mgd.

The SWUCA work group has worked diligently to encourage the SWFWMD to pursue the production of alternative sources of water instead of the restriction of existing allocated water uses in this area.

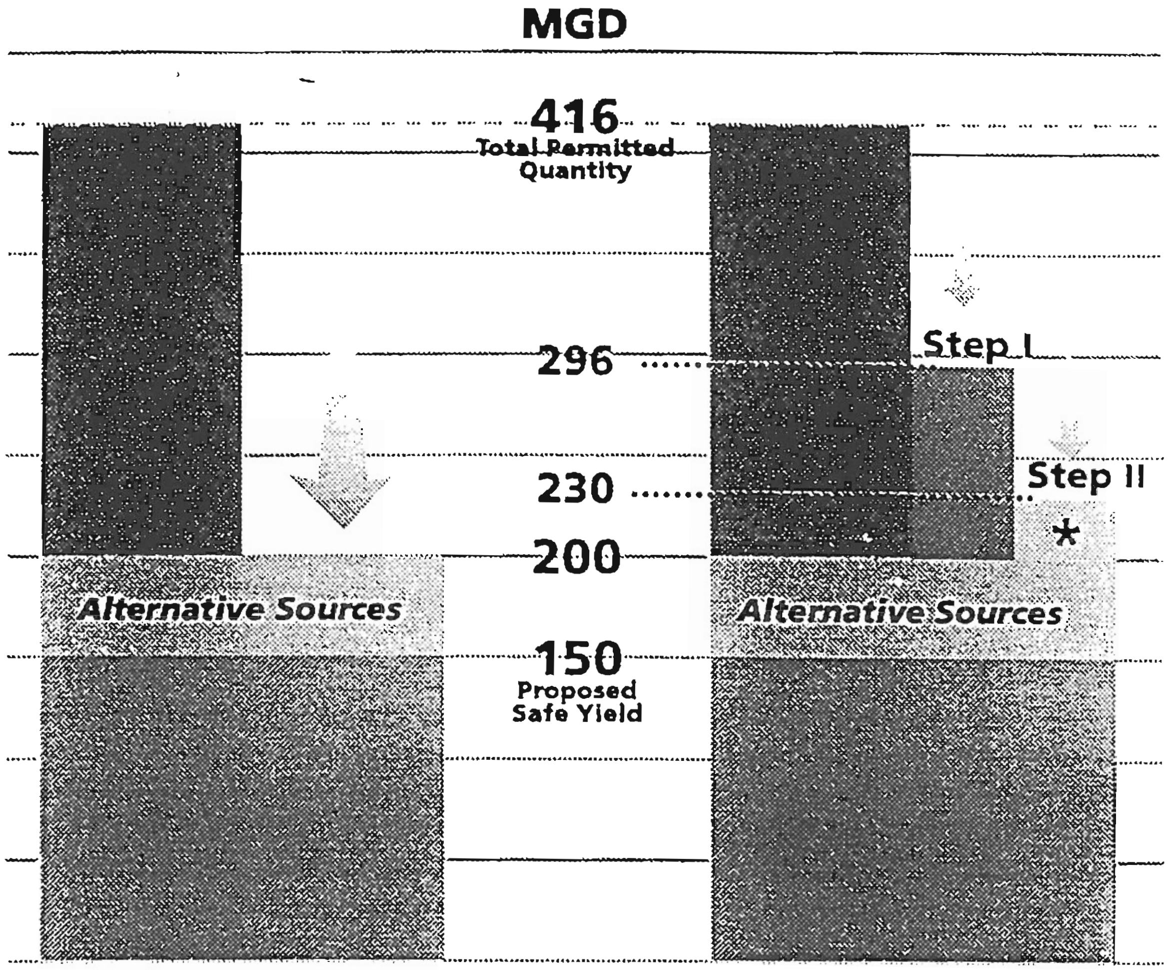
At its most recent SWUCA work group meeting, SWFWMD has proposed a 50 mgd supply of water through alternative sources for the ETBWUCA. (Graphic 4) Their new proposal also includes extending the moratorium on issuing new water use permits from the Most Impacted Area to include all of the ETBWUCA. This option does not currently include any water use restrictions on the remaining SWUCA.

The challenge for the vegetable and agricultural industry as a whole is to first determine whether or not the science utilized by the District is valid and reaches a reasonable prediction of the range of available water. The second major difficulty is the application of a rigid, regulatory scheme on a resource that is extremely dynamic, both seasonally and over drought and flood periods. One set of water use restrictions setting a safe yield of 150 mgd will not take into account a 10-year rainy period, nor a 10-year drought period.

A more complex and disturbing problem lies in the allocation of the water within an area that issues no new water use permits. The state law for all water management districts provides that if two applicants apply for the same water within an area, that their applications, if equally qualified, will be reviewed as a competing use. As agricultural permits come up for renewal within the ETBWUCA, other farmers as well as public supply, industry or mining interests could apply for the same quantity of water. Currently, the District would have to determine which of these competing users "best serves the public interest". See Section 373.233, <u>Florida Statutes.</u> None of the districts, including SWFWMD have created any criteria or method for determining what is in the public interest when reviewing


Eastern Tampa Bay Water Use Caution Area
Proposed Permitted vs. 1990 Estimated Water Use
Proposed Allocation
Draft 1991 Est. Use
MGD
0
20
40
60
80
100
120
Citrus
Row Crops
Other Ag
Public Supply
Mining
Industry
Recreational
Water Use Type

GRAPHIC 3



Option 1

- Reallocate based on high efficiency and based on highest use in previous five years
- Eliminate unused quantities

Option 2

Step I
- Reallocate based on high efficiency and based on permitted quantity
- Reduce unused quantities

Step II
- Percent reduction across board, hold reduced quantities in reserve

* Assumes permitted is 15% above actual

GRAPHIC 4

competing water use permit applications. Public supply would argue that drinking water is the highest and best use of water; therefore, its uses best serve the public interest.

The District's moratorium on water use permits within a large area will lead to competing applications. Without a rule mandating an allocation scheme that would be fair to agricultural interests, water will be eventually be lost to public supply.

The scarcity created by water use moratoriums and eventually a true competition over the available water resource will lead to an allocation system for water in the entire State of Florida. The allocation systems will rely on water management district regulations, legislative mandates and/or trading mechanisms.

The most likely forum for agriculture to effectively design an allocation system to allow for the continued viability of the agricultural industry would be the construction of rules within the water management districts. This allocation system could be based on the existing land uses and the needs and sources evaluations already developed by the Districts for certain regions within their jurisdiction. By providing that in agricultural areas, agricultural withdrawals would "best serve the public interest", agriculture could be seen to protect its industry from continued reductions in acreage as population centers grow in the Florida.

Since the comprehensive plans in most areas have already designated agricultural zones which effectively prohibit high density development in these areas, it would follow that agricultural activities should be given preference for the available water supply. In populated areas and areas designated as high density, the water use preference would be for a public supply or industry.

This would still not provide an allocation system for the transfer of water between the same user group. The exchange of permits within the same water use category should be encouraged within the district regulatory process in the area of permit moratorium. In providing a regulatory scheme that provides for the transfer of these permits within water use categories, a value will be developed based on the supply and demand dynamics in the system. The purchase and sale of these water permits would cause high efficiency of water use.

In summary, the apparent water resource crises identified the numerous areas in the state of Florida are precursors to the ultimate determination of allocation of the available water. Once scarcity has developed within areas of the state, the true battle will begin on which type of user categories should have access to the water. Since agricultural interests can least afford to convert to expensive water supply systems, they should be given preference, at least in their existing areas, over any other type of use. Public supply and industrial usage should be encouraged to explore new technologies, to develop alternate supplies and to assist in providing reuse and other water needs to other categories of water users.

WATER QUALITY ISSUES AFFECTING THE FLORIDA TOMATO INDUSTRY

C. D. Stanley and G. A. Clark

University of Florida,
Gulf Coast Research and Education Center

The issue of water quality can have two different meanings for agricultural producers in Florida. First, there is the quality of the water applied to the production area for irrigation, and second, the condition or quality of the water after it leaves the production area. Irrigation water quality with respect to salinity, iron content, pH, soluble solids, among others, always has been a major factor for profitable crop production. The quality of water once it leaves the application area and the effect that it may have on surface and groundwater resources has been of less concern until recent years. Environmental interests have been active to advocate governmental regulations to make agriculture more accountable for the fate of leached agrichemicals that are used for crop production. The potential for nutrients and pesticides to move readily through the soil profile and into water resources has been and will continue to be a volatile environmental and political issue.

Although the quality of drinking water always has been a public concern, it wasn't until the environmental movement of the 1960's and 1970's that governmental regulations began to affect the way things were done. The primary targets then were industries which could be identified as **point source** polluters, that is, those which used direct discharge of hazardous materials into water resources. With the advent of the Clean Water Act, many regulations were written to control these practices and, for the most part, have been effective. The evolution of policy toward control of water quality degradation has moved from concern for visible pollutants to non-visible pollutants, from control of point source pollutants to nonpoint source pollutants, from use of voluntary controls to mandatory controls, and increasing the use of "market" or economically related mechanisms.

How are current trends in water quality regulation going to affect the Florida tomato producer? Indirectly, there are two seemingly unrelated non-agricultural issues which will have an impact on agriculture in the long run. These are the regulation of wastewater treatment and stormwater runoff. These issues will affect agriculture in that the resolution of how they will be dealt with will ultimately determine the time table for development and implementation of water quality regulations which will eventually affect agriculture directly.

Two issues which will affect agriculture more directly include 1) control and regulation of non point source contamination of water supplies and 2) protection of wetlands. There is strong thinking among environmental protection advocates that agriculture has not been held accountable for its use of natural resources. Also, there is strong public perception, right or wrong, that agriculture does not always act responsibly with respect to the use of agrichemicals and that the industry as a whole must demonstrate responsible use.

Since water quality problems don't easily fit into political boundaries, there will likely be major battles waged from federal, state, and local entities as to what approach (voluntary or regulatory) should be used and to what extent regulations will be implemented. For example, in areas of the country where agricultural producers are heavily involved with federal farm programs, there is a significant amount of economic leverage that can be exerted to force "voluntary" grower compliance with installation of improved management practices (IMP). However, for a commodity area such as tomato production where there can be little or no involvement with federal programs and where production costs are so high, the governmental leverage for "encouraging" growers to voluntarily adopt IMP's is not effective. The alternative is to use a strong regulatory approach.

Initially, pesticides were the main issue and public perception was that widespread use was causing significant contamination of surface water and groundwater resources. This perception prompted the initiation of research studies designed to determine the extent to which this contamination was occurring. Many of these studies showed that widespread contamination was not occurring and that,in most cases, when pesticides were used in compliance of label restrictions for pests, crops, and soils, there appeared to be relatively low risk for movement into the groundwater. Although the perception of widespread contamination was not shown to be true, this effort resulted in tighter controls for use and application of pesticides.

The major focus of water quality concerns has changed from pesticides to applied nutrients (especially phosphorus and nitrogen) moving into surface water and groundwater resources. Again, since agriculture uses such large quantities of fertilizer, the public perception is that much of this fertilizer is moving off-site to nearby water resources. Also, there seems to be a perception by Congress that agricultural producers are not doing all that they can with respect to implementing IMP's to reduce potential water quality problems.

In an attempt to provide data that would be useful for regulators in making water quality control decisions, an ongoing voluntary rural well testing program initiated in 1987 in cooperation with the American Farm Bureau Federation was designed to develop a data base of water quality information. It involves testing rural wells for concentrations of nitrates and selected agricultural herbicides to determine the extent to which rural well contamination occurs. Over 35,000 rural residents from 15 states have participated to date. A recently published mid-project summary (1) reported that of the 34,215 wells that were tested, less than 4% of the wells had nitrate concentrations in excess of the drinking water standard (DWS) of 10 ppm. The EPA estimates that 2.4% of rural wells nationwide are in excess of the DWS (2). Overall, the nitrate levels varied considerably from region to region and with respect to sampling time, and where levels were high, well age and depth, soil type, and proximity to cropping area, feedlots, or chemical mixing area were contributing factors. Although the overall effort does not constitute using an unbiased sample since it was voluntary, it does represent an effort by advocates for agriculture to provide information that demonstrates responsible use of resources by agriculture.

A number of federal projects, including the Lake Manatee Watershed Demonstration (LMWD) project in Manatee County, have been started under a National Water Quality Initiative which began during the Bush administration with the purpose of evaluating and demonstrating management practices that reduce the likelihood of leaching or nutrient runoff. These projects are designed to demonstrate the effectiveness of selected management practices and to encourage voluntary grower adoption, thus, demonstrating to the public that agriculture seriously takes its responsibility to protecting water resources.

The primary LMWD project objectives are:

1. To assess, on grower-cooperator production areas (vegetable and citrus), the effect of current management practices on the nitrogen and phosphorus levels in groundwater and surface water

2. To assist growers in adopting water and fertilizer management practices that will reduce the amount of fertilizer nutrients (with emphasis on nitrates) loss, and

3. To couple the sampling program with existing groundwater computer models to enable demonstration to regulatory and decision-making bodies the extent of actual nutrient loadings from production areas in the watershed, and the consequences of various management changes.

On-site monitoring at two-week intervals of nitrate-N and phosphorus levels is accomplished using 10-20 ft deep multilevel sampling wells which allow simultaneous sampling at the different depths. The samples are analyzed at the Gulf Coast Research and Education Center (GCREC) and results are compiled to determine trends in changes of N and P concentrations throughout the growing seasons. In addition, companion research studies are being conducted at GCREC in tandem with this project to develop more information about improved management practices. Some of the recommended IMP's include: applying fertilizer at rates according to crop needs, use of the fully enclosed subirrigation (FESI) system in combination with reduced fertilizer applications as an improved water and nutrient management system, use of microirrigation with scheduling and fertigation, and multiple cropping.

Preliminary results from subirrigated tomato production sites have been mixed. In some instances where high rates of N were applied, elevated NO_3 levels (> 10 ppm) were observed in groundwater below cropping areas both early in the season and again late in the season periods after plastic was removed. In other cases, low concentrations were observed throughout the season including after plastic removal. There is some speculation that denitrification may be occurring in production areas where the water table is maintained high throughout the season, and future studies are being designed to evaluate this possibility.

Use of the FESI system has been beneficial for nutrient management when used in combination with reduced fertilizer applications. Since the system has no surface runoff during normal operation, the potential for surface water contamination is very low. Also, since water table levels can be maintained more uniformly throughout the field, less fluctuation occurs and there is less potential to leach fertilizer downward. Studies are being conducted at GCREC where tomato production using FESI maintained at three different water table levels during the growing season (18, 24, and 30 inches below the bed surface) in combination with three seasonal N fertilizer levels (160, 230, and 300 lb/acre). Results from two seasons of investigation show that no significant yield differences have been detected among all treatments or treatment combinations. Studies are continuing, but it appears that maintaining a lower water table level for water conservation purposes can be used with N fertilizer rates compatible with crop nutritional requirements with no compromise in yield.

The use of microirrigation is widely viewed as a conservation system for both water and nutrient application, but its success is totally dependent on management. In fact, a poorly managed microirrigation system can be quite ineffective in nutrient management since excessive irrigation applications can cause large quantities of nutrients to be leached. A recent lysimeter study was conducted at GCREC to investigate N leaching characteristics of different fertilizer formulations (slow release or conventional soluble) used with either microirrigation or seepage irrigation. Results showed the degree to which overapplication of microirrigation can cause substantial N loss using soluble fertilizer. Microirrigated treatments averaged 60.5% seasonal loss due to leaching compared to less than 1% loss with subirrigation.

In summary, activities such as the LMWD project are being conducted to provide information to give growers alternative and improved management practices. Action taken to resolve water quality issues that will affect agriculture in general will be driven by the perception of the problem by regulatory agencies, environmental protection advocates, the general public, agricultural research and education, and by politics. These perceptions may or may not always be based on scientific fact. The LMWD project and others like it are designed to provide scientific information and increase the data base regarding management of nutrients in the field that can be used to make responsible decisions concerning water quality protection. These projects will not be viewed as successful unless significant grower adoption of the improved management practices occurs.

What is the major water quality issue facing the Florida tomato industry? Probably convincing and demonstrating to policy makers that the industry is acting responsibly with respect to use of agrichemicals. If this doesn't happen, increased use of the governmental regulatory approach will become more likely. We have all seen the regulatory process at work in the past and present with regard to water quantity regulation in Florida. Similar action may be in store for water quality control unless public officials perceive that agricultural producers are taking these issues seriously and are doing what they can to preserve water quality.

References

1) American Farm Bureau Federation. 1992. Cooperative well water testing program for county bureaus: Summary update 1992. Amer. Farm Bureau Federation, Park Ridge, IL .

2) U.S. Environmental Protection Agency. 1990. National Pesticide Survey: Nitrate. Office of Water, Office of Pesticides and Toxic Substances. Washington, D.C.

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WATER QUANTITY ISSUES FACING THE FLORIDA TOMATO INDUSTRY

Gary A. Clark and Craig D. Stanley
University of Florida
Gulf Coast Research and Education Center
Bradenton, FL

Introduction

Irrigation is an agricultural practice that is inherently necessary to economically produce high value crops. Each year Water Management District allocation strategies and resultant permitted quantities become more restrictive. As a result, the successful irrigation managers will be those who are committed toward high level water management strategies and irrigation scheduling. Installation of a "conservative" irrigation system will not necessarily result in immediate reductions in water use. Management will be the key to conservative irrigation.

Crop Water Requirements vs. Irrigation Requirements

How do crop water requirements differ from irrigation requirements? Basically, crop water requirements refer to the water that is used by the crop, sometimes both plants and soil uses as transpiration and evaporation, to meet the evapotranspiration (ET) demand of the environment. Irrigation requirements are very different and refer to the quantity of water that needs to be applied by the irrigation system such that a sufficient quantity is placed within the root zone of the crop to be used to meet the crop water requirements. If that water is of low quality with respect to salinity, additional water, called the leaching requirement, must be added to maintain a favorable salt balance within the root zone.

The "efficiency" of the irrigation system (Es) is used to estimate irrigation requirements based upon crop water requirements. For example, if the daily crop water requirements averaged 3000 gallons per acre, and the irrigation system had an overall system efficiency of 75%, the irrigation requirement would be 4000 gallons per acre (3000/0.75). Irrigation system efficiency is based on the uniformity of application and application efficiency which are affected by elements such as irrigation system design and management.

Elements of Conservative Irrigation

Conservative irrigation depends on many elements some technically related and some are related to personal or individual characteristics. Technical elements include system type, design and installation, while, personal elements include management, education, and ambition. Many of these elements depend very heavily on the soil, crop, and water conditions at each site and all of these elements are equally important for successful, economic, and conservative use of a limited water supply.

The choice of system can influence the attainable level of system efficiency and conservation. However, as higher levels of efficiency are desired or required, proper design and installation are very important. Poorly designed and installed irrigation systems can result in low levels of application uniformity which in turn lowers the overall achievable irrigation system efficiency.

Management of the irrigation system involves scheduling the irrigation events and maintenance to keep the pump and power unit, irrigation lines and emission devices (drippers, etc.) clean and operational. The manager must also know the crop water requirements at stages of growth and times of the season. Too much water can leach fertilizer out of the root zone of the crop while too little water or poor timing of application can result in short term crop stress which will reduce plant growth and development. Irrigation systems that provide the user with higher levels of application efficiency, require higher levels of management to ensure successful and proper operation.

Finally education and ambition are very necessary for continued refinement and improvement to the water conservation efforts. The higher technologically advanced systems are more difficult to operate and maintain than previous "less efficient" systems. Additional information on managment, new products, soil additives, etc. is continuously being developed and provided through workshops, seminars, and field days. Thus, informed and innovative managers need to continually update their background in order to be successful as water resources become more limited.

Water Budgeting and Scheduling

Agricultural water requirements at the farm level need to be documented, itemized, and quantified. Water has many uses on the farm other than irrigation to meet crop needs during the growing season. Other uses include wetting the soil for field preparation and bed formation, maintain soil moisture during the fumigation period or to break down organic constituents, fill crop spray equipment, or to improve traction and reduce dust on dry, sandy roads. The amounts of water required for these operations is not well known, but may be estimated. Accurate records of actual needs, although generally not available, are preferred over estimations.

One of the largest water needs is for irrigation during the crop growth and development period. Data regarding tomato water requirements throughout the season have been developed regarding local production conditions and are available (Table 1). While these data provide good estimates of crop water use, they are only estimates of average conditions. Actual irrigation requirements are quite different and while they rely on the crop water requirements, they refer to the water that must be pumped from the water source, through the pipe distribution system, and into the crop root zone. As a result, farm level irrigation requirements depend very heavily on system design, field conditions, and management.

Proper water management in drip irrigated tomato production is essential for optimum plant growth and development and requires information about the water needs of the crop as well as the water-holding characteristics of the soil. Excessive irrigation can leach crop nutrients from the root zone which may in turn result in reduced growth and development of the plant. Soil moisture deficit through poor timing of water applications or insufficient amounts can also result in crop stress, thus reducing growth and development. Estimates of crop water requirements are generally based upon atmospheric conditions and demands for water.

Reference evapotranspiration (ETo) refers to the expected water use from a uniform green cover crop surface such as a grass and is generally reported as inches of water use over the surface. While this choice of units is appropriate for use with sprinkler irrigation systems, volumetric units are more appropriate for drip systems. Actual crop use is generally less and is determined by using a crop coefficient (kc) relating crop ET (ETc) to ETo and varies as well with stage of crop development. Typical daily ETc values for the southwest Florida area during the fall and spring tomato production periods for several transplanting periods are provided in Table 1 and are expressed as gallons of crop water use per acre per day. Irrigation amounts should then be determined and scheduled to meet the crop ET requirements as well as the other constraints of the field and irrigation system.

Soil properties should also be known and monitored for an effective irrigation management program. The volume of readily available water to the crop depends on the soil water holding properties and the crop root zone. Water should be applied when no more than half of the available water has been depleted. A well developed, drip irrigated tomato crop with a root zone at field capacity and roots that extend 8 to 10 inches from the drip tube has available water that ranges from less than 1000 gallons per acre in a very coarse sand, to 2000 gallons per acre in medium to fine textured sands, to more than 3000 gallons per acre in some of the heavier, finer textured soils. Therefore, some sandy soils with low water holding capacities will require frequent irrigations, such as daily, with relatively short durations during low crop ET periods or even multiple cycles per day during high crop ET periods. During the very high crop water use demand periods of the day, peak crop water use may exceed 1000 gallons per acre per hour. Therefore, to avoid short term water stress, some soils may require that the time interval between the end of one drip irrigation cycle and the start of the next be no greater than 1 hour. However, soils with greater water holding capacities can be managed with less frequent irrigations and longer irrigation durations. The irrigation run time should be sufficient to re-wet the active root zone to field capacity, apply needed chemicals (fertilizers), and meet the constraints of the irrigation system and scheduling program.

After the primary cash crop has been completed, the farm water budget must still continue. Other water uses may include irrigation to establish and maintain a cover crop between seasons for soil stabilization and soil enrichment, maintenance of field moisture levels for decomposition of previous crop residue, or periodic maintenance of the irrigation system (pumps, motors, pipes, filters, etc.). The water budget must be considered as an annual accounting of all water needs on the farm.

Proper water management in drip irrigated production systems requires knowledge of crop water requirements, soil water holding and water distribution properties, and close monitoring of the irrigation system, the crop, and atmospheric conditions. The information in this article is provided for use as an initial guideline to develop an effective and conservative water management program. Because actual field conditions and requirements vary, this information is intended for general management purposes only.

Table 1. Estimated crop coefficients (kc) and crop ET values for drip irrigated tomato plants in the southwest Florida area expressed in gallons per acre per day at five periods of time based on Days After Transplanting (D.A.T.) for transplants set at different periods[1]. (This table assumes 6 foot bed centers or 7260 linear bed feet per acre).

D.A.T.	kc	MONTH OF TRANSPLANTING					
		AUG	SEP	OCT	JAN	FEB	MAR
		-------- gallons per acre per day ------					
0 - 20	0.25	1000	1000	1000	600	800	900
20 - 40	0.50	2400	2200	2000	1800	2000	2200
40 - 60	0.80	3600	3200	2200	3200	3800	4000
60 - 80	0.80	3200	2700	2000	4000	4600	4600
80 - 100	0.70	2100	1800	1800	3600	4000	4000

[1] Data sources include University of Florida, Cooperative Extension Service Bulletin 205 "Potential Evapotranspiration Probabilities and Distributions in Florida"; and the Final Report to the Southwest Florida Water Management District on Project B-33 "Water Requirements and Crop Coefficients for Tomato Production in Southwest Florida".

Possible Use Rate Reductions and Alternatives to Methyl Bromide For Soil Pest Control

J.W. Noling
Citrus Research & Education Center
Lake Alfred, FL

In 1991 Methyl bromide (MBC) was detected at concentrations of 9 - 13 pptv (1 pptv=1 part in 10^{12}) in the upper stratosphere, and after laboratory reactivity tests, immediately implicated as a potentially major ozone depleter. Although as of yet unsubstantiated, EPA, enforcing the mandates of the Clean Air Act of 1990, is currently evaluating a proposal to cease production and use of MBC by the year 2000. Unfortunately the Clean Air Act, as currently written, does not allow for exemption even though it may be possible to significantly reduce emissions to a nonproblematic level considering other natural, but major oceanic sources of MBC production. The Clean Air Act is therefore the current obstacle which must be overcome to preserve MBC use for soil fumigation purposes in Florida. Any alterations in the Clean Air Act will undoubtedly require grower and commodity group lobbying support as well as a firm scientific basis to demonstrate the critical need for and the potential for significant reduction in use and more importantly of reductions in atmospheric emissions. At the same time it should also be recognized that intense efforts must also be made to identify and evaluate other chemical and nonchemical alternatives and the penalties or consequences for their use.

METHYL BROMIDE RATE REDUCTION STUDIES

Given the importance of MBC to Florida agriculture and apparent conflict of MBC use with federally mandated clean air standards, it was imperative that the ways and means of reducing levels of methyl bromide usage in agriculture were identified. Reducing dosage was considered as an alternative approach to reducing the net impact of manmade sources of methyl bromide on ozone destruction rather than a complete ban on use and production. Preliminary assessment of changes in current methyl bromide use practices in agriculture suggested that bed emissions and application dosages could be significantly reduced below current levels. For example, reducing the width of the raised plant bed from 36 to 24 inches could immediately reduce use rates by 33% in some crops because 2 chisels instead of 3 would be required to fumigate plants beds. Using thicker or new gas-tight plastic mulch row covering materials in combination with MBC formulations with increased chloropicrin content could also reduce application rates an additional 25-50%. With these relatively simple modifications the dissipation rate of gases into the air could be minimized, while hopefully still subjecting soil pests to lethal cumulative levels of methyl bromide. The studies which have been conducted and summarized here therefore had as their primary objective to reduce methyl bromide application rates for soil fumigation uses, relative to current practices, by at least 50%, utilizing lower application rates, narrower bed dimensions, and use of less permeable plastic mulch bed covering materials.

MATERIALS & METHODS

Four experiments were conducted at field locations in Lake Alfred, Quincy, and Ft. Lonesome Florida during the fall of 1992 and spring of 1993. Two of the three sites had previous history of severe root-knot nematode and weed infestation. In all experiments at least 4 treatments were evaluated (Table 1). As the commercial standard reference treatment (RT-Treatment 1), a white / black laminated polyethylene plastic film (1.5 mil, with a permeation constant PC to methyl bromide of 12.2) was sealed over the plant beds immediately following MBC soil fumigation at a broadcast equivalent rate of 400 lb / acre. Treatment 2, and in some cases treatment 3, utilized a white, highly methyl bromide impervious (1 mil, PC=2.6-4.8) polyethylene plastic film (Experimental unit# XUR-1551-3619-6, Dow Chemical Film Division, Fresno, CA) with MBC broadcast equivalent rates of 200 and 100 lb/acre. All methyl bromide treatments with the exception of treatment 3 at Ft. Lonesome which was a half rate of 67/33, was a formulation of 98% methyl bromide and 2% chloropicrin. In all cases, methyl bromide was soil injected using a Wallace and Tiernan proportionate flow meter calibrated to apply MBC at 100, 50, or 25% of the standard broadcast equivalent rate of 400 lbs per acre.

RESULTS

Table 1 attempts to summarize pest and crop yield responses relative to the standard commercial methods and rates of methyl bromide application. Without exception, use of MBC at a reduced rate of half (50%) or even one quarter (25%) of the standard broadcast rate was sufficient to provide equivalent nematode control and reduction of final harvest root gall severity levels caused by the root-knot nematode, Meloidogne incognita (Table 1). Effective and equivalent weed control was achieved at rate reductions of 50% but not in all cases at 75%. Loss of weed control was also observed in Quincy when a half dose of MBC was applied under standard 1.5 mil white/black polyethylene plastic mulch. In this case weed control was intermediate to that of the standard full rate of MBC and that of the untreated control. Tomato crop yields were equivalent, or in some cases (Lake Alfred, fall 1992) significantly higher than the commercial standard reference treatment and the untreated control.

Table 1. Crop and pest control responses observed at four Florida field locations during 1992-93 evaluating possible methyl bromide rate reductions utilizing lower application rates, narrower bed dimensions and use of less permeable plastic mulch bed covering materials.

				Treatment Response*		
Experiment Location	MBC Treatment	Mulch Type	PF	Nematode Control	Weed Control	Crop Yield
<u>Lake Alfred, Fall 1992 - Tomato</u>						
	1X	Standard	12.2	0	0	0
	.5X	Experimental	4.8	0	0	+
	.25X	Experimental	4.8	0	-	+
	0X - Control	Standard	12.2	-	-	-
<u>Lake Alfred, Spring 1993 - Tomato</u>						
	1X	Standard	12.2	0	0	0
	.5X	Experimental	4.8	0	0	0
	.25X	Experimental	4.8	0	0	0
	0X - Control	Standard	12.2	-	-	-
<u>Quincy, Spring 1993 - Tomato</u>						
	1X	Standard	12.2	0	0	0
	.5X	Experimental	4.8	0	0	0
	.5X	Standard	12.2	0,-	0,-	0
	0X - Control	Standard	12.2	-	-	0
<u>Ft. Lonesome, Spring 1993 - Squash</u>						
	1X	Standard	12.2	0	0	0
	.5X (98/2)	Experimental	4.8	0	0	0
	.5X (67/33)	Experimental	4.8	0	0	0
	0X - Control	Standard		-	-	-

*0	-	indicates no significant difference from standard commercial maximum broadcast rate equivalent of methyl bromide
+	-	indicates superior to standard MBC treatment
-	-	indicates significantly inferior to standard treatment

DISCUSSION

The results from these experiments demonstrate that it is possible to significantly reduce methyl bromide applications rates by as much as 50-75% without serious consequence to crop yields or nematode control. These reductions however appear only to be possible when combined with the use of the more impervious plastic mulch covers. The level to which weed or disease control may have to be complemented by other alternative measures is not known. Of particular concern was the unsatisfactory weed control at the lowest levels of MBC use. It should also be recognized that the more impervious cover may not alter total proportionate escape but may only retard the rate of gaseous diffusion of MBC from the mulch covered bed. It would appear that the slower rates of escape ultimately translated into the lethal, near equivalent levels of nematode control that was observed. It is also not clear to what extent the price of the new, less permeable plastic mulch will contribute to tomato production costs.

CHEMICAL ALTERNATIVES RESEARCH

A number of meetings in the past year and a half, sponsored by university, state, federal, and commodity group organizations have been conducted to organize a Methyl Bromide Task Force of representative cropping system and pest control experts to evaluate potential chemical and nonchemical alternatives to replace MBC for soil fumigation purposes. For your consideration Table 2 represents a synopsis of existing chemical alternatives and there pest control activities compared with that of MBC. Without exception, these alternatives were identified as being generally less effective or inconsistent than MBC, which results in lower crop yield and quality. Based on pest control activity, near equivalent replacement of MBC will probably require extensive evaluation of individual, and particularly of combined treatments of chloropicrin with either 1,3-D (Telone) or metham sodium (Vapam). Dazomet (Basamid) has also received considerable attention, particularly in terms of field evaluations within the past year 1992-93. At present it is not registered for food crop uses within the USA.

Table 2. Attributes and pest control effectiveness of other chemical fumigants compared to methyl bromide. Extracted from USDA Special Report "Methyl Bromide Substitutes and Alternatives. A Research Agenda for the 1990's." Jan. 1993.

	Methyl Bromide	Chloropicrin	Methyl Bromide/ Chloropicrin (67/33)	1,3-D	1,3-D/ Chloropicrin (83/17)	Basamid	Metam Sodium	Vorlex
Control Activity								
Insects	0	0	0	-	0	0	0	0
Nematodes	0	-	0	0	0	-	-	0
Plant Diseases	0	0	+	-	0	-	-	$\underline{0}$
Weeds	0	-	0	-	-	-	-	$\underline{0}$
Ease of Use	0	0	0	+	0	$\underline{0}$	-	0
Time for Treatment	0	$\underline{0}$	$\underline{0}$	-	-	-	-	-
Compatibility[1]	0	0	0	0	0	-	±	0
Treatment Costs	0	±	±	+	-	-	-	-
Crop Yield	0	-	+	-	0	-	-	$\underline{0}$
Crop Quality	0	-	0	-	0	-	-	$\underline{0}$
Environmental Effects	0	0	0	0	0	+	+	0
Worker Safety	0	0	0	+	+	+	+	+
Availability	0	0	0	-	-	-	0	-
Registration Status								
Food Crops	0	+	0	0	0	-	0	?
Nonfood Crops	0	0	0	0	0	0	0	?

Comments:

0 = Similar to Methyl Bromide
\+ = Better than Methyl Bromide
\- = Not as good as Methyl Bromide
? = Unknown

[1] *With current production systems*

It was also recognized that since many of the existing chemical alternatives are considerably less volatile than MBC, moving or diffusing through soil slowly, nonuniform concentration in soil is often regarded as the primary factor contributing to partial or insufficient levels of pest control and crop response inconsistency. To enhance pest control efficacy with these compounds, significant improvements of existing application delivery systems, as well as chemigational systems is needed.

NONCHEMICAL ALTERNATIVES

Currently soil solarization, the heating of soil by trapping incoming solar radiation under clear, polyethylene plastic mulch covers, is receiving probably the most research emphasis in terms of a nonchemical alternative to MBC. In most cases there is insufficient information on how best to employ soil solarization as a means of soil pest control. Serious shortcomings include high costs, problems and cost of plastic disposal if pursued on a broadcast basis, limited depth of pest control and the lack of suitable environmental and edaphic conditions necessary for practical and effective use. Potential use as a prestressing agent in combination with other means of pest control (ie. heat tolerant biocontrol agents or soil fumigants) are currently being explored. Until some form of further improvement or refinement is made, soil solarization will likely remain impractical for use in commercial agriculture for most of southern, peninsular Florida.

One such improvement which is being evaluated and which could significantly enhance pest control by itself or with soil solarization involves the combined use of heated water and/or pesticide application with soil solarization. In this case, the addition of heated water (150-210 F), introduced via a drip irrigation system or chisel injected during bed construction may eliminate the need for prolonged exposure to sublethal temperature, particularly at soil depth, as is now the case for soil solarization alone. These studies are currently in progress.

ACKNOWLEDGEMENTS: The author would like to thank Hendrix & Dail Sunbelt Services, Palmetto, FL, particularly that of Steve Lyerly for technical support, to all the growers and field personnel who contributed time and labor towards the successful completion of these experiments, and to Speedling Inc. for plant materials.

Table 3. Nematicides registered for use on Florida tomato

Row Application (6' row spacing - 36" bed)[5]

PRODUCT	BROADCAST (Rate)	RECOMMENDED CHISEL SPACING	CHISELS Per Row	RATE/ACRE Ft/Chisel	RATE/1000
FUMIGANT NEMATICIDES					
Methyl Bromide					
98-2	240-400 lb	12"	2	120-200 lbs	8.2-13.7 lb
80-20	225-350 lb	12"	2	112-175 lbs	7.7-12.0 lb
75-25	240-375 lb	12"	2	120-187 lbs	8.2-12.9 lb
7-30	300-350 lb	12"	2	150-175 lbs	10.3-12.0 lb
67-33	225-375 lb	12"	2	112-187 lbs	7.7-12.9 lb
57-43	350-375 lb	12"	2	175-187 lbs	10.3-12.9 lb
50-50	340-400 lb	12"	2	175-250 lbs	10.3-17.2 lb
Chloropicrin [1]	300-500 lb	12"	2	150-250 lbs	10.3-17.2 lb
Telone II [2]	12-15 gal	12"	2	6-7.5 gal	39.7-66.1 fl oz
Vapam	50-100 gal	5"	3	25-50 gal	1.1-2.2 gal
Vorlex Vorlex 201 [3]	30-50 gal	8"	2	6.7-11.1 gal	58.8-97.9 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.

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

[2] The manufacturer of Telone II and Telone C-17 has suspended their sale and distribution in all of Florida south of and including Dixie, Gilchrist, Marion, Volusia, and Flagler Counties.

[3] Vorlex used at higher rate for weeds, fungi, nematodes and soil insects. It is not clear to what degree stocks will be available since the manufacturer of Vorlex, NorAm Chemical Company, announced November 11, 1991 that it was voluntarily cancelling registration of both Vorlex and Vorlex 201.

[4] Use of methyl bromide for agricultural soil fumigation is now under special EPA review.

[5] 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 10, 1993 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

MBC

80 soil use
50 escape.

- 36" bed → 24' bed
mulch.

Permition facto ↑ with TO
new plastic.

- weed emergency.
- nematodes.

VAPAM 50gl/a.

Root gall Severity (0-10)

1993 - THE YEAR OF THE SNAKE
OR
WHAT HAPPENED WITH COBRA AND WHY

James P. Gilreath
Gulf Coast Research and Education Center
Bradenton, FL 34203
and
William M. Stall
Horticultural Sciences Department
Gainesville, FL 32611

The spring 1993 production season was one with many unusual experiences. There was relatively mild weather which allowed tomato production through much of the winter, a late cold spell with sustained high winds for two days which delivered salt spray over much of south Florida, and herbicide related problems the likes of which we had not experienced previously. In many cases, environmental conditions played a role in the damage resulting from herbicide use, but wind blown drift of herbicidal spray does not explain all of the herbicide related problems growers experienced this year.

Most of the herbicide problems centered around the use of Cobra in tomato and pepper row middles, but similar problems also occurred with Sencor/Lexone in a few instances. The purpose of this paper is to review the problems and what we believe or have demonstrated through research to be the cause of those problems.

Herbicide damage to crops from row middle applications usually involves spray drift. Paraquat (Gramoxone Extra) damage as a result of poorly shielded applications is familiar to many growers. Residual paraquat on plastic mulch as a result of unshielded, pretransplant broadcast applications also can cause considerable damage for at least 5 days after application. The same is true with Cobra, only the results may be more dramatic. Spray drift can and should be eliminated. Choose to not spray under windy conditions. If you must spray and the wind is within reason, use a drift retardant to reduce the size of spray droplets and use effective shields.

Drift retardants are not a magical panacea; they help, but they can't work miracles. One should not feel overly safe just because a drift control agent was used.

Not all shields are the same; some work better than others. Most growers build their own shields, but at least one is available commercially and appears to do a very effective job of eliminating drift under many conditions.

Even with a good shield problems can arise if the sprayer pressure is too high. What is too high? That depends somewhat on the herbicide being applied, but pressures of 50 psi or greater are too high for applications in sensitive crops, i.e. tomatoes. High pressure results in production of lots of small spray droplets which can escape from the shields as a mist. The forward movement of the sprayer adds to the problem as does the vertical movement of the boom relative to the ground when bed shoulders are not equal height as often occurs for various reasons. These descrepancies in the relationship of the boom to the beds and soil surface allow "windows" for the spray mist to escape and come into contact with the crop. Most growers use the same or a similar sprayer for herbicide application which they use for application of fungicides and insecticides. These sprayers are equipped with diaphragm pumps which are designed for high pressure applications and seldom can you get one to spray less than 50 psi. If you must use this type of spray rig, you can further reduce the pressure by installing a "T" fitting in the pressure line to the boom, attaching a gate valve and a hose returning to the sprayer tank, and using this valve as a throttling valve to reduce the pressure going to the nozzle tips. Tip selection is also important: use flat fan tips.

Although paraquat drift damage occurs, growers accept a certain amount because the effects are immediate and not systemic. This year we found out what Cobra drift could do. The effect takes a few days to show up, but when it does it really gets your attention. Cobra damage somewhat mimics 2,4-D damage with leaf crinkling and some other growth distortion. Spotting also may occur. Unlike Gramoxone damage, injury from Cobra continues to develop in severity for several days after first observed. The good news is that plants generally grow out of the damage within 2 weeks and make a normal crop. Cobra is not systemic in tomato. The young leaves which are present at the time of contact develop crinkling as they expand due to contact damage. Leaves formed after application are not affected. Anyone who has ever experienced 2,4-D damage is justified in uncontrolled panic, but experience indicates that moderate drift of Cobra is not as disastrous to the crop. Cobra is not related to 2,4-D and does not produce the type of damage common with 2,4-D. This is not to say that Cobra can not cause extensive damage to tomato plants, but the amount of damage most growers experienced thus far has been minimal and greatly compensated for by the excellent nightshade control obtained. If you wish to minimize Cobra drift damage, reduce the opportunity for drift.

Interestingly, Cobra has contacted tomato plants by other means than just physical drift. Just as we have experienced with paraquat, residual Cobra on polyethylene mulch can cause damage to tomato plants. Research conducted this spring and summer indicated that symptoms identical to those seen on farms develop from contact with residual Cobra. Paraquat is usually introduced to the tomato plant by rain drop splash, but dew and wind can work together to achieve the same goal. It appears the same mechanisms apply to Cobra. In this case, it takes about 3 to 5 days for appearance of initial symptoms. Symptom expression continues for several more days. Injury symptoms become less noticeable as new growth, free of injury, develops. Generally, damage is noticeable for only about 2 weeks.

Research has shown that paraquat residues on polyethylene mulch break down after approximately 5 days in August and a few days longer in January and February, but what about Cobra? Research conducted this spring indicated enough residual Cobra remains on polyethylene mulch to produce damage to young tomato plants for up to 10 days after application to mulch film. Thus, if you apply Cobra pretransplant and there is any chance Cobra got on the plastic mulch, you should wait at least 10 days after application before transplanting tomatoes into the field.

Another mechanism by which herbicides can contact young tomato plants is by movement of treated soil on to the bed surface or plants. Although not a common occurrence, it does happen. This was experienced by a number of growers this spring. Both Cobra and Lexone/Sencor injured tomato plants as a result of wind and rain blown movement of treated sand from row middles on to young plants. More spotting was observed in this case than with residues on mulch. Stem lesions appeared frequently. Blown sand accumulates in deposits on foliage and stems and rain water and dew solubilize the Cobra. Damage then develops in the areas of these deposits. That is why several growers observed more damage in drier portions of the field than in the wetter areas. There is not much one can do to minimize raindrop splash of treated sand, but some weed cover in middles did reduce herbicide injury significantly this spring. In fact, on one farm where Lexone was the problem, purple nutsedge infested areas had no injury while some adjoining portions of the field without nutsedge had to be replanted. We are not advocating cultivation of nutsedge in row middles, but we do feel that anything which minimizes movement of treated soil will help. Rye wind breaks can reduce wind speed in middles and help minimize soil movement. Wind breaks serve many other useful functions and are worth the effort. Perhaps one of the best ways to manage the problem of dry soil movement would be to manage soil moisture so that the middles are moist at the time of application. This is not always possible, as dry areas exist in fields for various reasons, but if a grower does what he (she) can and recognizes those conditions which favor development of a problem, he (she) may be able to avoid that problem.

One of the most frequently asked questions regarding herbicide residues on polyethylene mulch involves rinsing the mulch with water, either by rainfall or with a sprayer. Few growers have had good results with sprayer applications of water. There is little information available about how much water it takes to wash off herbicide residue once it has dried. Considering that it would take about 14,000 gallons of water to provide 1 inch of water to each acre of actual crop area (i.e., 3 ft wide bed x 3 rolls of plastic per acre) or about 0.6 gallon per square foot, it is not likely that one can apply enough water with a sprayer to rinse off herbicide residue. Once herbicide has dried on the mulch, one would have to apply enough water to solubilize the residue, then more water to rinse it from the mulch. Rainfall has the potential to keep the mulch wet long enough to solubilize a significant quantity of herbicide. Heavy showers could remove material from mulch once solubilized. How much rainfall does it take? Preliminary research with simulated rainfall indicates that 0.1 inch or more can reduce residual Cobra on mulch film, but several inches are required to reduce the level by about 50% as indicated by tomato plant phytotoxicity data. Spraying mulch with water is probably a waste of time. Rainfall can help reduce the likelihood of residual problems, but the best preventative of all is still to keep Cobra off of the mulch in the first place.

The problems growers experienced with Cobra this year involved young tomato plants. One means of reducing the possibility of Cobra damage to tomato is to wait until plants are larger before application to row middles. Previous research indicated injury from direct application of Cobra to tomato decreased as plant size increased. Once tomato plants are about 16 inches tall, damage from directed applications to row middles generally is minimal and has no effect on yield. Obviously, application under conditions of excessive wind or poorly shielded applications may cause damage, but using common sense and timing your application appropriately can minimize damage.

The ultimate method of avoiding Cobra damage is to not use it. But if you grow tomatoes and are plagued with nightshade, Cobra is a very effective tool. Few tomato growers are faint of heart or they would not be farmers. Taking educated chances is what it is all about. Just as it took time for growers to learn to use such advances as methyl bromide, polyethylene mulch, and micro-irrigation, so will it require some learning and experience to use new technology and herbicides effectively and safely. Obviously, any herbicide which controls nightshade is likely to be injurious to tomato plants. Careful use of Cobra can allow good nightshade control without crop damage. The ability to do this lies in the hands of the grower. If one uses common sense and follows the guidelines included in this paper, he (she) should be successful.

RELEASE POSSIBILITIES FROM THE IFAS TOMATO BREEDING PROGRAM

J. W. Scott
Gulf Coast Research and Education Center
Bradenton, FL 34203

A broad range of breeding projects has been ongoing in the IFAS tomato breeding program. It has become apparent that extensive testing of hybrids is unwieldy in light of the number and extent of the breeding projects. Furthermore, there are numerous private tomato breeders in Florida involved in hybrid breeding programs. Thus, the GCREC program is moving toward the development of breeding line releases, as opposed to finished (hybrid) releases. Several breeding lines are presently being considered for release and are the main topic of this report.

Micro-Gold - This is a miniature-dwarf, open-pollinated variety with gold fruit and is a companion to 'Micro-Tom', a variety released in 1989. It has been approved for release by the IFAS Cultivar Release Advisory Committee. As Micro-Tom, this variety can be grown in small pots (1 plant per 4" [10 cm] pot or 3 plants per 5" [12.5 cm] pots). The plants and fruit are slightly larger than Micro-Tom and the fruit do not hold as long on the vines. They may get 'glassy' when overripe. Flavor is mild.

Fla. 7421 - This is a heat-tolerant, bacterial wilt tolerant, open-pollinated variety. It is being released primarily for use in tropical regions affected by bacterial wilt. Fla. 7421 is also resistant to Fusarium wilt races 1 and 2, Verticillium wilt, gray leafspot, and has some tolerance to bacterial spot. Fruit are medium size (5 oz [140 g]); have excellent resistance to crack, rain check, and zippering; and good flavor. However, the fruit are prone to enlarged blossom scars, uneven ripening, and blossom-end rot. Fla. 7421 probably will not make a good hybrid parent. Bacterial wilt tolerance has been consistently good over several years of testing. There are few high quality varieties that are tolerant to bacterial wilt available and Fla. 7421 should be of benefit in some tropical regions.

Fla. 7324 - This is a heat-tolerant breeding line which has been extensively tested as an inbred line and as a parent in hybrid combinations. Fruit are medium size (5-6 oz [140 to 170 g]), generally free of defects except some zippering, and blossom scars are generally smooth. Flavor is only moderate so crosses with other parents possessing good flavor parents is suggested for further hybrid development. This line is a parent in hybrid Fla. 7249B which has performed consistently well in spring and fall crops over the past several years.

Fla. 7324 possibly will be released in conjunction with the hybrid 7249B. Fla. 7324 is resistant to Fusarium wilt races 1 and 2, and gray leafspot. Fla. 7324 has a strong vine with good fruit cover.

Fla. 7482B - This is a large-fruited tomato which is being released as an improvement over Fla. 7060, the large fruited parent of 'Solar Set'. Fla. 7482B is resistant to Fusarium wilt races 1 and 2, Verticillium wilt, and gray leafspot. Fruit are very firm, have smooth blossom-scars (n-like genes), are globe shaped but slightly oblong in the transverse direction and have good flavor. Fruit set is improved over that of Fla. 7060. As with Fla. 7060, there is some zippering and some radial cracking, but these are not expected to be serious defects.

Fla. 7547 - This is an inbred line with jointed pedicels which is resistant to Fusarium wilt race 3 in addition to the standard resistances mentioned above. Fruit are medium to large with good blossom scars and excellent shoulders which are resistant to cracking and rain check. Shape is a slightly flattened globe. This should make an acceptable parent if crossed with lines with reasonably large fruit and strong vines. Fruit color is good as this line has the crimson gene (og). Flavor is also good.

Fla. 7481 - This is a jointless inbred with Fusarium wilt race 3 resistance in addition to the standard resistances mentioned earlier. Fruit are medium to slightly-large with good blossom scars. Set is rather concentrated and vine cover is sparse but fair. Crosses with jointless lines with strong vines are suggested. Fruit color is good due to the crimson gene (og). Flavor is good but mild.

In the breeding of Fusarium race 3 resistant lines, I've found that homozygous resistant plants do not set fruit as well as heterozygous resistant plants. Therefore, using the above two lines in hybrid combinations should result in additional fruit setting ability that might not be predicted based on observations of these lines alone.

Other possibilities. A group of heat-tolerant lines with resistance to bacterial spot are being tested. It is hoped that a few of these may make good parents and there will be considerable testing the best lines next year. For this project, it is likely that a finished hybrid will be released along with one or more inbred lines resistant to bacterial spot.

CONTROL OF TOMATO FRUIT RIPENING USING GENE TECHNOLOGY

Donald J. Huber (Post/Harvest)
Horticultural Sciences Department
Fifield Hall, POB 110690
University of Florida
Gainesville, FL 32611-0690

SUMMARY

Trade journals, newspapers, and other media outlets are carrying the message that gene technology research is on the verge of directly impacting the manner in which we handle harvested produce. The tomato fruit represents one of the first beneficiaries of this research. The combined efforts of industry, government, and university laboratories have demonstrated the ability, using gene technology, to improve the postharvest quality and shelf-life of this important horticultural crop. While sharing the goal of improving postharvest characteristics, different organizations have devised somewhat different strategies for doing so. Researchers at Calgene and at universities both in the US and abroad have successfully "turned-off" a gene responsible for causing tomato fruit to soften. Researchers at Monsanto and at university and government labs, using various techniques, have developed tomato fruit with greatly reduced ethylene production. In both cases, the fruit exhibit reduced perishability and increased transportability. These features persist in fully ripe fruit, providing the opportunity for "full-ripe" harvest and, consequently, greatly improved fruit quality.

The purpose of this presentation is not to make recommendations or to promote any one product or practice to the exclusion of others. This issue will be determined in the fields, on the packinglines, in the transportation and marketing channels, and with close scrutiny of the economics.

INTRODUCTION

Since the emergence of interest in postharvest biology, significant progress has been made in our knowledge of how to optimize the quality and extend the shelf-life of horticultural commodities. Approaches have focused generally on the identification and implementation of suitable temperature and relative humidity management and, if economic or other market factors are warranted, the employment of controlled-atmosphere or modified-atmosphere environments. The efficacy of these techniques resides in their ability to reduce biological processes responsible for commodity deterioration, for example respiration and ethylene production. Conventional methods for preserving postharvest quality, while effective, are expensive and almost without exception temporary and dependent on the continued control of the *external* (storage) environment. Until recently, the only means for altering the perishability of fresh fruits and vegetables via manipulation of their *internal* (biological) environment have been through traditional plant breeding, a practice that takes advantage of natural gene transfer to develop germplasm with inherently improved storage potential and quality attributes.

The past 10 to 15 years have witnessed the development and application of a powerful array of methods for altering the basic biology of plant and other organisms. In practice, these methods involve artificially manipulating and transferring selected genetic material for the purpose of improving or modifying one or more biological characteristics. As any exposure to the popular media will attest, the application of gene technology has attracted some degree of controversy and criticism. This paper is not the forum for addressing the political or ethical issues surrounding these new technologies. Suffice to say, however, that the dissemination of misinformation does great disservice to the potential benefits of applied gene technology to the agricultural and medical fields alike.

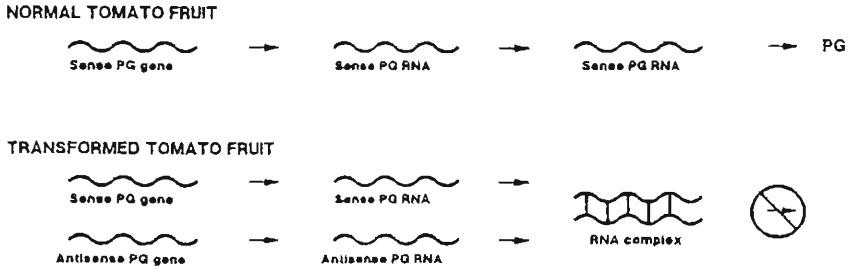
This presentation will specifically address the impact of gene technology on the quality attributes and postharvest biology and ripening of tomato fruit. The potential value of gene engineering for controlling the postharvest performance of tomato fruit is based on the fact that ripening is an active biological process that is dependent on the timely activation and expression of specific genes ("ripening genes"). These genes remain "dormant" or nearly so throughout the growth and maturation of the fruit. Eventually, these genes are activated, resulting in the production of gene products (enzymes) that propel and control the ripening process. Consequently, it is frequently these genes and gene products which have been targeted for gene technology research, the rationale being that reducing the accumulation of the products of ripening genes will in turn reduce the rate of ripening and maintain quality and prolong shelf-life. Given that fruit have attained an adequate stage of maturity, harvest will generally not interfere with the activation of ripening genes.

Although nearly every attribute of tomato fruit ripening and quality including firmness, pigmentation, sugar content, ethylene production, shelf-life, insect and pathogen resistance, and temperature tolerance has been targeted for improvement through gene technology, space limitations disallow coverage of all of these topics. This paper will focus on 2 general characteristics of tomato fruit biology which have been the subject of extensive gene-manipulation studies: 1) fruit texture and 2) ethylene biosynthesis.

FRUIT TEXTURE

The importance of firmness is well-recognized by individuals involved in tomato fruit handling and marketing operations. Although tomato fruit are always at some risk of injury from impact, compression, and vibrational bruises, they become increasingly susceptible during ripening, when the fruit soften considerably. For this reason, most tomato fruit are harvested and handled when mature-green or slightly beyond. Although the biology of fruit softening is not entirely understood, researchers long suspected that polygalacturonase (PG), a protein first reported in tomato fruit nearly 50 years ago, plays a role in the process. The protein is essentially absent in green tomato fruit but increases dramatically during ripening. The PG gene served as the first target for gene-manipulation studies with fruits.

The first reports of genetically transformed tomato fruit appeared in 1988 and represented the independent efforts of researchers at Calgene Fresh, Inc. (Sheehy et al., 1988) and at the University of Nottingham in the UK (Smith et al., 1988). The Calgene and Nottingham groups employed "antisense" technology to reduce the normal levels of PG found in ripening tomato fruit. The increase in PG during ripening is due to the expression of the normal or "sense" PG gene. The essence of the antisense technique is to insert into tomato genetic material an antisense (reverse) copy of the PG gene (DNA). Transformation (gene transfer) is accomplished via coincubation of either tomato cotyledons or stem tissue with the bacterium *Agrobacterium tumefaciens* harboring the new gene. Genetically altered plants ("transformants") are regenerated from the stem or cotyledon tissues, and the resulting fruit screened for levels of the targeted protein (PG). In fruit containing both the normal (sense) and altered (antisense) genes, expression of these genes results in the synthesis of both sense and antisense RNA. At this point, a "cancellation" effect occurs, preventing the accumulation of PG protein. This scenario is diagrammed below.



The issue of interest to individuals involved in the production and marketing of tomato fruit is whether the genetically altered fruit actually exhibit improved postharvest quality characteristics. It is quite clear that they do. Although some studies reported that insertion of the PG antisense gene exerted no effect on fruit firmness during normal postharvest ripening (Smith et al., 1988; Schuch et al., 1991), Kramer et al. (1992) observed a significant retention in firmness of the genetically transformed fruit at all ripening stages measured, from mature green through red-ripe. When a number of PG-antisense transformants were evaluated at multiple growing locations, a similar trend was observed: a reduction in PG resulted in firmness retention.

Aside from the apparent inconsistencies in the effects of the PG antisense gene on fruit firmness during ripening, reports are in full agreement that the postharvest performance of PG-antisense tomato fruit is improved in comparison to nontransformed controls. Fruit from transformed plants exhibited significantly improved transportability at all ripening stages (Schuch et al., 1991) and were less susceptible to the postharvest decay organisms *Geotrichum* and *Rhizopus* (Kramer et al., 1992). Furthermore, juice processed from transformed fruit exhibited significantly higher viscosity than juice prepared from nontransformed fruit. Fruit color and compositional features including pH and titratible acidity were not affected by the PG-antisense transformation.

ETHYLENE BIOSYNTHESIS

While studies proceeded on the transformation of tomato using the "antisense" PG gene, parallel research was being performed on the ethylene biosynthesis pathway. Like all fruits, the tomato produces low levels of ethylene throughout development. At the onset of ripening, ethylene production increases and is maintained throughout the ripening process. Exposure of preripe (mature green) tomato fruit to ethylene, a practice long employed by the fresh-market tomato industry, will accelerate the onset of ripening and assist in minimizing variability in ripening behavior within a given lot of fruit. Upon removal from ethylene exposure, tomato fruit continue to produce ethylene naturally. Unknown for many years was whether the high levels of ethylene produced during ripening were actually required for the continuation of ripening or simply a by-product. While work with the ethylene-action antagonist silver thiosulfate clearly suggested the requirement for ethylene throughout ripening (Tucker and Brady, 1987), more definitive proof has emerged from gene-manipulation experiments.

Shown below is the metabolic pathway for ethylene biosynthesis in higher plant tissues (Yang and Dong, 1993).

$$\mathbf{MET} \rightarrow \mathbf{SAM} \xrightarrow[\text{ACC SYNTHASE}]{} \mathbf{ACC} \xrightarrow[\text{ACC OXIDASE}]{} \mathbf{CH_2{=}CH_2}$$

where:

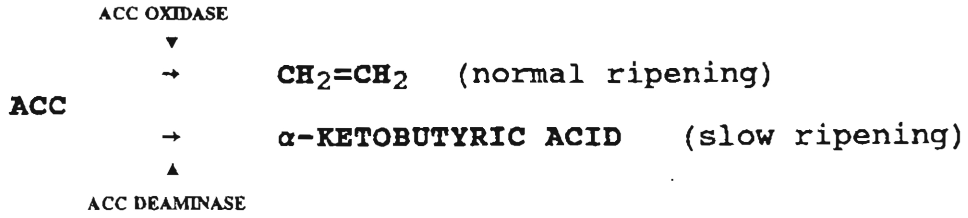
MET = methionine
SAM = S-adenosylmethionine
ACC = aminocyclopropanecarboxylic acid
CH_2=CH_2= ethylene
ACC synthase and ACC oxidase = control enzymes

The enzymes and intermediates in this pathway form the basis for other attempts to genetically modify the postharvest biology of tomato fruit. Two rather different approaches have been undertaken and will be considered in turn.

The first approach is similar to that employed in the PG studies and involves the use of antisense technology. In this case, however, the antisense methodologies were directed toward the proteins ACC synthase and ACC oxidase, key regulatory enzymes in the synthesis of ethylene. As the diagram indicates, inhibition of ethylene synthesis should occur if either of these proteins are targeted. Antisense transformants have been separately developed for ACC synthase (cooperative effort of the USDA Plant Gene Expression Center, Albany, CA and UC Berkeley) and ACC oxidase (Univ. of Nottingham). The behavior of the fruit of the plants containing the antisense gene for ACC synthase or ACC oxidase is similar and essentially dependent on the extent to which ethylene biosynthesis is inhibited. (Antisense transformants generally do not exhibit 100% inhibition of the targeted trait). Fruit from transformants containing the antisense gene for ACC synthase (Oeller et al., 1991) exhibited a 99.5% reduction in ethylene production and were for the most part unable to ripen except when the fruit were continuously exposed to ethylene or propylene. Antisense ACC oxidase transformants produced fruit exhibiting a 97.5% inhibition of ethylene production and ripened very slowly unless provided with ethylene (Hamilton et al., 1990).

The above work with ACC synthase and ACC oxidase antisense genes was thus designed to directly suppress the synthesis of enzymes involved in ethylene biosynthesis.

Another approach taken to genetically alter the ethylene production capacity and postharvest biology of tomato fruit was undertaken by researchers at Monsanto Company. The Monsanto group did not directly target the enzymes (ACC synthase and ACC oxidase) involved in ethylene biosynthesis. Rather, the procedure involved transforming tomatoes using a gene for an enzyme which reduced the natural levels of ACC available for ethylene production. The rationale for this work is diagrammed below.



As discussed earlier, the metabolism of ACC in plant is normally accomplished by ACC oxidase, resulting in the production of ethylene. The Monsanto group isolated a gene for another type of enzyme, ACC *deaminase*, derived from a specific strain of the soil bacterium *Pseudomonas* (Klee et al., 1991). As indicated in the diagram, ACC deaminase is capable of metabolizing ACC but *without* the production of ethylene. The consequence is that the levels of ACC available for ethylene production are greatly reduced. The product of ACC deaminase activity, α-ketobutyric acid, is a metabolite found naturally in plants. Tomato fruit containing the ACC deaminase gene exhibit an approximately 85 to 90% inhibition of ethylene production, a reduced rate of ripening, and greatly extended shelf-life and reduced perishability (Klee, 1993).

FUTURE PROSPECTS

The brief discussion above addressed several of the ongoing efforts to improve the postharvest biology of tomato fruit through the use of gene technology. Gene technology research has clearly demonstrated the ability to modify, with high specificity, selected attributes of postharvest behavior. The issue of concern, however, is whether the products of these research endeavors will be of value to growers and producers. Tomato fruit that do not ripen unless exposed to ethylene for a period of many days, or even weeks, for example, may not integrate into the current practices and interests of the tomato industry. Tomato fruit showing greatly reduced ethylene production and ripening inhibition show a much more normal ripening biology, however, if they remain attached to the vine. Can or will the industry adopt on a widespread scale the practice of a nearly ripe or full-ripe harvest given that the fruit when ripe possess the firmness properties necessary for shipping, superior pathogen resistance, and a shelf-life of many weeks?

As indicated at the outset of this paper, other attributes of tomato ripening biology and quality have also been targeted for gene manipulation work. Pigmentation, sugar composition, and other firmness-related proteins, to mention a few. While gene manipulation technology is very much in its infancy, the growth is occurring at an exponential rate. The future will undoubtedly witness the identification of additional genes that, when suitably altered, will result in marked improvements in the field and postharvest behavior of tomato fruit. Increased low/high-temperature tolerance, increased flavor and aroma, increased nutritional features, reduced pathogen susceptibility, reduced ethylene sensitivity, and improved yields represent but a few examples. These attributes may also be multiply targeted in order to alter any number of characteristics of tomato fruit biology.

While the successful application of gene technology has already been achieved for the tomato fruit, even greater potential may exist for other horticultural commodities, particularly those exhibiting an inherently high postharvest perishability. Strawberries and other small fruits must be harvested ripe or nearly ripe in order to ensure optimum quality. It is at this time when these fruit are extremely susceptible to pathogens, and mechanical and bruise injuries, problems which might be circumvented through the application of suitable gene manipulation. The technology may also remedy other pervasive postharvest problems, including russet spotting of lettuce, degreening of cucumbers, and watersoaking of watermelon tissue, disorders caused by exposure to pollutant ethylene and which might be avoided through genetic manipulation of ethylene sensitivity.

The application of gene manipulation for plant improvement will hopefully avoid the complex moral and ethical issues confronting the use of this technology in the disciplines of human development and medicine. What is now being accomplished for plants using gene engineering has, in many respects, been practiced for centuries with the natural selection, domestication, and controlled breeding of plants with the objective of generating offspring with improved value and use to humans. These endeavors will continue. Gene technology represents a fine tuning of this selection process in providing additional tools to manipulate plants, but with a sophisticated level of specificity and control.

REFERENCES

Hamilton, A.J., Lycett, G.W. and Grierson, D. 1990. Antisense gene that inhibits synthesis of the hormone ethylene in trangenic plants. Nature 346:284-287.

Klee, H.J. 1993. Ripening physiology of fruit from transgenic tomato (*Lycopersicon esculentum*) plants with reduced ethylene synthesis. Plant Physiol. 102:911-916.

Klee, H.J., Hayford, M.B., Kretzmer, K.A., Barry, G.F. and Kishore, G.M. 1991. Control of ethylene synthesis by expression of a bacterial enzyme in transgenic tomato plants. Plant Physiol. 3:1187-1193.

Kramer, M., Sanders, R.A., Sheehy, R.E., Melis, M., Kuehn, M. and Hiatt, W.R. 1990. Field evaluation of tomatoes with reduced polygalacturonase by antisense RNA. *In*: A. Bennett and S.O. Neill, eds. Horticultural Biotechnology, pp. 347-355. Wiley-Liss, New York.

Kramer M., Sanders, R., Bolkan, H., Waters, C., Sheey, R.E. and Hiatt, W.R. 1992. Postharvest evaluation of transgenic tomatoes with reduced levels of polygalacturonase: processing, firmness and disease resistance. Postharvest. Bio. Technol. 1:241-255

Oeller, P.W., Min-Wong, L., Taylor, L.P., Pike, D.A. and Theologis, A. 1991. Reversible inhibition of tomato fruit senescence by antisense RNA. Science 254:437-439.

Sheehy, R.E., Kramer, M. and Hiatt, W. 1988. Reduction of polygalacturonase activity in tomato fruit by antisense RNA. Proc. Natl. Acad. Sci. 85:8805-8809.

Smith, C.J.S., Watson, C.F., Ray, J., Bird, C.R., Morris, P.C., Schuch, W. and Grierson, D. 1988. Antisense RNA inhibition of polygalacturonase gene expression in transgenic tomatoes. Nature 334:724-726.

Tucker, G.A. and Brady, C.J. 1987. Silver ions interrupt tomato fruit ripening. J. Plant Physiol. 127:165-169.

Yang, S.F. and Dong, J.G. 1993. Recent progress in research of ethylene biosynthesis. Bot. Bull. Acad. Sin. 34:89-101.

NEW DEVELOPMENTS IN THE MANAGEMENT OF FUSARIUM CROWN AND ROOT ROT OF TOMATO IN SOUTHWEST FLORIDA

R.J. McGovern[1], L.E. Datnoff[2], I. Secker[3], C.S. Vavrina[1], J.C. Capece[1], and J.W. Noling[4].

[1]University of Florida-IFAS, Southwest Florida Research and Education Center, Immokalee, FL, 33934, [2]University of Florida-IFAS, Everglades Research and Education Center, Belle Glade, FL 33430, [3]University of Florida-IFAS, Horticultural Sciences Department, Gainesville, FL, 32611, [4]University of Florida-IFAS, Citrus Research and Education Center, Lake Alfred, FL.

ABSTRACT

Experiments were conducted in Southwest Florida during 1992-93 to examine the potential of fumigants, the biocontrol agent Trichoderma harzianum, and tomato cultivars to reduce Fusarium crown and root rot in naturally infested tomato fields. An experiment was also conducted at SWFREC-Immokalee from 14 Apr. to 8 June, 1993 to evaluate the effectiveness of soil solarization and fumigants to inactivate the causal fungus, Fusarium oxysporum f.sp. radicis-lycopersici (FORL), buried at depths of 2, 6, and 9 in. Crown rot incidence and severity were significantly reduced in naturally infested soil by the fumigants methyl bromide/chloropicrin 67:33 [Terr-O-Gas (300-360 lbs/A)] and 1,3-dichloropropene/chloropicrin 83:17 [Telone C-17 (21.4 gals/A)], and the tomato cultivar NVH-4471. Crown rot incidence was also reduced by prior infection of tomato transplants with T. harzianum. Soil solarization consistently reduced FORL populations at depths of 2, 6, and 9 in. throughout the experiment. Populations of FORL were also significantly reduced at 2 and 6 in. after 2 weeks, and at 9 in., 4 weeks following application of Terr-O-Gas (400 lbs/A) and simultaneous fumigation with metham sodium [Vapam (100 gals/A)] plus chloropicrin [HMS Chloropicrin 100 (100 lbs/A)].

INTRODUCTION

Fusarium crown and root rot caused by the fungus Fusarium oxysporum f. sp. radicis-lycopersici (FORL), has consistently been the most prevalent soilborne disease of tomato in Southwest Florida. The fungus causes root rot accompanied by a very characteristic brown discoloration at the soil level.

The lower leaves of infected plants turn yellow and the entire plant may wilt around the time of first harvest. An incidence of crown rot in excess of 50% was commonly observed in tomato fields in southwest Florida during the 1992-93 season. Outbreaks of FORL have also occurred in tomato transplant production houses during the same period. The pathogen is favored by cool soil temperatures and forms rugged resting spores (chlamydospores) which enable it to survive in the soil and plant debris for many years. The fungus has also been isolated from contaminated styrofoam transplant trays (McGovern, unpublished data) and tomato stakes (8). In addition to chlamydospores FORL also produces microconidia and macroconidia, the former of which has been implicated in the aerial dispersal of the fungus in greenhouses (13).

Fumigation with methyl bromide/chloropicrin provides significant, but by no means complete control of crown rot in the field (2,10). However, the classification of methyl bromide as an ozone depleter by the EPA and its probable phase-out necessitates evaluation of alternative management strategies for crown rot in the field. Currently, there are no commercial tomato cultivars which have resistance to FCRR in the field and transplant house, and the resistance/ tolerance of commonly used Florida cultivars has not been characterized.

There is a potential for the biological control of crown rot through the use of beneficial fungi and bacteria because FORL competes weakly with other soilborne microorganisms (6). Research has indicated that crown rot can be reduced in the field through the use of the fungal biocontrol agent Trichoderma harzianum (7,15).

Soil solarization has been shown to be effective in reducing many soilborne pathogens (4). This technique employs clear plastic to trap the radiant energy of the sun which in turn results in an elevation of soil temperature. The goal of solarization is, therefore, to sufficiently raise soil temperatures so that soilborne pathogens (bacteria, fungi) as well as other pests will be destroyed. Solarization is primarily used on a commercial scale in areas with dry climates such as Israel and California which have little cloud cover to impair solar radiation. Solarization reduced the natural incidence of Verticillium and Fusarium wilts in west central Florida (11,12), and buried populations of Pseudomonas solanacearum, Phytophthora capsici, and FORL in Northern Florida (1), but had not been previously tested in Southwest Florida.

ALTERNATIVE FUMIGANTS AND BIOLOGICAL CONTROL

Objective

Our objective was to compare the effectiveness of methyl bromide/chloropicrin 67:33, metham sodium delivered either through soil injection or chemigation, 1,3-dichloropropene/ chloropicrin 83:17, and the biocontrol agent T. harzianum in reducing Fusarium crown rot.

Materials and Methods

Three different field experiments were conducted in cooperation with tomato growers in the Immokalee area. Fields (Pomello fine sand) naturally infested with FORL were chosen based on previously high incidences of crown rot or a long cropping history with tomato. Fields were thoroughly cultivated and wetted prior to bed formation and fumigation to promote adequate distribution of the fumigants. Thirty six inch wide beds mulched with 1.25 mil black plastic on 6 ft centers were used in all experiments. Conventional cultural and pest management practices for staked tomatoes were employed.

Experiment 1. The first fumigant experiment compared methyl bromide/chloropicrin 67:33 (Terr-O-Gas 67) at 360 lbs/A, metham sodium (Vapam) at 75 and 100 gals/A, and a control (water only). Terr-O-Gas 67 was applied on 6 Oct., 1992, and Vapam on 13-15 Oct., 1992. Terr-O-Gas was injected at a depth of 8 in. using a tractor drawn superbedder with 3 chisels spaced 9 in. apart. Beds were immediately covered plastic mulch. Vapam was prediluted in 60 gallons of water and was chemigated into mulched beds through a single plastic irrigation tube. The irrigation tubing had an 18 in. emitter spacing was placed off-center on top of the soil. The daily high soil temperatures during fumigation ranged from 85.3-87.5F (University of Florida-IFAS, SWFREC-Immokalee Weather Station).

Each treatment was replicated 5 times using 100 ft blocks which were arranged in a randomized complete block design. Transplants of the tomato cultivar Cobia were planted on 27 Oct., 1992 using an 18" spacing. Plants were watered by combining drip irrigation and water table management (seep irrigation). The marketable fruit from 10 plants within each block were harvested. Following mean separation by treatment (Least Squares Difference procedure, p=0.05, SAS Statistical Institute, Inc., Cary, NC) yields were converted to ton/A equivalents. Ten additional plants were rated for crown rot on 27 Jan., 1993 and 15 Feb., 1993. Crown rot was evaluated using a 0-3 rating scheme (0=no crown rot, 3=extensive internal discoloration) following uprooting and longitudinal sectioning of the plants at their crowns.

Experiment 2. Treatments in the second fumigant experiment consisted of Terr-O-Gas 67 at 300 lbs/A, metham sodium (Busan 1020) at 100 gals/A, and an untreated control (no fumigant). Terr-O-Gas and Busan were injected 7 in. into the soil using a tractor-drawn superbedder by means of 3 and 6 chisels, respectively, spaced 11 in. apart on 2 Nov., 1992. Immediately following fumigant application beds were covered with plastic mulch. The daily high soil temperature was 86.1F.

Each treatment was replicated 6 times using 120 ft. blocks arranged in a randomized complete block design. Transplants of the tomato cultivar Agriset were planted on 23 Nov., 1992 using an 18 in. spacing. Plants were irrigated by means of seep irrigation. Yield data was obtained on 9 Feb. and 13 Feb., 1993, and crown rot was evaluated on 19 Feb. and 5 Mar., 1993 using previously stated methods.

Experiment 3. A third experiment compared Terr-O-Gas 67 at 300 lbs/A, Vapam at 100 gals/A, 1,3-dichloropropene/chloropicrin 83:17 (Telone C-17) at 21.4 gals/A, the simultaneous application of Vapam (50 gals/A) and Telone C-17 (21.4 gals/A), an untreated control, and each of the these treatments in combination with T. harzianum. Fumigants were applied using a tractor-drawn superbedder at a depth of 9.5 in. on 28 Jan., 1993. Terr-O-gas or Telone C-17 were injected into the soil using 3 chisels spaced 11 in. apart, and Vapam was injected by means of 6 chisels at the same spacing. Beds were mulched with plastic immediately following fumigation. The daily high soil temperature was 65.6F.

Transplants of the tomato cultivar Sunny were produced in Sunshine II Mix (Fisons Horticulture, Inc., Downers Grove, IL) or the same medium amended with 2.0×10^5 conidia of T. harzianum (Kodak, Rochester, NY)/g of medium. Each treatment was replicated 6 times using 60 ft split plots (+/- T. harzianum) arranged in a randomized complete block design. Transplants were planted on 28 Jan., 1993 using an 18 in. spacing. Plants were irrigated by means of seep irrigation. Yield and crown rot data were obtained on 30 Apr., 1993 using previously stated methods with the exception that the entire split plot was harvested. Plants were harvested only once because of damage sustained following a severe storm in March.

Results and Discussion

Although Fusarium crown rot incidence was very high (95-100%) in all field experiments during 1992-93, disease severity was generally reduced in comparison with the two previous growing seasons. The fungus may have been inhibited due to milder than normal winter temperatures; the mean high soil temperatures recorded for November and December at SWFREC were, respectively, 3.1F and 2.6F higher than historical norms (based on a 30 yr. average at Moore Haven, FL).

Terr-O-Gas treatments significantly reduced both the incidence and severity of crown rot in all field experiments (Tables 1-3). Metham sodium (Vapam, Busan 1020) application did not to consistently reduce either disease severity and incidence. The application of Telone C-17 significantly reduced both crown rot incidence and severity. No synergistic or additive interactions in crown rot suppression were observed between Telone C-17 and Vapam or between _T_. _harzianum_ and any fumigant treatment. However, disease incidence was significantly lower in plants treated with _T_. _harzianum_ than untreated plants (Table 4).

No significant differences in yield were observed among the treatments perhaps owing to the overall decreased crown rot severity in comparison to previous seasons. The extremely low yields obtained in experiment 3 can be attributed to severe storm damage and a subsequent high incidence of bacterial spot which curtailed the experiment, permitting only one harvest.

Suppression of crown rot by methyl bromide/chloropicrin and the lack of control observed with metham sodium was similar to that previously reported (2,10). Delivery of metham sodium via chemigation did not improve its efficacy against FORL in comparison with chisel injection. The lack of effectiveness of metham sodium may be related to its limited lateral distribution (9). It is possible that the use of irrigation tubing with closer emitter spacings, employment of two irrigation tubes per bed, burial of the tube(s) near the bed center, or a combination of all three techniques could improve the effectiveness of this fumigant. Another approach to increasing the distribution of metham sodium may be provided by surface application rapidly followed by rotovation.

The reduction of crown rot incidence by _T_. _harzianum_ confirms previous work in Florida (7). This biocontrol agent and others under investigation could play a significant role in integrated management of the disease in both the field and transplant house. The use of Telone C-17 to decrease crown rot has not been previously reported and needs to be confirmed over multiple seasons.

SOIL SOLARIZATION

Objective

Our objective was to evaluate the effectiveness of soil solarization, alone and in combination with methyl bromide/ chloropicrin, or metham sodium plus chloropicrin in decreasing populations of FORL. An 8 week period from April through June was chosen to coincide with the end of tomato production and to avoid the start of the rainy season in Southwest Florida.

Materials and Methods

Inoculum of FORL was produced by growing the fungus in covered beakers containing dried, finely ground, sterilized tomato shoots moistened with a 0.1% (w/v) aqueous solution of asparagine. After incubation for one month at 77F, the infested tomato tissue was aseptically dried in a laminar flow hood and thoroughly mixed with sterile soil (fine Pomello sand) at a ratio of 1:20 (W/W). The initial FORL population was determined to be approximately $1.0x10^5$ colony-forming units/g of soil by plating serial dilutions on Komada's selective medium for Fusarium oxysporum (5). One gram of FORL inoculum was placed in sealed packets formed of Versapor-3000 membrane filters (Gelman Sciences, Ann Arbor, MI), which permitted air and water exchange.

These membranes were enclosed in nylon mesh bags and attached with electrical tape 2, 6 and 12 in. from the top of wire field flags. Flags containing FORL inoculum were soaked for 1 hour to pre-wet the inoculum. Four flags were buried in holes dug in the center of 12x12 ft field plots at SWFREC-Immokalee. Soil treatments included solarization using 2 mil Polyon 201 clear stabilized polyethylene mulch (Polyon Barkai, Kibutz Barkai, Israel), Terr-O-Gas 67 (400 lbs/A), Vapam (100 gals/A plus chloropicrin [HMS Chloropicrin 100 (100 gals/A)], solarization plus Terr-O-Gas (200 lbs/A), solarization + Vapam (100 gals/A) plus Chloropicrin (100 lbs/A), and an untreated control. Each treatment was replicated 5 times using plots arranged in a randomized complete block design.

The field was thoroughly wetted prior to fumigation which occurred on 14 Apr., 1993. Methyl Bromide-Chloropicrin and Chloropicrin alone were injected at a depth of 5 in. by means of 12 chisels spaced 12 in. apart using a tractor-drawn custom application device. Metham Sodium was diluted in water and applied by means of watering cans. The daily mean high soil temperature was 86.3F. All fumigated plots were immediately covered with a temporary 1 mil clear plastic mulch which was removed 7 days following fumigation. Plots treated with a combination of solarization and fumigation were covered with Polyon 201 mulch prior to removal of the temporary mulch which was pulled away from underneath. The water table was maintained below 12 in. throughout the experiment.

Soil temperature was monitored hourly in a solarized and nonsolarized plot by means of thermocouples buried at 2, 6, and 12 in. using a CR-10 datalogger (Campbell Scientific, Inc., Logan, UT 84321). Due to equipment failure soil temperature data was only obtained for the second half of the experiment. Buried inoculum of FORL was recovered from each plot at 2, 4, 6, and 8 week intervals and holes in the mulch were resealed with duct tape. Each packet of inoculum was serially diluted and plated on 3 plates of Komada's medium. Colony counts were recorded following incubation of plates for 3 days at 77F.

Results and Discussion

Temperatures measured in the plot mulched with clear plastic were consistently higher than those recorded in the nonsolarized plot at all three depths (Figure 1), and were comparable to temperatures achieved through solarization in other areas of Florida (1,11,12). Daily mean high temperatures at depths of 2, 6 and 12 in. were increased respectively, by 14.4, 19.1, and 27.3 degrees F through solarization.

Due to movement during burial, actual placement of inoculum packets at the lowest depths averaged 9 in. instead of 12 in. In general, colony forming units of FORL were significantly reduced by solarization at 2 in. throughout the experiment (Figure 2). Consistent reductions in FORL populations due to solarization were also observed at 6 in. throughout the experiment, and at 9 in. beginning 4 weeks after the start of solarization (Figures 3 and 4). In general, Terr-O-Gas at rates of either 200 or 400 lbs/A, and Vapam plus chloropicrin significantly decreased populations of FORL at 2 in. and 6 in. at all sampling times, and at 9" commencing 4 weeks after fumigation. Combination of solarization and Vapam plus Chloropicrin appeared to be more effective against FORL than either treatment alone. Unexpectedly high FORL colony counts detected at 8 weeks with Vapam plus Chloropicrin (6 in.) and Terr-O-gas (9 in.) probably do not represent actual population increases of the fungus. A more likely explanation for such results would be that the fungal propagules may have resided in a soil pocket which excluded the fumigants.

Reduction of FORL inoculum through solarization has not been previously reported in a subtropical area. Although population decreases following solarization did not approach those produced by fumigants, the possibility remains that heating may have impaired the ability of surviving propagules of FORL to cause disease. This hypothesis will be tested in future experiments. Since solarization is more similar to pasteurization than sterilization it could actually promote populations of beneficial microorganisms which would further reduce disease (3). Another beneficial approach may be provided by the combination of biocontrol and solarization.

RESISTANCE/TOLERANCE

Objective

Our objective was to screen commonly used south Florida tomato cultivars and a newly introduced cultivar for resistance or tolerance to Fusarium crown rot. Resistance may be defined as the relative ability of a plant to avoid infection while tolerance generally implies its ability to produce an adequate yield despite infection.

Materials and Methods

A commercial production field (Pomello fine sand) naturally infested with FORL was formed into 36 in. beds which were fumigated with Terr-O-Gas 67 at 350 lbs/A on 14 Aug., 1992. Fertilization consisted of a bottom mix of 1100 lbs/A of 4-16-8 incorporated at bed formation and a top mix of 1200 lbs/A of 17-0-28 placed in 1.5 in. groves 8 in. from the bed shoulders at the time of fumigation. Immediately following fumigation, beds were covered with 1.25 mil black plastic mulch.

Seven week-old transplants of 6 currently used tomato cultivars, Agriset-761, Olympic, PAP-34281, Solarset (Petoseed Co., Inc., Saticoy, CA), Sunny (Asgrow Seed Co., Inc., Kalamazoo, MI), Merced, and NVH-4471 (Rogers NK, Minneapolis. MN). were planted on 22 Oct., 1992 using an 18 in. spacing. Each cultivar was replicated 9 times using 30 ft blocks arranged in a randomized complete block design. Plants were irrigated by means of seep irrigation. Conventional cultural and pest management practices for staked tomatoes were employed. Yield data was obtained on 15 Jan. and 28 Jan., 1993, and crown rot was evaluated on 19 Feb., 1993 using previously stated methods.

A separate experiment was conducted in a controlled environment chamber using seedlings of the same tomato cultivars. Following the methods of Sanchez, et al (14), 10 seeds of each cultivar were surface disinfested in 0.5% sodium hypochlorite for 2 minutes, rinsed in sterile water, and placed on plates of carnation leaf agar containing one week-old cultures of an FORL isolate. Three plates containing a total of 30 seeds were used to evaluate the resistance of each cultivar. Plates were incubated in the dark at 74F until seedling emergence, and then were transferred to a Convirons PGR-15 controlled environment chamber (Convirons, Controlled Environments, Inc., Winnipeg, Manitoba, Canada) set at a constant temperature of 68F with a 12 hour photoperiod. The presence or absence of brown lesions at the root-shoot junction (hypocotyl) typical of FORL was recorded 14 days after seedling emergence.

Results and Discussion

The new cultivar NVH-4471 exhibited a high degree of resistance in terms of both reduced incidence and severity of Fusarium crown rot in the field (Table 5). NVH-4471 was also significantly more resistant at the seedling stage (Table 6). Its yields were intermediate to the other cultivars tested and produced significantly lower culls, including those rejected because of gray wall. In general, Merced and Agriset were tolerant to FORL and produced significantly higher yields than the other four more susceptible cultivars. Because seasons and cultural situations vary, it is important to test all new cultivars on a small scale over a number of seasons before initiating major production changes.

To date, no races of FORL have been identified, unlike the fungus Fusarium oxysporum f.sp. lycopersici (Fusarium wilt) which may be divided into 3 races, each requiring different resistance genes. Nevertheless, this possibility cannot be ruled-out especially when a selection pressure (strong resistance) is placed on the fungus. Therefore, the deployment of resistant cultivars should be integrated with other management strategies to prolong their usefulness.

SUMMARY

New management practices were identified which reduced the incidence of Fusarium crown and root rot of tomato in the field and/or populations its fungal pathogen. These strategies included the use of the resistant tomato cultivar NVH-4471, fumigation with Telone C-17, and soil solarization. Crown rot incidence was also reduced by the biocontrol agent Trichoderma harzianum. It will be necessary to confirm and extend these results through further experimentation because of possible site and seasonal variations.

When considered independently, these management techniques may not adequately reduce crown rot and should be integrated with the use of disease-free transplants, optimization of cultural practices, and rotation with a non-susceptible crop. Research is also needed to develop an effective program to manage crown rot in the transplant house.

REFERENCES

1. Chellemi, D.O., S.M. Olson, J.W. Scott, D.J. Mitchell, and R. McSorley. 1993. Evaluation of soil solarization for management of soilborne pests. NFREC Research Report 93-B. University of Florida-IFAS, North Florida Research and Education Center, Quincy, FL 32351.

2. Jones, J. P. and A. J. Overman. 1985. Management of Fusarium wilt, Fusarium crown rot, Verticillium wilt (Race 2), southern blight, and root-knot of tomato on fine sandy soils. Proc. Fla. State Hort. Soc. 98:229-231.

3. Katan, J. 1980. Solar pasteurization soils for disease control: status and prospects. Plant Dis. 64:450-454.

4. Katan, J. and J.E. DeVay. 1991. Soil Solarization: historical Perspective, principles and uses. pp 23-37 In J. Katan and J.E. DeVay, Eds. Soil Solarization. Boca Raton, FL: CRC Press. 267 pp.

5. Komada, H. 1975. Development of a selective medium for quantitative isolation of Fusarium oxysporum from natural soil. Rev. Plant Prot. Res. 8:114-125.

REFERENCES (con.)

6. Marois, J. J., and Mitchell, D. J. 1981. Effects of fumigation and fungal antagonists on the relationship of inoculum density to infection incidence and disease severity in Fusarium crown rot of tomato. Phytopathology 71:167-170.

7. Marois, J. J., D. J. Mitchell and R. M. Sonoda. 1981. Biological control of Fusarium crown rot of tomato under field conditions. Phytopathology 71:1257-1260.

8. McGovern, R.J. and L.E. Datnoff. 1992. Fusarium crown and root rot: Reevaluation of management strategies. pp 75-86 In C.S. Vavrina Ed. Proc. Florida Tomato Institute. Vegetable Crops Special Series SS-HOS-1, Vegetable Crops Department, University of Florida-IFAS, Gainesville, FL 32611.

9. Noling, J.W. 1991. Metham sodium application via drip irrigation systems. Nematology Circular No. 196. Fla. Dept. Agric. & Consumer Serv., Division of Plant Industry.

10. Overman, A. J. and J. P. Jones. 1984. Soil fumigants for control of nematodes, Fusarium wilt, and Fusarium crown rot on tomato. Proc. Fla. State Hort Soc. 97:194- 197.

11. Overman, A. J. 1985. Off-season land management, soil solarization and fumigation for tomato. Proc. Fla. State Hort. Soc. 44:35-39.

12. Overman, A.J. and J.P. Jones. 1986. Soil solarization, reaction, and fumigation effects on double-cropped tomato under full-bed mulch. Proc. Fla. State Hort. Soc. 99:315-318.

13. Rowe, R. C., J. D. Farley, and D. L. Coplin. 1977. Airborne spore dispersal and recolonization of steamed soil by Fusarium oxysporum in tomato greenhouses. Phytopathology 67:1513-1517.

14. Sanchez, L. E., R. M. Endo, and J. V. Leary. 1975. A rapid technique for identifying clones of _Fusarium oxysporum_ f.sp. _lycopersici_ causing crown- and root-rot of tomato. Phytopathology 65:726-727.

15. Sivan, A., Ucko, O., and I. Chet. 1987. Biological control of Fusarium crown rot of tomato by _Trichoderma harzianum_ under field conditions. Plant Dis. 71:587-592.

TABLE 1. Effect of Chisel-Injection of Terr-O-Gas 67 and Chemigation of Vapam on the Incidence and Severity of *Fusarium* Crown Rot, and Yield in the Tomato Cultivar Cobia.

Treatment	Mean Disease Incidence (%)[1]	Mean Disease Severity (0-3)[3]	Mean Fruit Yield (Tons)/A[4]
Control	100.0a[2]	2.02a	5.80a
Vapam (75gal/A)	98.0a	2.14a	6.80a
Vapam (100gal/A)	97.0a	2.20a	5.31a
Terr-O-Gas 67 (300lb/A)	69.0b	1.12b	6.78a

---

[1] Arc sine transformation of percentages was performed prior to statistical analysis; untransformed data is presented.

[2] Means within columns followed by different letters are significantly different ($p=0.05$) by LSD (SAS Statistical Institute, Inc., Cary, NC).

[3] Crown rot was evaluated using a 0-3 rating scheme (0=no crown rot, 3=extensive internal discoloration) following longitudinal sectioning of plant bases.

[4] Mean fruit yields based on the combined data from two harvests of 10 plants/block. Following mean separation, yields were converted to ton/A equivalents.

TABLE 2. Effect of Terr-O-Gas and Busan 1020 on the Incidence and Severity of Fusarium Crown Rot, and Yield in the Tomato Cultivar Agriset.

Treatment	Mean Disease Incidence (%)[1]	Mean Disease Severity (0-3)[3]	Mean Fruit Yield (Tons)/A[4]
Control	99.16a[2]	1.42a	14.02a
Busan 1020 (100gal/A)	88.33b	1.31ab	15.09a
Terr-O-Gas 67 (300lb/A)	88.33b	1.02b	15.55a

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[1] Arc sine transformation of percentages was performed prior to statistical analysis; untransformed data is presented.

[2] Means within columns followed by different letters are significantly different (p=0.05) by LSD (SAS Statistical Institute, Inc., Cary, NC).

[3] Crown rot was evaluated using a 0-3 rating scheme (0=no crown rot, 3=extensive internal discoloration) following longitudinal sectioning of plant bases.

[4] Mean fruit yields based on the combined data from two harvests of 10 plants/block. Following mean separation, yields were converted to ton/A equivalents.

TABLE 3. Effect of Various Fumigants on the Incidence and Severity of Fusarium Crown Rot, and Yield in the Tomato Cultivar Sunny.

Treatment	Mean Disease Incidence (%)[1]	Mean Disease Severity (0-3)[3]	Mean Fruit Yield (Tons)/A[4]
Control	95.0a	0.94a	1.78a
Vapam (100gal/A)	94.0a	0.97a	1.66a
Telone C-17 (21.4 gal/A)	46.0b	0.38bc	1.43a
Telone C-17 (21.4gals/A) + Vapam (50gal/A)	42.0b	0.46b	1.53a
Terr-O-Gas (300lb/A)	26.0b	0.20c	1.54a

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[1] Arc sine transformation was performed prior to statistical analysis; untransformed data is presented.

[2] Means within columns followed by different letters are significantly different (p=0.05) by LSD (SAS Statistical Institute, Inc., Cary, NC).

[3] Crown rot was evaluated using a 0-3 rating scheme (0=no crown rot, 3=extensive internal discoloration) following longitudinal sectioning of plant bases.

[4] Mean fruit yields based on one harvest of 60 ft plots. Following mean separation, yields were converted to ton/A equivalents.

TABLE 4. Effect of The Biocontrol Agent *Trichoderma harzianum* on Incidence and Severity of Fusarium Crown Rot, and Yield in the Tomato Cultivar Sunny.

Treatment[1]	Mean Disease Incidence (%)[2]	Mean Disease Severity (0-3)[4]	Mean Fruit Yield (Tons)/A[5]
Control	65.8a[3]	0.61a	3.23a
T. harzianum	52.5b	0.54a	3.16a

---

[1] Transplants of the tomato cultivar Sunny were produced in Sunshine II Mix (Fissons Horticulture, Inc., Downers Grove,IL) or the same medium amended with 2.0 x 105 conidia of *T. harzianum* (Kodak, Rochester, NY)/g of medium.

[2] Arc sine transformation was performed prior to statistical analysis; untransformed data is presented.

[3] Means within columns followed by different letters are significantly different ($p=0.05$) by LSD (SAS Statistical Institute, Inc., Cary, NC).

[4] Crown rot was evaluated using a 0-3 rating scheme (0=no crown rot, 3=extensive internal discoloration) following longitudinal sectioning of plant bases.

[5] Mean fruit yields based on one harvest from 60 ft plots. Following mean separation, yields were converted to ton/A equivalents.

TABLE 5. Effect of Tomato Cultivar on the Incidence and Severity of Crown Rot, and Yield

Tomato Cultivar	Mean Disease Incidence(%)	Mean Disease Severity (0-3)[3]	Mean Fruit Yield (Tons/A)[4]	Mean % Culls[5]	Mean % Gray Wall[6]
Olympic	77.8a[2]	0.76b	13.02c	12.48bcd	5.48bc
PAP-34283	73.3a	0.73ab	12.56c	16.68ab	4.42bc
Solarset	71.1a	1.02a	13.58c	19.52a	21.18a
Merced	62.2a	0.63b	17.81a	10.59cd	0.17c
Sunny	62.2a	0.79ab	14.12bc	12.29bcd	7.22b
Agriset-761	60.0a	0.68b	15.91b	14.89bc	3.84bc
NVH-4471	15.6b	0.10c	15.56b	8.09d	0.16c

[1] Arc sin transformation was performed prior to statistical analysis; untransformed data is presented.

[2] Means within columns followed by different letters are significantly different (p=0.05) by LSD (SAS Statistical Institute, Inc., Cary, NC).

[3] Crown rot was analysed using a 0-3 rating scheme (0=no crown rot, 3=extensive internal discoloration) following longitudinal sectioning of plant bases.

[4] Mean fruit yields based on the combined data from two harvests of 10 plants/block. Following mean separation, yields were converted to ton/A equivalents.

[5] Mean % culls was calculated by weight and was based on total harvested fruit (marketable fruit + culls)

[6] Mean % of Gray wall was based on the total number of fruit (marketable fruit + culls) from the first harvest only.

Table 6. Effect of Tomato Cultivar on the Incidence of Crown Rot in Seedlings Inoculated with *Fusarium oxysporum* f.sp. *radicis-lycopersici*.

Tomato cv:	Olympic	PAP-34283	Solarset	Merced	Sunny	Agriset	NVH-4471
Mean Crown Rot (%):	73.3abc[1]	76.6ab	93.3a	60.0bc	90.0a	50.0c	20.0d

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[1] Means followed by different letters significantly different ($p=0.05$) by LSD (SAS Statistical Institute, Inc., Cary, NC).3

FIGURE 1. EFFECT OF SOLARIZATION ON DAILY MAXIMUM SOIL TEMPERATURE AT SWFREC-IMMOKALEE, MAY 13 TO JUNE 8, 1993

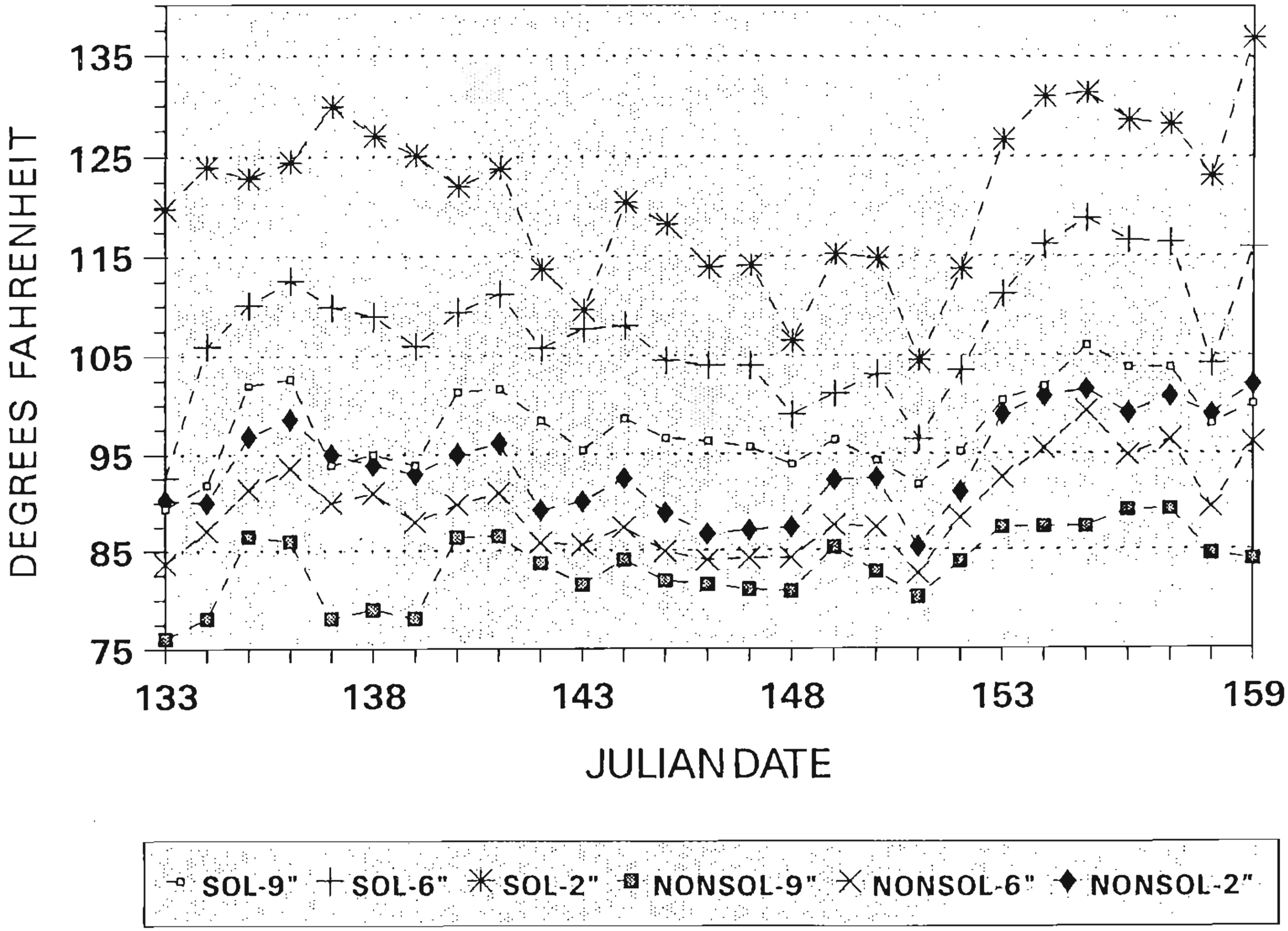
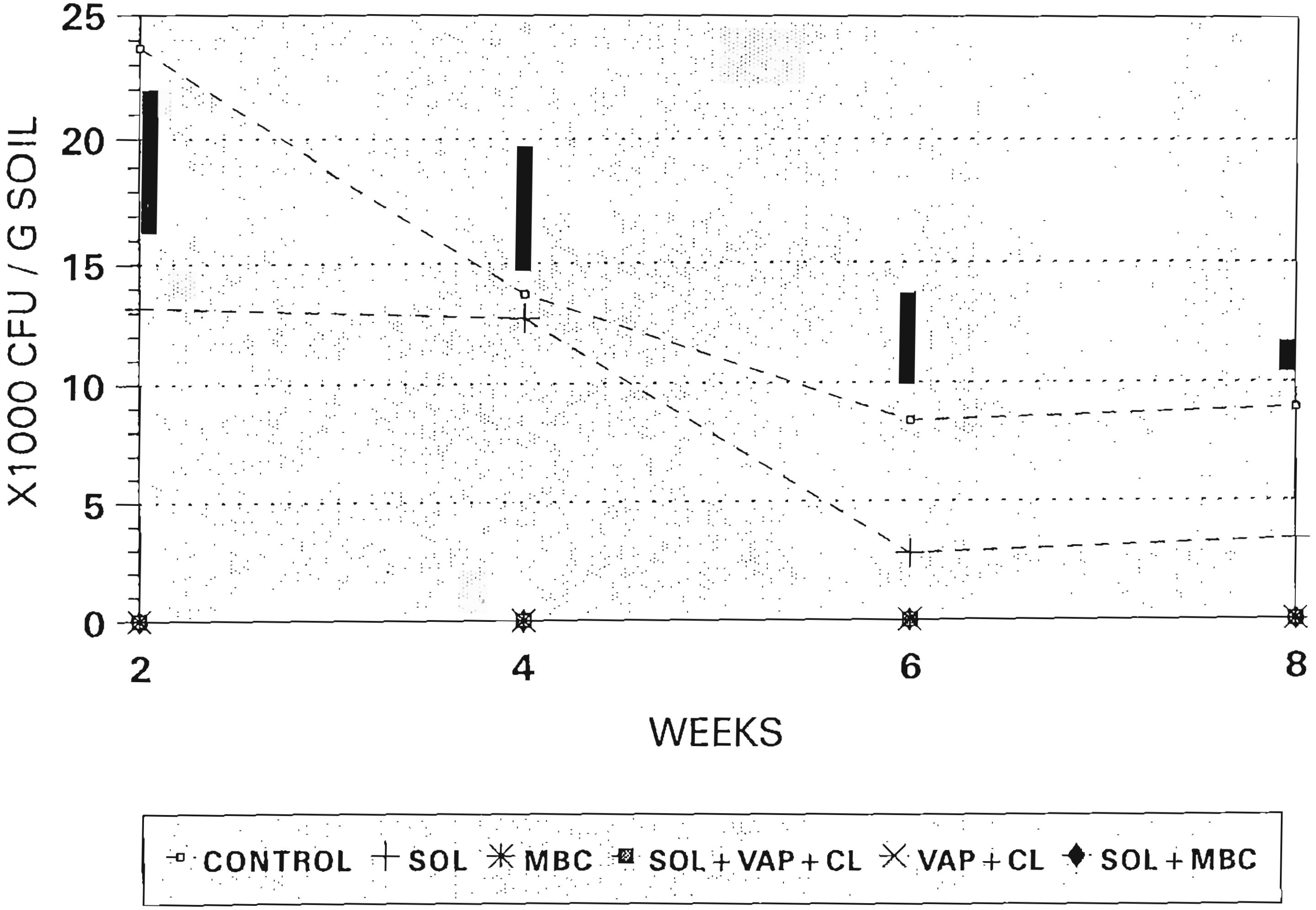
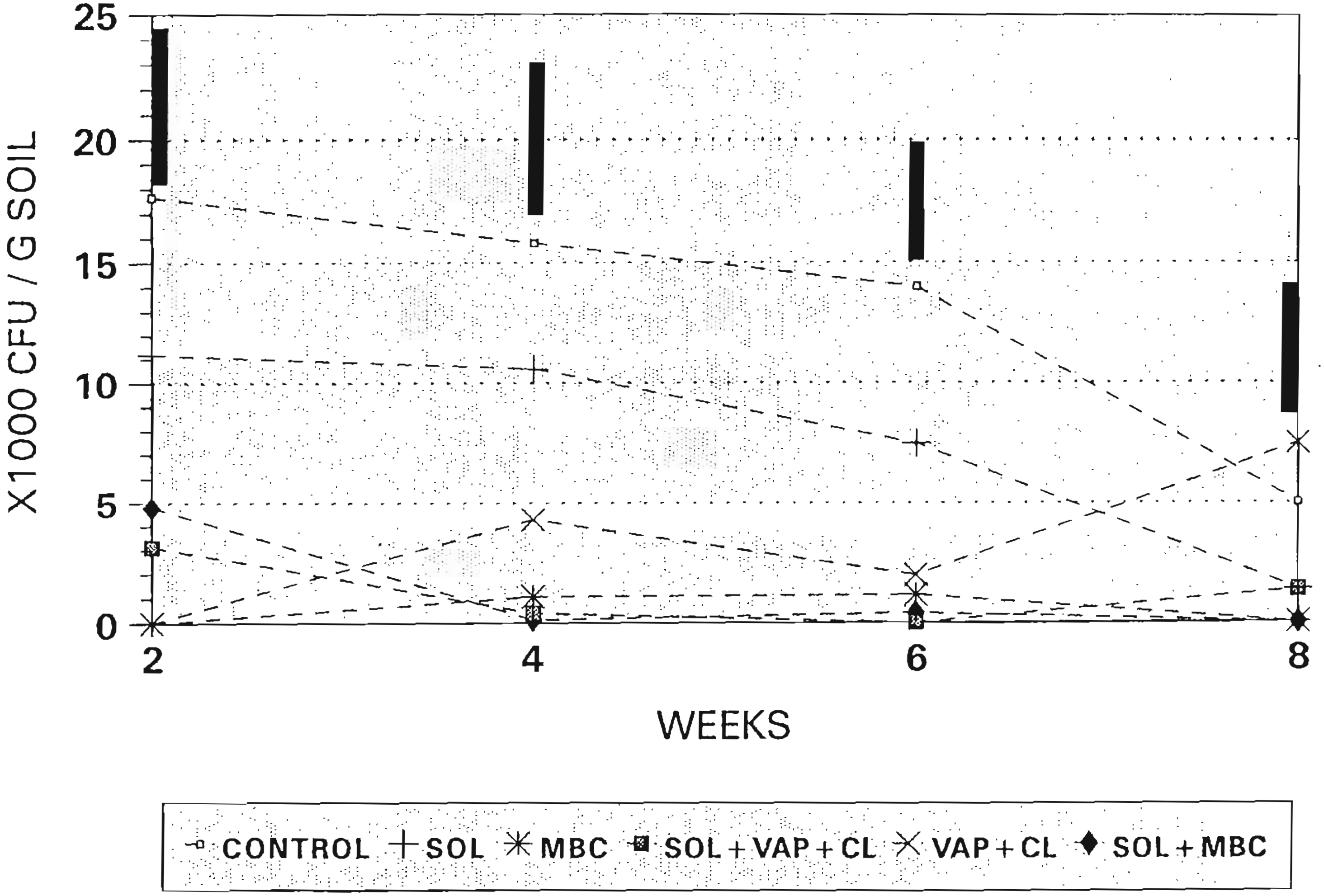


FIGURE 2. INFLUENCE OF SOLARIZATION AND FUMIGATION ON FORL POPULATIONS AT 2"



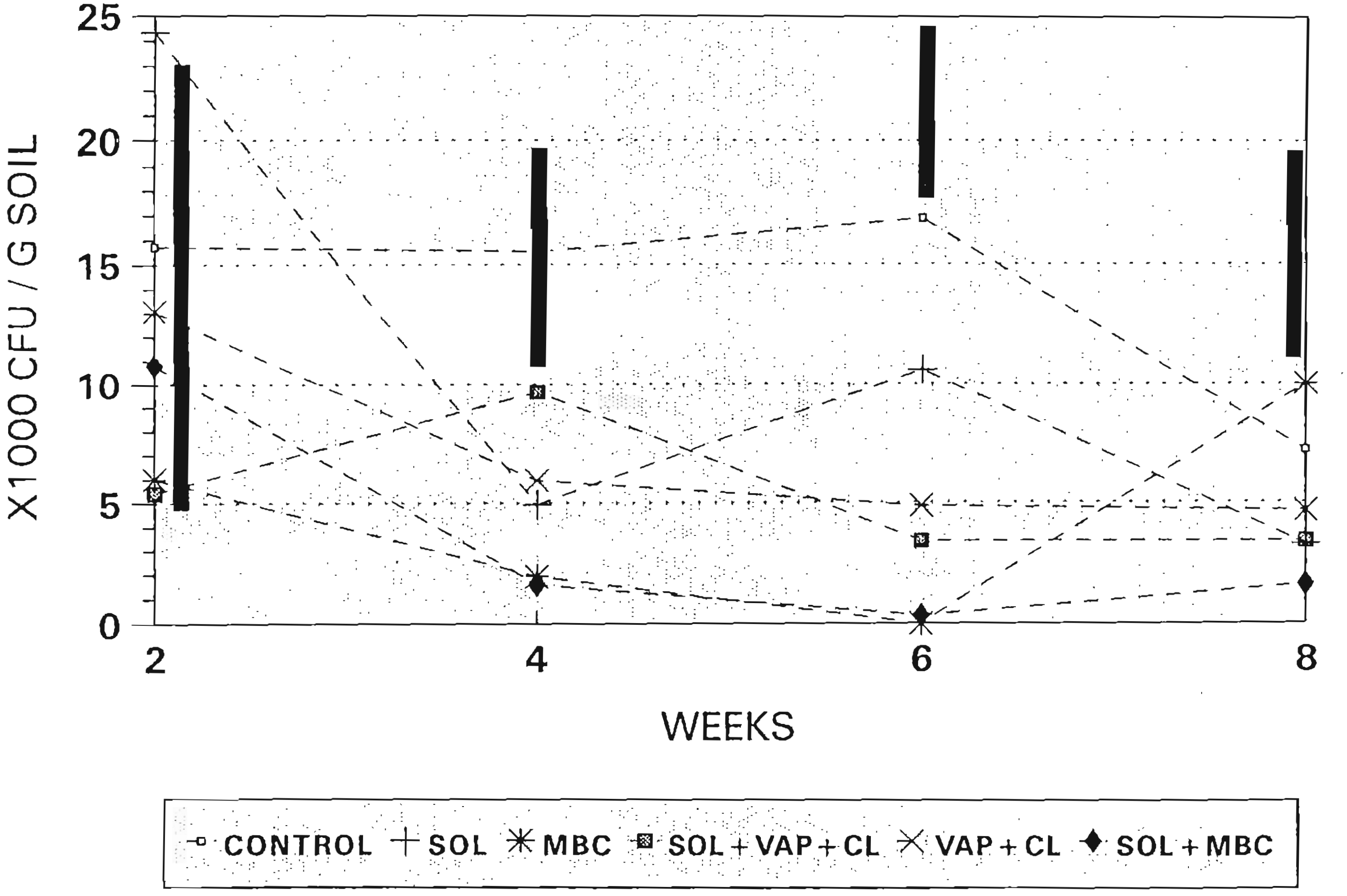
(BARS = LSD VALUES AT P = 0.05, SAS STATISTICAL ANALYSIS)

FIGURE 3. INFLUENCE OF SOLARIZATION AND FUMIGATION ON FORL POPULATIONS AT 6"



(BARS=LSD VALUES AT P=0.05, SAS STATISTICAL ANALYSIS)

FIGURE 4. INFLUENCE OF SOLARIZATION AND FUMIGATION ON FORL POPULATIONS AT 9"



(BARS=LSD VALUES AT P=0.05, SAS STATISTICAL ANALYSIS)

REFLECTIONS ON THE 1993 LATE BLIGHT EPIDEMIC RELATIVE TO FUTURE DISEASE MANAGEMENT PRACTICES

D. P. (PETE) WEINGARTNER
Agricultural Research and Education Center
Hastings, FL

Late blight is a destructive disease affecting both potato and tomato. It is caused by a fungus, *Phytophthora infestans*, which earned its deserved infamy by destroying the Irish potato crop in the mid-1840's, leading to the Great Potato Famine (1). Late blight has occurred in Florida potatoes for as long as the crop has been grown in the state (4). Following a decade of relative calm, late blight caused great alarm in the Florida potato and tomato industries during 1992-93. My objective in this brief, generalized report, is to place the 1993 late blight epidemic into historical perspective and to offer several observations on management of the disease in Florida potatoes and tomatoes.

Five major events relative to the history of late blight management occurred in Florida. The first was the introduction of late blight into North America, probably in the 1840's (1), and establishment of *P. infestans* in North American potatoes. At the turn of the century the disease was ubiquitous in potato and late blight was one of the first potato diseases in Florida during the early 1900's (4). It did not occur in Florida tomatoes until the 1940's (2).

The first occurrence of late blight in Florida tomatoes is another important event because it most likely indicated introduction of a new "strain" of *P. infestans* into the pathosystem. The fact that some, but not all potato strains of *P. infestans* attack tomato, whereas most tomato strains go to potato (3) suggests that a new strain to Florida was introduced probably on potato during the mid 1940's. Once the disease was described in tomatoes, it was reported most every year in some section of the state.

A third major event in Florida late blight history occurred with the introduction and use of the ethylene bisdithiocarbamate fungicides (EDBC's) such as nabam and maneb. These fungicides provided outstanding control of late blight in both potato and tomato and revolutionized disease control in these crops (4).

Development of resistant potato cultivars during the 1940's and 50's was believed to be a major breakthrough.

However, multiple races of P. *infestans* exist and resistance was quickly overcome. (1).

Until recently the next major event in late blight management was the development of highly effective systemic fungicides such as metalaxyl. Use of metalaxyl, especially in the seed potato industry, apparently reduced incidence of late blight in Florida to an occasional observation. During the past 8-10 seasons, late blight in both Florida potatoes and tomatoes has been an infrequent visitor. The 1992-93 epidemic was a sudden departure from this trend.

The most wide spread epidemic of late blight in both Florida potatoes and tomatoes in modern agriculture, and perhaps the most wide spread ever, occurred in 1992-93. Although a relatively few fields were severely defoliated, the disease was reported in nearly all potato and tomato producing sections of Florida (D. P. Weingartner, personal observations).

Multiple factors played a role in the 1992-93 epidemic: (i) Late blight was present in several potato seed tuber regions and the potential for introduction into Florida in seed was high; (ii) Resistance to metalaxyl was introduced or developed in Florida populations of P. *infestans*; (iii) Ideal weather conditions (particularly precipitation) occurred during early phenology of the crop at nearly all locations.

The importance of a final discovery made during the 1993 late blight outbreak may have greater implications for late blight management in the future than it had on last years epidemic. The late blight fungus exists as two mating types--A1 and A2. Sexual reproduction and the resulting development of durable survival structures (called oospores) of the fungus can only occur when both mating types coexist in the same population. Until the mid-1980's, only the A1 mating type was known to exist outside of Mexico, the apparent center of origin of P. *infestans*. Similarly, sexual reproduction of P. *infestans* and development of oospores was known to occur in nature only in the central highlands of Mexico (1).

Samples of late blight from Florida were sent during 1993 to Dr. Fry's laboratory at Cornell University and to Drs. R. W. Goth and K.L. Deahl with the USDA in Beltsville. All laboratories confirmed presence of both A1 and A2 mating types of P. *infestans* in Florida.

The impact of this discovery on managing late blight in Florida is unclear. Although oospores of other species of Phytophthora can survive in soil for long periods of time, little is known concerning the contribution of oospores of P. *infestans* in the disease cycle of late blight (1).

A totally integrated approach to management of late blight will be essential in the coming year. Important components should include: Sanitation -- destroy all cull piles, eliminate all volunteer tomato and potato plants. Do not save seed potatoes for fall plantings. Certification -- plant only certified seed potatoes and tomato transplants. Adhere to a recommended fungicide program using a contact fungicide; avoid long durations of foliage leaf wetness during irrigation.

Acknowledgements

Late blight reports and/or samples were collected by Glades Crop Care and Ciba personnel, Drs. Bob McGovern and Phyllis Gilraith. Analyses of *P. infestans* for metalaxyl sensitivity and/or mating types were performed by Drs. S. B. Goodwin and W. E. Fry, Cornell University, Drs. R. W. Goth and K. L. Deahl, USDA Beltsville, and Ciba Laboratories, Vero Beach, FL.

LITERATURE CITED

1. Fry, W. E., S. B. Goodwin, A. T. Dyer, and J. M. Matuszak, A. Drenth, P. W. Tooley, L. S. Sajkowski, Y. J. Koh, B. A. Cohen, and L. J. Spielman, K. L. Deahl, D. A. Inglis, and K. P. Sandlan. 1993. Historical and recent migrations of *Phytophthora infestans*: Chronology, Pathways, Implications. Plant Disease 77:653-661.

2. Jones, J. P., G. F. Weber, and D. G. A. Kelbert. 1969. Tomato diseases in Florida. University of Florida Agricultural Experiment Station Bulletin 731. 88pp.

3. Vartanian, Varoujan, G., and Robert Endo. 1985. Overwintering hosts, compatibility types and races of *Phytophthora infestans* on tomato in Southern California. Plant Disease 69:516-519.

4. Weingartner, D. P. 1982. Lessons learned from the potato late blight epidemic of 1982. Proceedings Florida State Horticultural Society 95:308-312.

ADVANCES IN THE MANAGEMENT OF TOMATO MOTTLE GEMINIVIRUS

Jane E. Polston
Assistant Professor of Plant Pathology
University of Florida, IFAS,
Gulf Coast Research and Education Center
Bradenton, FL

David J. Schuster
Professor of Entomology
University of Florida, IFAS,
Gulf Coast Research and Education Center
Bradenton, FL

Daniel Chellemi
Assistant Professor of Plant Pathology
University of Florida, IFAS
North Florida Research and Education Center
Quincy, FL

SUMMARY

A study of the movement of tomato mottle virus (TMoV) was undertaken during the spring seasons of 1992 and 1993 in commercial production fields in the Palmetto/Ruskin area. The study was designed to characterize and model the movement of TMoV into and through tomato fields in order to optimize virus management recommendations. Results from several different analyses of this data suggest that the most important type of spread is primary, that is, TMoV which enters the field from outside, but the most common type of spread in tomato fields is secondary, that is, TMoV which comes from infected plants within the field. These results suggest that more emphasis should be placed on preventing the introduction of TMoV into the field at the beginning of the season.

INTRODUCTION

Our understanding of tomato mottle virus (TMoV) has improved significantly over the last several years. What was once thought to be a virus found potentially anywhere within the agricultural environment is now known to be confined mainly to tomato plants themselves. High rates of infection thought to be the potential anywhere are now known to be primarily the result of the overlapping of production cycles. Transmission of the virus, which can occur in a variety of ways among plant viruses, has been shown to be limited to the adult whitefly vector (*Bemisia tabaci* Genn.). Transmission through seed and transmission by mechanical means in the field have been eliminated as possibilities.

Tomato mottle virus has become an established part of tomato production in most areas of Florida. Management practices have been recommended and successfully implemented. The management of this virus depends upon two main factors: managing the whitefly vector and limiting overseasoning sources of the virus. Though management of tomato mottle can be achieved in many cases the costs of this control are high. New areas of focus and concern are designed to reduce the expenses associated with tomato mottle control. Management practices need refinement for optimal effectiveness.

BACKGROUND AND EXPERIMENTAL DESIGN. An understanding of the movement of tomato mottle virus is central to developing optimal management practices. Little is known of 1) the percent of infected plants which are infected from sources from outside the field, and from sources inside the field, 2) the speed of virus movement within a field, 3) the factors that affect how rapidly the virus moves from infected to healthy plants, and 4) factors related to production that affect virus movement. An intensive field experiment designed to study the movement of tomato mottle virus in four commercial tomato fields was conducted during the spring cropping seasons of 1992 and 1993 in the Palmetto/Ruskin production area. Fields were planted with tomatoes between 20 and 28 January in 1992 and between 23 January and 5 February in 1993. Briefly, plots containing 144 plants (12 rows by 12 plants) were selected at random within each field, one plot per acre of field. Nine yellow sticky traps (2"x 2") were set 3 per row in the first, sixth and twelfth rows, equidistant within rows. All plants within each plot were examined each week for symptoms of TMoV. Positive plants and their location were recorded each week. Adult whitefly bodies on sticky traps were counted and recorded each week, at which time old sticky cards were replaced with new ones. Every other week samples from 10% of the plants in each plot were collected and analyzed for the presence of TMoV, in order to corroborate visual assessment of virus incidence. Though analysis of the data is still in progress, a number of important conclusions can already be drawn.

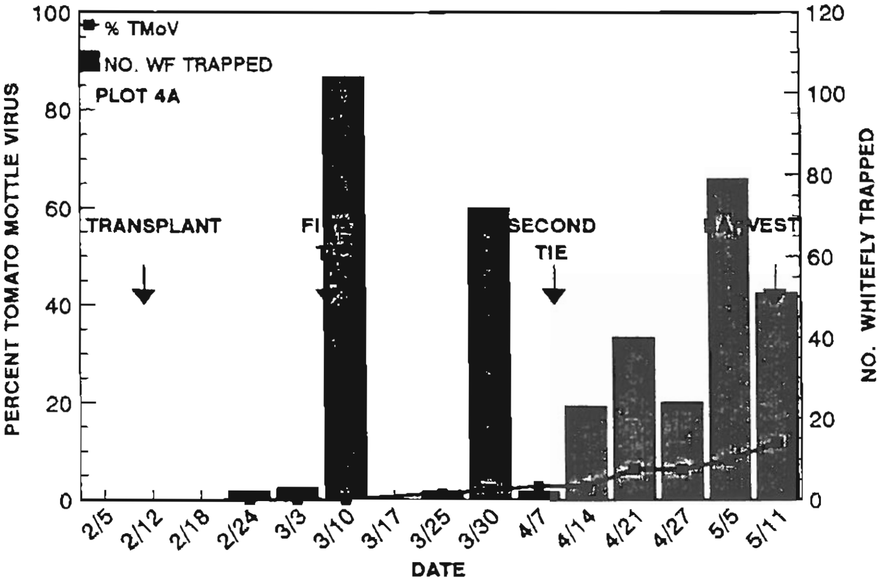
TOMATO MOTTLE INCIDENCE. Virus incidence in most of the plots studied was low to moderate in both years (Table 1). The highest incidence studied, 35%, occurred at the end of the season in a plot in the 1993 study. Many plots had little or no virus. Whitefly incidence and virus incidence were generally higher in 1993 than in 1992. Many fields exhibited a substantial amount of variation in TMoV incidence among the plots within the same field.

TABLE 1. Incidence of tomato mottle virus in 1992 and 1993 epidemiology experimental plots

YEAR - FIELD	NO. OF PLOTS	RANGE OF FINAL %TMoV/ PLOT	MEAN FINAL %TMoV/FIELD
1992 FIELD 1	7	1.4 - 23.6%	6.7%
1992 FIELD 2	11	0.0 - 6.3%	2.1%
1992 FIELD 3	8	0.0 - 3.5%	1.2%
1992 FIELD 4	11	1.4 - 12.5%	4.4%
1993 FIELD 1	8	10.4 - 34.7%	22.6%
1993 FIELD 2	9	2.8 - 12.5%	8.1%
1993 FIELD 3	9	0.0 - 4.9%	0.9%
1993 FIELD 4	8	0.0 - 11.8%	2.1%

MOVEMENT OF TOMATO MOTTLE VIRUS. The movement of virus into healthy tomato plants throughout the season was examined. Typically, the frequency of infected plants was very low at the beginning of the season and increased very slowly until several weeks before harvest when the frequency of infected plants increased more dramatically (Figure 1). Disease progress models were fitted to these data with good correlations between the models and the data. These models suggested that most of the infected plants in most of the plots were the result of secondary spread; that is, movement of virus from plant to plant within the same field (Figure 1A). However there were some plots, all within Field 1, 1993, in which several models fit equally well. This strongly suggests that there was more than one type of TMoV source for this field (Figure 1B). These plots had the highest incidences of virus within the study. An examination of the areas surrounding these plots revealed an abandoned fall tomato field less than one mile to the northeast of this field. This fall field had been tested in January 1993 and was found to have almost 100% TMoV incidence. To summarize, in 71 plots in 8 fields, the highest incidences of TMoV were found in one field which was located near a fall-planted tomato field which had a very high incidence of TMoV. Analysis of that spring field showed that there was more than just secondary spread within the field. Most likely, the fall tomato field served as a source of virus well into March of the spring season.

1A



1B

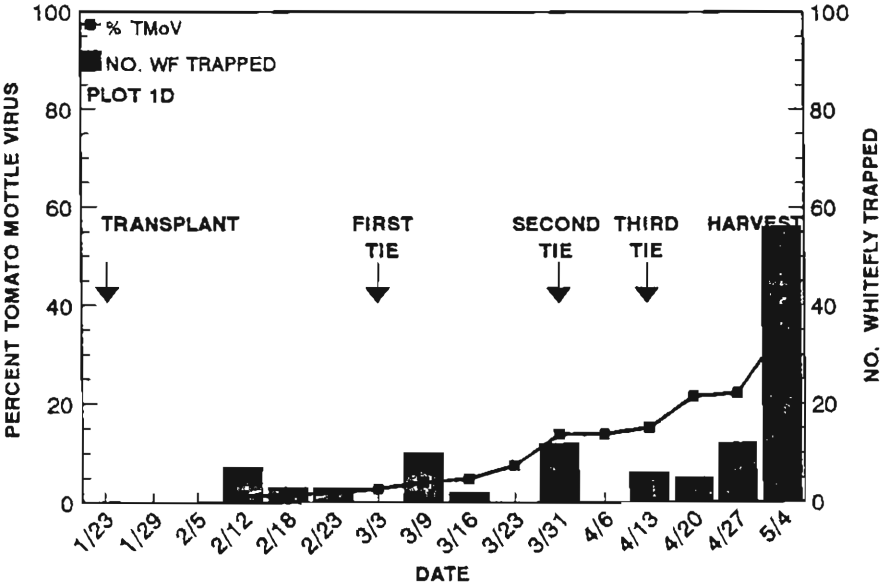


Figure 1. Incidence of tomato mottle virus and the number of whiteflies trapped throughout the season in two plots from spring 1993 production season. 1A. Disease progress curve is the result of small amount of primary spread early in the season; most of the virus incidence in this plot is due to secondary spread. 1B. Disease progress curve is the result of both primary and secondary spread throughout much of the season.

The impact of fields which bridge production cycles cannot be overstated. For example, in the Palmetto/Ruskin area, observations in January and February 1993 revealed that virus incidence was highest in those fields planted the earliest (Table 2). In most cases, plantings in December and early January had much higher incidences of TMoV than fields planted in mid to late January and February. This is not remarkable considering the fact that many fall fields were still being picked into early January. These fields were examined in mid January and TMoV incidence was always near 100% and whiteflies were seen in abundance (Table 3). Extending the time between fall and spring plantings by even a few weeks can reduce the amount of TMoV early in the season and reduce the need for excessive pesticide applications.

Table 2. Incidence of tomato mottle virus in different plantings within the same field (spring planting, 1993).

FIELD	PL'TING DATE	%TMoV ON 3/10/93
FIELD A	7 JAN 1993	1.5%
	15 JAN 1993	1.2%
FIELD B	1 JAN 1993	30.0%
	15 JAN 1993	7.5%
	23 JAN 1993	2.6%

Table 3. Increase in tomato mottle incidence in fall 1992 tomato fields between fall and spring 1993 seasons.

FALL FIELD	FALL FIELD, %TMoV ON 15 OCT. 1993	FALL FIELD, %TMoV ON 15 JAN. 1993
FIELD A	94%	100%
FIELD B	34%	100%
FIELD C	-	90%
FIELD D	-	100%
FIELD E	-	85%
FIELD F (PLNT'D EARLY DEC.)	-	80%

could be due to one or more factors: the yellow sticky trap is unsuited for estimating whitefly populations, or only viruliferous whiteflies are the main determinate of virus movement, and their representation in the total whitefly population varies greatly. So much so that estimates of whitefly populations are useless for estimating the liklihood of virus spread. To illustrate, in Figure 1A, large flights of whiteflies were caught in early March, but did not result in increases in TMoV. These whiteflies were probably coming from nearby potato fields, and very few had the opportunity to acquire virus before entering this tomato field. Once in the field, timely pesticide applications removed most of the whiteflies before they could acquire TMoV from infected plants and spread it within the field. It would seem that a very small population of viruliferous whiteflies is all that is required for rapid spread within a field.

No relationship was seen between production practices, such as tying and pruning, and virus incidence (Figure 1A,B). Though theoretically these mechanical interventions in plant development could cause whiteflies to move and subsequently spread TMoV, no increase in TMoV could be seen that corresponded to the timing of these practices.

IMPLICATIONS FOR MANAGEMENT OF TMoV. The results of this study have several implications for the management of tomato mottle virus. The first is that virus spread is being limited but not eliminated by relatively frequent pesticide applications. Secondary spread is occurring within fields, by possibly a relatively small population of viruliferous whiteflies. These viruliferous whiteflies probably represent a very small percent of the total whitefly population which exists in a field at any one time. The situation is different when a source of viruliferous whiteflies exists nearby. Spread in the field is then the result of incoming viruliferous whiteflies plus those few already present in the field due to the infected plants present in the field. Superior management then requires that stricter measures be taken to minimize the number of infected plants early in the season. This would reduce the number of sources of TMoV, reducing the secondary spread and impacting significantly on the total frequency of TMoV-infected plants throughout the season. If fewer infected plants existed in the field, this would permit fewer pesticide applications for vector control. Tomato mottle can enter the field early in the season through one or more of the following means: viruliferous whiteflies coming from nearby abandoned fields, viruliferous whiteflies coming from nearby fields in which herbicide-treated tomato fields have been allowed to regrow, viruliferous whiteflies coming from TMoV-infected volunteer tomatoes, and in transplanting TMoV-infected tomato plants. The following recommendations are supported by this study:

DISTRIBUTION OF TOMATO MOTTLE VIRUS IN FIELDS. The distribution of TMoV-infected plants was highly aggregated in most of the plots, a characteristic of secondary spread (Figure 2). This TMoV movement from plant to plant within the fields accounted for most of the infected plants present in fields by the end of the season. The earliest infected plants served as sources of virus for nearby plants, most commonly those within the same row, though some virus movement occurred between rows. Secondary spread was found in all fields and therefore, was independent of the management practices used. This has consequences for changes in control practices. If more effort was put into preventing virus from entering fields especially in the first few weeks after transplanting, better control would be achieved, and probably at a lower cost due to less need for applications of pesticides for whitefly control.

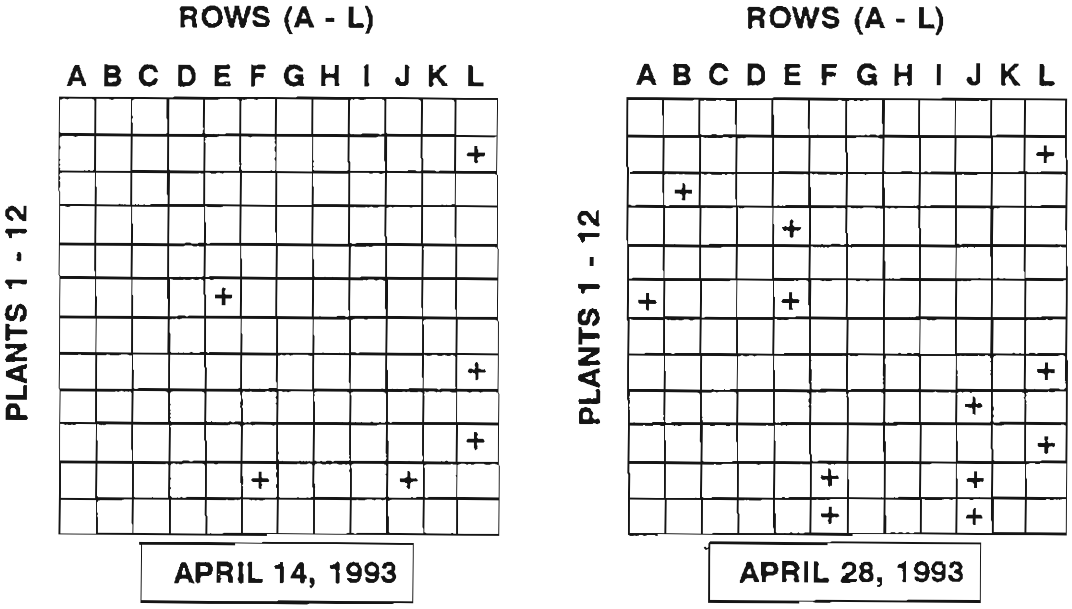


Figure 2. Distribution and spread of tomato mottle virus in the same plot over a two week period. + = tomato mottle virus-infected plant.

CORRELATION OF VIRUS WITH WHITEFLY TRAP CATCHES. The above results are even more interesting in light of the poor correlation that was found between whitefly trap catches and virus incidence (Figure 1A,B). Increases in whitefly trap catches did not coincide with increases in TMoV incidence. Even though secondary spread is occurring in the fields and most often that spread is among plants in the same row, essentially no correlation could be found between adult numbers on sticky traps and the incidence of TMoV. This

1) Avoid planting tomatoes near sources of viruliferous whiteflies such as abandoned fields, and fields in which the plants have been allowed to regrow following herbicide application. In addition, a delay in planting of two or three weeks can greatly reduce the amount of virus entering the field early in the spring season.

2) Use timely pesticide applications to reduce the whitefly population and reduce the amount of secondary spread. If there is no TMoV-infected plants in the field, pesticide applications can be reduced (but not eliminated).

3) Produce or purchase tomato transplants which have not been exposed to viruliferous whiteflies (ie not propagated near tomato production fields).

Progress Toward a More Sustainable Pest Management Program for Tomato

D. J. Schuster[1], P. A Stansly[2], D. G. Dean[1], J. E. Polston[1]
and G. S. Swanson

In 1976-77 a state-wide outbreak of Liriomyza spp. leafminers threatened the Florida tomato industry. Up to 90% defoliation was noted on unsprayed tomatoes in a commercial field (Schuster 1978). This outbreak and the unavailability of effective insecticide alternatives resulted in increased grower support for an extension-sponsored integrated pest management (IPM) program that was started in 1976-77 in southeast Florida (Pohronezny & Waddill 1978). This program is based upon periodic sampling and application of insecticides on the basis of action thresholds (Schuster & Pohronezny 1989). Prior to this, tomato growers routinely applied insecticides twice weekly, usually combining an insecticide for caterpillar control with an insecticide for leafminer control. With acceptance of the IPM program, insecticide use and industry-wide outbreaks of leafminers and other pests declined dramatically. A survey conducted in 1984-86 indicated that about 40% of the growers used commercial scouting, i.e. firms providing primarily scouting service or persons hired on the growers' payroll with primary responsibilities for scouting (Pohronezny et al. 1989). Even growers who did not use commercial scouting were affected by the program and decreased their insecticide use. During this period, new insecticides with activity on leafminers, tomato pinworm (TPW) (Keiferia lycopersicella (Walsingham)) and other pests became available and helped to sustain this program.

In 1988, a devastating outbreak of the sweetpotato whitefly, Bemisia tabaci Gennadius (SPWF), reversed many of these gains in IPM. Losses due to increased control costs, irregular ripening, and the SPWF-transmitted tomato mottle virus (TMoV) were estimated at about $125 million in 1991. Most growers began spraying twice weekly and some three times or more weekly to avoid losses. Insecticides and cultural practices were identified which have contributed to the successful management of the SPWF that growers currently are experiencing (Price et al. 1988, Schuster et al. 1989, Stansly & Schuster 1990, Stansly et al. 1991, Stansly & Schuster 1992). Despite the successes with

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[1] Gulf Coast Research and Education Center, 5007 60th St. E., Bradenton, FL 34203

[2] Southwest Florida Research and Education Center, P.O. Drawer 5127, Immokalee, FL 33935

the SPWF, growers currently are experiencing renewed problems with old pests especially leafminers and the TPW.

Resistance of the SPWF to insecticides has been documented in Florida (Stansly et al. 1991). Resistance of the TPW to Pydrin and Lannate has been documented in California and Mexico (Brewer et al. 1993, Schuster et al. unpublished data) and is suspected in Florida. Even though new and effective insecticides for control of leafminers, TPW and SPWF are under development by industry, they are not available for the latter two pests and their timely availability is being hampered by increasing environmental and regulatory requirements. Therefore, insecticides cannot be depended upon to ensure the long term sustainability of the Florida tomato industry. Indeed, the sustainability imparted by individual insecticides to date has been ephemeral. The use of insecticides is often easier and less expensive in the short term but will result in continued development of insecticide resistance and outbreaks of old or new pests in the long term.

Numerous preventive and reactive management approaches have been or are being developed for tomatoes in Florida. Many of these have been presented previously and have been adopted to varying degrees by growers. However, these approaches must become integral parts of overall management philosophies and programs rather than adjuncts to insecticidal control if true, long term sustainability is to be achieved.

Preventive Management Approaches

Cultural Manipulations

Crop Associations. No cultivated hosts other than tomato, tomatillo, and bean and no significant wild hosts have been found for TMoV (Polston et al. 1993, McGovern et al. 1991). Therefore, new crops should not be planted near or adjacent to previously infected tomato crops, abandoned tomato fields awaiting destruction or areas with volunteer tomato plants. Tomato crops should be destroyed as soon as harvest is completed and destruction should be continued through the fallow period to reduce the amount of inoculum of TMoV for subsequent crops. We have observed that dense plantings of cover crops such as sorghum have reduced the numbers of volunteer tomato plants greatly; however, such fields should be inspected periodically to ensure no TMoV infected plants survive.

Spring tomato fields should be destroyed as early as possible and the fall crops planted as late as possible to extend the crop-free summer period as long as possible. Although we don't believe viruliferous SPWF adults from the spring crops can survive more than about 4 weeks, we have observed numerous whitefly adults and higher TMoV infection rates when crop-free periods are about 6 weeks or less. Therefore, growers are encouraged to extend the summer period from 6-8 weeks to help ensure reduced inoculum of TMoV for fall crops.

Fall cherry tomato fields often are transplanted earlier than fresh market fields in west-central Florida and, as a result, often have a higher incidence of TMoV. Since they can serve as a reservoir for the virus for later planted fields, cherry tomatoes should be isolated from old spring fields as well as new fall fields.

We understand the economic constraints under which growers must operate, but growers need to be aware of the consequences of decisions based upon immediate economic concerns. For instance, in the spring of 1992, growers in west-central Florida experienced a severely depressed market for their tomatoes. Spraying programs were curtailed or reduced early allowing SPWF populations to increase to levels higher than those of the previous spring. Destruction of some spring fields also was delayed into July and a few even later. As a result, SPWF numbers and TMoV infection rates were higher in August of 1992 than in the preceding year. Earliest planted fall fields were the most affected by the virus. Market conditions for west-central tomato producers were much improved for the fall crop. Consequently, the harvest period was extended into December and overlapped with the planting of spring fields. Again, SPWF numbers and TMoV infection rates in the new spring fields were higher than the previous year and the earliest planted spring tomatoes were the most severely impacted. Levels of SPWF and TMoV in Southwest Florida were also high in spring for similar reasons.

As indicated with TMoV, some crops have pests in common while others do not. Tomato, eggplant and potato are suitable hosts of the TPW (Schuster 1989) as well as leafminers. Since adults can migrate to tomato as the eggplant and potato crops are harvested, tomatoes should not be planted near or adjacent to these crops, particularly in the spring.

A year and half trapping survey in west-central Florida indicated higher populations of SPWF adults on cabbage, cucurbits, potatoes and cherry tomatoes at times when populations were lower on tomato (Schuster et al. 1992). In Southwest Florida movement of whiteflies from cucurbits and potatoes to tomatoes has also been documented (Stansly, unpublished). Thus, fall-planted tomatoes should not be planted near or adjacent to cherry tomato or cucurbit crops and spring-planted tomatoes should not be planted near cabbage, potatoes or cherry tomatoes.

Weed Management. Weeds may impact tomatoes by serving as reservoirs of pests or diseases in addition to competing with the crop for water, nutrients and light. _Solanum americanum_ Mill. (American black nightshade) and _Bidens alba_ (L.)DC.(common beggartick) have been shown to be suitable hosts of the leafminer _Liriomyza trifolii_ (Burgess)(Zoebisch & Schuster 1987) while American black nightshade was not a host of the TPW (Schuster 1989). Nearly 80% of the leafminers on weeds were parasitized (Schuster et al. 1991). _Ludwigia_ spp. (water primrose), Indigofera hirsuta Harv. (hairy indigo), and Chamaesyce spp. (spurge) have been shown to be the main wild hosts of the SPWF in west-central and Southwest Florida. These weeds, particularly water primrose, are not only acceptable hosts for the whitefly but also are among the most abundant weeds in both production areas. However, the numbers of SPWF adults trapped in weeds tended to parallel those trapped in the cultivated crops, and were high in weeds after crop destruction but declined to very low numbers during the summer off-season (Schuster et al. 1992). Thus, the crops tended to be more of an influence on the populations in the weeds than the reverse. As with leafminers, mortality of SPWF nymphs in weeds due to parasitization and apparent predation was high, ranging from 40 to 90% in 1991 and from 10 to 70% in 1992 (Schuster et al. 1992). Thus, weeds may serve more as reservoirs of beneficial insects than of pest insects. Before making decisions regarding management of weeds on field perimeters, growers or their scouts should inspect the weeds periodically to assess the density of populations of leafminers, the SPWF, and other pests and to assess the degree of leafminer and SPWF natural mortality. Growers may wish to encourage the growth of certain weeds such as water primrose so that they can serve as sources of natural enemies.

Soil Mulches. Polyethylene soil mulch coated either with aluminum film or paint has been shown to reflect ultraviolet light thereby repelling aphids attempting to land on plants and delaying the infection of virus(es) that they transmit (Kring & Schuster 1992). These films plus either yellow or orange also have been shown to delay infestations of the SPWF and the TMoV that it transmits (Csizinszky et al. unpublished data). Applying soybean oil (Natur'l Oil) to the yellow plastic enhanced the effect of the mulch. Some growers have tried aluminum film mulch and have indicated reduced plant growth in fall-planted crops due, apparently, to reflected heat. We have not been able to document reduced yields even when the film was used in August. Nevertheless, we are suggesting that growers use aluminum mulch in spring crops since aphids are more abundant then and they are not affected by yellow or orange mulches. We suggest that yellow or orange mulches be used on fall crops since they have resulted in low yields when used with spring crops but higher yields when used on fall crops.

Trap Crops. Certain cultivated and uncultivated host plants may serve as trap crops for invading insect infestations. The SPWF has been shown to prefer cucurbit crops and eggplant over tomato, okra and beans for oviposition (Schuster et al. unpublished data). Utilization of these host plants as border plantings, strip crops or interplantings may serve three purposes. First, they may attract invading SPWF adults and inhibit their movement into the tomato crop, thereby reducing initial infestations. Second, these plants are not hosts or carriers of TMoV and may serve as a means for 'trapping' the virus by intercepting and maintaining viruliferous whiteflies. Subsequent generations of the whitefly would not be viruliferous and could not carry the virus to tomato. Third, trap crops also may serve as refuges for beneficial insects attacking the SPWF. Cucurbit trap crops reportedly are being used in the Middle East and Cuba with success.

Squash currently is being investigated as a potential trap crop for the SPWF on tomato. In replicated field trials at Bradenton, more SPWF adults were observed on squash than on tomato, eggplant or okra. In a preliminary trial in a commercial tomato field, squash was planted in 100 ft long sections of 3 rows and alternated with 100 ft sections of 3 rows transplanted about 2 weeks later with tomato. More SPWF adults were observed on squash than on tomato but no impact on the number of adults on tomato adjacent to the squash was observed relative to tomato adjacent to the tomato. Further trials are underway comparing longer sections of rows and different numbers of rows.

Biological Control. *Liriomyza* spp. leafminers are considered to be secondary pests of tomato (Oatman & Kennedy 1976). At least 14 species of wasp parasitoids attack these leafminers on nonsprayed tomatoes in Florida (Schuster & Wharton unpublished data). The most abundant parasitoids are *Diglyphus* spp., *Neochrysocharis punctiventris* (Crawford) and *Opius dissitus* Muesebeck. *Diglyphus* and *Neochrysocharis* are larval parasitoids with the former being an exoparasitoid (feeds on the leafminer larva from the outside of the leafminer larva body) and the latter being an endoparasitoid (feeds on the leafminer larvae from within the leafminer larva body). *Opius dissitus* is a larval-pupal parasitoid (lays its eggs in the leafminer larva in the leaf but completes its development after the leafminer larva has exited the leaf and pupated on the plastic mulch). Up to 90% parasitism in nonsprayed tomatoes has been observed in Florida. In commercial fields using selective insecticides to kill leafminers and conserve parasitoids, parasitism can reach 100% (Schuster unpublished data). As mentioned previously, weeds also can serve as an important reservoir of these parasitoids.

The TPW has been shown to be attacked by a number of parasitoids in Florida including three larval, and one egg parasitoid (Peña & Waddill 1983). Parasitism of TPW larvae in commercial fields can range from 40-60% with higher rates occurring later in the crop, especially after harvest. Egg parasitism ranges as high as 60-90% with the higher rates occurring at lower egg densities (Peña & Waddill 1983). These natural enemies could contribute to the pest management program if integrated with selective insecticides and other approaches such as the mating disruption technique.

A two year survey of Florida and selected sites around the Caribbean Basin have indicated at least 15 species of parasitoids are attacking SPWF in this region (Evans et al. unpublished data). In a survey of predator species attacking SPWF on unsprayed tomato in Florida, at least 11 species were identified including lady beetles, true bugs, lacewings, and spiders (Dean and Schuster unpublished data). A survey recently has been completed to study the temporal distribution of predator species attacking SPWF on unsprayed tomato. Results indicate that spiders are the first predators to invade tomato but that Orius bugs are the most numerous in the spring (Fig. 1). Furthermore, as many as 100 predators have been collected from a single tomato plant in fields not sprayed with insecticides. Unfortunately, nearly 10 times as many SPWF adults also occur. The challenge, then, becomes how to encourage the increase of predator species early enough to reduce or inhibit the late season increase of the SPWF. Methods for releasing commercially available predators and methods for attracting and maintaining naturally occurring predators are under investigation.

A lacewing, Chrysoperla rufilabris, is being reared commercially and is reported to be adapted to the warm, moist climate that exists in Florida. This generalist predator is being considered for inoculative or augmentive releases against SPWF since it was found to accept nymphs readily in laboratory experiments even in the presence of aphids which were not preferred (Dean & Schuster, unpublished data). Whey/yeast/sugar mixtures have been applied weekly to tomato and have resulted in increased oviposition by naturally occurring lacewing adults (Table 1).

Parasitism of the SPWF on collards has reached >90% but not until after large infestations developed. As indicated previously, high rates of parasitism and apparent predation also have been observed on weed hosts of SPWF growing near or adjacent to commercial tomato fields. Parasitism is particularly high on weed species in south Florida (Stansly & Schuster 1990, 1992). In a field trial carried out at SWFREC during June-July 1993 it was determined that percent parasitization of whitefly pupae on Okra averaged 56% over a 4 week period, twice or more that observed on cotton (31%), eggplant (25%) collards (25%) or cowpea (12%). Thus some plant species may be more conducive to whitefly parasitization than others.

Parasitism and predation of the SPWF in commercial tomato fields generally has been low, probably due to the use of broad spectrum insecticides. Means of encouraging parasitoid and predator movement into tomato fields in conjunction with reduced use of insecticides are needed. Trap crops and strip crops are being evaluated as a means of interfering with the movement of the SPWF into a tomato crop and for encouraging the buildup and dispersal of natural enemies.

Host Plant Resistance

Although there are currently no commercial cultivars resistant to the important arthropod pests attacking tomato in Florida, research is underway to transfer resistance in wild tomato species to cultivated germplasm. *Lycopersicon hirsutum* Humb. & Bonpl. and *L. hirsutum* f. *glabratum* C. M. Mull have demonstrated resistance to the TPW, and *Liriomyza* spp. leafminers and the SPWF. There is apparent linkage of wild characteristics with resistance since selection for horticultural characteristics has resulted in resistance being diminished. Glandular trichomes present on *L. hirsutum* and *L. hirsutum* f. *glabratum* are responsible for resistance to many tomato pests including the TPW. These trichomes are of a different type and of different densities than those found on cultivated tomatoes. Reduced numbers of eggs deposited by both the TPW and leafminers and also slower and poorer development of TPW larvae have been observed on these wild species compared to commercial cultivars.

The wild tomato species, *L. pennellii* (Corr.)D'Arcy, has demonstrated resistance to SPWF and leafminers. Research currently is underway to transfer this resistance to cultivated types. Resistance in this wild species also is linked to glandular trichomes which may cause difficulty in transferring the resistance. Host plant resistance also is being investigated as an alternative management tactic for TMoV. *L. chilense* Dunal has demonstrated resistance to this virus in the field (Scott & Schuster 1991), and efforts are underway to transfer this resistance to cultivated types.

Reactive Management Approaches

Conventional Pesticides

A thorough summary of all of the pesticidal research of pests of tomatoes is beyond the scope of the present discussion. Much of the recent pesticidal research, especially with regard to the SPWF, has been summarized in previous reports to this Institute (Price et al. 1988, Schuster et al. 1989a, Stansly & Schuster 1990, Stansly et al. 1991, Stansly & Schuster 1992). Many of the insecticides currently in use on tomatoes in Florida are listed in Table 2. Agri-Mek and Trigard have been available for use against leafminers as specific exemptions under the provisions of section 18 of the U.S. Federal Insecticide, Fungicide, and Rodenticide Act as amended. Renewals have been submitted by FFVA. Recent pesticidal evaluations are summarized in Tables 3-7.

When action thresholds are exceeded, insecticides are selected which will kill the target pest(s) but which also will conserve natural enemies. Therefore, many of the insecticides have been evaluated for their impacts on the target pest and on non-target beneficial species, primarily parasitoids of *Liriomyza* spp. leafminers (Table 2). Certain pesticides such as methomyl and permethrin were found to be highly toxic to all lifestages of parasitoids evaluated. Others such as methamidophos were lifestage specific in their toxicity while others such as endosulfan were species specific. Therefore, it is important to know which lifestage(s) of which parasitoid is(are) most abundant in a field before selecting an insecticide.

It is possible during the scouting process to estimate percent parasitism of leafminer larvae due to larval parasitoids. A larval parasitoid can be categorized as either endo- or exo-parasitic based upon location of the larva or pupa relative to the leafminer larva. However, since this cannot be accomplished with a hand lens until larvae are visible, usually about three or four days following oviposition, parasitism could be underestimated. Selecting pesticides in Table 2 with the minimum effect on the lifestages of specific parasitoids observed should further minimize the overall effect of the pesticidal application on leafminer parasitoids.

Biorational Pesticides

Biorational pesticides have been defined differently by different individuals. For the purposes of this discussion, we will define them as products, usually, but not necessarily, of biological origin, which have some detrimental impact on the target pest but have minimal or no impact on the environment or non-target organisms. The detrimental impacts may include direct toxic effects, repellency or growth regulator effects. Non-target organisms can include any living entity but we will focus on natural enemies of the target pests.

Perhaps the most commonly used biorational pesticide products are those containing the bacterial organism Bacillus thuringiensis (Bt). This organism produces toxins which are contained as crystals inside the resting stage spores produced by the bacterium. When these spores are ingested by the insect, the toxins are released in the insect's gut where they perforate and kill cells in the gut lining. The toxins are highly specific for lepidopterous pests with high alkalinity in their gut. Different strains of the bacterium may contain different complements of different toxins. Most products (Biobit, Condor, Cutlass, Dipel, Foil, Javelin, Larvo-BT, MVP, and others) contain B. thuringiensis var. kurstaki (Btk) but some new products (Xentari) contain B. thuringiensis var. aizawai (Bta) or conjugates of the two varieties (Agree). All Bt toxins are susceptible to ultraviolet light and generally do not persist in the field for more than several days. One product (MVP) incorporates a biological process for encapsulating the Bt toxin to provide some field protection. Since Bt products use different strains, varieties, and formulations, they may not be equally effective against specific pests. For instance, laboratory bioassays of selected products against TPW larvae suggest that Condor and Javelin are more effective than Agree (Table 3). Although these products are toxic to TPW larvae in the laboratory, control in the field generally is poor because larvae feed inside leaves and fruit. Other Bt products have been evaluated in the field and have been effective against armyworm larvae when applied weekly (Tables 4-6). Unfortunately, not all products have been evaluated simultaneously. Bt's generally are not toxic to parasitoids (Table 2).

Oils, soap, and detergents are additional biorational products which may be useful in IPM programs. Oils may either be of petroleum origin (Saf-T-Side, Sunspray Ultrafine, Super Savol, Stylet Oil, and others) or of plant origin (Natur'l). They may kill certain insects such as aphids and whiteflies and may also repel them thus delaying or inhibiting the plant viruses they transmit. Research on these effects have been summarized previously at this Institute (Schuster et al. 1989, Stansly & Schuster 1990, Stansly et al. 1991, Vavrina & Stansly 1991) and elsewhere (Schuster et al. 1989b, Butler et al. 1993). Petroleum oils may vary in their distillation temperature ('heaviness') or distillation temperature range (purity) and, therefore, may vary in their insecticidal and phytotoxic properties. Soaps and detergents kill small, soft-bodied insects although the mode of action is under debate. They may destroy the waterproofing of the insect cuticle, thereby destroying its water management ability, or they may wet the spiracles, thereby suffocating the insect. M-Pede is the only soap or detergent currently registered for use as an insecticide on tomato. The effects of selected soaps and detergents on specific lifestages of the SPWF in the laboratory (Price et al. 1988, Schuster et al. 1989) and on SPWF control in the field (Schuster et al. 1989b, Stansly et al. 1991) have been summarized previously. Different detergent products appeared to be similar in their toxicity to SPWF adults in the greenhouse (Butler et al. 1993) but may differ in their phytotoxic properties. Vavrina & Stansly (1991) observed phytotoxicity with multiple applications of one detergent at rates as low as 1%. A single application at 1% resulted in less than 5% foliar injury. Soaps and detergents have no residual activity. Because soaps, detergents and oils must contact the insect to kill it or must coat the foliage to repel them, thorough coverage is necessary, especially of the underside of leaves for SPWF control. Preliminary research indicates that oils and soap may be relatively non-toxic to specific lifestages of two lacewing species.

Azadirachtin (the active component of extracts of seeds of the neem tree) also has demonstrated activity on certain insects. Azadirachtin has been shown to be effective against the SPWF in laboratory and greenhouse evaluations on ornamentals (Price et al. 1990, Price & Schuster 1991). Evaluations on field-grown tomatoes have been promising but not as consistent (Stansly & Schuster 1992, Table 7: see Agridyne, Margosan-O, Align, & ATI-720F). Azadirachtin products also have demonstrated efficacy against armyworm larvae on tomato (Table 5) and pepper (Table 6). Osborne et al. (1991) found that the azadirachtin product Margosan-O did not reduce the level of SPWF parasitization relative to an unsprayed control.

Mating Disruption. Being extremely specific and furthermore of biological origin, pheromones qualify as biorational agents when used for insect control. The mating disruption technique has been developed for management of the TPW on tomato (Jenkins et al. 1990). With the technique, males are inhibited from locating and mating with females following the mass application of the female-produced sex attractant pheromone. With reduced mating comes reduced fertility and fewer larvae. Since mated females are not affected, mated females migrating into fields will deposit viable eggs, primarily on the field perimeter. Therefore, the technique should be used preventively and combined with careful scouting. Spraying of field perimeters may be necessary, particularly if heavy infestations of the TPW exist nearby and if fruit are present.

Three formulations are registered with EPA for applying the pheromone. One consists of mixing hollow fibers containing the pheromone in an adhesive and applying the mixture to tomato stakes (NoMate TPW, Scentry Inc.). Another formulation consists of plastic spirals impregnated with the pheromone which can be wrapped around tomato branches or tying string (Scentry Inc.). Another consists of a membrane impregnated with the pheromone which is incorporated into a plastic dispenser which can be hung on tomato branches or the tying string (CheckMate TPW, Consep Inc.). The three formulations have not been evaluated simultaneously in Florida but the two Scentry formulations were evaluated in 1992 at Ruskin. Using a 90% reduction in male captures in sticky traps baited with the female pheromone as an estimate of efficacy, the sticky fiber formulation gave 6 weeks of control and the spiral formulation gave 7 weeks of control in a spring 1992 trial. In a commercial trial near Immokalee, a sticky fiber formulation (NoMate) gave 8 weeks of protection by the same criteria (Stansly & Schuster 1992) The membrane formulation currently is under investigation at Bradenton and has been field-tested in a commercial field in Southwest Florida. There were few captures in sticky traps inside the protected area through 11 weeks post-application when the trial was terminated (Figure 2). A sprayable formulation is under development but is not registered. In the above spring 1992 trial, it gave 8 weeks of control. Since labels recommend the products be applied about 2 weeks after transplanting, two applications will be necessary to give season-long control.

References Cited

Brewer, M. J., D. J. Schuster, J. T. Trumble & B. Alvarado-Rodriguez. 1993. Tomato pinworm (Lepidoptera: Gelechiidae) resistance to fenvalerate from localities in Sinaloa, Mexico and California, U.S.A. Trop. Agric. (in press).

Butler, G. D., Jr., T. J. Henneberry, P. A. Stansly & D. J. Schuster. 1993. Insecticidal effects of selected soaps, oils and detergents on the sweetpotato whitefly: (Homoptera: Aleyrodidae). Fla. Entomol. 76:161-167.

Jenkins, J. W., C. C. Doane, D. J. Schuster, J. R. McLaughlin & M. J. Jimenez. 1990. Commercial applications of sex pheromone for control of the tomato pinworm, pp. 269-280. In

E. L. Ridgway, R. M Silverstein & M. N. Inscoe. [eds.], Behavior-modifying chemicals for insect management. Marcel Dekker, Inc., New York.

Kring, J. B. & D. J. Schuster. 1992. Management of insects on pepper and tomato with UV-reflective mulches. Fla. Entomol. 75:119-129.

McGovern, R. J., P. A. Stansly, J. E. Polston, D. J. Schuster & E. Hiebert. 1991. Alternate hosts of the Florida tomato geminivirus, pp. 12-19. In C. S. Vavrina [ed.], Proceedings Florida tomato institute, Univ. Fla., IFAS, Vegetable Crops Special Series SS-VEC-01.

Osborne, L. S., K. Hoelmer and D. Gerling. 1991. Prospects for biological control of Bemisia tabaci, pp. 48-61. In C. S. Vavrina [ed.], Proceedings Florida tomato institute, Univ. Fla., IFAS, Vegetable Crops Special Series SS-VEC-01.

Pohronezny, K. & V. Waddill. 1978. Integrated pest management--development of an alternative approach to control tomato pests in Florida. Univ. Fla. Ext. Plant Pathol. Rpt. No. 22.

Pohronezny, K., D. J. Schuster, R. Tyson, P. Gilreath, R. Mitchell, R. Brown, V. H. Waddill, R. McSorley, J. Price, W. Summerhill, W. Dankers & R. Sprenkel. 1989. The impact of integrated pest management on selected vegetable crops in Florida. Univ. Fla., Agric. Expt. Stn. Bull. 875.

Polston, J. E., E. Hiebert, R. J. McGovern, P. A. Stansly & D. J. Schuster. 1993. Host range of tomato mottle virus, a new geminivirus infecting tomato in Florida. Plant Disease (in press).

Price, J. F. & D. J. Schuster. 1991. Effects of natural and synthetic insecticides on sweetpotato whitefly Bemisia tabaci (Homoptera: Aleyrodidae) and its hymenopterous parasitoids. Fla. Entomol. 74:60-68.

Price, J. F., D. J. Schuster & J. B. Kring. 1988. Management of the sweetpotato whitefly on tomato crops in south Florida. Univ. Fla., IFAS, Bradenton GCREC Res. Rpt. BRA1988-15.

Price, J. F., D. J. Schuster & P. M. McClain. 1990. Azadirachtin from neem tree (Azadirachta indica A. Juss.) seeds for management of sweetpotato whitefly [Bemisia tabaci (Gennadius)] on ornamentals. Proc. Fla. State Hort. Soc. 103:186-188.

Schuster, D. J. 1978. Vegetable leafminer control on tomato. Insecticide & Acaricide Tests. 3:108.

Schuster, D. J. 1989. Development of tomato pinworm (Lepidoptera: Gelechiidae) on foliage of selected plant species. Fla. Entomol. 72:216-219.

Schuster, D. J. & K. Pohronezny. 1989. Practical application of pest management on tomatoes in Florida, pp.275-282. In Tomato and pepper production in the tropics. Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan.

Schuster, D. J. & J. E. Polston J. F. Price. 1992. Reservoirs of the sweetpotato whitefly for tomatoes in West-Central Florida. Proc. Fla. State Hort. 105:311-314

Schuster, D. J., J. F. Price, J. B. Kring & P. H. Everett. 1989a. Integrated management of the sweetpotato whitefly on commercial tomato. Univ. Fla., IFAS, Bradenton GCREC Res. Rpt. BRA1989-12.

Schuster, D. J., P. H. Everett, J. F. Price & J. B. Kring. 1989b. Suppression of the sweetpotato whitefly on commercial fresh market tomatoes. Proc. Fla. State Hort. Soc. 102:374-379.

Schuster, D. J., J. P. Gilreath, R. A. Wharton & P. R. Seymour. 1991. Agromyzidae (Diptera) leafminers and their parasitoids in weeds associated with tomato in Florida. Environ. Entomol. 20:720-723.

Scott, J. W. & D. J. Schuster. 1991. Screening of accessions for resistance to the Florida tomato geminivirus. Rpt. Tomato Genetics Cooperative 41:48-50.

Stansly, P. A. & D. J. Schuster. 1990. Update on sweetpotato whitefly, pp. 41-59. In W. M. Stall [ed.], Proceedings Florida tomato institute, Univ. Fla., IFAS, Vegetable Crops Special Series SS-VEC-001.

Stansly, P. A., D. J. Schuster & G. L. Leibee. 1991. Management strategies for the sweetpotato whitefly, pp. 20-42. In C. S. Vavrina [ed.], Proceedings Florida tomato institute, Univ. Fla., IFAS, Vegetable Crops Special Series SS-VEC-01.

Stansly, P. A. & D. J. Schuster. 1992. The sweetpotato whitefly and integrated pest management of tomato, pp. 54-74. In C. S. Vavrina [ed.], Proceedings Florida tomato institute, Univ. Fla., IFAS, Vegetable Crops Special Series SS Hos 1.

Vavrina, C. S. & P. A. Stansly. 1991. Detergents and oils: rates, mixtures, and phytotoxicity, pp. 43-47. In C. S. Vavrina [ed.], Proceedings Florida tomato institute, Univ. Fla., IFAS, Vegetable Crops Special Series SS-VEC-01.

Zoebisch, T. G. & D. J. Schuster. 1987. Suitability of foliage of tomatoes and three weed hosts for oviposition and development of *Liriomyza trifolii* (Diptera: Agromyzidae). J. Econ. Entomol. 80:758-762.

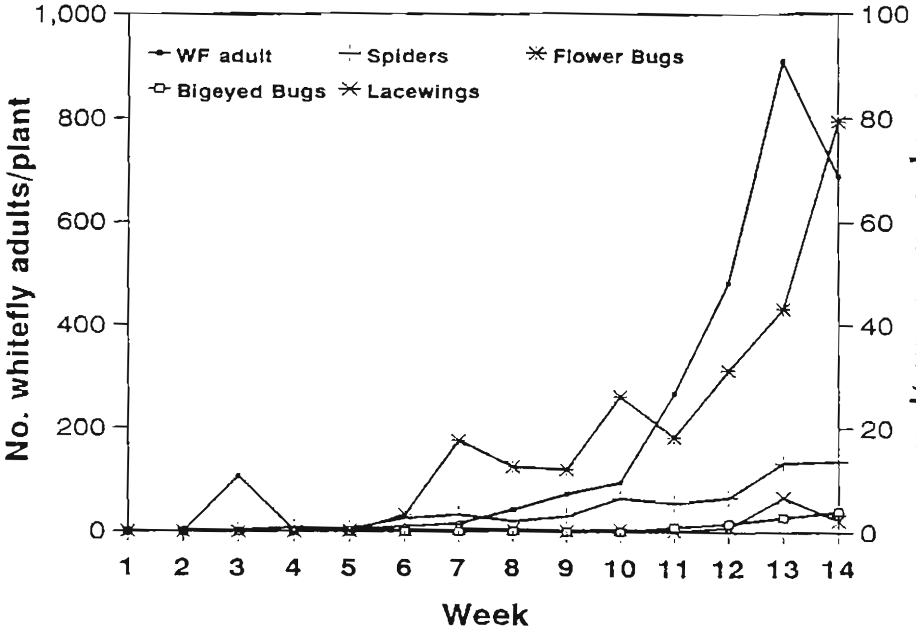

Figure 1. Numbers of sweetpotato whitefly and predator adults trapped on unsprayed tomato plants, GCREC Spring 1993.

Mating Disruption Demonstration for Tomato Pinworm Control
Immokalee Florida 1993

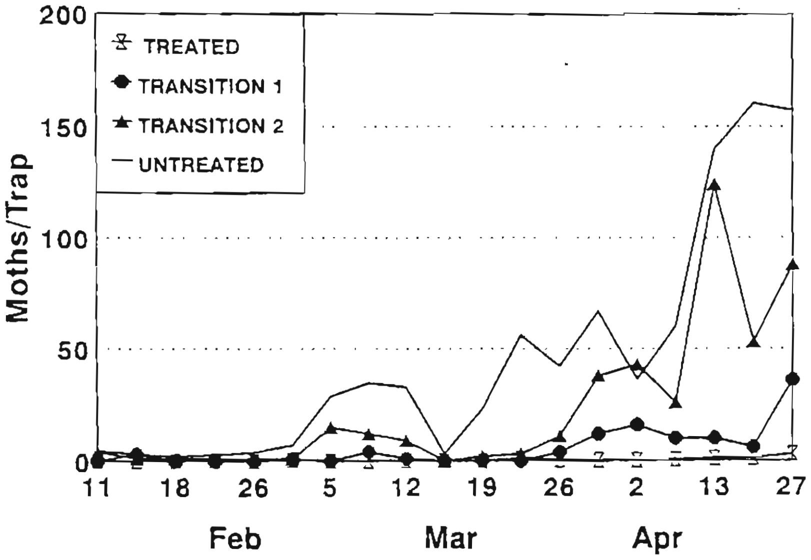

Figure 2. Transition 1: edge of treated area, Transition 2: 40 ft. outside area.

Table 1. Oviposition by lacewing adults in field-grown tomatoes either unsprayed or sprayed weekly with a whey:sucrose:yeast preparation, Fall 1992.

Treatment	Sampling date			
	20 Oct	27 Oct	3 Nov	10 Nov
	No. of groups of eggs/12 plants			
Sprayed	4.5	7.0	6.5	10.5
Unsprayed	0.0	1.0	0.5	3.5
	No. of eggs/12 plants			
Sprayed	18.5	34.0	38.0	38.0
Unsprayed	0.0	2.0	1.0	14.5
	No. of eggs/group			
Sprayed	4.1	4.9	5.9	3.6
Unsprayed	0.0	2.0	2.0	4.1

Table 2. Toxicity of insecticides utilized in Florida tomato production to parasitoids of *Keiferia lycopersicella* and *Liriomyza* spp. leafminers.*

Insecticide common name	*Keiferia* parasitoid	*Liriomyza* spp. parasitoids		
	Apanteles sp.	*Diglyphus intermedius*	*Neochrysocharis punctiventris*	*Opius bruneipes*
Abamectin (Agri-Mek)	----	++(adults,pupae) +++(larvae)	+(adults), ++(pupae) +++(larvae)	---- ----
Bacillus thuringiensis (Dipel)	----	+	+	----
Cyromazine (Trigard)	----	+	+	----
Endosulfan (Thiodan)	----	+++(adults, larvae) ++(pupae)	++++(adults, larvae) +++(pupae)	----
Fenvalerate (Pydrin)	+	+++(adults, larvae) ++(pupae)	+++(adults) ++(larvae, pupae)	+
Methamidophos (Monitor)	----	++++(adults) +++(larvae), +(pupae)	++++(adults) ++(larvae,pupae)	----
Methomyl (Lannate)	++++	++++	++++	++++
Permethrin (Ambush/Pounce)	++++	++++	++++	++

*Relative toxicity ranges + = <25%; ++ = 25 to <50%; +++ = 50 to <75%; and ++++ = $\geq$75%. Only adults evaluated for *Apanteles* and *Opius*. A dashed line indicates the parasitoid was not evaluated.
Sources: Waddill (1978); Schuster unpublished data.

Table 3. Control of tomato pinworm larvae on tomato in the laboratory, GCREC Bradenton, Summer 1992.

Treatment	Rate amount/100gal	% larval survival* 24hr	48hr	72hr	6 days	Days to pupation	% pupation*	Days to adult emergence	% adult emergence*
				Post-infestation treatment					
Agree 50WP	1.0lb	86a**	85a	84a	70a	12.5ab	44a	20.2ab	36a
Condor OF	1.0qt	55b	33c	20c	10c	14.2a	8b	21.5a	8b
Javelin WG	1.0lb	64b	52b	44b	40b	12.8ab	8b	21.0a	6b
Lannate 1.8L	2.0qt	11c	1d	0c	0c	----	0b	----	0b
Check (water)	---	91a	90a	90a	80a	11.0b	62a	18.2b	24a
				Pre-infestation treatment					
Agree 50WP	1.0lb	90a	84a	82a	76a	13.5a	28b	18.1a	24b
Condor OF	1.0qt	21c	15c	12c	0c	----	0c	----	0c
Javelin WG	1.0lb	72b	53b	51b	28b	----	0c	----	0c
Lannate 1.8L	2.0qt	2d	0d	0d	0c	----	0c	----	0c
Check (water)	---	84a	83a	82a	64a	11.8b	52a	18.6a	36a

*Data were transformed arcsine $\sqrt{\%/100}$ prior to analyses but are presented in original scale.

**Means within columns followed by the same letter are not significantly different at the P<0.05 level, Duncan's multiple range test.

Single leaflet plots with 10 replicates, five larvae placed on each leaflet either before or after dipping in pesticidal preparations, leaflets placed in cups with moistened filter paper and observed for mortality and development.

Table 4. Control of the southern armyworm and tomato pinworm on tomato in the field, GCREC Bradenton, Spring 1992.

Treatment	Rate lb (AI)/acre	No. tomato pinworm leafrolls/ 4 min. search	Fruit / 10 plants Undamaged No.	Wt (lb)	Armyworm damaged No.	Wt (lb)
Dipel WP	1.0*	26.8b-d	339.0b-d	98.8b	7.0e	1.7cd
ABG-6092 WP	0.68*	19.3de	392.3a-d	108.4b	9.5de	1.8cd
AC 303,630 3SC	0.2***	0.0f	442.3a-c	120.2b	1.0e	0.4d
AC 303,630 3SC	0.1***	0.0f	341.8b-d	91.8b	0.8e	0.1d
AC 303,630 3SC	0.1	0.0f	491.3a	124.9ab	0.5e	0.1d
AC 303,630 3SC	0.05***	1.0f	408.8a-d	117.1b	1.0e	0.2d
Agree 50WP	1.0*	38.5ab	425.8a-d	116.5b	43.3b	9.8b
CGA-269941 50WP	1.0*	25.0cd	421.3a-d	105.0b	33.3b-d	6.5bc
CGA-269941 50WP	0.5*	33.3bc	356.3b-d	98.8b	40.0bc	9.1b
Javelin WG	1.5*	16.5de	379.8a-d	103.3b	16.8c-e	3.9cd
Kryocide 96%	8.0lb*	26.8b-d	378.8a-d	106.7b	16.3c-e	3.4cd
Lannate 1.8 L	0.45	20.5de	417.0a-d	113.5b	0.8e	0.1d
MK-244 0.16EC	0.01	0.8f	415.0a-d	114.9b	0.5e	0.1d
Mk-244 0.16EC	0.0075	2.5f	426.3a-d	116.3b	1.0e	0.2d
RH-5992 2F	0.25***	18.5de	445.0ab	174.6a	0.5e	0.1d
RH-5992 2F	0.12***	27.5b-d	429.5a-d	131.5ab	2.5e	0.5d
RH-5992 2F	0.06***	17.8de	423.0a-d	127.5ab	8.0e	2.0cd
Check (water)	-	45.8a	300.0d	89.5b	69.8a	16.1a

*Amount of product.

**Means within columns followed by the same letter are not significantly different at the P<0.05 level, Duncan's multiple range test.

***Combined with B-1956 at 0.07% v/v.

Single row plots, 15 ft long, replicated 4 times, transplanted 10 Feb., 9 application between 19 Mar. and 29 May using a hand-held CO_2 sprayer @ 60 psi with a single nozzle with D-5 disk and #45 core delivering 60 gpa. Whole plant search tomato pinworm leafrolls on 2 & 4 June. Fruit harvested 14 and 26 May and separated as to those undamaged and those damaged by armyworm larvae.

Table 7. Control of insects on tomato in the field, GCREC Bradenton, Spring 1993, a. sweetpotato whitefly control, b. geminivirus symptom incidence, c. leafminer and tomato pinworm control, d. yield.

Treatment and Rate	(AI)/acre	No. sweetpotato whitefly immatures/30 leaflets				
		Eggs	Crawlers	Sessile nymphs	Pupae	Pupae exuviae
Agri-Mek 0.15EC	0.01 lb	69.0ab*	196.0a	67.3a	44.0a	23.3a-c
Ambush 2 EC	0.2 lb					
+ Monitor 4 EC	0.75 lb	12.0bc	21.3c	12.8c-e	6.0c	8.8bc
ATI-720F	0.44 lb	26.0bc	89.8bc	45.8a-c	24.3a-c	37.8ab
CGA215944 25WP	0.265 lb	69.5ab	61.0bc	56.8ab	35.5ab	30.0a-c
CGA215944 25WP	0.132 lb	72.8ab	97.5bc	41.5a-d	36.5ab	37.0ab
Danitol 2.4 EC	0.2 lb					
+ Monitor 4 EC	0.75 lb	6.3c	9.5c	5.8de	2.3c	1.8c
Danitol 2.4 EC	0.13 lb					
+ Monitor 4 EC	0.75 lb	11.8bc	12.0c	23.8b-e	3.8c	3.5c
ICIA 0321 1EC	0.03 lb	30.8bc	30.0c	13.0c-e	9.5c	7.5bc
ICIA 0321 1EC	0.03 lb					
+ Monitor 4 EC	0.75 lb	2.3c	5.8c	2.5e	1.3c	0.3c
SN 85292 3.67 SC	0.38 lb	11.5bc	40.3c	7.8c-e	1.3c	7.3bc
SN 85292 3.67 SC	0.25 lb					
+ Thiodan 3 EC	1.0 lb **	16.3bc	47.0bc	19.5b-e	11.3bc	5.8c
Check (water)	---	115.8a	141.0ab	78.3a	41.0a	42.3a

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*Means within a column followed by the same letter are not significantly different at P<0.05 level, Duncan's multiple range test.

**Alternated weekly with Thiodan 3 EC at 1.0 lb AI/acre.

Three row 20 ft plots on 5 ft centers, replicated times, transplanted 23 March, 12 applications between 30 March and 22 June using a high clearance sprayer @ 200 psi operated at 3.4 mph with #3 disks and 25^{O} cores delivering 60 to 120 gpa using 4 to 8 nozzles per row. All plants examined weekly for symptoms of tomato mottle geminivirus. All control and yield data collected from 10 plants of middle row. The numbers of leafmines and tomato pinworm foliar damages totalled over 2 whole plants searches. The numbers of sweetpotato whitefly immatures and tomato pinworm larvae and foliar damages totalled on 10 leaflets collected from the upper third of plants on 2 (pinworm) 3 (whitefly) sample dates. Yields totalled over 4 harvests.

Table 7b. Geminivirus symptom incidence.

Treatment and rate(AI)/acre		% geminivirus infected plants							
		29 Apr	6 May	13 May	20 May	27 May	4 June	11 June	17 June
Agri-Mek 0.15EC	0.01 lb	2.5a*	6.0a	6.0a	6.0a	6.0a	10.2a	15.4a	16.2a
Ambush 2 EC	0.2 lb								
+ Monitor 4 EC	0.75 lb	0.6a	1.3ab	1.9ab	1.9a	2.6a	4.6ab	5.2a-c	5.2a-c
ATI-720F	0.44 lb	0.0a	0.6b	0.6b	2.6a	3.2a	4.5ab	4.5bc	7.7a-c
CGA215944 25WP	0.265 lb	2.0a	2.6ab	5.8a	5.8a	7.8a	11.0a	11.0ab	12.9ab
CGA215944 25WP	0.132 lb	1.3a	5.1ab	7.0a	8.3a	9.6a	12.2a	14.1ab	15.4ab
Danitol 2.4 EC	0.2 lb								
+ Monitor 4 EC	0.75 lb	1.3a	1.9ab	1.9ab	3.2a	4.5a	4.5ab	5.8bc	6.4a-c
Danitol 2.4 EC	0.13 lb								
+ Monitor 4 EC	0.75 lb	1.3a	2.0ab	3.9ab	4.5a	5.2a	6.5ab	7.1a-c	8.4a-c
ICIA 0321 1EC	0.03 lb	2.5a	3.2ab	3.8ab	3.8a	5.1a	5.8ab	7.1a-c	11.0a-c
ICIA 0321 1EC	0.03 lb								
+ Monitor 4 EC	0.75 lb	0.0a	0.6b	1.9ab	1.9a	1.9a	2.6b	3.2b	5.2bc
SN 85292 3.67 SC	0.38 lb	0.0a	1.3ab	3.2ab	3.2a	3.9a	6.5ab	7.2a-c	7.2a-c
SN 85292 3.67 SC	0.25 lb								
+ Thiodan 3 EC	1.0 lb **	0.6a	3.2ab	3.2ab	3.2a	3.2a	3.9ab	3.9bc	4.5c
Check (water)	---	1.9a	3.8ab	5.9a	7.9a	8.5a	10.5a	11.7ab	12.4ab

---

*Data were transformed arcsine of the square root of %/100 but are presented in the original scale. Means within a column followed by the same letter are not significantly different at P<0.05 level, Duncan's multiple range test.

**Alternated weekly with Thiodan 3 EC at 1.0 lb AI/acre.

Table 7c. Leafminer and tomato pinworm control.

Treatment and Rate (AI)/acre		No. leafmines/ 2 min search		No. pinworm foliar damages/ 4 min search		No. pinworm/ 20 leaflets			
						Foliar damages		Larvae	
		Small	Large	Mines	Leafrolls	Mines	Leafrolls	Live	Dead
Agri-Mek 0.15EC	0.01 lb	10.6b*	45.0d	42.8a	53.3f	5.5b	3.5b	1.8b	1.8a
Ambush 2 EC	0.2 lb								
+ Monitor 4 EC	0.75 lb	18.5ab	191.3bc	49.3a	108.8b-d	20.5ab	8.8ab	7.8ab	8.5a
ATI-720F	0.44 lb	20.3a	173.8c	51.5a	59.8ef	21.3ab	8.0ab	5.3ab	4.3a
CGA215944 25WP	0.265 lb	14.8ab	202.8bc	54.0a	92.5c-f	20.3ab	5.0b	7.3ab	4.5a
CGA215944 25WP	0.132 lb	11.8ab	204.8bc	39.0ab	76.0d-f	11.8ab	7.0b	4.0b	3.0a
Danitol 2.4 EC	0.13 lb								
+ Monitor 4 EC	0.75 lb	19.3a	256.5ab	42.5a	122.3a-c	25.5a	18.5a	9.8ab	5.8a
Danitol 2.4 EC	0.2 lb								
+ Monitor 4 EC	0.75 lb	12.8ab	231.0bc	41.5a	101.0c-e	23.8a	11.0ab	6.3ab	4.0a
ICIA 0321 1EC	0.03 lb	17.8ab	308.0a	34.8ab	83.5c-f	26.0a	13.3ab	13.0a	6.0a
ICIA 0321 1EC	0.03 lb								
+ Monitor 4 EC	0.75 lb	14.0ab	196.3bc	22.5b	56.8ef	10.0ab	3.8b	3.8b	4.0a
SN 85292 3.67 SC	0.38 lb	20.3a	217.3bc	50.0a	161.5a	19.5ab	9.3ab	7.5ab	5.8a
SN 85292 3.67 SC	0.25 lb								
+ Thiodan 3 EC	1.0 lb **	15.3ab	228.5bc	41.3a	117.8b-d	20.8ab	12.3ab	6.5ab	3.8a
Check (water)	---	12.0ab	224.5bc	43.5a	147.5ab	22.8ab	12.3b	7.0ab	4.0a

---

*Means within a column followed by the same letter are not significantly different at $P<0.05$ level, Duncan's multiple range test.

**Alternated weekly with Thiodan 3 EC at 1.0 lb AI/acre.

Table 7d. Yield

		Fruit yield/10 plants				
		Undamaged		Pinworm damaged		Wt(lb)/ fruit
Treatment and Rate	(AI)/acre	No.	Wt(lb)	No.	Wt(lb)	
Agri-Mek 0.15EC	0.01 lb	455.8a-c*	150.9a	17.5b	4.8b	0.330ab
Ambush 2 EC	0.2 lb					
+ Monitor 4 EC	0.75 lb	435.3a-c	142.4ab	56.5a	17.8a	0.326ab
ATI-720F	0.44 lb	430.5a-c	145.9ab	23.0b	6.5b	0.337ab
CGA215944 25WP	0.265 lb	412.8c	145.8ab	23.8b	7.5b	0.351a
CGA215944 25WP	0.132 lb	413.8c	136.4ab	26.0b	7.2b	0.327ab
Danitol 2.4 EC	0.2 lb					
+ Monitor 4 EC	0.75 lb	465.3a	150.3a	41.5ab	11.06ab	0.320b
Danitol 2.4 EC	0.13 lb					
+ Monitor 4 EC	0.75 lb	418.5bc	133.2b	41.3ab	11.1ab	0.315b
ICIA 0321 1EC	0.03 lb	458.5ab	146.1ab	38.3ab	14.0ab	0.322ab
ICIA 0321 1EC	0.03 lb					
+ Monitor 4 EC	0.75 lb	430.0a-c	137.7ab	21.3b	6.3b	0.320b
SN 85292 3.67 SC	0.38 lb	427.0a-c	144.2ab	37.0ab	10.5ab	0.334ab
SN 85292 3.67 SC	0.25 lb					
+ Thiodan 3 EC	1.0 lb **	417.3bc	140.3ab	32.3ab	10.2ab	0.336ab
Check (water)	---	418.8bc	132.6b	42.8ab	14.3ab	0.320b

---

*Means within a column followed by the same letter are not significantly different at P<0.05 level, Duncan's multiple range test.

**Alternated weekly with Thiodan 3 EC at 1.0 lb AI/acre.

Table 8. Spray dates, number of nozzles per row and gallonage for whitefly/pinworm spray trial at SWFREC, Spring 1993.

DATES	**RED NOZZLES/ROW**	**VOLUME/ACRE** (GALLONS)
6-27 April	4	63.8
30 April-11 May	6	89.1
14-21 May	8	99.0

DATES	**LILAC NOZZLES/ROW**	**VOLUME/ACRE** (GALLONS)
6-16 April	4	25.3
20 April-4 May	6	38.0
7 May-21 May	8	50.6

Field-grown "Sunny" tomatoes transplanted 8 March into single rows on plastic mulched beds 36 inches wide on 6 ft with subsurface seepage irrigation. RCB design, with 4 replications and 10 treatments with plots 3 rows by 24 feet. Applications made with a tractor-mounted hydraulic boom sprayer with drop nozzles using Albuz @ ATR Lilac (Stylet Oil) or Albuz@ ATR Red nozzles. JMS Stylet Oil and Newday detergent sprayed twice a week, other treatments once a week. Greenhouse raised tomato plants that had been exposed to tomato mottle geminivirus (TMOV) infected whitefly and exhibited systems of TMOV were interplanted 12 Mar 93. Whiteflies sampled weekly, adults by black pan sample 24 hours after spraying, nymphs, pupae and tomato pinworm larvae from one trifoliate each row in each plot taken from the 5, 6 or 7th leaf top to bottom at the highest position pupal exuviae were observed, and eggs from the same number of first fully expanded trifoliates. Counts on immatures using a 1 cm arena placed in 4 positions on the leaf. Harvest (18 plants/plot) graded for size, weight, damage and marketability. Marketable tomatos held in paper sacks in the laboratory to evaluate for irregular ripening.

Table 9a. Adult sweetpotato whitefly sampled black beat pan method (3 strikes per plant) from 3 plants per row (Through 28 April) or 1 per row subsequently.

		Days Post Planting							
Treatment	Rates	30	37	44	51	58	65	72	Average
Ambush 2E	0.2 lbs ai/acre	0.93 bc	7.21 de	8.59 bcde	9.20 cd	44.36 b	26.89 cde	45.61 def	20.66 bcde
Ambush 2E + Monitor 4	0.2 lbs ai/acre 0.75 lbs ai acre	0.47 cd	6.20 de	5.19 de	1.64 de	9.11 d	10.97 e	14.58 fg	6.88 de
Asana XL 0.66E	7 oz product/acre	0.81 cd	12.56 cd	14.81 abc	8.66 cde	39.61 b	26.61 de	52.42 cde	22.21 bcd
Asana XL 0.66E + Monitor 4	7 oz product/acre 0.75 lbs ai/acre	0.34 cd	8.30 cde	7.79 cde	2.61 de	9.81 c	14.58 e	28.92 efg	10.31 cde
Check	Untreated	4.04 a	23.41 a	16.15 ab	19.59 a	67.03 a	130.50 a	166.56 a	61.04 a
Karate 1EC	0.03 lbs ai/acre	0.46 cd	15.31 bc	12.58 abcd	8.22 cde	38.53 b	57.00 bc	43.61 def	25.10 bcd
Karate 1EC + Monitor 4	0.03 lbs ai/acre 0.75 lbs ai/acre	0.15 d	4.99 de	2.41 e	1.06 e	2.11 c	4.03 e	4.86 g	2.80 e
Newday	0.05% solution*	0.75 cd	14.61 bc	13.93 abc	6.21 cde	50.67 ab	69.17 b	93.25 b	35.51 b
JMS Stylet Oil	0.75% solution	0.82 cd	14.51 bc	11.69 abcd	11.41 bc	44.22 b	31.42 cde	82.94 bc	28.15 bc
YB656	0.0361 lbs ai/acre	1.54 b	18.10 a	18.41 ab	18.84 ab	55.14 ab	49.72 bcd	68.89 bcd	32.95 b

*This is not an error. It is 0.05%

Table 9b. Percent plants infected by tomato mottle geminiviru (TMoV) during sample interval and over all sample intervals.

		Dates						
Treatment	Precount	14APR93	21APR93	28APR93	05MAY93	12MAY93	19MAY93	Average
Ambush	9.6	7.0	50.8 a	29.7	45.2 abc	62.2 bcd	89.3	37.9 ab
Ambush + Monitor	6.8	5.5	43.8 ab	24.3	29.9 cd	70.7 abc	42.1	30.1 bc
Asana	6.2	6.0	32.3 bc	34.8	59.6 a	52.7 cd	58.3	32.9 abc
Asana + Monitor	7.9	0.6	27.5 c	18.6	37.7 bcd	48.3 d	61.9	27.2 bc
Check	8.3	6.2	43.9 ab	38.1	53.2 ab	84.4 a	100.0	41.1 a
Karate	8.4	8.2	39.2 abc	24.4	56.0 ab	81.3 ab	84.1	35.6 abc
Karate + Monitor	6.8	3.4	32.8 bc	16.5	19.2 d	43.8 d	67.2	26.6 c
Newday	7.4	8.7	35.7 bc	25.8	50.4 abc	86.7 a	79.2	37.4 abc
Stylet Oil	8.6	10.4	39.8 abc	25.9	61.0 a	86.3 a	44.4	36.6 abc
YB656	6.3	6.5	28.53 c	28.8	60.8 a	72.7 ab	61.5	33.7 abc

Table 9c. Immature whitefly stages, parasitized pupae, and tomato pinworm larvae per 36 cm^2 from a 9 leaf sample by sample date.

	Whiteflies							
Treatment	Eggs	Small Nymphs	Large Nymphs	Pupae	Parasites	Total Immatures	Live Pinworms	Dead Pinworms
Ambush + Monitor	30.33 cd	9.42 de	3.21 cd	0.67 cd	0.21 bc	13.50 ef	0.70	0.29
Ambush	81.33 ab	15.00 bcd	6.92 bc	1.71 cd	0.17 bc	23.70 cde	0.50	0.00
Asana + Monitor	30.33 cd	11.17 cde	4.08 cd	1.21 cd	0.17 bc	16.62 def	0.83	0.04
Asana	59.83 bcd	10.67 de	5.04 bcd	2.42 cd	0.04 c	18.17 cdef	1.17	0.00
Check	102.83 a	33.33 a	23.54 a	9.79 a	3.42 a	70.08 a	1.71	0.04
Karate + Monitor	26.62 d	7.04 e	1.08 d	0.25 d	0.00 c	8.38 f	0.17	0.04
Karate	79.96 ab	14.71 bcd	8.38 bc	3.12 c	0.67 bc	26.87 cd	0.75	0.08
Newday	82.92 ab	29.75 a	18.50 a	6.37 b	1.12 b	55.75 b	2.00	0.08
Stylet Oil	63.58 bc	19.75 b	5.79 bcd	2.17 cd	0.54 bc	28.25 cd	1.17	0.04
YB656	78.17 ab	17.21 bc	10.42 b	3.33 c	0.25 bc	31.21 c	1.37	0.00

Table 9d. Production from 18 plants per plot, Spring 1993 whitefly trial at SWFREC.

	Marketable		Non-Marketable		
Treatment	Number	Weight (lbs)	Number	Weight (lbs)	Irreg. Ripen.(%)
Ambush + Monitor	257.50 ab	89.07 ab	35.50 bc	11.03 bc	82.56 abc
Ambush	208.75 bcd	72.25 bc	63.25 bc	12.20 bc	87.79 abc
Asana + Monitor	217.25 bc	76.67 bc	41.50 bc	11.43 bc	77.86 c
Asana	197.00 cd	67.54 bc	79.25 bc	22.35 b	88.12 abc
Check	85.25 f	31.37 e	165.75 a	37.55 a	93.61 ab
Karate + Monitor	293.50 a	105.07 a	29.50 c	6.48 c	76.78 c
Karate	186.50 cd	66.23 c	76.00 bc	12.58 bc	82.06 bc
Newday	165.25 cde	57.83 cd	66.25 bc	16.90 bc	91.29 ab
Stylet Oil	114.00 ef	38.32 de	88.25 b	19.62 bc	90.14 ab
YB656	157.75 de	56.15 cd	67.50 bc	19.12 bc	93.91 a

Table 10a. Control of Southern Armyworm on staked Tomato, Fall 1992 at SWFREC. Mean number of larvae counted by six categories and mean percent defoliation over 8 sample dates.

	Rate	Larvae			Total	
	(a.i. 100 gal)	Small	Medium	Large	Southern Armyworm	Defoliation %
Treatment						
AC303630*	0.05	3.58 a	0.05 b	0.01 b	3.66 ab	1.76 b
AC303630	0.1	0.84 b	.02 b	0.01 b	0.87 c	0.38 b
AC1*	0.1	1.46 ab	0.00 b	0.00 a	1.46 bc	0.37 b
AC2*	0.2	0.71 b	0.02 b	0.01 b	0.73 c	0.24 b
Check		3.58 a	1.05 a	0.51 b	5.33 b	10.80 a
Grower Standard		1.14 b	0.00 b	0.00 b	1.14 c	0.69 b

* Plus adjuvant (4oz APSA-80®/gal).

Table 10b. Total tomato production per 10 plants for 3 harvests, Fall 1992 at SWFREC.

	Marketable Fruit		Wormy Fruit	
Treatment	(No.)	(Lbs.)	(No.)	(Lbs.)
AC303630*	382.50 a	140.92 b	40.25 a	13.52 a
AC303630	462.75 a	176.22 a	5.25 a	2.02 a
AC1*	452.00 a	167.53 ab	7.50 a	2.62 a
AC2*	401.25 a	148.68 ab	5.25 a	2.00 a
Check	119.50 b	46.48 c	113.75 b	38.53 b
Grower Standard	433.75 a	166.90 ab	5.50 a	2.35 a

*Plus adjuvant (4oz APSA- 80®/gal).

Same cultural practices and sprayer used as above. Four nozzles per row for the first 2 applications, delivering 64 gpa. Remaining applications were made with 6 nozzles per row, delivering 95.5 gpa. Armyworms were monitored weekly, 3 days post-treatment, by examining 5 randomly selected plants per plot for larvae and egg masses and rating for per cent defoliation. Plots were harvested three times and fruit were weighed, culled and checked for worm damage. In each plot, the same plants, randomly selected during the initial harvest, were used. Harvest dates were 3, 17 and 30 Nov. Grower check Biobit FC®(2qts/100gal).

APPENDIX A

TOMATO VARIETIES FOR FLORIDA

D. N. Maynard
Gulf Coast Research & Education Center
Bradenton, FL 34203

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 1200 25-pound cartons per acre. The potential yield of varieties in use should be much higher than average.

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

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

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

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

CURRENT VARIETY SITUATION

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

'Sunny' has been the leading tomato variety in Florida for many years having been planted on about 80% of the acreage in some years. There has been a dramatic reduction in acreage planted to 'Sunny' in the last three seasons because of the availability of several newly-released competing varieties. In the 1992-93 season, 'Sunny' was still the leading variety statewide with just under 30% of the acreage. It had maintained its preeminence on the east coast, but had declined precipitously in other areas.

'Agriset 761' was the second most important variety statewide having been planted on just under 30% of the acreage. Most of the 'Agriset 761' plantings were in southwest and west central Florida.

'Solar Set' was planted on about 10% of the state's acreage with most being planted in the southwest, west central, and Dade County areas.

'Bonita' was planted on about 8% of the state's acreage; most of the 'Bonita' plantings were in Dade County, accounting for about 60% of the acreage there.

'BHN 26' and 'Sunbeam' were grown on just under 5% of the state's acreage; 'BHN 22', 'Heatwave', and 'Merced' on about 2% of the acreage; and 'Cobia', 'Colonial', 'Duke', and 'Olympic' on about 1% of the acreage.

Many other named varieties and experimental lines were grown on very small areas in the 1992-93 season.

TOMATO VARIETY TRIAL RESULTS

Summary results listing the five highest yielding and five largest fruited varieties from trials at the Gulf Coast Research and Education Center, Bradenton; Ft. Pierce Agricultural Research & Education Center; and North Florida Research & Education Center, Quincy, for the Spring 1992 season are shown in Table 1. High total yields and large fruit size were produced by 'Sunbeam' and Fla 7249B at Bradenton and 'Olympic', 'Agriset 761', 'Bonita', and Fla 7249B at Fort Pierce. 'Sunny' was among the high yielding varieties at all locations. 'Mountain Spring', 'Merced', 'Olympic', and 'Sunbeam' had large fruit size in two of the three locations.

Summary results listing outstanding entries in order from trials at the Gulf Coast Research & Education Center, Bradenton; Ft. Pierce Agricultural Research & Education Center; and North Florida Research & Education Center, Quincy for the Fall 1992 season are shown in Table 2. High yields and large fruit size were produced by 'Heatwave' and 'Agriset 761' and Fla 7249B at Fort Pierce and by 'Merced' at Quincy. High yields were produced by Fla 7249B at two of the three locations. Large fruit size was produced by 'Merced' at all locations.

It is important to note that the same entries were not included in all of the trials.

Table 1. Summary of University of Florida tomato variety trial results, Spring 1992 (1).

Location	Total yield	Large fruit size
Bradenton	Fla 7375[1]	Mountain Spring
	Sunbeam	Merced
	Sunny	Olympic
	PSX 860889	Sunbeam
	Fla 7249B	Fla 7249B
Fort Pierce	Olympic[2]	Olympic
	Agriset 761	Agriset 761
	Bonita	Fla 7249B
	Fla 249B	Bonita
	Sunny	Solar Set[3]
Quincy	Colonial[4]	Mountain Spring
	XPH 10000	Merced
	Fla 743	XPH 10009
	Fla 75	Sunbeam
	Sun	Tango

[1] Nine other entries had total yield similar to Fla 7375.

[2] There was no statistical difference in total yield among the 12 entries in this trial.

[3] Six other entries had average fruit weight similar to that of 'Solar Set'.

[4] Nine other entries had total yield similar to 'Colonial'.

Seed Sources:
Agrisales: Agriset 761
Asgrow: Solar Set, Sunbeam, Sunny, XPH 10000, XPH 10009
Petoseed: Colonial, Olympic, PSX 860889
Rogers NK: Bonita, Merced, Mountain Spring, Tango
University of Florida: Fla 7249B, Fla 7375, Fla 7430, Fla 7435

For spring and fall 1992 combined, 'Merced' and Fla 7249B had high total yields and/or large fruit size in six instances, 'Agriset 761' and 'Sunny' in four instances and 'Olympic', 'Solar Set', and 'Sunbeam' in three instances each.

It should be noted that in some of these trials, there were little or no significant differences among the entries. This indicates that there are a large number of varieties that produce large yields and have large fruit size which are available to growers. In some instances, other factors may dictate the selection process.

Table 2. Summary of University of Florida tomato variety trial results, Fall 1992 (1).

Location	Total yield	Large fruit size
Bradenton	XPH 10013	Merced
	Fla 7375	Tango
	Fla 7423	NVH 4471
	Fla 7249B	XPH 10005
	PSX 805588	Shady Lady[1]
Fort Pierce	Heatwave	Agriset 761
	Agriset 761	Merced
	Sunny	Heatwave
	Fla 7249B	Fla 7249B
	Fla 7423	Fla 7430
		Solar Set[2]
Quincy	NC 92308[3]	90-0196
	Solar Set	Merced
	Merced	NC 92226
	PSX 805588	91-0046
	Fla 7249B	NC 92222
		XPH 10013[4]

[1] Thirteen other entries had average fruit weight similar to 'Shady Lady'.

[2] Three other entries had average fruit weight similar to 'Solar Set' and Fla 7430.

[3] Thirteen other entries had total yields similar to NC 92308 and Fla 7249B.

[4] Twelve other entries had average fruit weight similar to NC 92222 and XPH 10013.

Seed Sources:
Agrisales: Agriset 761
Asgrow: Solar Set, Sunny, XPH 10005, XPH 10013
N.C. Agricultural Experiment Station: NC 92308, NC 92222, NC 92226
Petoseed: Heatwave, PSX 805588
Rogers NK: Merced, NVH 4471, Tango
Sakata: 90-0196, 91-0046
Sunseeds: Shady Lady
University of Florida: Fla 7249B, Fla 7375, Fla 7423, Fla 7430

TOMATO VARIETIES FOR COMMERCIAL PRODUCTION

The varieties listed have performed well in University of Florida trials conducted in various locations. Those varieties designated as FOR TRIAL should be evaluated in trial plantings before large-scale production is attempted.

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

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

Colonial (Petoseed). A midseason, jointless hybrid. Fruit are deep globe shape with green shoulders. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), Alternaria stem canker, Gray leaf spot. **FOR TRIAL**.

Heatwave (Petoseed). An early, large, jointed, uniform-green fruited hybrid. Determinate. Fruit is set under high temperatures (90-96°F day/74-78° night). For late summer or fall plantings. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), Alternaria stem canker, Gray leaf spot.

Merced (Rogers NK). Deep-globe shaped fruit are produced on determinate vines. Jointed hybrid. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), Gray leaf spot, Tobacco mosaic virus. **FOR TRIAL.**

Olympic (Petoseed). An early determinate, jointed hybrid. Fruit are deep oblate with green shoulders. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), Alternaria stem canker, and Gray leaf spot. **FOR TRIAL**.

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

Sunbeam (Asgrow). Deep-globe shaped fruit are produced on determinate vines. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and race 2), Gray leaf spot, Alternaria. **FOR TRIAL**.

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

REFERENCE

1. Maynard, D. N. 1993. Vegetable variety trial results in Florida for 1992. Fla. Agr. Expt. Sta. Circ. S389.

APPENDIX B

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 $N-P_2O_5-K_2O$)in Tables 1 and 2 represent the optimum amounts of these nutrients needed for maximum production (7).

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, 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.

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.

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

	Nutrient requirements	Supplemental applications	
Soil	lbs/A $N-P_2O_5-K_2O$	lbs/A $N-P_2O_5-K_2O$	Number of Applications
Irrigated Mineral	160-160-160	30-0-20	0-4
Marl	120-160-160	30-0-20	0-3
Rockdale[1]	120-200-180	30-0-20	0-3

[1] A portion of the phosphorus (25 pounds per acre) in the super or triple super form should be placed in the drill or under the plug-mix to supply an adequate amount for germinating seedlings or transplants.

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-.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 (2,4,8).

Table 2. 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_2-O_5-K_2O	Number of Applications
Mineral	2-3	160-160-160	30-0-20	0-2
Rockdale	2-3	120-200-180	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 nutrient. For most micronutrients, a very fine line exists between sufficiency and toxicity. Foliar application of major nutrients (nitrogen, phosphorus, or potassium) has not been shown to be beneficial where proper soil fertility is present. For more information on foliar micronutrient fertilization of tomatoes, consult the Commercial Vegetable Fertilization Guide, Circular 225-C (2).

Fertilizer application

Nonmulched Crops. Apply all phosphorus and micronutrients, and no more than one-half of the nitrogen and potassium prior to planting and incorporate by disking or rototilling. Increased fertilizer efficiency can be realized by a "modified broadcast" method where the needed fertilizer is broadcast in the bed area only, rather than over the entire field. For rates, see Table 1. Incorporation will place some fertilizer near the transplant root or germinating seed. The remaining nitrogen and potassium fertilizer can be banded in an area on both sides of the row just ahead of developing root tips through the early part of the growing season.

Several supplemental sidedress band applications of nitrogen and potassium may be needed after leaching rainfall. These are applied on the bed shoulders just ahead of the expanding root system, until 2 to 4 weeks before the end of harvest period. A shallow cultivator sweep will cover the fertilizer and help correct bed erosion. Liquid fertilizer can be used by knifing it into the soil, using caution to avoid root damage.

Strip mulch. The strip mulch system uses a narrow 10- to 12-inch strip of polyethylene mulch laid over a fertilizer band to help reduce fertilizer leaching. With the strip mulch system, broadcast and incorporate all of the phosphorus and micronutrients with 20 percent of the nitrogen and potassium. The remaining nitrogen and potassium should be applied in a band 2 to 3 inches deep and covered with the mulch strip in an inverted "U" fashion so that the highest point is directly over the fertilizer band. Tomatoes can then be planted in a single row to one side of the strip. No additional fertilizer is usually required although sidedressings may be needed after leaching rains. This system is less costly than the full-bed mulch system, but does not have all the advantages such as fumigant and fertilizer efficiency, weed control, and growth enhancement.

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 2). 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.

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, 9).

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. On Rockdale soil, a small amount of superphosphate (25 pounds phosphorus per acre) should be applied in the drill area to support germinating seedlings or transplants.

Mulched Production with Drip Irrigation. Where drip irrigation is used, drip tape or tubes should be laid 2 to 3 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. However, it is important to begin with rather high rates of N and K_2O to ensure young transplants are established quickly.

Suggested schedules for fall and spring crop nutrient injections are presented in Table 3. 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 (5).

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. On a trial basis, for overhead irrigated tomatoes, apply one-third of the total required nitrogen as sulfur-coated urea (SCU) or isobutylidene diurea (IBDU) 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, 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 4.

Growers with drip irrigation can obtain faster analyses for N by using a plant sap quick test. Several kits have been calibrated for Florida tomatoes (3). Interpretation of these kits is provided in Table 5. More information is available on plant analysis (6).

LITERATURE CITED

1. Hanlon, E. A., and G. J. Hochmuth. 1989. Calculating fertilizer rates for vegetable crops grown in raised-bed cultural systems in Florida. Univ. Fla. Coop. Ext. Special Series, SS-SOS-901.

2. Hochmuth, G. J. 1988. Commercial vegetable fertilization guide. Univ. Fla. Coop. Ext. Circ. 225-C.

3. Hochmuth, G. J., P. R. Gilreath, E. A. Hanlon, G. A. Clark, D. N. Maynard, C. D. Stanley, and D. Z. Haman. 1988. Evaluating Plant-N status with plant sap quick-test kits. Proc. 1988 Florida Tomato Institute. SS-VEC-801, pp 6-14.

4. Hochmuth, G. J. and E. A. Hanlon. 1989. Commercial vegetable crop nutrient requirements. Univ. Fla. Coop. Ext. Circ. 806.

5. Hochmuth, G. J., and G. A. Clark. 1991. Fertilizer application and management for micro (drip) irrigated vegetables in Florida. Univ. Fla. Coop. Ext. Serv. Special Series Public. SS-VEC-45.

6. Hochmuth, G., D. Maynard, C. Vavrina, and E. Hanlon. 1991. Plant tissue analysis and interpretation for vegetable crops in Florida. Univ. Fla. Coop. Ext. Serv. Special Series Public. SS-VEC-42.

7. Kidder, G., E. A. Hanlon, and G. J. Hochmuth. 1989. IFAS standardized fertilization recommendations for vegetable crops. Univ. Fla. Coop. Ext. Special Series, SS-SOS-907.

8. Lorenz, O. A., and D. N. Maynard. 1980. Knott's handbook for vegetable growers, Second ed. Wiley-Interscience, New York.

9. Shuler, K. D., and G. J. Hochmuth. 1990. Fertilization guide for vegetables grown in full-bed mulch culture. Univ. Fla. Coop. Ext. Circ. 854.

Table 3. Schedules for N and K_2O injections for mulched tomatoes on soils testing low in K for situations where zero or 30 lb N and K_2O per acre are applied dry in the bed.

		Week														Season
	Dry fert.[y]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	total
Season	(lb/A)	lb per acre per week[z]														(lb/A)
Fall	0	10.5	10.5	10.5	14	14	17.5	17.5	17.5	14	14	10.5	10.5	-	-	161
	30	0	7	10.5	10.5	14	14	14	14	14	14	10.5	10.5	-	-	162
Spring	0	7	7	10.5	10.5	10.5	14	14	14	14	14	14	14	10.5	7	161
	30	0	7	7	7	10.5	10.5	10.5	14	14	14	10.5	10.5	10.5	7	163

[y] Dry fertilizer is the amount of N and K_2O incorporated in the bed. These schedules assume no banded fertilizer.

[z] Pounds per acre per week at 7, 10.5, 14, and 17.5 are 1, 1.5, 2, and 2.5 lb. per acre per day. Acre is based on 6-ft. spacing or 7260 linear bed foot of bed per acre (43,560 sq. ft.).

Table 4. 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	5-leaf stage	Deficient	<3.0	0.3	3.0	1.0	0.3	0.3	40	30	25	20	5	0.2
			Adequate range	3.0	0.3	3.0	1.0	0.3	0.3	40	30	25	20	5	0.2
				5.0	0.6	5.0	2.0	0.5	0.8	100	100	40	40	15	0.6
			High	>5.0	0.6	5.0	2.0	0.5	0.8	100	100	40	40	15	0.6
	MRM leaf	First flower	Deficient	<2.8	0.2	2.5	1.0	0.3	0.3	40	30	25	20	5	0.2
			Adequate range	2.8	0.2	2.5	1.0	0.3	0.3	40	30	25	20	5	0.2
				4.0	0.4	4.0	2.0	0.5	0.8	100	100	40	40	15	0.6
			High	>4.0	0.4	4.0	2.0	0.5	0.8	100	100	40	40	15	0.2
			Toxic (>)								1500	300	250		
	MRM leaf	Early fruit set	Deficient	<2.5	0.2	2.5	1.0	0.25	0.3	40	30	20	20	5	0.2
			Adequate range	2.5	0.2	2.5	1.0	0.25	0.3	40	30	20	20	5	0.2
				4.0	0.4	4.0	2.0	0.5	0.6	100	100	40	40	10	0.6
			High	>4.0	0.4	4.0	2.0	0.5	0.6	100	100	40	40	10	0.6
			Toxic (>)											250	
	MRM leaf	First ripe fruit	Deficient	<2.0	0.2	2.0	1.0	0.25	0.3	40	30	20	20	5	0.2
			Adequate range	2.0	0.2	2.0	1.0	0.25	0.3	40	30	20	20	5	0.2
				3.5	0.4	4.0	2.0	0.5	0.6	100	100	40	40	10	0.6
			High	>3.5	0.4	4.0	2.0	0.5	0.6	100	100	40	40	10	0.6

Continued

Table 4. 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	During harvest period	Deficient	<2.0	0.2	1.5	1.0	0.25	0.3	40	30	20	20	5	0.2
			Adequate	2.0	0.2	1.5	1.0	0.25	0.3	40	30	20	20	5	0.2
			range	3.0	0.4	2.5	2.0	0.5	0.6	100	100	40	40	10	0.6
			High	> 3.0	0.4	2.5	2.0	0.5	0.6	100	100	40	40	10	0.6

Table 5. Suggested nitrate-N concentrations in fresh petiole sap for tomatoes.

Stage of growth	NO_3-N conc. (ppm)
Transplant to 1-inch fruits	600-800
One-inch fruits to first harvest	400-600
Main harvest	300-400

APPENDIX C

Weed Control in Tomatoes[1]

William M. Stall and J. 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.

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. 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

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[1] This document, Fact Sheet HS-200, was reviewed November 1992, by the Florida Cooperative Extension Service. For more information, contact your county Cooperative Extension Service office.

[2] Professor, Horticultural Science Dept., Institute of Food and Agricultural Sciences, University of Florida, Gainesville; Assoc. Professor, Gulf Coast Research and Education Center, Bradenton, Florida.

Trade names, where used, are given for the purpose of providing specific information. They do not constitute an endorsement or guarantee of products named, nor does it imply criticism of products not named.

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 4-6 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

Herbicide	Labelled Crops	Time of Application to Crop	Rate (lbs. AI./Acre)	
			Mineral	Muck
DCPA (Dacthal W-75)	Established Tomatoes	Posttransplanting after crop establishment (non-mulched)	6.0 - 8.0	---
		Mulched row middles after crop establishment	6.0 - 8.0	---
Remarks: Controls germinating annuals. Apply to weed-free soil 6-8 weeks after crop is established and growing rapidly or to moist soil in row middles after crop establishment. Note label precautions of replanting non-registered crops within 8 months.				
Diquat (Diquat H/A)	Tomato Vine Burndown	After final harvest	0.375	---
Remarks: Special Local Needs (24c) label for use for burndown of tomato vines after final harvest. Applications of 1.5 pts. material per acre in 60-120 gals. of water is labelled. Add 16-32 ozs. of Valent X-77 spreader per 100 gals. of spray mix. Thorough coverage of vines is required to insure maximum burndown.				

Weed Control in 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>Mineral</th><th>Muck</th></tr>
<tr><td>MCDS (Enquik)</td><td>Tomatoes</td><td>Postemergence directed/ shielded in row middle</td><td>5 - 8 gals.</td><td>---</td></tr>
<tr><td colspan="5">Remarks: Controls many emerged broadleaf weeds. Weak on grasses. Apply 5-8 gallons of Enquik in 20-50 gallons of total spray volume per treated acre. A non-ionic surfactant should be added at 1-2 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 5-6 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 maxiumum of 1.0.lb ai/acre within crop season.. Avoid applications for 3 days following cool, wet or cloudy weather to reduce possible crop injury. Label states control of many annual grasses and broadleaf weeds including, lambsquarter, fall panicum, <i>amaranthus</i> sp., Florida pusley, common ragweed, sicklepod, and spotted spurge.</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 1-2 inches. Incorporate same day as applied. For direct-seeded or transplanted tomatoes.</td></tr>
<tr><td>Napropamid
(Devrinol 2E)
(Devrinol 50WP)</td><td>Tomatoes</td><td>Surface treatment</td><td>2.0</td><td>---</td></tr>
<tr><td colspan="5">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.</td></tr>
<tr><td>Paraquat
(Gramoxone Extra)</td><td>Tomatoes</td><td>Premergence; Pretransplant</td><td>0.62 - 0.94</td><td>---</td></tr>
<tr><td colspan="5">Remarks: Controls emerged weeds. Use a non-ionic spreader and thoroughly wet weed foliage.</td></tr>
<tr><td>Paraquat
(Gramoxone Extra)</td><td>Tomatoes</td><td>Post directed spray in row middle</td><td>0.47</td><td>---</td></tr>
<tr><td colspan="5">Remarks: Controls emerged weeds. Direct spray over emerged weeds 1-6 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.</td></tr>
</table>

Weed Control in 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>Mineral</th><th>Muck</th></tr>
<tr><td>Sethoxydim (Poast)</td><td>Tomatoes</td><td>Postemergence</td><td>0.188 - 0.28</td><td>---</td></tr>
<tr><td colspan="5">Remarks: Controls actively growing grass weeds. A total of 4 1/2 pts. product per acre may be applied in one season. Do not apply within 20 days of harvest. Apply in 5-20 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 (1 1/2 pts.) to perennial grasses emerging from rhizomes etc. Consult label for grass species and growth stage for best control.</td></tr>
<tr><td>Trifluralin
(Treflan EC)
(Treflan MTF)
(Treflan 5)
(Treflan TR-10)
(Tri-4) (Trilin)</td><td>Tomatoes (except Dade County)</td><td>Pretransplant incorporated</td><td>0.75 - 1.0</td><td>---</td></tr>
<tr><td colspan="5">Remarks: Controls germinating annuals. Incorporate 4 inches or less within 8 hours of application. Results in Florida are erratic on soils with low organic matter and clay contents. Note label precautions of planting non-registered crops within 5 months. Do not apply after transplanting.</td></tr>
<tr><td>Trifluralin
(Treflan EC)
(Treflan MTF)
(Treflan 5)
(Treflan TR-10)
(Tri-4) (Trilin)</td><td>Direct-Seeded tomatoes (except Dade County)</td><td>Post directed</td><td>0.75 - 1.0</td><td>---</td></tr>
<tr><td colspan="5">Remarks: For direct-seeded tomatoes, apply at blocking or thinning as a directed spray to the soil between the rows and incorporate.</td></tr>
</table>

APPENDIX D

INSECT CONTROL IN TOMATOES

July 1993

Dr. Freddie Johnson, Extension Entomologist,
Dept. of Entomology & Nematology, IFAS,
University of Florida, Gainesville, FL

INSECT CONTROL IN TOMATOES

Ants

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
carbaryl (Sevin)	5 B	20 - 40 lb	0
Pyrethrins + Piperonyl Butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0

Aphids

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
aliphatic petroleum (JMS Stylet Oil)	97.6% EC	see label	see label
azinphosmethyl (Guthion)	2S, 2L (EC)	2 - 3 pt	up to day of harvest
diazinon (AG 500)	4 EC	1/2 pt	1
dimethoate (Cygon)	4 EC	1/2 - 1 pt	7
endosulfan (Thiodan) (Phaser)	3 EC	2/3 - 1 1/3 qt	2
esfenvalerate (Asana XL) (potato aphid)	0.66 EC	5.8 - 9.6 fl oz	1
malathion	5 EC	1 1/2 - 2 pts	1
methamidophos (Monitor)	4 EC	1/2 - 1 1/2 pt	7
methomyl (Lannate)	1.8 L	2 - 4 pt	1
mevinphos (Phosdrin)	4 EC	1/4 - 1/2 pt	1
methyl parathion	4 EC	1 - 3 pt	15
oil (Sun Spray)*	98.8%	1 - 2 gal/100 gal H2O	warning-read label
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

Aphids (cont.)

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
soap, insecticidal (M-Pede)	49% EC	1 - 2 gal/100 gal H2O	0

* 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.

Armyworms

See also: Beet, Fall, Southern, and Yellow-Striped Armyworm

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
Bacillus thuringiensis	See individual brand labels		
carbaryl (Sevin)	5 B	20 - 40 lb	0
chlorpyrifos (Lorsban) (except cherry tomatoes)	50 W	2 lb	14
diazinon (AG 500) (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)	1.8 L	1 - 2 pt	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

See also: Armyworms

Beet Armyworms

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
esfenvalerate (Asana XL) (aids in control)	0.66 EC	5.8 - 9.6 fl oz	1
methomyl (Lannate)	1.8 L	2 - 4 pts	1

See also: Armyworms

Beet Armyworms (cont.)

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
permethrin* (Ambush)	2 EC	3.2 - 12.8 oz	up to day of harvest
(Pounce)	3.2 EC	2 - 8 oz	

* 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.

Fall Armyworms

See also: Armyworms

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
carbaryl (Sevin)	80S (WP)	1 1/2 - 2 1/2 lb	0
diazinon (AG 500)	4 EC	3/4 - 1 pt	1
methomyl (Lannate)	1.8 L	2 pt	1
methoxychlor	4 L	1 - 3 qt	1 for 1 3/4 qt 7 for 1 3/4+ qt

Southern Armyworms

See also: Armyworms

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
diazinon (AG 500)	4 EC	3/4 - 1 pt	1
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
methomyl (Lannate)	1.8 L	2 - 4 pt	1
permethrin* (Ambush)	2 EC	3.2 - 12.8 oz	up to day of harvest
(Pounce)	3.2 EC	2 - 8 oz	

* 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.

Yellow-Striped Armyworms

See also: Armyworms

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	3 - 6 pt	up to day of harvest for 3 pts 14 - 3+ pts
endosulfan (Thiodan) (Phaser)	3 EC	1 1/3 qt	2
esfenvalerate (Asana XL) (Western Yellow Striped)	0.66 EC	5.8 - 9.6 oz	1

Banded Cucumber Beetles

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	1 1/2 - 2 pt	0
diazinon (AG 500)	4 EC	3/4 - 1 pt	1

Blister Beetles

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
cryolite (Kryocide)	96 WP	15 - 30 lb	wash fruit
endosulfan (Thiodan)	3 EC	2/3 - 1 1/3 qt	2
methoxychlor	4 L	1 - 3 qt	1 for 1 3/4 qt 7 for 1 3/4+ qt

Cabbage Loopers

See also: Loopers

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
Bacillus thuringiensis	See individual brand labels.		0
cryolite (Kryocide)	96 WP	15 - 30 lb	wash fruit
endosulfan (Thiodan) (Phaser)	3 EC	1 - 1 1/3 qt	2
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
malathion	5 EC	1 1/2 - 2 pt	1
methyl parathion	7.5 EC	1 - 1 1/2 pts	15
methomyl (Lannate)	1.8 L	2 - 4 pt	1
permethrin* (Ambush) (Pounce)	2 EC 3.2 EC	3.2 - 12.8 oz 2 - 8 oz	up to day of harvest
Pyrethrins + Piperonyl Butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0
Rotenone (Rotacide)	EC	1 gal	0

* 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.

Colorado Potato Beetles

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	1 1/2 pt	up to day of harvest
carbaryl (Sevin)	80S (WP)	2/3 - 1 1/4 lb	0
endosulfan (Thiodan) (Phaser)	3 EC	2/3 - 1 1/3 qt	2
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
methoxychlor	4 L	1 - 3 qt	1 for 1 3/4 qt 7 for 1 3/4+ qt
methyl parathion (Penncap M)	2 EC	4 pts	15
permethrin* (Ambush) (Pounce)	2 EC 3.2 EC	3.2 - 12.8 oz 2 - 8 oz	up to day of harvest

Colorado Potato Beetles (cont.)

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
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% liquid	2/3 gal	0
rotenone (Rotacide)	EC	1 gal	0

* 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.

Corn Earworms

See also: Tomato Fruitworms

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	3 - 6 pt	up to day of harvest for 3 pt or less; 14 for 3+ pt
Bacillus thuringiensis	See individual brand labels		0
Pyrethrins + Piperonyl Butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0

Crickets

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
carbaryl (Sevin)	5 B	20 - 40 lb	0
Pyrethrins + Piperonyl Butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0

Cucumber Beetle

See also: Banded Cucumber Beetle

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion) (banded cucumber beetle)	2S, 2L (EC)	1 1/2 - 2 pts	up to day of harvest

Cucumber Beetle (cont.)

See also: Banded Cucumber Beetle

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
Pyrethrins + Rotenone (Pyrellin)	EC	1 1/2 - 2 pts	0
Pyrethrins + Piperonyl Butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0
Rotenone (Rotacide)	EC	1 gal	0

Cutworms

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
Bacillus thuringiensis	See individual	brand labels	0
carbaryl (Sevin)	80S (WP)	2 1/2 lb	0
carbaryl (Sevin)	5 B	20 - 40 lb	0
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
malathion	5 EC	1 1/2 - 2 pt	1
methomyl (Lannate) (varigated cutworm)	1.8 L	2 pt	1
permethrin* (Ambush) (Pounce) (granulate cutworm)	2 EC 3.2 EC	3.2 - 12.8 oz 2 - 8 oz	up to day of harvest
Rotenone (Rotacide)	EC	1 gal	0

* 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.

Darkling Beetles

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
carbaryl (Sevin)	5 B	20 - 40 lb	0

Drosophilas (fruit flies, vinegar flies)

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	1 1/2 - 2 pt	0
diazinon (AG 500) (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)	EC	1 gal	0

European Corn Borers

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	2 - 3 pt	up to day of harvest
carbaryl (Sevin)	80S (WP)	1 1/2 - 2 1/2 lb	0
Pyrethrins + Rotenone (Pyrellin)	EC	1 1/2 - 2 pts	0

Flea Beetles

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	2 - 3 pt	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
endosulfan (Thiodan) (Phaser)	3 EC	2/3 - 1 1/3 qt	2
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
methyl parathion	4 EC	1 - 3 pt	15
methyl parathion (Penncap M)	2 EC	2 - 4 pt	15
methoxychlor	4 L	1 - 3 qt	1 for 1 3/4 qt 7 for 1 3/4+ qt
pyrethrins + piperonyl butoxide (Pyrenone)	66% L (EC)	2 - 12 oz per 100 gal	0

Flea Beetles

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
Pyrethrins + Rotenone (Pyrellin)	EC	1 1/2 - 2 pts	0
Rotenone (Rotacide)	EC	1 gal	0

Fleahoppers

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
malathion (Cythion)	5 EC	1 1/2 - 2 pts	1
Pyrethrins + Rotenone (Pyrellin)	EC	1 - 2 pts	0

Garden Symphylans (Symphylans)

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
fonofos (Dyfonate)	10 G	20 lb	preplant, broadcast
Diazinon (AG 500)	4 EC	10 qt	preplant, broadcast

Grasshoppers

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	2 - 3 pt	up to day of harvest
carbaryl (Sevin)	5 B	20 - 40 lb	0
carbaryl (Sevin)	80S (WP)	2/3 - 1 7/8 lbs	0
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
mevinphos (Phosdrin)	4 EC	1/2 - 1 pt	1
Rotenone (Rotacide)	EC	1 gal	0

Hornworms (tomato hornworm, tobacco hornworm)

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	3 - 6 pt	up to day of harvest for 3 pt or less; 14 for 3+ pt
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
endosulfan (Thiodan) (Phaser)	3 EC	2/3 - 1 1/3 qts	2
esfenvalerate (Asana XL) (tomato hornworm, tobacco hornworm)	0.66 EC	2.9 - 5.8 fl oz	1
methomyl (Lannate)	1.8 L	2 - 4 pt	1
methyl parathion (Penncap M)	2 EC	4 pt	15
permethrin* (Ambush) (Pounce)	2 EC 3.2 EC	3.2 - 12.8 oz 2 - 8 oz	up to day of harvest

* 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

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
carbaryl (Sevin)	80S (WP)	1 1/2 - 2 1/2 lb	0

Leafhoppers

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	2 - 3 pt	up to day of harvest
carbaryl (Sevin)	80S (WP)	2/3 - 1 1/4 lb	0
dimethoate (Cygon)	4 EC	1/2 - 1 pt	7

Leafhoppers (cont.)

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
methoxychlor	4 L	1 - 3 qt	1 for 1 3/4 qt 7 for 1 3/4+ qt
methyl parathion	4 EC	1 - 3 pt	15
mevinphos (Phosdrin)	4 EC	1/2 - 1 pt	1
pyrethrins + rotenone (Pyrellin)	EC	1 - 2 pts	0
Pyrethrins + Piperonyl Butoxide (Pyrenone)	66% L (EC)	2 - 12 oz	0
Rotenone (Rotacide)	EC	1 gal	0
soap, insecticidal (M-Pede)	49% EC	1 - 2 gal/100 gal H2O	0

Leafminers

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	1 1/2 - 2 pt	up to day of harvest
diazinon (AG 500)(dipterous leafminer)	4 EC	1/2 pt	1
diazinon	50 WP	1/2 lb	1
dimethoate (Cygon)	4 EC	1/2 - 1 pt	7
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
methyl parathion (Penncap M)	2 EC	2 - 4 pt	15
oxamyl (Vydate L) (serpentine leafminers) except Liriomyza trifolii	2 EC	2 - 4 pt	1
permethrin* (Ambush) (Pounce)	2 EC 3.2 EC	3.2 - 12.8 oz 2 - 8 oz	up to day of harvest
pyrethrins + rotenone (Pyrellin)	EC	1 - 2 pts	0

Leafminers (cont.)

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
Rotenone (Rotacide)	EC	1 gal	0

* 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.

Loopers

See also: Cabbage Looper

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
Bacillus thuringiensis	See individual brand labels		
methomyl (Lannate)	1.8 L	2 - 4 pt	1
pyrethrins + rotenone (Pyrellin)	EC	1 - 2 pts	0

Mealy Bugs

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
malathion (Cythion)	5 EC	1 1/2 - 2 pts	1

Mites

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
dicofol (Kelthane) (Pacific, tropical, two-spotted, tomato russet, spider mites)	MF (4 EC)	3/4 - 1 1/2 pt	2
endosulfan (Thiodan) (Phaser) (tomato russet mite only)	3 EC	1 1/3 qt	2
malathion (Cythion)	5 EC	1 1/2 - 2 pts	1
malathion (spider mites only)	5 EC	1 1/2 pt per 100 gal	1
methyl parathion	4 EC	1 - 3 pt	15

Mites (cont.)

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
mevinphos (Phosdrin)	4 EC	1/2 - 1 pt	1
Pyrethrins + Rotenone (Pyrellin)	EC	1 1/2 - 2 pts	0
soap, insecticidal (M-Pede) (tomato russet mite only)	49% EC	1 - 2 gal/100 gal H2O	0
sulfur (tomato russet mite only)	see individual brand labels		

Mole Crickets

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
diazinon	14 G	7 lb	preplant
diazinon (AG 500)	4 EC	1 qt	preplant, broadcast

Pinworms (tomato pinworm)

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	3 - 6 pt	up to day of harvest for 3 pt or less; 14 for 3+ pt
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
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)	1.8 L	2 - 4 pt	1
methyl parathion (Penncap M)	2 EC	4 pts	15

Pinworms (tomato pinworm) cont.

Insecticide		Formulation	Formulation Rate/Acre	Min Days to Harvest
permethrin*	(Ambush) (Pounce)	2 EC 3.2 EC	3.2 - 12.8 oz 2 - 8 oz	up to day of harvest
pheromones+	(NOMATE TPW Spiral) (NOMATE TPW Fiber)	------ READ LABEL CAREFULLY -------------		

* 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.

\+ The product functions by destroying mating communication of adult moths.

Plant Bugs

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
carbaryl (Sevin) (tarnished plant bug)	80S (WP)	1 1/2 - 2 1/2 lb	0
pyrethrins + rotenone (Pyrellin)	EC	1 - 2 pts	0
soap, insecticidal (M-Pede)	49% EC	1 - 2 gal/100 gal H2O	0

Psyllids

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
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

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
Bacillus thuringiensis	See individual brand labels		0

Sowbugs

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
carbaryl (Sevin)	5 B	20 - 40 lb	0

Stinkbugs

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion) (green stinkbugs)	2S, 2L (EC)	1 1/2 - 2 pt	up to day of harvest
carbaryl (Sevin) (suppression)	80S (WP)	1 1/2 - 2 1/2 lb	0
endosulfan (Thiodan) (Phaser)	3 EC	1 - 1 1/3 qt	2
Pyrethrins + Rotenone (Pyrellin)	EC	1 1/2 - 2 pts	0

Thrips

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	2 - 3 pt	up to day of harvest
malathion (Cythion)	5 EC	1 1/2 - 2 pts	1
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 H2O	0

Tomato Fruitworms (corn earworm)

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	3 - 6 pt	up to day of harvest for 3 pt or less; 14 for 3+ pt
Bacillus thuringiensis	See individual brand labels		0
carbaryl (Sevin)	80S (WP)	1 1/2 - 2 1/2 lb	0

Tomato Fruitworms (corn earworm) cont.

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
chlorpyrifos (Lorsban) (except cherry tomatoes)	50 W	2 lb	14
cryolite (Kryocide)	96 WP	15 - 30 lb	wash fruit
endosulfan (Thiodan) (Phaser)	3 EC	1 1/3 qt	2
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
methamidophos (Monitor)	4 EC	1/2 - 1 1/2 pt	7
methomyl (Lannate)	1.8 L	2 - 4 pt	1
methyl parathion (Penncap M)	2 EC	4 pts	15
permethrin* (Ambush) (Pounce)	2 EC 3.2 EC	3.2 - 12.8 oz 2 - 8 oz	up to day of harvest

* 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.

Tuberworms

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	2 1/4 - 3 pt	0

Vegetable Weevil

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
Pyrethrins + Rotenone (Pyrellin)	EC	1 1/2 - 2 pts	0

Whiteflies

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
azinphosmethyl (Guthion)	2S, 2L (EC)	1 1/2 - 2 pt	up to day of harvest
chlorpyrifos (Lorsban) (except cherry tomatoes)	50 W	2 lbs	14

Whiteflies (cont.)

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
endosulfan (Thiodan) (Phaser)	3 EC	2/3 qt/100 gal H2O- use 100 - 200 gal/A	2
esfenvalerate (Asana XL)	0.66 EC	5.8 - 9.6 fl oz	1
malathion (Cythion)	5 EC	1 1/2 - 2 pts	1
methamidophos (Monitor) (apply in tank mix with pyrethroids)	4 EC	1 1/2 - 2 pts	7
permethrin (Ambush) (except cherry tomatoes) Apply as a tank mix with Monitor for ground spray only	25 W	3.2 - 12.8 oz	0-Ambush 7- Monitor
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 H2O	0

* Permethrin (Ambush) 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.

Wireworms

Insecticide	Formulation	Formulation Rate/Acre	Min Days to Harvest
diazinon	14 G	21 - 28 lb	preplant
diazinon	4 EC	3 - 4 qt	preplant, broadcast
dichloropropene (Telone) (Vorlex)	II, C-17 L	see labels see labels	

APPENDIX E

TOMATO PLANT DISEASE CONTROL GUIDE

T.A. Kucharek
Plant Pathology Dept.
University of Florida
Gainesville, FL 32611

Crop	Chemical	Maximum Rate/Acre/		Min. Days To harvest	Pertinent Diseases	Select Remarks
		Appl.	Crop			
Tomato	For best possible chemical control of bacterial spot, a copper fungicide must be tank-mixed with a maneb or mancozeb fungicide.					
	Ridomil 2E	8 pts. per treated acre	12 pts.	-	Pythium diseases	See label for use at and after planting
	Kocide 101, Blue Shield, or Champion WP'S	4 lbs.	-	NTL[1]	Bacterial spot	
	Kocide 606, Cuproxat, Champion or Champ FL'S	5 1/3 pts.	-	NTL[1]	Bacterial spot	
	Basic copper sulfate (CP or Tri-Basic) WP'S	4 lbs.	-	NTL[1]	Bacterial spot	
	Copper count N	3/4 gal.	-	NTL[1]	Bacterial spot	
	Maneb 80WP	3 lbs.	21 lbs.	5	Early blight Late blight Grey leaf spot Bacterial spot[2]	

[1] Not within 5 days when tank mixed with maneb or mancozeb fungicides.
[2] When tank-mixed with a copper fungicide.

Crop	Chemical	Maximum Rate/Acre/ Appl.	Maximum Rate/Acre/ Crop	Min. Days To harvest	Pertinent Diseases	Select Remarks
Tomato (Cont'd)	Manex or Manex Plus Zinc F4 FL's	2.4 qts	16.8 qts.	5	Early blight Late blight Gray leaf spot Bacterial spot[1]	
	Dithane DF, Penncozeb or Manzate 200 DF'S	3 lbs.	21 lbs.	5	Early blight Late blight Gray leaf spot Bacterial spot[1]	
	Penncozeb or Dithane M-45 WP'S	3 lbs.	21 lbs.	5	Early blight Late Blight Gray leaf spot Bacterial spot[1]	
	Dithane F-45 or Manex II FL'S	2.4 qts.	16.8 qts.	5	Early blight Late blight Gray leaf spot Bacterial spot[1]	
	Bravo 720 or Terranil 6L FL's	3 pts.	-	1	Early blight Late blight Gray leaf spot Target spot	

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[1] When tank-mixed with a copper fungicide

		Maximum Rate/Acre/		Min. Days		
Crop	Chemical	Appl.	Crop	To harvest	Pertinent Diseases	Select Remarks
Tomato (Cont'd)	Bravo 90DG or Terranil 90DF	2 1/4 lbs. 2.3 lbs.	-	1	Early blight Late blight Gray leaf spot Target spot	
	Bravo W-75	3 lbs.	-	1	Early blight Late blight Gray leaf spot Target spot	
	Bravo 500, Chloronil 500, Chlorothalonil 4L, Evade, or Supanil FL'S	4 pts.	-	1	Early blight Late blight Gray leaf spot Target spot	
	Ridomil Bravo 81W	3 lbs.	-	1	Late blight Early blight Gray leaf spot Target spot	
	Ridomil MZ58 WP	2 lbs.	-	5	Late blight	
	Benlate 50WP	1 lb.	-	1	Leaf mold Botrytis Sclerotinia	

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[1] Do not exceed limits of mancozeb active ingredient as indicated for Dithane, Penncozeb, Manex II or Manzate 200 (e.g. 16.1 lbs. a.i. for Dithane M45 80WP equals 21 lbs. of formulation for Dithane M-45 or 33.5 lbs formulation of Ridomil MZ-58.

Crop	Chemical	Maximum Rate/Acre/ Appl.	Crop	Min. Days To harvest	Pertinent Diseases	Select Remarks
Tomato (Cont'd)	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.[1]		7	Late blight	

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[1] Maximum/crop is 3.0 lbs. a.i. of metalaxyl from Ridomil/copper, Ridomil MZ58, & Ridomil Bravo 81W

University of Florida - USDA Research on Pesticide Residues and Cultural and Handling Practices for Fresh Fruits and Vegetables.

There is increasing public and government concern over the use of chemical pesticides on fresh fruits and vegetables. Although there have been some recent programs to identify how much and what kind of pesticides growers and packers are actually using on food crops, none of these have tried to relate cultural and handling practices to the occurrence of pesticide residues in food. We at the University of Florida, in conjunction with the U.S. Department of Agriculture, are embarking on a study that we hope will begin to address these issues. The potential benefits of a study of this type could be two fold. First, it could help determine if the occurrence or lack of residues on tomatoes and other fruits and vegetables is in fact related to factors or practices that are under the control of growers or packers. Secondly, if it is found that residues are related to certain growing and handling practices, then it may be possible to identify how these practices could be modified or substituted to reduce the residue levels without substantially disrupting yields or the cost of production.

In order to achieve these objectives and benefits, we will need the cooperation of those of you in the industry. With the assistance of the Florida Agricultural Statistics Service we will soon begin surveying growers and packers in the state about the general and specific cultural and handling practices they used during the 1990-91, 1991-92 and 1992-93 seasons. Once these surveys have been completed, the data will be aggregated and statistical procedures will be employed to determine if any relationship between cultural practices and residues exist.

One of our primary concerns in the development of this survey was to make the questionnaire as short and simple as possible. Hopefully this means that it will require less than 30 minutes to complete. The purpose of this study is to relate cultural and handling practices to residues at an aggregate level. It is not our purpose to link the actions of individual growers or packers to the occurrence of residues. The cooperation of growers and packers is essential to the success of this study. We welcome any questions you would care to share with us on the issue.

Richard Kilmer
Professor & Graduate Coordinator
Food & Resource Economics
University of Florida
P.O. Box 110240
1189 McCarty Hall
Gainesville, FL 32611-0240
telephone: 904-392-2297

Tom Stevens
Visiting Assistant Professor
Food & Resource Economics
University of Florida
P.O. Box 110240
1094E McCarty Hall
Gainesville, FL 32611-0240
telephone: 904-392-5036

UNIVERSITY OF
FLORIDA

Institute of Food and Agricultural Sciences