PRO 519

2002 Florida Tomato Institute

PROCEEDINGS

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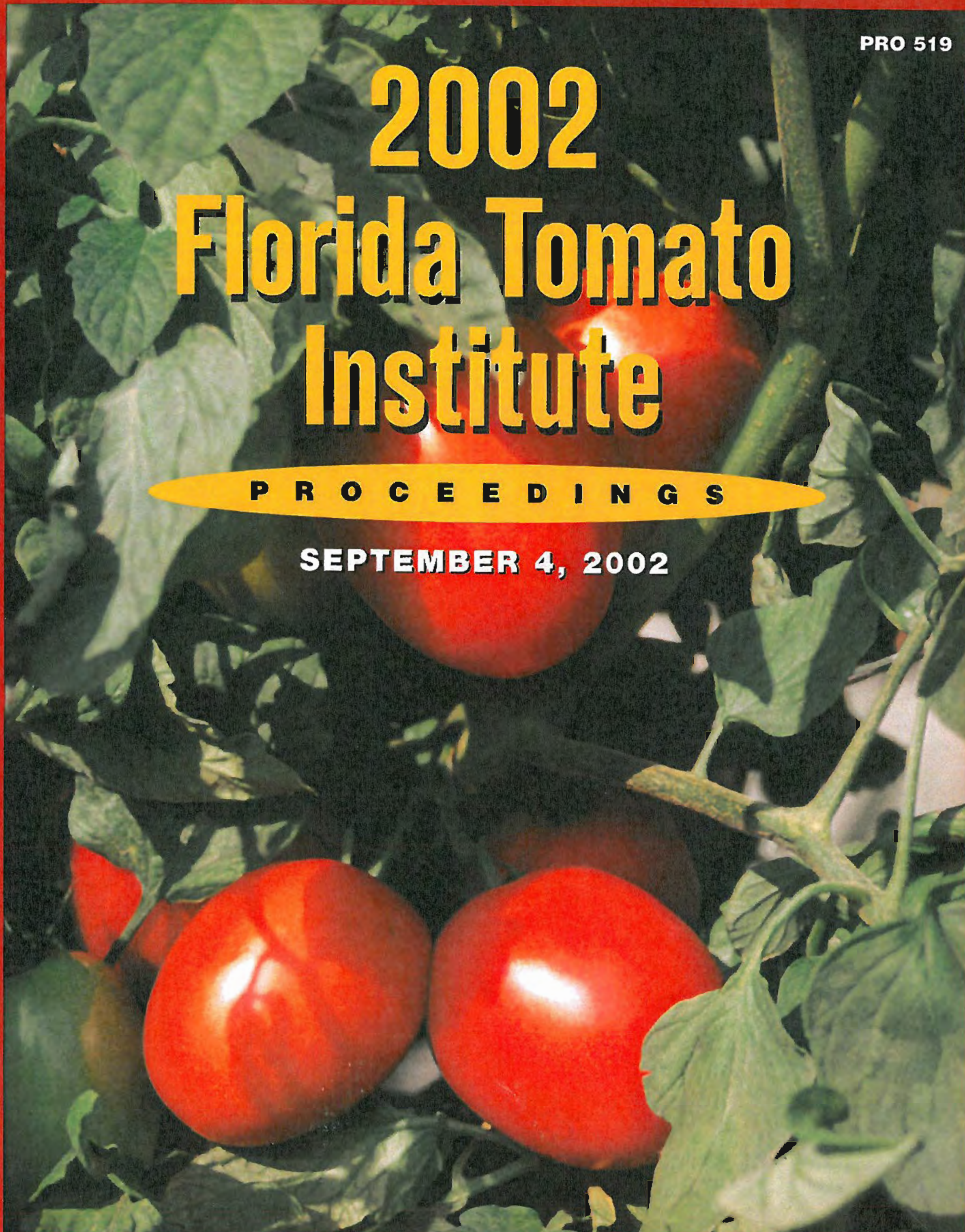

Citrus & Vegetable MAGAZINE

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2002 Tomato Institute Program

Ritz Carlton • Naples, Florida • September 4, 2002

a.m. *Moderator: Ed Hanlon, Center Director, SWFREC, UF, Immokalee*

8:45 **Welcome:** Charlie Vavrina, SWFREC, UF, Immokalee

8:50 **Opening Remarks** - Mike Martin, Vice President for Agriculture and Natural Resources, UF-IFAS, Gainesville

9:00 **Tomato Wars** - Reggie Brown, Florida Tomato Committee, Orlando

9:15 **Pest Management Trends in Spanish Greenhouse Tomatoes** - Phil Stansly, SWFREC, UF, Immokalee; Alberto Urbaneja, Koppert Biological Systems S.L., Aguillas (Murcia) Spain, **pg. 2**

9:35 **Update on Tomato Flavor** – Elizabeth Baldwin, USDA-ARS, Winter Haven; John Scott, UF, GCREC, Bradenton, **pg. 7**

9:55 **Food Safety Education and Implementation Program for Florida Produce** - Galen Frantz and H. Charles Mellinger, Glades Crop Care, Jupiter, **pg. 15**

10:15 **Total Maximum Daily Loads (TMDLs), Best Management Practices (BMPs): What They Mean to The Future of Farming in South Florida -** Bill Bartnick, FDACS, Tallahassee, David Neill, Triangle Farms, Ft. Pierce, **pg. 17**

10:45 **The Methyl Bromide Critical Use Exemption Submission for Florida Tomatoes** - Mike Aertz and Dan Botts, FFVA, Orlando, **pg. 18**

11:15 **Addressing Microbial Hazards in Tomato Fruit after Harvest** - Jerry Bartz, Plant Pathology Department, UF, Gainesville, **pg. 21**

11:35 Lunch

p.m. *Moderator: Gene McAvoy, Hendry County Extension Service, LaBelle*

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

2:00 **Project Status and Possible Variety Releases from the IFAS Tomato Breeding Program** - Jay Scott, GCREC, UF,Bradenton, **pg. 25**

2:20 **Tomato Yellow Leaf Curl Virus : Breaking the Cycle** - Jane Polston, GCREC, UF, Bradenton, **pg. 29**

2:40 **Management of Tomato Spotted Wilt Virus and its Vector, Thrips** - Steve Olson, Tim Momol, Julie Stavisky and Joe Funderburk, NFREC, UF, Quincy, **pg. 34**

3:00 **Integrated Management of Bacterial Spot on Tomatoes** - Tim Momol, Steve Olson, Paula King, NFREC, UF, Quincy; Jeff Jones, Aleksa Obradovic, Botond Balogh, Plant Pathology Department, UF, Gainesville, **pg. 39**

3:20 **Perspectives on a Decade of Late Blight in Florida Tomatoes (and Potatoes)**- Pete Weingartner and Denise Tombolato, Plant Pathology Dept., UF, Gainesville, **pg. 42**

3:40 **Update on Insecticides for Whitefly & Leafminer Control** - Dave Schuster and Sandra Thompson, GCREC, UF, Bradenton; Phil Stansly and Jim Conner, SWFREC, UF, Immokalee, **pg. 51**

4:00 Adjourn

Control Guides:

Water Management for Tomato – Eric H. Simmone, Horticultural Sciences Department, UF, Gainesville, **pg. 61**

Fertilizer and Nutrient Management for Tomato – E.H. Simonne and G.J. Hochmuth, Horticultural Sciences Department, UF, Gainesville, **pg. 64**

Chemical Disease Management for Tomatoes – TomKucharek, UF, Plant Patholgy Dept., Gainesville, **pg. 70**

Nematicides registered for Use on Florida tomatoes – Joe Noling, UF, CREC, Lake Alfred, **pg. 73**

Weed Control in Tomato – William M. Stall, Horticultural Sciences Dept., UF, Gainesville; James P. Gilreath, CREC, Bradenton, **pg. 74**

Tomato Varieties for Florida – Donald N. Maynard, UF, CREC, Bradenton; and Stephen M. Olson, UF, NFREC, Quincy, **pg. 79**

Selected Insecticides Approved for Use on Insects Attacking Tomatoes - S. E. Webb, UF, Gainesville; P.A. Stansly, Immokalee; D.J. Schuster, Bradenton; and J.E. Funderburk, IFAS Gainesville, **pg. 83**

Pest Management Trends in Spanish Greenhouse Tomatoes and Prospects for Biological Control of Whiteflies

Phil Stansly[1], and Alberto Urbaneja[2],
[1]University of Florida, Immokalee,
[2]Koppert Biological Systems S.L., Aguilas (Murcia) Spain

Spain is a major tomato producer that harvested 3.7 million tons (296 million 25 lb boxes) from 147,000 acres in 1998. Almost 40% of this production consisted of fresh market tomatoes grown in greenhouses on the southern Mediterranean coast in the communities of Andalucía and Murcia. Approximately 58% of these tomatoes were exported, primarily to northern Europe.

Transplanting in greenhouses begins in late summer with a possible additional planting in late winter. Harvesting begins in October, peaks in March but continues through early summer. The best prices usually occur in winter when there is little competition from greenhouses in Northern Europe or elsewhere. Spanish production methods are steadily improving, principally through upgrading of greenhouses from traditional low roofed structures little more than grape arbors covered with polyethylene film, to large, high-roofed, multiple units often provided with automatically controlled heating and ventilation, that may be fitted with pest-excluding screen. Nevertheless, attitudes can favor a strategy of low costs rather than expensive inputs to improve yield and quality. Consequently, there are several quality issues, including pesticide use, of concern to consumers and inherent in the annual shift in northern Europe from local sources to tomatoes and other vegetables from southern Europe and North Africa.

As in most of the hot regions of the world where tomatoes are intensively cultivated, the whitefly *Bemisia tabaci* is a key pest, due primarily to its role as virus vector. Southern Spain is plagued by two types of tomato yellow leaf curl virus (TYLCV), Israeli and Sardinian, as well as the chlostroviruses tomato chlorosis virus (ToC) and cucurbit vein yellowing virus (CVYV), the latter only on cucurbits. Curiously, although biotype "B" or *B. argentifolii* has been detected in southern Spain and may still be present, it has apparently been displaced by the native biotype "Q". "Q" is a worth adversary, perfectly happy on pepper, and a better transmitter of TYLCV than "B" that just as quickly develops resistance to pesticides. Cultural practices in Spain also lend themselves to whitefly and virus problems, with overlapping crop cycles, and enclosed pest populations that favor rapid selection for resistance. It is little wonder that everything but the kitchen sink is constantly being thrown at the whitefly, and that resistance to imidacloprid first reared its ugly head in Spain.

Against this background it might seem like madness to think about biological control which admittedly can do nothing against the incoming vector. Yet the pressure is on from the buyers to reduce pesticide use and provide at least a portion of the produce using IPM methods that include only natural enemies and "soft" chemicals. Fortunately, most growers are already conditioned to use soft insecticides because of the almost universal practice of bumblebee pollination. Nevertheless, the success of biological control depends on limiting the impact of primary virus spread from outside sources through the use of one or a combination of tactics. These tactics include TYLCV-resistant (tolerant) varieties, whitefly-excluding structures, and late planting dates that avoid the bulk of migration from the previous season's crop. Alone or together these tactics can create a sufficient safety net against virus to contemplate the use of biological control.

The first success of biological control in the region came in pepper, especially in the Cartegena area where crops are planted in late fall or early winter. This cropping system allows enough time early in the crop cycle for establishment of the necessary beneficials including, in addition to *Eretmocerous* for whitefly control, the mite *Amblyseis cucumeris* and the minute pirate bug *Orius laevigatus* that effectively control the key pest, western flower thrips. Still, there had been sufficient interest for Koppert Biological Systems, the principal supplier of bumblebees and natural enemies in the region, to develop a technical plan for biologically based IPM in tomatoes. The objective of this large project was to test this plan under a variety of commercial conditions. Nineteen greenhouses were identified for the study, covering all the main growing areas for protected tomato production (**Fig. 1**). Twelve of the 19 were designated as IPM, meaning that biological control would be used. The remaining 7 used only conventional (insecticidal) control (**Fig. 1**). Ten of the greenhouses were included in one of 5 IPM/conventional (grower standard) sharing location and growing practices except for the pest management system. Pests and diseases were monitored weekly by the designated Koppert technician. All pesticide applications were noted. In addition, leaf samples were taken, observed under a binocular microscope, and incubated to collect parasitic wasps that were later identified.

The core of the technical plan for tomato first depended on whitefly control using a species of parasitic wasp *Eretmocerus eremicus*, originally imported from America, and reared by Koppert in Holland on the greenhouse whitefly, *Trialeurodes vaporariorum*. However, observations in Almería and Cartagena had shown that *E. eremicus* was sooner or later displaced in both tomato and pepper by a native species coming in from outside, *E. mundus*. These observations led to the decision by Koppert to develop a rearing program in Spain for *E. mundus* on using *B. tabaci* as a host. Additional natural enemies used in the plan included the plant bug *Macrolophus caliginosus*, also for whitefly control, a tomato race of the mite *Phytoseilus persimilis* for spider mites, and *Diglyphus isaea* for leafminers. The choice of pesticides used if necessary was based on the Koppert Side Effects Guide (www.koppert.com).

Work on the rearing system for *E. mundus* progressed rapidly, and 3 weeks into the project enough became available to incorporate it into the project. The greenhouses had already been divided into 4 equal sectors for monitoring purposes, so we released *E. mundus* in two diagonally opposed sectors and *E. eremicus* in the other two sectors. Release rates were the same for both species and determined by the technician, generally 3 wasps/m^2/week during 5 to 8 weeks.

A wide variety of broad-spectrum insecticides, selective insecticides and fungicides were used in the greenhouses studied (**Table1**). The Koppert Side Effects Guide (www.koppert.com) was used to estimate impact of pesticide applications on natural enemies. The guide provides 3 numbers that were summed to provide an "incompatibility rating". One number from 1 (none) to 4 (severe) rates side effects on pupae of *E. eremicus* or the another closely related species. Another number, also from 1 to 4, rates effects on adults. The third gives the number of weeks (from 0 to 12) of residual effect. Incompatibility ratings ranged from 2 to 18 and averaged 16.1 for broad-spectrum insecticides, 4.6 for selective insecticides and 2.8 for the fungicides used in the greenhouses studied. Incompatibility ratings for all applications made in a greenhouse were divided by the number of weeks the greenhouse was monitored (usually through harvest) to obtain a biocontrol incompatibility index for each greenhouse.

Applications of pesticides were almost 70% more frequent and twice as many products were used in conventional greenhouses compared to IPM greenhouses, (**Table 2**). Broad-spectrum insecticides constituted 21% of the products used in conventional greenhouses compared to 11% in IPM greenhouses. Seven of 12 IPM greenhouses did not use any broad-spectrum insecticides. The biocontrol incompatibility index was almost 3 times greater in conventional greenhouses compared to IPM greenhouses. IPM growers were more likely provide themselves with an additional margin of safety by using TYLCV-tolerant varieties (5 out of 12) compared to only one conventional grower.

Incidence of parasitized pupae of *B. tabaci* averaged 50.7% in IPM greenhouses compared to 2.2% in conventional greenhouses. *E. mundus* accounted for 85% of all *Eretmocerus* species recovered from *B. tabaci* with *E. eremicus* bringing up the remaining 15%. In general, *E. mundus* only failed to become established where the incompatibility index exceeded 5. The only exception was Motril3 where large numbers of whiteflies were constantly coming in from outside (average 60/trap/week) maintaining high populations on plants despite broad-spectrum insecticides used early in the crop cycle and high levels (80-90%) of parasitism later.

Whitefly numbers were similar and generally low in IPM and conventional greenhouses used for comparison (**Table 2**). In spite of the overall differences in pesticide use, there was not always a contrast within IPM/conventional pairs. For example the two greenhouses at Cañada1 were both new and tightly sealed against insects. Consequently there were few insect pests including whiteflies and almost no pesticide use in either. Mean incidence of parastiized pupae on leaf samples from the IPM greenhouse was 28.8 compared to 2.1, in the conventional greenhouse where no parasites had been released. However, insufficient ventilation resulted in late season fungus problems, mostly due to *Botrytis*, and considerable fungicide was used. At Motril2 the grower's strategy was to use broad spectrum pesticides early in the crop cycle and biological control later backfired when virus problems persisted and considerable amounts of pesticides continued to be used in both greenhouses. Parasitism was low at about 3% in both greenhouses and levels of whitefly infestation similar in both.

In contrast to these two examples, tank mixes applied in 22 applications at the conventional greenhouse Aguilas1 brought the total broad-spectrum products applied up to 41 whereas none were applied at the IPM greenhouse in the same location. Estimated incidence of parasitized *B. tabaci* in the IPM greenhouse was 43% compared to nothing in the conventional greenhouse. Two major influxes of whiteflies were registered in weeks 40 and 43 (**Fig. 2**). As likely a result, ten times more *B. tabaci* were seen in week 44 on leaves in the IPM greenhouse compared to the conventional greenhouse. Nevertheless, when the trial was ended at week 50 the situation had reversed, with almost 5 times more *B. tabaci* observed on leaves in the conventional greenhouse compared to the IPM greenhouse.

These and other examples made it clear that:

- While Spanish tomato growers have traditionally relied heavily on broad-spectrum pesticides to control insect and mite pests, trends are toward more diversified management systems that include tolerant varieties, pest-excluding structures, selective pesticides and increasingly, biological control.
- Whitefly populations were comparable between IPM/conventional greenhouse pairs despite fewer applications and softer pesticides used in IPM greenhouses.
- *E. mundus* was better able to become established than *E. eremicus* on the key pest, *B. tabaci* in tomato greenhouses, where it appeared to contribute significantly to control of *B. tabaci*, provided the incompatibility index for pesticide use was not above 5.
- Continued movement toward tolerant varieties and screened greenhouses should reduce the risk from TYLCV, raising the tolerance level for whitefly and further opening the door to biological control in protected tomato production of southern Spain.

Fig. 1. Study location with number and management system of greenhouses monitored in each.

Location	IPM	Conventional
Mazarrón	2	
Aguilas	2	1*
Cañada	2	2*
El Ejido	1	1*
Motril	4	1*
Gran Canarias	1	
Tenerife		
Total	12	

* Paired comparisons.

Fig. 2. Numbers of whiteflies captured on yellow sticky traps and on plants in two greenhouses at the same location using identical growing conditins except for the pest management system.

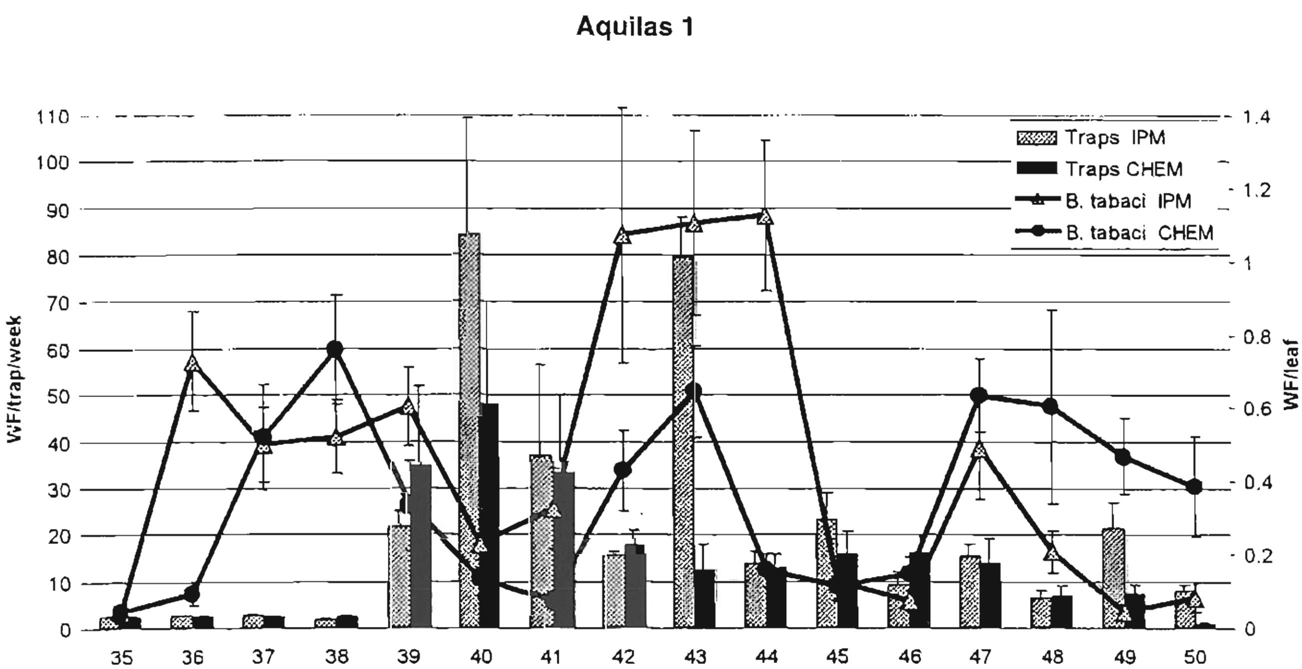

Table1. Pesticides used in greenhouses under study and side effects ratings of: (1) harmless, (2) slightly harmful, (3) moderately harmful, or (4) very harmful from (http://www.koppert.nl/) summed for pupae and adults *E. eremicus* or the closest other species plus mean number of weeks of residual effect.

Broad Spectrum Insecticide	Incompatibility Rating*	Selective Insecticide (w) targeted whitefly	Incompatibility Rating*	Fungicide	Incompatibility Rating*
Asephate	15	Abamectine	8	Benomyl	2
Bifentrin	18	Amitraz	8	Bromopropylate	2
Chlorpyrifos	17	Azadiractin	4	Captan	2
Cypermethrin	18	*B. thuringiensis*	2	Carbendazim	3
Deltametrin	18	Buprofezin (w)	3	Clorothalonil	2
Endosulfan	15	Cyromazine.	2	Copper	2
Fenitrotion	14	Fenbutatin Oxide	2	Cymanazil	5
Fenpropatrin	18	Flufenoxuron	8	Cymoxanil	3
Imidacloprid (foliar)	10	Heptenofos	8	Cyproconazol	3
Malathion	18	Hexithiozox	3	Cyprodinil	2
Methomil	16	Imidacloprid (soil)	5	Dimethomorph	3
Oxamil (foliar)	18	Lufenuron	4	Dinocap	6
Tau Fluvalinate	14	Oxamil (soil)	5	Fludioxonil	2
Tralometrine	16	HMO*	4	Folpet	2
		Potassium Soap	4	Iprodion	2
		Pymetrozine	3	Mancozeb	2
		Pyridaben	8	Metalaxil	3
		Pyriproxyfen	5	Metiram	6
		Tebufenpyrad	3	Myclobutanil	2
		Teflubenzuron	2	Nuarimol	3
				Nuarimol	3
				Procimidon	2
				Procloraz	2
				Propamocarb	2
				Pyrimethanil	2
				Sulfur	7
				Thiofanate Methyl	2
				Tiram.	4
				Triadimenol	2
				Vinclozolin	2
				Zineb	2
Average	16.1		4.6		2.8

*Sum of side effects ratings for adult wasps + side effects ratings for pupae + number of weeks residual.
**Horticultural mineral oil

Table 2. Duration of study, number of pesticide applications and products included, and the number of those classified as broad spectrum insecticides, selective insecticides/acarasides or fungicides, total score for all pesticides used, index of biocontrol incompatibility, numbers of whiteflies on sticky traps, and leaves and percentage pupae parasitized in 19 Spanish greenhouses.

IPM Greenhouses	Cultivar	Duration (weeks)	Applications (Nₒ)	Products (Nₒ)	Broad Spectrum (No)	Selective (No)	Fungicide (No)	Incom-patibility Score*	Index** of Incompatibility	Whiteflies (No./trap/wk)	Whiteflies No/leaf	Parasitism (%)
Ágilas1	Tolerant	17	12	28	0	17	11	77	5	21.5	0.5	43.3
Cañada1	Susceptible	22	6	9	0	2	7	25	1	7.9	0.3	28.8
Cañada2	Susceptible	28	23	25	4	3	18	116	4	7.5	2.5	41.1
El Ejido1	Susceptible	17	6	17	0	11	6	68	3	50.6	2.9	51.3
Motríl2	Susceptible	29	41	41	7	16	18	253	9	14.9	0.5	2.2
Average		22.6	17.6	24.0	2.2	9.8	12.0	107.8	4.4	20.5	1.3	33.3
Comparative Conventional Greenhouses												
Águilas1	Tolerant	19	22	71	41	7	23	679	36	14.3	0.3	0
Cañada1	Susceptible	22	6	9	0	2	7	25	1	8.6	0.2	0
Cañada2	Susceptible	26	25	26	5	2	19	134	5	1.6	0.7	0
El Ejido1	Susceptible	17	14	14	0	11	3	95	6	40.4	1.8	5.5
Motríl2	Susceptible	29	48	48	10	20	18	377	13	20.6	0.5	3.9
Average		22.6	23.0	33.6	11.2	8.4	14.0	262.0	12.2	17.1	0.8	0.8
Additional IPM Greenhouses												
Ágilas2	Tolerant	16	6	14	0	7	7	48	3	88	2.7	50.4
Tenerife	Tolerant	20	6	20	0	5	15	64	4	25.4	1.2	84.6
Mazarrón1	Tolerant	23	5	10	0	2	8	26	1	1.6	0.2	No Data
Mazarrón2	Tolerant	21	10	16	0	10	6	56	3	17	1.5	30.2
Motríl1	Susceptible	23	24	24	5	11	8	155	7	6.7	0.2	4.2
Motríl3a	Susceptible	21	21	21	6	9	6	151	7	29.4	2.3	82.9
Motríl 3b	Susceptible	20	20	20	5	10	5	149	7	47.1	3.9	90.2
Average		20.6	13.1	17.9	2.3	7.7	7.9	92.7	4.6	30.7	1.7	57.1
Additional Conventional Greenhouses												
G. Canarias 1	Susceptible	13	38	38	2	15	21	160	12	62.3	0.2	No Data
G. Canarias2	Susceptible	21	28	74	2	45	27	287	14	48.7	1.1	No Data
Average		17	33.0	56.0	2.0	30.0	24.0	223.5	13.0	55.5	0.6	

*Sum of incompatibility ratings for all products used.
**Score / weeks of monitoring

Update on Tomato Flavor

Elizabeth A. Baldwin[1] and John W. Scott[2]

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The Florida tomato industry has suffered from competition from greenhouse-grown cluster tomatoes (*Lycopersicon esculentum* Mill.) from Canada and Europe and from "vine-ripe" tomatoes from Mexico. The cluster tomatoes give the impression of "vine-ripe" and labor/production costs are low in Mexico compared to the U.S. The advantages for Florida produce over Mexican-grown fruit are technology and quality. Quality of glasshouse grown fruit has been reported to be inferior to field-grown (Delal et al., 1967) and most tomatoes grown in Mexico include the *rin* gene, which has been shown to be lower in aroma volatiles and less preferred in sensory studies compared to normal cultivars by work accomplished under previous support from the Tomato Committee (Baldwin et al., 1995, 2000). Nevertheless, these tomatoes are sold as "vine ripes" since the increased firmness allows for harvesting with color.

Repeat buys depend more on internal quality factors such as flavor and texture. However, lack of selection targets for breeders has inadvertently compromised flavor quality for tomato and other fruits. This has led to consumer dissatisfaction with tomato flavor in general. Identification of important flavor compounds would enable breeders to select for high flavor cultivars. Tomato flavor is based on sugar and acid levels, as in all fruits, but can be enhanced by a profile of desirable aromatics. Tomato flavor can also be impaired by bitter alkaloid compounds and unbalanced or undesirable aroma components. The volatile composition of tomatoes is complex with over 400 compounds, 30 of which are present in concentrations of ≥ 1 part per million (ppm), and 16-20 of those that show odor activity (based on odor threshold) (Buttery, 1993). Previous years of work has led us to believe that the *rin* gene reduces aroma volatile levels, cultivars with high lycopene can enhance flavor, and that a certain fruity/floral note found in tomatoes from Dr. John Scott's breeding lines could lead to development of a premium tomato variety if combined with a desirable sugar/acid balance and good horticultural characteristics.

Over the past few years, we have been studying the effect of genetic material, harvest maturity, and handling practices on tomato flavor quality. These studies, done in cooperation with students and faculty of the University of Georgia and University of Florida, as well as Syngenta Seeds, Inc., have revealed that tomato cultivars differ in flavor compounds (Baldwin et al., 1991), especially when the *rin* gene is incorporated (Baldwin et al., 2000). We also showed that aroma compounds play an important role in addition to sugars and acids in tomato flavor (Baldwin et al.1998). In addition, measurement of total soluble solids (TSS) as and indicator of sweetness in tomato fruit does not relate significantly to sensory data for sweetness perception. The ratio of TSS to titratable acidity (TA) or of sucrose equivalents (SE)/TA better correlates to human perception of sweetness in tomatoes (Baldwin et al., 1998). This is because the acidity level affects perception of sweetness, and SE is derived from an actual measurement of individual sugars, whereas TSS contains compounds other than sweet sugars (cell wall material, acids, etc.).

The most important information is that of the starting genetic material, since this cannot be improved upon after harvest. However, the effect of preharvest environmental conditions, harvest maturity, and postharvest handling practices (i.e., temperature abuse) can degrade the quality inherent in the genetics. In these studies we have seen that immature green tomatoes do not ripen with the acceptable quality as do mature green fruit. In addition, mature green fruit ripen with similar quality to breaker and turning fruit, and contain similar levels of flavor compounds. Therefore, there is not much advantage to harvesting with color, except to insure elimination of the immature green fruit that are responsible for inconsistent flavor quality in the commercial gas/green tomato product.

This explains some of the dissatisfaction that consumers have with the flavor of fresh tomatoes purchased in the supermarket. We also saw that chilling abuse reduced levels of flavor volatile compounds and that a difference in flavor quality was noted by trained panelists between chilled and non-chilled fruit (Maul et al., 1999). We are in the process of determining the important flavor compounds (and ratios of compounds) in tomato fruit that are responsible for fresh 'tomato-like' flavor or undesirable off-flavors. A greater understanding of the compounds that comprise a desirable tomato aroma profile, and a greater understanding the biological pathways involved, would give breeders and molecular biologists a target for genetic manipulation for improved flavor cultivars.

Materials and Methods

For the quality trials at GCREC, tomato (*Lycopersicon esculentum* Mill.) cultivars were grown in a completely randomized block design with three blocks and ten plants per plot over numerous seasons (fall and spring crops, and occasionally at Homestead for a winter crop; 1999-2002). Cultivars, were sampled in the field from three blocks, and informally evaluated for flavor by 2-6 people. From this screening, generally, 6-10 cultivars were selected for sensory and instrumental/chemical analysis to represent a range in flavor for normal tomatoes for comparison to the best *rin* hybrids in the field, transgenic fruit (UC82B transaminase), high pigment (crimson) tomato cultivars, and tomato lines selected for a fruity/floral aroma character. Other fruit were grown in statistical plots, replicated over the growing season 3 times in Naples by Syngenta Seeds, Inc.

Experienced sensory panels. For the experienced panel, the 6 to 10 cultivars were evaluated that represent a range in tomato flavor quality, the best tasting *rin* hybrids, and some transgenic fruit for spring '98. The fruit were harvested at stage 6 maturity and brought to the laboratory for sensory analysis by an experienced panel of 25+ participants. The panelists were served a sample representing at least 3 to 4 fruit cut in wedges. The samples were coded, sampled by panelists in random order and rated for overall flavor, sweetness and sourness on a 9 point scale (9 = highest intensity, 1 = lowest), with unsalted cracker and water taken between samples. Subsamples were also taken and immediately homogenized for chemical analysis (Baldwin et al., 1998).

Trained panels. Samples from the three different plots that showed a range of flavor characteristics were harvested and transported to Gainesville, FL. In other studies the fruit were shipped to Athens, GA, or remained in Winter Haven, FL (Syngenta Seeds, Inc.), depending on the year, for analysis by an 8- 15-member trained descriptive panel whose panelists had been trained to identify, measure and monitor numerous characteristics in fresh tomatoes using a 15 cm line scale (15 cm = highest intensity, 0 = not detected). Previous training and other data had shown that these panels were able to successfully differentiate among fresh tomato samples representing different genetic material, maturity, and/or storage conditions. Just prior to sensory analysis, samples were coarsely chopped into a puree using a food processor. Panelists were served 40-50 g of tomato puree in 114 mL plastic cups, sealed with lids and labeled with a two-digit random number. Panelists were instructed to open the lid of each sample, rate its aroma, and then proceed with the flavor and taste descriptors. Subsamples were taken for chemical analysis including by gas chromatography (GC), gas chromatography-olfactometry (GCO), high pressure liquid chromatography (HPLC), and electronic nose (E-NOSE).

Chemical flavor analysis. Composite subsamples (3 samples/cultivar), representing parts of 5 fruit (from 3 field plots) that were sampled by the panel were blended, held 180 s and processed as described previously for volatile, soluble solids (SS), pH, and titratable acidity (TA) (Baldwin et al., 1991, 1992). Volatile components that are abundant, or that have been reported to have significance for tomato or other fruit flavors (Baldwin et al., 1992; Buttery and Ling 1993a,b; Buttery et al., 1989) were analyzed including: acetone, methanol, ethanol, 1-penten-3-one, hexanal, *cis*-3-hexenal, *trans*-2-hexenal, 2+3-methylbutanol, *trans*-2-heptenal, 6-methyl-5-hepten-2-one, *cis*-3-hexenol, linalool, -nitro-2-phenylethane, geranylacetone, phenylethanol, 2-isobutylthiazole, and β-ionone. Some of these volatiles are considered to be important because of their high odor units (Buttery and Ling, 1983a,b; Buttery et al., 1989).

Color measurements. Color measurements were determined using a Minolta CR-300 Chroma Meter. External color was taken in the equatorial plane of the fruit, and internal color was a composite of three locations to determine the red-ripe stage for sampling. There were 10 fruit per genotype per block sampled. 'L' measures color where higher numbers indicate a lighter color, higher 'a' values indicate more red color, while higher 'b' values indicate more yellow/green color, and the 'a/b' ratio indicates relative red color where higher numbers indicate greater redness.

Firmness and shelf life determinations. For spring '98 fruit, firmness was measured with a pressure tester with a 1 kg (2.2 lb) weight and a 1.5 cm (0.6 in) contact plate for 5 seconds. The contact plate was placed over locules in 10 fruit per genotype per block. Lower values indicate firmer fruit. Ten fruit per genotype per block per harvest maturity (turning or table ripe stage, stage 3 or 6) were run over a tomato grader and brought into the laboratory where they were stored at ambient temperature (~75°F) until unacceptable for marketing. The maximum shelf life was 18 days.

Results and Discussion

Over the past few years, we have established that harvest maturity (Maul et al., 1998), storage temperature (Maul et al., 1999), and genetics (Baldwin et al., 1991, 2000) are the major reasons for poor quality tomato flavor. These studies have been done in cooperation at the USDA lab in Winter Haven, University of Florida tomato breeding program in Bradenton, and postharvest and food science faculty and students at the University of Florida Horticulture and Food Science Departments in Gainesville and the Food Science Department at the University of Georgia. Of special importance to the Florida industry, we have shown that incorporation of the *rin* gene can result in flavor problems in the resulting hybrid lines, even in fruit harvested with color (Baldwin et al., 2000).

Color data (not shown) indicated that that the commercial *rin* showed less red color than the other cultivars, while the Fla. 7060 *rin* was not significantly different from 'Solar Set' and statistically more red than the Fla. 7060 parent. On the other hand, the *rins* showed less deformation (data not shown), while the commercial *rin* fruit exhibited 12.2 days shelf life, almost twice as long as the 7060 *rin*, almost three times that of 'Solar Set', and almost six times that of Fla. 7060. Meanwhile, the 7060 *rin*, showed almost three times longer shelf life compared to the Fla. 7060 parent. So, even though these two *rin* hybrids did well in the sensory study, the commercial *rin* had low color and the 7060 *rin* did not show significantly longer shelf life compared to 'Solar Set'. This demonstrates the difficult situation with *rin* hybrids. The *rin* gene needs to be put into high flavor, color and firmness backgrounds to achieve acceptable flavor, color and shelf life extension.

High lycopene tomatoes may garner health benefits due to the anti-oxidant, anti-cancer activity of lycopene (Nguyen and Schwartz, 1999). Furthermore, lycopene breakdown products, such as β-ionone, are important flavor compounds and the high color makes for attractive fruit. This means that high lycopene cultivars may result in better flavored, better looking, and more healthy tomatoes (Buttery and Ling, 1993a,b; Buttery et al., 1999; Nguyen and Schwartz, 1999), and may compensate for the lower color and aroma associated with *rin* hybrids when crossed with them (the crimson gene og^c and og^c x *rin*) (Baldwin et al., 1991, Baldwin et al., 2000).

In conclusion, the best tomato flavor is a balance of sugars, acids and volatiles. More volatiles are generally desirable if they are in the right proportion. As we have seen before, solids do not necessarily relate to sweetness in tomato. The *rin* gene lowered volatile synthesis in the lycopene-*rin* hybrid compared to the lycopene parent and insertion of the *rev* gene did not result in higher sugar levels. The high lycopene tomatoes generally did well in sensory analyses. Nevertheless, all genetic improvements can be mitigated by preharvest environmental factors, harvest maturity and temperature abuse during storage.

Acknowledgements

We would like to thank Dr. Kawal Tandon, Dr. Fernando Maul, Ms.Margery Einstein, Ms. Karen Pritchett, and Ms. Holly Sisson for their advice and technical assistance. This work was partially funded by the Florida Tomato Committee and through a CRADA with Syngenta Seeds, Inc.

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Table 1. Experienced taste panel (37 people) evaluation of selected tomato genotypes grown at Bradenton, Florida in spring 1998.

Genotype	Sweetness[z]	Sourness[z]	Overall Flavor[y]
Fla. 7859	5.6 a[x]	4.5 ab	6.1 a
Exp. Seed Co. *Rin*	5.1 ab	4.6 ab	5.8 ab
Fla. 7060	4.9 ab	3.8 ab	5.3 bc
(7060^2 *rin* X 7060)	4.8 b	4.9 b	5.2 bc
UC82B	4.1 c	4.1 a	4.7 c
UC82B-deaminase	3.7 c	4.3 a	3.5 d

[y]Rated on a 1-9 scale where 1 was poor and 9 was excellent.
[x]mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

Table 2. Trained descriptive panel analysis of 1999 fall tomato fruit courtesy of Dr. Rob Shewfelt and Dr. Kawal Tandon of the University of Georgia.

TRAINED PANEL DESCRIPTORS FALL '99			
BREEDER COMMENTS	CULTIVAR	SWEETNESS	TOMATO-LIKE
Bitter, sour, terrible	201	25.0	40.6
Sweet, medium sour	207	31.6	50.3
Bland	212	20.78	44.7
Solar Set - balanced	215	29.0	48.1
Fla 7859 - high lycopene	216	24.5	54.7
Florida 47 - industry standard	217	24.9	44.1

^{z}Rated on a 150mm line scale where 1 was low intensity and 150 was high

Table 3. Consumer panel for 1999 fall tomato fruit courtesy of Dr. Rob Shewfelt and Dr. Kawal Tandon of the University of Georgia.

CONSUMER PANEL FALL '99				
	TASTES GREAT		ACCEPTABLE	
CULTIVAR (Breeder comments)	HARVESTED RED RIPE	HARVESTED BREAKER	HARVESTED RED RIPE	HARVESTED BREAKER
201 (Bitter, sour, terrible)	24.1	28.3	74.1	79.2
207 (Sweet, medium sour)	30.2	22.2	84.9	75.9
212 (Sweet, medium sour)	38.9	35.2	79.6	88.9
215 (balanced)	25.9	20.4	81.5	83.3
216 (high lycopene)	31.5	47.2	85.2	84.9
217 (Fla.47 - industry std)	33.3	34.0	94.4	94.3

Table 4. Experienced Panel spring 2000

CULTIVAR (Breeder comments)	SOURNESS	SWEETNESS	OVERALL FLAVOR
314 (Gardner - sweet)	4.24 a	4.70 a	4.87 a
308 (Solar Set)	4.26 a	4.32 ab	4.62 ab
318 (og + rin)	3.28 b	4.63 a	4.62 ab
310 (og - balanced)	4.36 a	4.16 a-c	4.51 ab
E02 (bland)	4.58 a	3.49 c	4.18 ab
E301 (terrible)	4.59 a	3.54 bc	3.81 b

[z]Rated on a 1-9 scale where 1 was poor and 9 was excellent.
[y]mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

Table 5. Cultivars evaluated in fall 2000

Cultivar, Breeder comments	Sweetness	Sourness	Flavor
319, crimson, acid	4.1 C	4.6 A	4.4 AB
339, Fla 7816 (release possible	4.1 C	3.7 BCD	3.9 AB
340, 'Solar Set'	5.1 AB	4.2 ABC	4.8 A
341, Fla. 7945 crimson	4.5 BC	3.5 CD	4.4 AB
342, *rin*/crimson hybrid	4.0 C	3.2 D	3.7 B
343, sweet	5.4 A	4.0 ABC	4.8 A

Table 6. Cultivars evaluated in spring 2000

Cultivar, Breeder comments	Sweetness	Sourness	Flavor
213, balanced sweet	4.2 BC	5.8 A	4.6 AB
223, acid, delta carotene	3.6 C	5.9 A	3.9 B
228, fruity, floral, veg	5.2 A	3.5 D	4.9 A
246, 'Solar Set'	4.8 AB	4.2 C	4.8 A
247, FL 47	4.2 BC	4.5 BC	4.8 A
248. *rin*/crimson hybrid	4.8 AB	3.5 D	4.7 AB
251. possible release	4.6 AB	5.0 B	4.9 A

Fig. 1 COLOR SUGARS ACIDS SPRING 2001

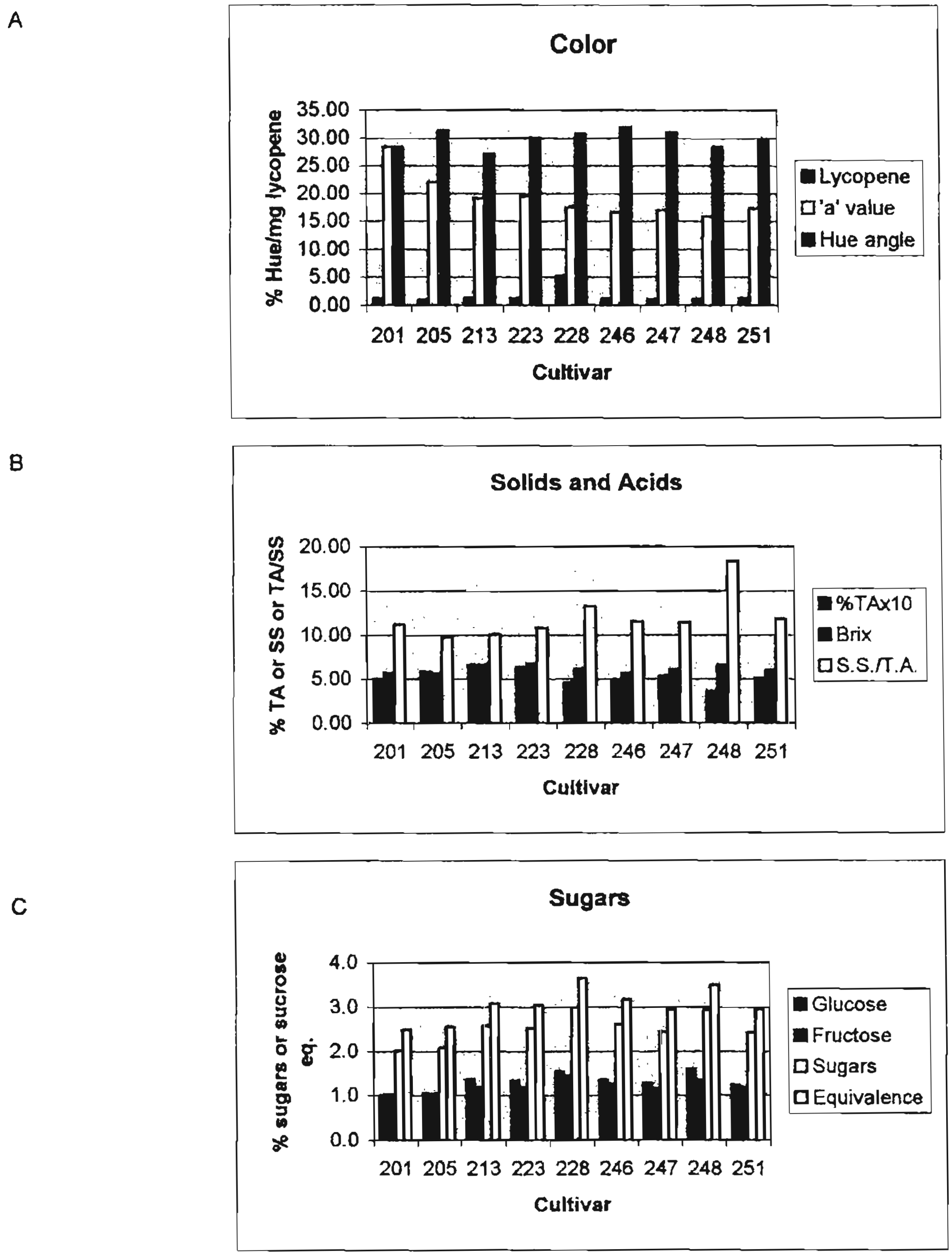


Fig. 2 VOLATILES SPRING 2001

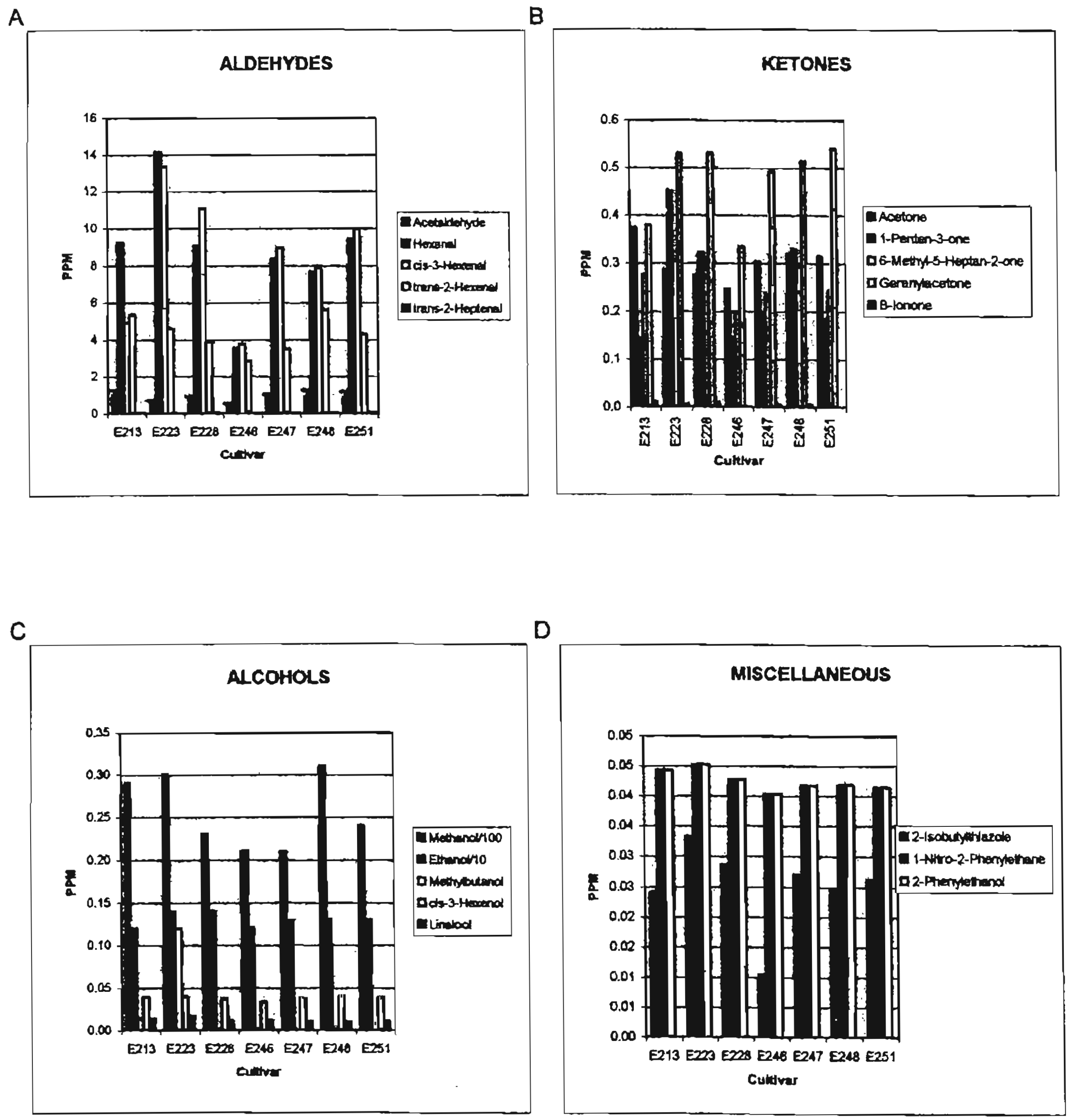
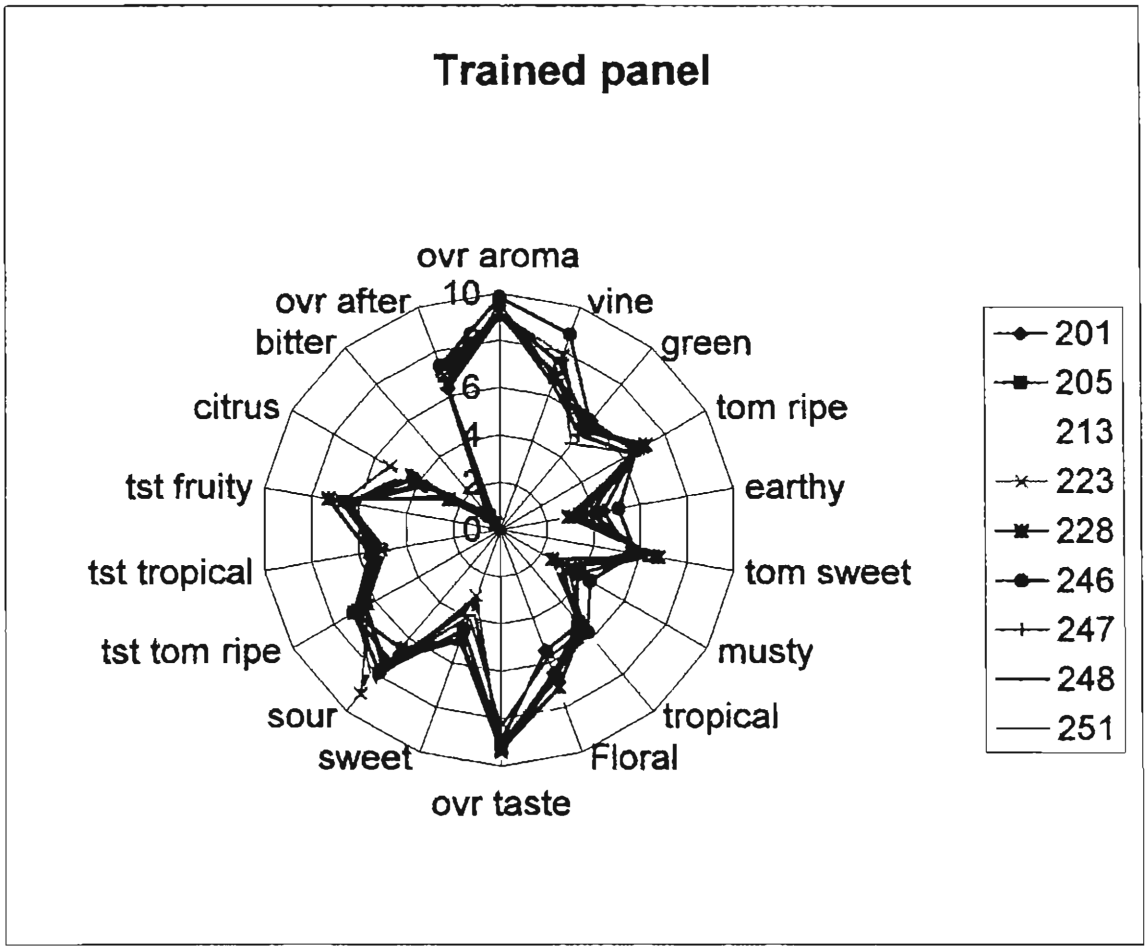


Fig. 3 Trained panel evaluation for spring 2002



Food Safety Education and Implementation Program for Florida Produce

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Glades Crop Care, Inc. (GCC) became involved in food safety about 3 years ago, when a lettuce grower client received a letter from his buyer demanding that he meet certain standards in order for them to continue doing business. The concerns of that buyer and many others since then originated from an increase in the number of food-borne illness in recent years associated with fresh fruit and vegetables.

The need for a nationwide food safety initiative came about because of several important recent trends. Foremost are the globalization of our food supply, a marked increase in fresh produce consumption, and consumer demand for a wider variety of fresh fruits and vegetables year round. Additional pressure for a high level of microbial food safety comes from the fresh cut industry, which offers an array of ready-to-eat, pre-cut salads, fruits (notably melons) and vegetables. Changes in U.S. demographics play a role; for example, a higher percentage of the population is elderly as baby boomers grow older. The elderly may have compromised immune systems or chronic diseases, and consequently, more people are especially susceptible to food-borne illnesses.

With these consumer trends, unfortunately, has come a nationwide increase in produce-related illnesses. The following figures come from *Food Safety Begins on the Farm: A Grower's Guide*, published by Cornell University as part of a national effort to develop Good Agricultural Practices (GAP's), jointly sponsored by the Cooperative State Research, Education and Extension Service, the U.S. Department of Agriculture and the U.S. Food and Drug Administration (this GAP task force includes representatives from the University of Florida and Georgia). Between 1970 and 1997 per capita consumption of fruits in the U.S. went up 24%, from 577 to 718 pounds. With this increase, however, the number of outbreaks of food related illnesses has steadily risen. Between 1996 and 2000, 113 outbreaks with 3,805 individual cases associated with produce were reported to the Food and Drug Administration.

In these outbreaks, bacterial human pathogens outnumbered other types of pathogens as the disease-causing agents. The most common of these bacterial pathogens are *Salmonella* spp. and *E. coli* O157:H7, which accounted for over 75% of produce-related outbreaks between 1988 and 1998. These bacteria belong to groups that have both human and animal reservoirs, and are also associated with fecal contamination. These facts help explain why food safety experts place great emphasis on worker health, safety and hygiene and on the management of animals, manure and other biosolids in and around farms where fruits and vegetables are grown. In fact, a farm's management of toilet facilities, handwashing stations and the cleanliness of the water used for irrigating, spraying and processing the crop can pass or fail a food safety audit. For produce run through a packinghouse or hydro-cooler, the same issues can be even more important!

But there is important good news. Recent testing by the Food and Drug Administration shows that 98.4% of the samples from U.S. production are free of microbial contamination from eight commodities. Out of 687 samples, 11 tested positive for *Salmonella* and *Shigella*. A 1999 survey of imported produce showed 94% to be free of pathogens. FDA, as of July 15, 2002 has still not decided whether to import Mexican-grown cantaloupes due to the frequent *Salmonella poona* contamination (*The Packer*, July 15, 2002).

The upsurge in produce-related illnesses prompted the FDA Center for Food Safety and Applied Nutrition and the USDA to publish their *"Guidance for Industry – Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables"*. This guidance document addresses microbial food safety hazards and good agricultural management practices used to grow, harvest, wash, sort, pack and transport fruit and vegetables sold to consumers in an unprocessed or minimally processed form. The program is voluntary and can be used by both domestic and foreign producers to help ensure the safety of their products.

Implementation of a Food Safety Program

Obviously, much attention is being paid to the auditing aspect of food safety programs. The audit results are essentially all that matters to some buyers. However, it is important to keep the audit in perspective. Passing an audit is a good thing, especially passing with a high score—but it is not the most important thing! The critical issue is the soundness and effectiveness of the entire food safety program. Whatever happens on the day of the "snapshot" audit means little if the program is not conscientiously applied every day. If we liken food safety to a Broadway production, the audit could be seen as a dress rehearsal. Good dress rehearsals only happen after lots of careful preparation and practicing. To carry this analogy a bit further, the dress rehearsal audit precedes what the producer hopes is a long run of flawless performances.

The basic steps involved in implementing your food safety program include: (1) Learn the requirements: The minimal requirements of a food safety program can be found in the publications mentioned above. Further information can be found in Federal and State regulations, which address such issues as sanitary facilities for workers and Good Manufacturing Practices for packinghouses. For many (if not most) situations, fortunately, the relevant regulations have already been identified and have been incorporated into program guidelines available from several sources. Growers and packers alike are advised to familiarize themselves with those program requirements that are relevant to their situations.

(2) Self-evaluation: The next step is to take a careful, critical look at each step in the production process to identify areas where risks of contamination occur. Evaluating water quality, worker hygiene practices and sanitation facilities is especially important, since these are the most common means of introducing contaminants to fresh produce. Operators who are unsure about what risks exist in their farms or facilities should seek outside help, not only for the initial evaluation but for identifying practical mitigation steps as well.

(3) Program implementation may be relatively easy or may involve considerable skill in managing personnel and resources as well as some expense. On-site requirements, such as properly managing biosolids, excluding animals from active production areas, cleaning and sanitation, pest control, and refurbishing walls and ceilings with old chipped or flaking paint in cold storage areas may require considerable outlay. It is advisable to prioritize which items pose the greatest contamination risks and thus demand immediate attention. Tackling the critical issues first, then addressing other details allows stepwise, economical and timely risk reduction. As practices and facilities are modified, periodic re-evaluation of the system is beneficial.

(4) Documentation: Growers and packers are already per-

forming many requirements of a good food safety program. The critical issue is whether these good practices are being documented. Such documentation may mean the difference between survival and disaster should an outbreak result in your operation being scrutinized. In the inevitable legal actions following an outbreak, documentation of every step in the process is critical to demonstrate that due diligence was exercised in safeguarding a food product. Such record keeping need not be burdensome. Logbooks and checklists need to contain all relevant information, but should also be as streamlined and easy-to-use as possible.

(5) An independent Third Party Audit is an important program component. In some situations audits are demanded by an outside party, thus allowing little preparation time. Increasingly, growers and packers are taking a proactive stance toward food safety by taking the implementation steps described above before this happens. This allows auditing to occur when an operator is satisfied that his system is functioning satisfactorily and has had his food safety system in use for some period of time. Be certain that the various logs and forms that make up the documentation process are being used consistently. At the time of an audit, operators are expected to produce their documentation and to allow a complete and thorough inspection of the farm, crew or facility.

(6) Audit reporting may take several forms. Under the PrimusLabs.com system, the audit findings are submitted on-line. The graded results are usually returned by e-mail. The grower/packer can get access to his results by e-mail, from the auditor or from PrimusLabs.com via a personalized web page arranged for by the grower/packer and maintained by Primus Labs. Alternate reporting formats may be used by other certifying organizations. However, the use of the Internet for reporting is an expanding trend. For example, the recently introduced USDA GAP/GHP Verification Program posts audit activity at their website.

(7) Certification, the use of the certifying body's logo and other privileges associated with an outstanding food safety program will also depend on the certifying body. You should establish early on exactly what level of public access to your auditing results you want, and the format that it should take. Some costs may be involved in this final aspect, and we recommend that these costs and requirements be thoroughly investigated and understood.

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The Packer. July 15, 2002. Page A3.

Total Maximum Daily Loads (TMDL), Best Management Practices (BMPs): What They Mean to the Future of Farming in South Florida

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The row crop agricultural sector comprises approximately 15% of the agricultural acreage and 35% of the farm gate sales in Florida, and includes many of the more intensive agricultural operations statewide. Given the conventional cultural practices (i.e., double cropping, plasticulture, higher vegetable synthetic fertilizer inputs), the row crop industry, which includes vegetable and field crops, is under increasing scrutiny to control nonpoint source discharges. Toward this end, TMDLs and BMPs have emerged as the principal "drivers" of state water quality efforts. TMDLs, as authorized under the federal Clean Water Act and the state's Florida Watershed Restoration Act, are by definition the maximum amount of a given pollutant that a water body can absorb or assimilate and still maintain its designated use(s). BMPs, likewise, have more recently garnered increased statutory standing, and are generally defined to mean practices based on research, field-testing and expert review to be the most effective and practicable means to improve water quality in agricultural discharges.

Under state law, TMDLs will be developed, allocated, and implemented through a watershed-based management approach that addresses the state's 52 major hydrologic basins in five primary groups, with each group scheduled to undergo a cycle of five phases on a recurring, rotating schedule. Florida agriculture is clearly affected, in that Chapter 403.067, Florida Statutes, state that in implementing TMDLs, the Florida Department of Environmental Protection (FDEP) acting as the lead administering agency is to consider non-regulatory and incentive based programs; including BMPs, cost-sharing, waste minimization, pollution prevention and public education. Given this inextricable regulatory link, BMPs have become self-implementing water quality cornerstones for agriculture, and commodity groups are rapidly scrambling to develop baseline practice coverage. The Florida Department of Agriculture and Consumer Services, working in concert with grower organizations, UF-IFAS, FDEP and water management districts, recently embarked on a mission to develop a BMP manual for the row crop industry, which heretofore has not developed a broad-based, comprehensive manual. Organizational efforts to date include the development and formation of a Steering Committee, various technical Working Groups, and a core contract to ensure BMP manual delivery.

Also germane to this presentation is a commercial vegetable grower's perspective on TMDL issues; namely, general receptivity of BMPs in production settings, economic and regulatory pressures associated with farming in increasingly urbanized, South Florida, and agriculture's efforts to date to participate in water quality improvements.

Materials and Methods

In order to formulate a BMP approach, a number of inter and intra-state BMP reference manuals were consulted, as well as other generally recognized technical guidance documents. These documents consisted of USDA-Natural Resources Conservation Service, Field Office Technical Guide (standards), Conservation Technology Information Center's "Core 4" Program, and state water management district agricultural permitting and Basis of Review criteria. Following synthesis of these materials, a Mission Statement and Model Table of Contents were produced to help guide the development and formation of the Row Crop BMP manual. The major chapters appear below and will be further amplified upon during the Tomato Institute presentation:

- Introduction: BMP History and Purpose
- Front-End BMP Decision Tree Tool
- Pest Management
- Sediment Management
- Conservation Buffers
- Irrigation and Nutrient Management
- Water Resources Management
- Seasonal or Temporary Operations
- BMP Implementation
- Accountability
- Incentive Programs Information Chapter
- Glossary
- Appendices

Results and Discussion

The ten-member Steering Committee and existing contract deliverable dictate that a camera-ready BMP manual is produced by approximately January 2003. Draft rudimentary chapters now exist for Pest Management, Irrigation and Nutrient Management, Sediment Management and Conservation Buffers. Concurrent with the development of a comprehensive Row Crop BMP manual is a recognition of candidate cost-share BMPs to be earmarked for future consideration in an "Applicant's Handbook" cost-share manual. Ultimately, TMDL, BMP and water quality success for the row crop industry will rest with the successful adoption of practices, widespread implementation and employment in TMDL impaired watersheds, selective cost-sharing of cost-prohibitive practices, and re-infusion of scientific research into BMP manuals over time.

Acknowledgements

We would like to thank the members of the Row Crop BMP Steering Committee and subordinate Workgroups for technical assistance. Partial funding for this project is provided by the Florida Department of Agriculture and Consumer Services.

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The Methyl Bromide Critical Use Exemption Submission for Florida Tomatoes

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Methyl bromide (MB) issues are already having a profound impact and weighing heavily on the minds of plastic-culture crop producers in Florida, and these issues are far from being resolved on either a local, national or international level. In fact, with the 70 percent reduction in the availability of MB taking effect at the end of this calendar year, and the 100 percent phase-out looming a mere two years from now, producers will feel an even more enhanced impact from further loss of MB shortly.

So what happens after January 1, 2005 with the complete phase-out of MB in the U.S. and other such developed countries? Will Florida producers ever again be able to use MB after that final phase-out date to help grow their crops? Realistically, things may not appear overly encouraging, except for one single possibility, that being through attainment of a MB Critical Use Exemption (CUE). At the Ninth Meeting of the Parties to the Montreal Protocol held in September 1997, in Decision IX/6, the Parties offered this "Critical Use Exemption" idea to control MB uses after the final phase-out date. It is important to note that for developed countries such an exemption, if approved, would not be effective until January 2005, and for developing countries, January 2015. For the 2003 and 2004 calendar years and corresponding production seasons, MB availability will be frozen at the 70 percent reduction level, with no option for additional MB availability.

According to the Montreal Protocol, originally signed by the U.S. and 166 other countries, exemptions from MB phase-out for critical uses are allowed, provided certain conditions are met. Those applying for a CUE must fulfill a ghastly multitude of informational requirements. Among some of the particulars: (a) the exemption will be allowed only if there are no technically and economically feasible alternatives or substitutes available to the user that are acceptable from the standpoint of environment and health, and are suitable to the crops and circumstances of the nomination; and, (b) that production and consumption of MB for a critical use will be permitted if: 1) all technically and economically feasible steps have been taken to minimize the critical use and any associated emission of MB; 2) MB is not available in sufficient quantity and quality from existing stocks of banked or recycled MB; and, 3) it is shown that an appropriate effort is being made to evaluate, commercialize and secure national regulatory approval of alternatives and substitutes.

The petition must also demonstrate that research programs are in place to develop and deploy these alternatives and substitutes. The Montreal Protocol also stipulates that users applying for a CUE must prove that a lack of MB availability will result in what was called a "significant market disruption," and that there is a true lack of "technically and economically feasible alternatives." Significant market disruption, as it is understood at this point, means that a single individual farmer could not plant that crop without having access to MB. To address potential alternatives, CUE submitters must present arguments that focus on each and every highlighted item contained in both an International Matrix of proposed alternatives, as set by the United Nations Environment Program's Technical and Economic Assessment Panel (TEAP) and the Methyl Bromide Technical Options Committee (MBTOC), and, a National Matrix of proposed alternatives, set by EPA and USDA.

TEAP issued a report in April 2001 that provided an outline of the prototype and status of the CUE process. Although originally scheduled for an "early 2002" release, EPA did not officially announce that it was soliciting applications for MB critical uses in the U.S. until a May 10, 2002 Federal Register Notice. This FR Notice stated that the government would be presenting a single, national petition to the international community, which includes the Parties to the Protocol. The extended time lag is significant in that any CUE petition submitted to EPA must now be completed and sent in on or by September 9, 2002.

After September 10, when the petitions are EPA's possession, EPA and USDA will have the daunting task of reviewing each and every U.S. petition submitted for critical use designation. EPA/USDA must complete their review by the end of 2002 and prepare the U.S. nomination to be sent to the Montreal Protocol Parties. In January 2003, the U.S. State Department will present the CUE nomination to the Secretariat, after which MBTOC will make consensus recommendations to TEAP, who will make consensus recommendations to the Parties by fall 2003. At that point, the Parties will render a decision to authorize or deny CUE petitions during their 15th meeting of the Parties, to be held by the end of 2003. From then until late 2004, approved exemptions will be formally allocated for use starting January 1, 2005.

The CUE petition process, overall, is proving to be very problematic. It is extremely difficult to understand the rationale behind many of the final procedures that found their way to the 26-page CUE questionnaire. A total lack of understanding and appreciation for the economic and production practice complexities associated with plastic-mulch culture of specialty crops for fresh market distribution from Florida is apparent. Concerns raised originally in November 2001 regarding earlier iterations of the questionnaire still exist. During public meetings sponsored by EPA and USDA for interested persons to discuss the parameters of a CUE, EPA stated that the CUE application methodology was to resemble the course of action established for requesting a Section 18 Emergency Exemption. Under Section 18 of the Federal Insecticide, Fungicide and Rodenticide Act, the EPA Administrator must determine that **an emergency condition exists.** With the CUE program, however, the applicant must demonstrate that **there are no technically and economically feasible alternatives, that associated use and emissions from MB are minimized, and that there have been and will be past and future efforts to find alternatives.** Because the criteria differ and because an international panel will review and consent to the U.S. nominations, the information needed to make a case for a CUE is significantly more detailed than what is submitted under the Section 18 program. To put it succinctly, the data collection and reporting criteria required in the CUE form do not compare whatsoever to a typical Section 18 submission. Nevertheless, in anticipation of the introduction of a CUE process, specialists representing Florida agriculture continued to participate in various CUE related meetings with staffs from both the Air Office and the Office of Pesticide Programs at EPA.

The main item emphasized in the CUEs from Florida is providing the analysis of research data to determine the economic and technical feasibility of potential alternatives at the farm level. The petitions attempt to capture the regional economic characteristics of crop production for the targeted crops. And, where possible, the petitions attempt to describe enterprise level impacts, especially where regional or crop specific differences exist. Although this type of behind-the-scenes work surrounding the CUE process has been ongoing for more than a year, the formal Florida tomato CUE petition preparation started with a meeting on May 13, a mere 3 days after publishing of the F.R. Notice. During this meeting, field researchers, ag economists, registrants, growers, commodity groups, and representatives from EPA gathered in Orlando to determine what the CUE questionnaire entailed, how the questionnaire should to be filled out, what needed to be done in order to properly fill out the questionnaire, and who/how would accomplish every detail necessary. Florida is fortunate in that we received a significant grant this year specifically to focus on MB alternatives work. A total of 13 projects were approved for funding, with three of these projects concentrating specifically on preparation of a CUE petition; one on the economic component of the petition, one on the field-level data collection component, and one coordinating the petition preparation.

The goal of the CUE process for Florida is to include all crops in the petition that can provide necessary information, to build record to support future needs, and to have direct involvement of all interested commodity groups and suppliers of alternatives. In all likelihood, a total of four CUE petitions will be submitted for Florida. One petition is specifically for tomatoes, with that petition further broken down into four subsections, to represent geographic/environmental/production practice differences of the different tomato production areas within the state. Of the three other petitions, one will be for other solanaceous crops, one will be for cucurbit crops, and one will be for strawberries. Each petition will be based on the best available information to document the "current" status. Alternatives information will be taken from a pool of more than 500 studies that analyze substitutes to MB.

The procedures followed in order to successfully generate an appropriate CUE petition are as follows:

For determining the location of MB use and pertinent personal contact information for Florida's CUE requests: Overall details surrounding the CUE are defined, including what crops are involved in the CUE, how long the exemption is being requested (3 years), and, the amount of MB being requested for the site. This work was accomplished in cooperation with impacted commodity group representatives and appropriate grower-level contacts.

To provide details on the historical use of MB as required in the CUE for individual crops, production techniques and cropping years: Specialists documented specifics on production practices, times of harvest, yields, prices and revenue received per acre. Cost particulars associated with MB utilization are documented comparing pounds of MB applied per acre, MB price per pound, the cost of applying the MB per acre, other application costs such tarps and tarping, the number of acres treated, and the overall cost per acre. Specifics on the cost of soil preparation, fertilizing, irrigation, planting, harvesting, other non-MB pest control costs, other operating costs, fixed and overhead costs are summarized comparing to costs for typical equipment used, material costs per acre, labor costs per acre, and cumulative costs per acre. In addition to the required baseline year of 2001, historical information since the announced regulatory review collected in 1995 are captured and summarized as best as possible.

For defining the feasibility of alternatives to MB: The technical support for alternatives are analyzed to provide an overview of why alternative pest management strategies are or are not effective under Florida conditions at this time. This analysis draws upon the existing trial work sponsored and carried out in Florida since 1995. Information on alternatives to MB is provided from studies that were conducted in a scientifically sound manner. Summaries of these studies include a description of the experimental methodology used, application rates, application intervals, pest pressure, weather conditions, and varieties of the crop tested. If study results are unfavorable, these results are still reported as well. Where local conditions or regulatory requirements prevent the use of proposed alternatives, this is clearly defined and documented. In addition, a detailed regime of alternative pest control practices envisioned for post-2005 crop production is projected.

Specific alternative pest controls are identified on an active ingredient by active ingredient basis as to exact pests targeted, the formulation and percent of active ingredient projected for use, the envisioned application rate per acre, the projected price per unit of the product, the estimated cost of applying the product per acre, the possible number of acres treated, the theorized number of applications, and the overall speculated cost per acre. Non-chemical alternatives are identified and described in a similar manner if applicable. Expected yields and revenues are projected on a crop-by-crop basis estimating product grades, yields per acre, farmgate prices, and final expected revenues. Costs associated with changes in operational practices resulting from having to incorporate MB alternatives in 2005 also needed hypothesizing, including equipment, material, and labor costs provided in singular and cumulative fashions.

The crops that have been identified as having the most potential for being impacted by a MB phase-out are tomatoes, peppers, eggplant, squash, cucumbers, strawberries, watermelons and ornamentals. Not considering the impact this may have on food security in the U.S., the MB phase-out will have a devastating impact on Florida agriculture, given current technology.

Because no known alternatives exist at this time that will effectively substitute for MB, Florida is estimated to lose more than $620 million in shipping point value of fresh fruit, vegetables and fresh citrus (worth more than $1 billion in total sales in Florida), and, more than 13,000 jobs. Without access to MB via a CUE, the state is projected to reduce agricultural acreage by more than 43 percent if no suitable alternatives are developed and implemented. The primary beneficiary of Florida not attaining a MB CUE will be Mexico, who as a developing country will have an additional 10 years to use MB in producing and marketing their crops. According to University of Florida research, production in Mexico is projected to increase significantly for tomatoes (80%), peppers (54%), cucumbers (7%), and eggplant (143%), all commodities in which Florida currently is the #1 U.S. producer. According to USDA, Florida agriculture accounts for about 38 percent of the pre-plant MB use in the U.S., and produces approximately 45 percent of all the fresh tomatoes consumed in this country. Florida tomato production acreage has dropped approximately 40 percent of late, largely due to competition from Mexico. Because Mexico will not phase-out its MB use until 2015, the loss of MB in the U.S. will allow this trend to continue and possibly accelerate.

The ability to generate and potentially attain CUEs for crops particularly affected by the phase-out of MB could alleviate some of the devastating impacts temporarily, until suitable technically and economically feasible alternatives or substitutes are developed. Producing CUEs is the first step in assuring that significant market disruption from lack of access to MB is avoided. Researchers and the user community have made sure that all technically and economically feasible steps have been taken to minimize any threat of tragedy. As early as January 2003, and continuing throughout the phase-out period, Florida will face the fact that MB will not available in sufficient quantity from exiting stocks. These CUEs help prove that Florida is making an appropriate effort in evaluating, commercializing, and assisting to secure regulatory approval of alternatives and substitutes.

The U.S. is *the* major user of MB worldwide. Being the major user, the U.S. request will be heavily scrutinized by the international Parties to the Montreal Protocol. Much activity surrounding efforts to find an alternative for MB has occurred and continues to be ongoing. However, to give a perspective of the mindset a Florida tomato CUE petition is up against, a report issued in 1998 by the MBTOC stated that: "Alternatives have been identified for virtually all uses of MB, and many of them are in use in different places around the world." Furthermore, the Chairman of MBTOC publicly stated, "don't waste time on CUE argument," while the TEAP Chairman still believes that "MB should have been cancelled in the U.S. in 1995 under the Clean Air Act." Even EPA admits, "it's hard for us to find allies" among the signatories to the Protocol. While there may indeed be decent replacements for MB in certain instances or circumstances, most of the replacements are still either too costly, far less effective, or are still impractical to implement on farms.

Addressing Microbial Hazards in Tomato Fruit After Harvest

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Two potential microbial hazards have been associated with fresh market tomatoes sold in the US. Direct losses due to postharvest decays have been associated with the inoculation of tomatoes by plant pathogens during postharvest handling (Bartz, 1980; Ceponis et al., 1986), whereas indirect losses have been associated with the contamination of tomatoes by certain human pathogens. Primarily due to weather conditions, occasional outbreaks of postharvest decays accompany field production of tomatoes. While postharvest decay losses are uncommon, they are not unusual, particularly during rainy periods. A theoretical, but greater risk involves the contamination of fruit by enteric pathogens of humans.

Trace-back analyses of outbreaks of certain intestinal illnesses by the US Center for Disease Control and Prevention (CDC) have implicated fresh tomato fruit as potential source of the causal pathogens. In 1993, one such trace-back led investigators to conclude that a packinghouse in South Carolina was the source of a multistate outbreak of salmonellosis (CDC, 1993; Wei et al., 1995). After a visit to the implicated packinghouse, investigators reported that it was a "modern tomato packing plant" (Memorandum, CDC "EPI-AID Trip Report: Multistate outbreak of *Salmonella* serotype *Montevideo* infections Epi-93-79-1"). Tomatoes were dumped into a warmed chlorinated bath and subsequently treated with three chlorinated and one non-chlorinated spray. The chlorine content was 40 to 60 ppm. The duration of the treatment was not mentioned nor was the water pH. Only 5% of the truckloads leaving the packinghouse were involved, which suggested a truck or receiver problem. Nevertheless, the packinghouse was implicated and a shortage of free chlorine in the dump tank was suggested as the faulty procedure.

Since then, other outbreaks have been traced back to tomato fruit. In late1998 and early 1999, *Salmonella baildon* sickened at least 85 people in several states (AMS, 1999; Susman, 1999). The tomatoes were traced to two packers in Florida and contamination of the fruit in the field by wild or domestic animals was suspected. Fortunately, the pathogen was not isolated from the tomatoes. In fact, bacteria responsible for food-borne illnesses have never been directly isolated from Florida-grown tomatoes.

The literature is clear that the pathogens responsible for various food-borne infections can be harbored by fresh tomatoes (Wei et al., 1995; Zhuang et al., 1995). The organisms could be transferred to tomatoes from various wildlife and other animals in any growing area (National Advisory Committee on Microbiological Criteria for Foods, 1999). The causal agents not only survive on fruit, but also can multiply under certain conditions (Wei et al., 1995; Zhuang et al., 1995).

Consumers expect producers to be aware of potential hazards in their products and to take steps to minimize any risk (Buzby et al., 2001; Powell, 2001). Recent legal actions document what can happen to thriving businesses that ignore or are ignorant of hazards or fail to be proactive (Buzby et al., 2001). Jack-in-the Box fast-food outlets in the Pacific Northwest in 1993 were not concerned about the emerging bacterium, *Escherichia coli* strain O157:H7, and had no reason to suspect that it would cause problems for their products. Yet, when more than 700 people were sickened and four children died due to undercooked hamburgers that had been contaminated with the organism, Jack-in-the- Box, Inc. lost more than $160,000,000 in sales over the first 18 months after the outbreak. Even false accusations by the media can cause industries millions in losses. In the spring of 1996, the California strawberry industry was falsely accused of shipping fruit contaminated with *Cyclospora cayetanensis*. The actual source was Guatemalan raspberries, however California growers suffered a loss of $20 to 40 million in sales due to the initial accusation (Powell, 2001). The potential loss of business, legal costs and other damage associated with disease outbreaks being traced to fresh produce has led supermarket and fast-food chains to demand independent audits of producers as a condition of purchase (Brasher, 2001).

Given the number of boxes of tomatoes shipped out of Florida over the years and the absence food-borne illness outbreaks actually traced to those tomatoes, one could conclude the risk of contamination is non-existent. However, as noted above, Florida tomatoes were suspected of being involved in one outbreak. Effective hazard control dictates that food industries do everything possible to produce a wholesome product and this fact must be communicated to consumers (Powell, 2001).

A major microbial hazard control step for fresh market tomatoes is having them washed with an effective sanitizer at the packinghouse. Currently, the accepted sanitation treatment is to chlorinate dump tanks and flumes at the packinghouse (Sherman et al., 1981). However, the level of chlorine required and other parameters of the treatment have never been completely established. Sherman et al. (1981) offered recommendations for controlling fruit rot pathogens in dump tanks and flumes. The water should be chlorinated to 100 to 150 ppm free chlorine at pH 6 to 7.5 and be at a temperature at least 10°C higher than that of the fruit. Based on direct tests on the sensitivity of human pathogens to chlorine (Dychdala, 1991), 100-ppm free chlorine should be more than enough to decontaminate fruit surfaces. However, Zhuang et al. (1995) reported a 1 to 10% survival rate of *Salmonella* in or on contaminated fruit treated for 2 min with up to 320 ppm of chlorine at pH 7.0. Wei et al. (1995) reported that treatment of tomatoes contaminated with *S. montevideo* with 100 ppm chlorine for 2 min failed to eliminate the bacterium.

The objective of this study was to determine chlorine concentrations and use conditions that would eliminate and/or prevent dispersal of a five-strain cocktail of *Salmonella* that was allowed to dry on the surface of tomato fruit.

Materials and Methods

Five serovars of *Salmonella, S. agona, S. gaminara, S. michigan, S. montevideo*, and *S. poona*, were kindly provided by Dr. Linda J. Harris, U. Ca., Davis. Rifampicin resistance was induced in the strains to allow easier recovery of Salmonella from treated fruit. Maintenance of the cultures and production of inoculum followed standard microbiological procedures. For production of inocula, cultures were grown in liquid culture, removed by centrifugation and washed twice with phosphate buffer saline (PBS) (Sigma-Aldrich, St. Louis, MO) to eliminate substances that would react with the test sanitizers. All five strains were combined as a cocktail and diluted in phosphate buffered saline (PBS) for all experiments to obtain an approximate inoculum level of 1.0×10^9 CFU/ml.

The growth (number of colony forming units) of the wild type and rifampicin resistant strains were compared in broth with and without the antibiotic to make sure the antibiotic resistant strains were environmentally as fit as the wild type strains. Recovery efficiency was compared with two types of dilution plate techniques to select the best one for future tests.

Tomato Treatments

Ten 10-υL samples of the bacterial suspension were spotted at separate locations on blemish free portions of the fruit surface for a total of 1.0 x 10^8 CFU/tomato. The spots were allowed to dry for 1 h before treatment. In subsequent tests, various types of wounds and the stem scar were inoculated with the *Salmonella* cocktail.

Chlorine stock solutions were prepared from a sodium hypochlorite concentrate, diluted to 50, 100, or 150 ppm with phosphate buffer and adjusted to pH 6.5, 7.5, and 8.5. The free chlorine concentration was verified using methods approved by the US Environmental Protection Agency.

Whole pink or green tomatoes inoculated and dried as above were placed in a circulating water bath. Water temperatures were adjusted to 25, 35, or 45°C depending on the test. The circulating water bath simulated a flume as found in tomato packinghouses. Tomatoes were removed at 15, 30, 60 or 120 seconds after being placed in the bath. Each sampling interval consisted of three single-fruit replicates. The single fruit were placed in sterile Stomacher™ bags (Fisher, Fair Lawn, NJ) containing 100 ml Butterfield's buffer (BPB). The bags were closed, periodically shaken and fruit surfaces rubbed for 1 min to recover viable *Salmonella* (Beuchat et al., 2001; Zhuang et al., 1995). Samples of the BPB wash were serially (1:10) diluted into pour plates with TSA (rif+). Samples of the water in the bath were also plated to determine the population washed from the fruit surfaces due to water immersion and the mechanical action of the circulating bath.

The first tests on chlorine efficacy featured 50-ppm free chlorine at pH 6.5, 7.5 or 8.5 to determine the effect of pH on elimination of *Salmonella* from contaminated fruit and to establish the best pH for tests of chlorine concentration and solution temperature. Subsequent tests were conducted with 100 and 150-ppm chlorine and pH 6.5 at solution temperatures of 25, 35, or 45°C (77, 95 or 113° F, respectively). Tomatoes with various wounds (puncture, shaved area or stem scar) were inoculated as above and treated with 150-ppm chlorine at pH 6.5 and 25 and 35°C as described in tests on surface populations. All chlorine treatments were prepared from an approximately 50,000 mg/L stock solution and tested for free chlorine levels with Hach® chlorine test kits after adjusting pH, before tomato addition and after the last sampling. Sodium thiosulfate at 0.1% was included in the recovery buffer to eliminate residual chlorine.

Aqueous solutions of alternative sanitizers were prepared at maximum allowable concentrations and used to treat inoculated tomatoes for up to 2 min. Surviving populations of *Salmonella* were then recovered from the treated tomatoes as described for tests with chlorinated water. The sanitizers and concentration included acidified sodium chlorite at 1200 ppm and pH 2.3 to 2.9 (Alcide Corp., Redmond, WA). The concentration of sodium chlorite was verified with an iodometric titration, (Document No. 1635, Rev. 02 and Document No. 1615, Rev. 09—Alcide Corp., 1999). Chlorine dioxide (ClO_2) at 5 mg/L was produced by dilution of a stock solution produced from a dry release formulation in a paper satchel (Tri Nova, LLC., Forest Park, GA). The concentration of chlorine dioxide in the stock solution was determined through an iodometric titration (Tri Nova, LLC, Forest Park, GA). A stock solution of 30% hydrogen peroxide (H_2O_2) was diluted to 50,000 mg/L. The concentration of H_2O_2 was confirmed on a diluted sample of the stock solution with the Reflectoquant™ strips for the range 0.2-20 mg/L (EM Industries, Inc, Gibbstown, NJ). Ozone at 1.3 ppm was prepared with a portable ozone generator Annox HFC-1000. Concentrations in a dilution were measured with Accuvac® ampules in the range of 0-1.5 mg/L with a Hach® DR/890 colorimeter. Peroxyacetic acid (PAA) composed of 15% active ingredient (Tsunami 100™) was diluted to 80 mg/L (Ecolab©, Inc., St. Paul, MN). PAA concentrations were measured with Reflectoquant™ strips in the range of 1.0-22.5 mg/L (EM Industries, Inc., Gibbstown, NJ).

Results and Discussion

Based on the literature and popular recommendations, 50-ppm free chlorine is more than 50 times more concentrated than the amount required to kill suspended cells of *Salmonella* within 2 min. However, when cells are allowed to dry on deposits on tomato fruit, they are clearly more difficult to kill. A few bacteria on the fruit survived exposure to 50-ppm free chlorine for 2 min (Fig. 1). Samples of the water in the scale model flume were negative for Salmonella. Bacteria washed off the fruit were killed and, as a result, could not accumulate in the water. The 50-ppm solution was slightly more effective at pH 6.5 than at 7.5 or 8.5. This is consistent with the literature on the species of chlorine in solution and the solution pH (White, 1999). Hypochlorous acid predominates over hypochlorite ion at pH levels less than 7.5. Hypochlorous acid is between 20 and 300 times more effective in killing various bacteria than is hypochlorite ion.

When fruit are dumped into a simulated water flume containing plain water, populations of *Salmonella* on the fruit decrease by 1 to 2 logs within 2 min. This represents suspension in the water of about 9 X 10^5 CFU/fruit. By contrast, 90 to 99 % of the bacteria were removed from the fruit surface, whereas a substantial number remained. The bacteria suspended in the water will likely contaminate nearby fruit and eventually equipment down stream from the flume. Ultimately, the entire packingline will be a source for contamination of the tomatoes that are being packed. The *Salmonella* cocktail was killed more rapidly at 150 as compared with 100 or 50 ppm, particularly with shorter exposure intervals. Complete elimination of *Salmonella* from the fruit surface occurred only with the 150-ppm concentration, but required the full 2-min exposure.

The chlorine solutions warmed to 35 or 45°C were more effective than the 25°C solution (Figure 3). There was no statistical difference in efficacy between the 35 or 45°C solutions.

When wounds (punctured, shaved or stem scar) were inoculated with the *Salmonella* cocktail, treatment with 150-ppm chlorine at pH 6.5 and 25 and 35°C had little effect on populations in the wound. This is consistent with the literature. Wei et al. (1995) and Zhuang et al. (1995) both reported that *Salmonella* suspensions placed on the stem scar region of tomatoes were not inactivated (decreased by up to 99 but not 100%) by subsequent exposure to 100 or up to 320 ppm chlorine, respectively for 2 min.

Although chlorinated water does not disinfect various wounds on tomatoes that have been contaminated with Salmonella or other hazardous microorganisms, which includes decay pathogens, it can inactivate deposits on the skin and prevent accumulations in the water of dump tanks, flumes or washers. By inactivating skin deposits and preventing water accumulations, proper water chlorination minimizes microbial hazards in fresh market tomatoes. Proper water chlorination is defined as maintaining at least 150 to 200 ppm free chlorine in water at a pH of 6.0 to 7.5 and a temperature of 35 to 45°C. The tomatoes should have a residence time of at least 1 min. The free chlorine concentration should be measured frequently since the chemical reacts rapidly with tomato surfaces as well as various materials accompanying the fruits when they are dumped into the packinghouse water system. Alternatively, an oxidation-reduction potential (ORP) system can be installed, which automatically maintains a set ORP. The set ORP should be determined prior to the addition of tomatoes when the system has been filled, warmed and chlorinated to the desired range.

The "proper water chlorination" described above will also prevent the accumulation of bacterial and fungal decay pathogens and will prevent fruit from becoming inoculated in the flume (Bartz et al., 2001). Both the pH range and the solution temperature are critical components of proper water chlorination. Higher pH solutions do not have more stability in the tank than to those in the 6.0 to 7.5 range, but are slower acting (Bartz, unpublished).

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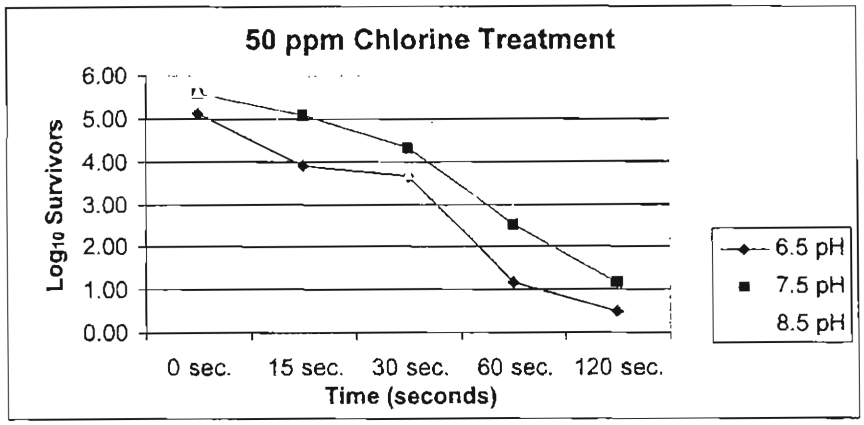

Figure 1. Effect of pH on the efficacy of chlorinated water for removing dried deposits of Salmonella from tomato surfaces.

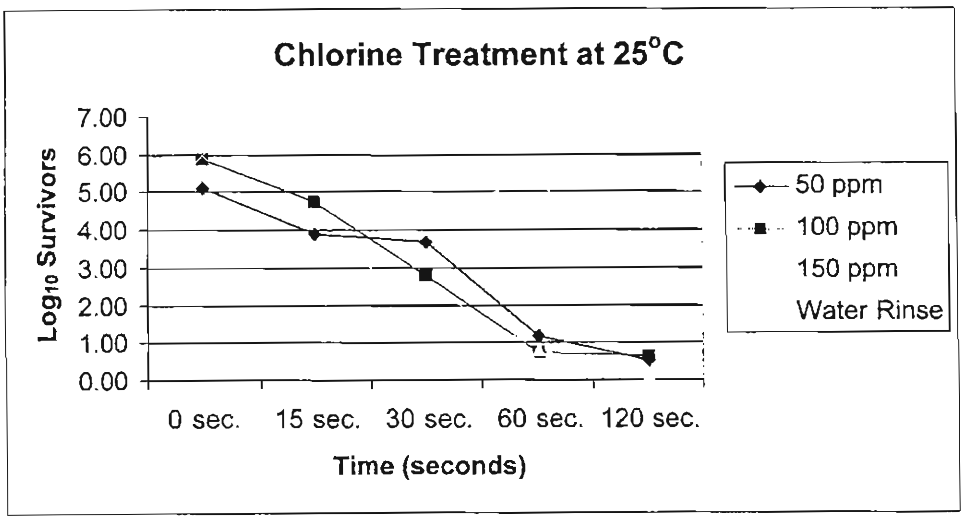

Figure 2. Effect of concentration on the efficacy of chlorinated water for removal of dried deposits of Salmonella from tomato surfaces.

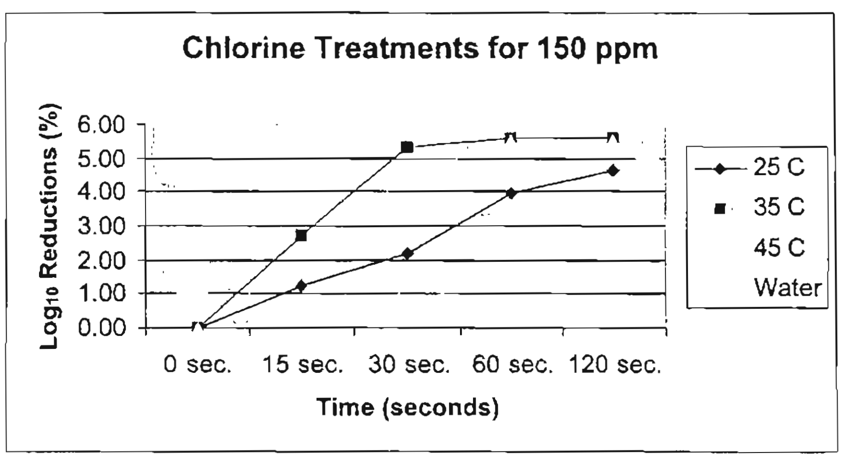

Figure 3. Effect of temperature on the efficacy of chlorinated water for removing Salmonella from surface contaminated tomatoes.

Project Status and Possible Variety Releases from the IFAS Tomato Breeding Program

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The University of Florida tomato breeding program is one of only two public fresh market tomato breeding programs developing varieties in the United States. Breeding projects involve the three broad areas of yield, disease resistance, and fruit quality. In the last decade emphasis has been placed on the development of breeding line releases to the seed industry, who then make finished hybrids or use the inbreds to make new inbreds of their own. In spring 2001, members of the Research Subcommittee of the Florida Tomato Committee requested that finished hybrids be released from the breeding program and emphasis has shifted toward that end since that time. Herein is a summary of the status of various breeding projects that will highlight some of the latest developments in the program that involve both inbred development and finished hybrid release candidates.

Yield

Since I arrived in 1981, the development of heat-tolerant inbreds has received major emphasis. This is because heat-tolerant tomatoes set fruit better not only under high temperature conditions prevalent in all Florida districts in the fall, but also during other stress conditions such as cool weather. It is impossible to select for cold tolerance directly in Florida due to the erratic and short duration of cool conditions. It is a challenge to obtain lines with good heat-tolerance, crack and check tolerance necessary for the summer rainy season, and with large fruit size. Crossing a heat-tolerant, medium fruit sized parent with a large-fruited, heat-sensitive parent results in hybrids with commercial fruit size and a good degree of heat-tolerance (Scott et al., 1986, 1997). 'Solar Set' was released in 1989 using this concept and it has been an important fall variety in Florida during the 1990's. 'Solar Set' is not as widely grown today as it used to be, but it generally has not been replaced by a comparable heat-tolerant variety. I maintain that it is in the growers best interest to grow a heat-tolerant variety in their early fall plantings in case there is a good early market. To illustrate this compare 'Solar Set' to 'Florida 47' and 'Florida 91' in Table 2 of Maynard et al., (2002) and assume a $10 per box market.

A major breeding philosophy of mine is that eventually there will be primarily heat-tolerant varieties grown in the state because of their more reliable fruit setting ability. Why has this not come to pass? Thus far, the heat-tolerant parents have not been good enough. Possibly this will change with the development of Fla. 8044. This inbred set fruit very well in summer 2001 when many normally good heat-tolerant lines did not set well. Fla. 8044 had excellent fruit set plus the fruit were large, firm, smooth (*n-4* nipple gene), and high in lycopene due to the crimson (og^c gene). In spring 2002, Fla. 8044 ripened earlier than all other large fruited tomatoes grown at GCREC. After three harvests of breaker and riper fruit in a yield trial, it had significantly higher yield than all other genotypes in the trial and had fruit size comparable to 'Florida 47' **(Table 1)**. Hybrids made in spring 2002 are presently being tested with this inbred and it is anticipated that 8044 will have a significant impact on the Florida tomato variety picture within a few years.

Increasing yield is one method to improve a grower's bottom line. Another method to improve profits is to reduce production inputs. The development of compact growth habit (CGH) tomatoes for Florida would allow growers to eliminate staking and pruning operations. Further, development of jointless varieties would allow for mechanical harvesting thus further reducing production costs. The concept being used was first reported from the North Carolina State breeding program (Ozminkowski et al., 1990) and Dr. Randy Gardner was kind enough to provide improved inbreds to begin breeding work in Florida. The CGH plant habit involves use of a brachytic (*br*) gene and genes controlling prostrate growth. Resulting plants have a concentrated fruit set on vines without apical dominance that do not outgrow the plastic mulch. In Homestead double rows can be grown like peppers, while single rows are more appropriate in other Florida growing districts. At this point the best hybrids have jointed stems and these will be tested on grower farms in the 2002-2003 season. Fla. 8107 will be one of the hybrids being tested on grower farms **(Table 2)**.

Disease Resistance

Bacterial spot. Since this is the most ubiquitous disease problem in Florida and it is not easy to control by other means, a large breeding effort has been made over the last 20 years. Despite this I have yet to release any varieties. This is largely due to multigenic genetic control of resistance and a shift in races of the pathogen in Florida (Scott et al., 2002). Originally, Florida had race T1 but this has been largely replaced with race T3 that is antagonistic to race T1 (Jones et al., 1998). More recently another race has been discovered in Florida (Astua-Monge, 2000). It is not known how serious this new race will be. Our best horticultural inbreds have resistance to race T3 only. Hybrids heterozygous for resistance (one resistant parent, one susceptible parent) have a good tolerance level. A small number of hybrids were tested in spring 2002 and none were outstanding although a few will be tested further. This fall 58 hybrids will be tested under conditions conducive to bacterial spot, and it is hoped that at least one will merit release in the near future. Only by deploying large acreages of race T3 tolerant varieties will the stability of the resistance be possible to determine. Work is underway to incorporate resistance to the new race into T3 resistant and other inbreds.

Bacterial wilt. In 1995, the heat-tolerant bacterial wilt tolerant open-pollinated variety 'Neptune' was released. Tolerance of 'Neptune' or hybrids with it as a parent resulted in about 70% healthy plants on grower fields infested with the pathogen in north Florida where susceptible varieties had 10% healthy plants. One hybrid that showed commercial potential was Fla. 7514, which did well in numerous yield trials around the state. In 2001, studies at NFREC have shown that the tolerance of 'Neptune' is increased by Actigard, thus the release of Fla. 7514 could now be of benefit to growers in North Florida and elsewhere that want to grow tomatoes on bacterial wilt infested fields. Seed companies with interest in producing seed of this hybrid should contact me. Otherwise, a major problem in breeding for resistance to this disease is that it has been difficult to obtain high levels of resistance in lines with large fruit size. Apparently there is a repulsion linkage of a resistance gene with a factor controlling large fruit size. This linkage may have been broken in Fla. 8109, a large-fruited inbred with resistance comparable to the small-fruited resistant source line Hawaii 7997 in summer 2001 and spring 2002 tests. More testing is underway in summer 2002. If the results hold Fla. 8109 will usher in a new era in developing bacterial wilt resistant varieties since fruit size will no longer be a problem.

Geminiviruses. Two viruses have been reported in Florida, tomato mottle virus (ToMoV) and tomato yellow leaf curl virus (TYLCV). The latter is more prevalent and the symptoms more severe. Resistance to ToMoV was discovered in the wild species *Lycopersicon chilense* in 1990 and resistance genes have been introgressed into tomatoes. We now have inbreds with good resistance to both geminiviruses, and the horticultural attributes are nearing that of other inbreds that can be use to make commercial hybrids. Hybrids will need to have resistance in both parents to provide the best resistance since heterozygous hybrids have intermediate resistance that would not be adequate under high disease pressure. It will be a few years before varieties are available to Florida growers, but it is anticipated that the resistance will be stable and effective against a broad range of geminiviruses.

Spotted wilt. Fla. 7964, a hybrid being considered for release, is described in the last section of this paper. New resistant inbreds have been developed and new hybrids are being evaluated at GCREC. All spotted wilt resistant hybrids derive their resistance from the *Sw-5* gene that is selected for resistance using a molecular marker developed by a team headed by Dr. Mikel Stevens while a post-doctoral scientist in my laboratory. A virus strain that overcomes the *Sw-5* gene has been identified in Hawaii and resistance to this strain was discovered in an accession of *Lycopersicon peruvianum*. Interspecific F_1's have been obtained. Mike Stevens is presently making the first backcross to tomato at BYU using two inbreds from my breeding program including Fla. 8044. We will work cooperatively to develop improved resistant inbreds from this material in case the *Sw-5* gene is overcome by the pathogen in Florida. Dr. Stevens also discovered resistance in one of our geminivirus resistant lines derived from *L. chilense*. Selections for improved horticultural characteristics in this material were made in spring 2001 at NFREC. This material offers another possibility should *Sw-5* be overcome.

Quality

Flavor. In the supermarket, cluster tomatoes generally sell for higher prices than field tomatoes, often selling for a dollar more per pound. Sometimes greenhouse hydroponic tomatoes are sold for a higher price as well. Large fruit size is not an issue since cluster tomatoes are not large fruited. Cluster tomatoes are supposed to be of superior quality, but the flavor is generally not better than field or other tomatoes in the market. Much of what is said in this section should be considered in the context of Florida growers competing with the higher priced tomatoes, such as cluster tomatoes in the marketplace. I have been studying tomato flavor in cooperation with Dr. Elizabeth Baldwin of the USDA for about 10 years. She has summarized some of our work in a paper published in these proceedings. We also are working with Dr. Harry Klee, a Molecular Geneticist in the Horticulture Department at the University of Florida and have worked with Dr. Rob Shewfelt, a Food Scientist at the University of Georgia. Flavor is a complex trait that is not easy for breeders to work with (Scott, 2002).

Our aim is to develop a tomato variety that has good levels of sugars and acids with expression of a fruity/floral note that is controlled by certain aromatic volatiles. The volatiles controlling the fruity/floral note are not known definitively. Expression of this note and others are subject to environmental variation, which hampers breeding progress. This fall, Dr. Alex Csizinszky is assisting us by testing lines with desirable flavor under high salt levels to determine if the increased salts will improve flavor and the expression of the fruity/floral note. High salts have been shown to improve tomato flavor but fruit size was reduced (Mizrahi, 1982).

High lycopene. Medical literature has shown lycopene to be beneficial as an antioxidant that reduces the risk of several cancers. One method to increase lycopene is to develop varieties with the crimson (og^c) gene. This gene increases lycopene by 50% over that of normal tomatoes. It should be noted that the lycopene levels of "normal" tomatoes varies with variety and is often not known. Tomatoes with better red color tend to be higher in lycopene. Our goal is to develop crimson tomatoes with the superior flavor characteristics noted above. These tomatoes could be marketed as a more healthful product (functional food) as well as for their flavor. Possibly such a variety would have to be grown under high salt conditions that would reduce fruit size and yield. However, such a product would be competing with the cluster tomatoes as a gourmet product, so fruit size would not be an issue.

The greater return in the market would compensate for the slightly reduced yield and increased handling costs since fruit would have to be harvested at the breaker stage. The goal is to provide Florida growers with a superior variety and we will move as quickly as possible toward such a release once evaluations of the variety are supportive. Otherwise, many of these same quality characteristics will be incorporated as possible into any hybrids that are released in the general program.

Hybrids for Evaluation

Listed below are hybrids being considered for release that are available for grower trials. All varieties are resistant to fusarium wilt races 1 and 2, verticillium wilt race 1, and gray leafspot. Additional resistances are mentioned with the specific hybrid.

Fla. 7973 - A jointed hybrid with resistance to fusarium wilt race 3 that is similar to 'Floralina' but with improved fruit size, blossom scar smoothness and reduced blossom-end rot. It has performed well in all Florida districts and in western North Carolina. It is a joint University of Florida-North Carolina State hybrid with the same parent from NC State as is in 'Floralina'. The Florida parent has been improved. It is an early-midseason hybrid with a vine similar to 'Floralina' that should not require pruning. It is not heat-tolerant and will perform best when grown in late fall or spring crops. Growers should consider this hybrid even if they do not have fusarium wilt race 3 problems.

Fla. 7964 -A jointed hybrid with resistance to spotted wilt virus. Since this virus is of primary concern in north Florida it would be of interest primarily to growers who grow there or elsewhere in the southeastern US. It has performed well in west and north Florida and in the mountains of North Carolina. Fruit size is good, but not as large as 'Florida 47', thus pruning might be helpful and growers might want to experiment with some pruning. It is a mid-season variety with good vine size and fruit cover. It has moderate heat-tolerance. It should be compared primarily to other spotted wilt resistant varieties that are released or being tested for release. Sakata Seed Co. is producing a large quantity of seed that will hopefully be available by spring 2003. A release is anticipated in 2003. Sakata has right of first refusal on this hybrid.

Fla. 7885B -A heat-tolerant hybrid with an improved parent from that used in Fla. 7885, a hybrid that did well in previous testing. Available heat-tolerant varieties have one heat-tolerant parent but Fla. 7885B has two. This results in superior fruit set under high temperature conditions and trials indicate this hybrid matures one week sooner than other heat-tolerant varieties under early fall conditions in Florida. Fruit have very smooth blossom scars so Fla. 7885B can be successfully grown in all Florida growing seasons. It is an early season hybrid with an exceptional vine cover in the top of the plant.

HMX 1803-formerly NC 99405 is a joint hybrid between my program and the NC State breeding program of Dr. Randy Gardner. Seed is being produced and trials are being carried out by Harris-Moran Seed Co. Larger volumes of seed should be available for testing in the fall 2002 crop. It is a jointless, heat-tolerant hybrid that has performed well in all Florida growing districts. This is the first jointless hybrid that can compete with existing heat-tolerant hybrids that all have jointed stems. Blossom scars are smooth and the variety yields and grades well during all growing seasons, not just the early fall. It has early-midseason maturity and good vine cover. Pruning is not necessary, but moderate pruning might be of benefit under some conditions, such tests have not been conducted. It is resistant to fusarium wilt race 3. There is concern about fruit softening after fruit reach the table ripe stage and this could prevent release. Growers should try 1803 on their farms to monitor firmness under their conditions.

Fla. 7810- is heat-tolerant and resistant to fusarium crown and root rot. It has performed consistently well in trials over a number of years. It has early to mid-season maturity. The medium sized vine provides adequate fruit cover and should not require pruning.

Several inbreds in various projects look promising as parents and other hybrids will be available in 2003 pending trials at GCREC this fall. Any growers interested in testing experimental hybrids should contact me.

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Table 1. Marketable yield, fruit size, and culls for selected tomato genotypes after three harvests of breaker and riper fruit at Bradenton, Florida, Spring 2002.

Genotype	Marketable yield (lb/plant)	Fruit size (oz)	Culls (% by wt.)
Fla. 8044	16.63 a[z]	7.44 a	13.1
Fla. 8045	12.33 b	5.56 f	9.2
Fla. 8042B	11.87 bc	4.91 f	7.4
HMX 1803	10.55 b-d	5.91 d-f	15.0
Fla. 7771	9.63 cd	5.73 e-f	15.4
Fla. 7949B	9.11 de	7.09 a-c	22.3
Fla.. 47	8.31 de	7.35 ab	8.5
Sanibel	7.89 de	6.80 a-d	19.0
Fla. 7946	6.89 e	6.19 c-e	10.0
			ns

[z] Means in columns not followed by the same letter are significantly different by Duncan's Multiple Range Test at $P \leq 0.05$.

Table 2. Marketable yield, fruit size, and cull percentage for compact habit and control genotypes during spring 2002 at Bradenton, Florida.[z]

Genotype[y]	Marketable yield (lb./plant)	Fruit size (oz.)	Culls (% by wt.)
Fla. 8107	9.79	7.9	28.0 ab[x]
Fla. 8108	9.61	6.5	17.7 b
Florida 47	6.55	7.6	28.0 ab
Sanibel	5.93	6.5	37.0 a
	ns	ns	

[z] Two blocks of 5 plant plots, plants were not staked, breaker fruit were harvested three times at one week intervals.

[y] 728 and 726 are compact growth habit hybrids.

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

Tomato Yellow Leaf Curl Virus: Breaking the Cycle

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Tomato yellow leaf curl virus (TYLCV) is one of the most significant and damaging viruses to tomato. Unfortunately it is also one of the most difficult viruses of tomato to manage due to a combination of factors:

TYLCV is moved from plant to plant by an insect vector, the whitefly (*Bemisia tabaci* biotype B or *B. argentifolii*). This whitefly is highly mobile and can fly short distances unaided or can move much longer distances with the assistance of wind.

TYLCV can be acquired by both immature and adult forms of the whitefly and once acquired can be transmitted for the life of the insect, which can be as long as several weeks. The whitefly can feed and reproduce rapidly on tomato, and can build to high populations densities in a short period of time. The whitefly can feed and reproduce on many other hosts besides tomatoes.

TYLCV can infect at least 25 plant species besides tomato (all TYLCV hosts are also hosts of the whitefly). This means that TYLCV has multiple plant host reservoirs (when tomatoes are not present) and alternate hosts (when tomatoes are present).

This daunting list of characteristics might lead one to believe that TYLCV cannot be managed, and in some locations and situations that has been true. However, the virus does have several biological limitations that can be exploited for successful management. In addition, there are points in this disease cycle where that can be exploited to slow the spread of the virus, decrease virus incidences in tomato fields, and reduce the impact of the virus on tomato yields. Some examples are:

- TYLCV can only be transmitted by whiteflies. Interference with whitefly populations reduces the spread to the virus.
- The insect vector has to feed to transmit. Probing the plant does not result in transmission. Tactics that can take advantage of this will help reduce the spread of TYLCV.
- The insect vector appears to transmit TYLCV with greatest frequency in the first few days of its life, with transmission efficiency decreasing as it ages. Tactics that reduce whitefly development on TYLCV-infected plants will decrease the rate of TYLCV spread.
- Infected tomatoes in the field are the most important source of TYLCV, since large populations of viruliferous whiteflies can build rapidly under such conditions. Tactics that reduce the number of infected plants, the time that they are present in the field, and the size of the whitefly population will contribute to a reduction n TYLCV incidence and spread.

TYLCV Disease Cycles

As previously stated, a solid understanding of the annual disease cycle of TYLCV is very helpful in the management of TYLCV. However, the annual disease cycle of the virus varies among the tomato production regions in Florida due to the different times of tomato production. Following is a diagram and brief description of the TYLCV cycle in two regions, West Central and Southwest Florida. These cycles can be used to see at a glance the movement of TYLCV throughout the year, and are designed to help the grower in decision making and to understand the reasoning behind the management tactics described following the disease cycles.

West Central Florida

Wholesale tomato production, which occupies most of the tomato acreage, occurs at two times of the year, fall (late July through December) and spring (mid January through June) (Figure 1). Approximately four to five plantings separated by a week to two weeks are made by each grower at the beginning of each season. Fields tend to be small to moderate in size. This is more intensive tomato production than Southwest Florida, and most fields are located within 5 miles of at least one other field. There is sometimes no break between the end of the fall and the beginning of the spring season due to growers leaving their fields for many weeks to be picked by pinhookers. The presence of a gap between the two seasons is dictated by weather and market conditions. There are a few small fields of retail tomatoes (u-pick tomatoes) that are present between the fall and spring seasons and during the summer between the spring and fall season. There can be continuous tomato production in the field in West Central Florida.

Whiteflies and TYLCV transmission are of the greatest concern in the early fall season (mid August until late September) when incoming whitefly populations can be very high. There is also some concern in the spring season (February and March) due to warming temperatures (greater whitefly reproduction and movement) and over-wintering tomato fields.

The most important sources of TYLCV in the West Central Florida production region are tomato fields that have TYLCV-infected plants that bridge the two wholesale market production seasons. These fields can be retail market tomato production fields (u-picks that are maintained for extended harvests), abandoned tomato fields, and fields maintained for many weeks for "pinhookers". All these fields have a tendency to have high whitefly populations and high incidences of TYLCV-infected plants due to sub-optimal whitefly and virus management. The closer a new field is to one of these fields, the greater the potential impact on the new field.

Southwest Florida

Wholesale tomato production, which occupies almost all of the tomato acreage, occurs as series of sequentially planted fields which are started as early as late August with the final harvests occurring in April. Fields tend to be fairly large, with some tomato plantings occupying several hundred acres. Some fields are isolated by 6 or more miles from another tomato field, while others are within 5 miles of another tomato field. Growers plant tomatoes in fields sequentially from August through January, so fields of different ages overlap with each other **(Figure 2)**. There is a large break in tomato production in the summer, from about May to August. At that time the only tomatoes present are in fields at research facilities in the early part of the summer and in planthouses as transplants-in-production.

TYLCV-infected plants occur at low incidences throughout most of the growing season. This is due in part to low whitefly populations that are present through most of the growing season. Populations can rise if temperatures are warmer than usual. Whiteflies and TYLCV transmission are of the greatest concern in the spring. As whitefly populations rise early in the spring, incidences of TYLCV-infected plants increase, and older fields start to become sources of TYLCV for the last plantings in the spring. With the results that TYLCV incidences are highest in March and April. This coincides with higher temperatures which dictate higher rates of feeding and egg laying resulting in higher whitefly populations.

Management Tactics for TYLCV

Following is a list of the methods used to manage TYLCV.

Many of these should be used at the same time. However, even all these methods combined have been shown to be inadequate when a source of TYLCV-infected plants that have moderate to high populations of viruliferous whiteflies is within a few miles of a field of young susceptible crop plants. (The chemical recommendations are consistent with regulations present in Florida in 2002.)

Chemical Control of Whiteflies.

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

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

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

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

Cultural Practices

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

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

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

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

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

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

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

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

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

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

Summary

There are a number of tactics available that when employed together can be very effective in managing TYLCV. The timing of the application of these tactics can be critical to their efficacy and decisions should be made using an accurate understanding of the TYLCV disease cycle.

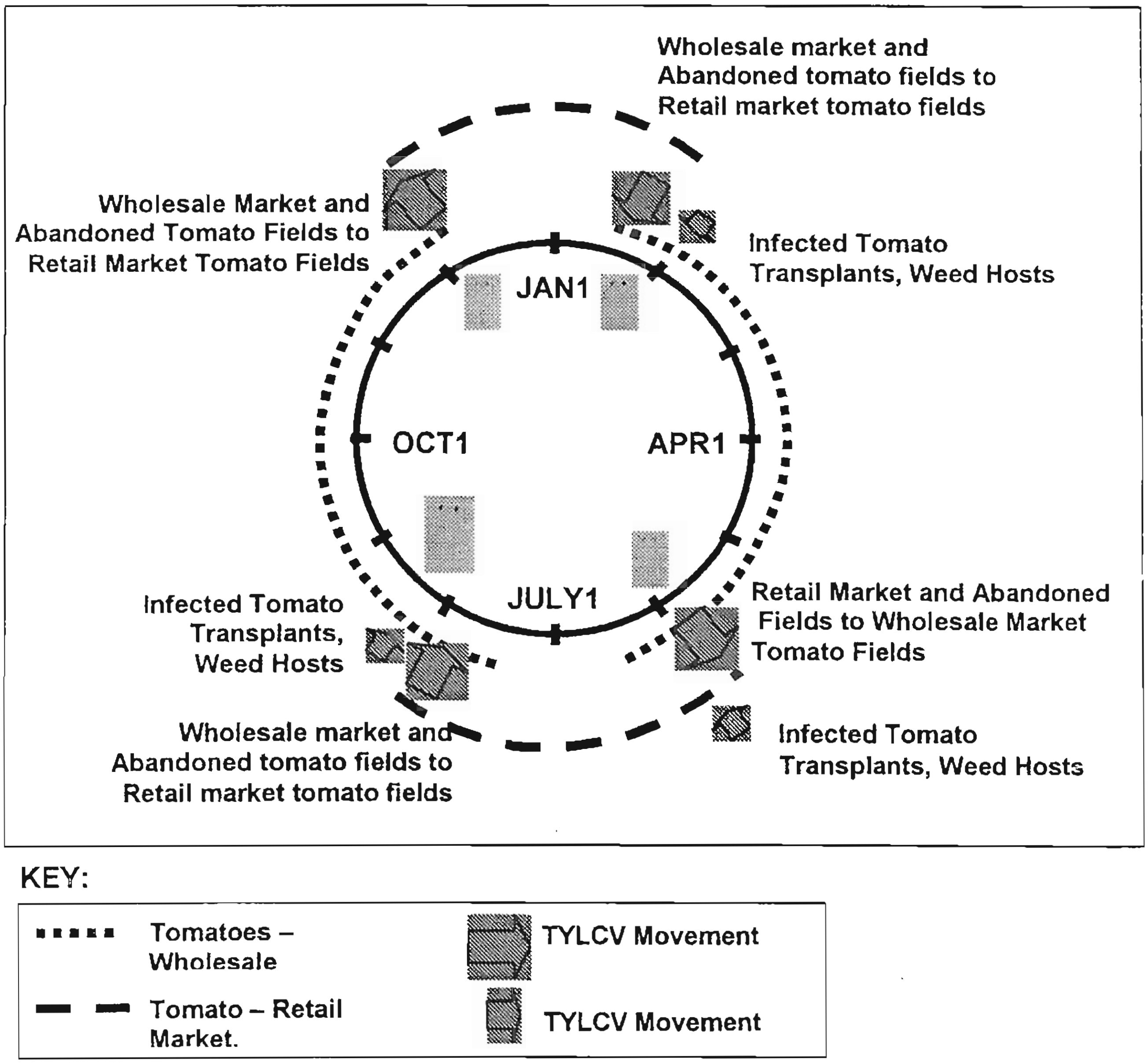
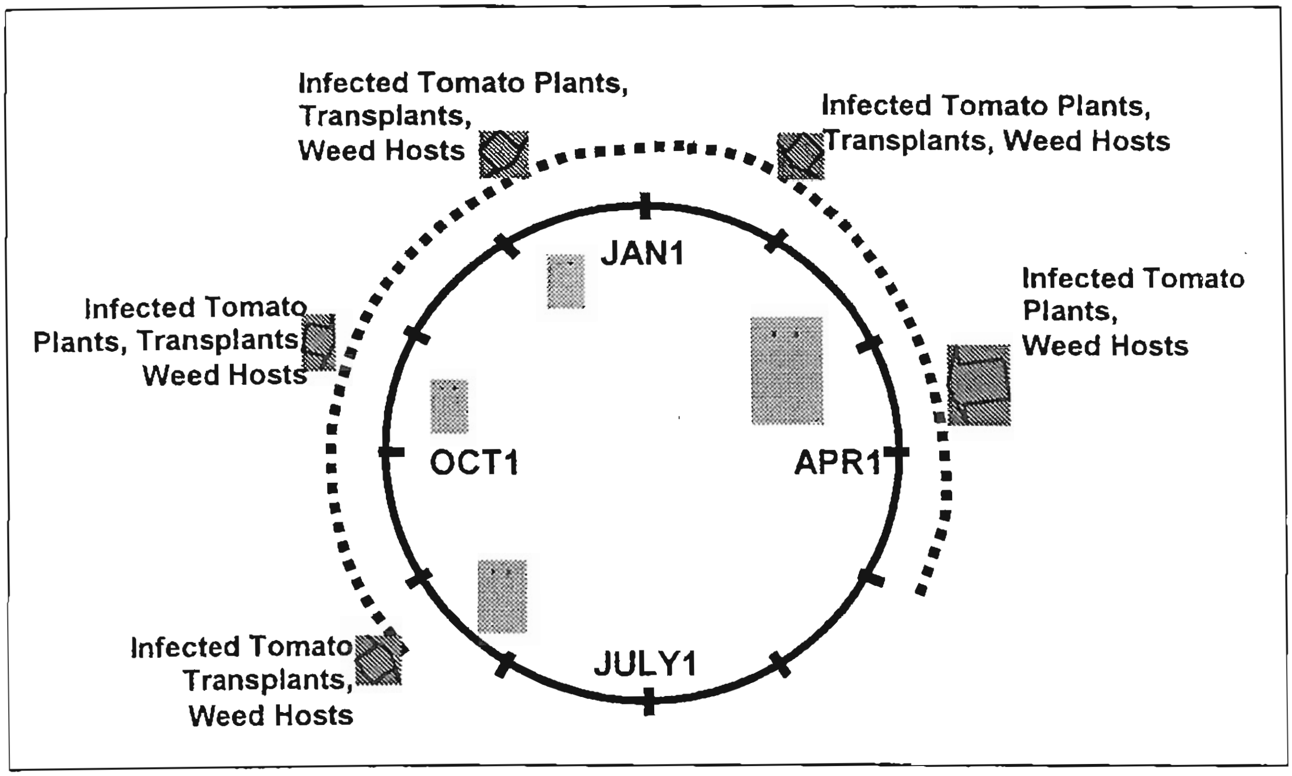


FIGURE 1. ANNUAL DISEASE CYCLE OF TYLCV-WEST CENTRAL FLORIDA



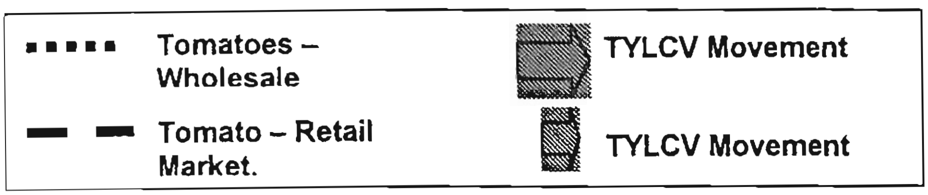


FIGURE 2. ANNUAL DISEASE CYCLE OF TYLCV-SOUTHWEST FLORIDA

Management of Tomato Spotted Wilt Virus and its Vector, Thrips

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

For the past 6 years experiments have been conducted at the North Florida Research and Education Center (NFREC), Quincy to investigate tactics that can reduce WFT numbers and incidence of TSW. Potential management strategies would include those which prevent or slow the initial movement of thrips onto plants in the tomato fields, which would reduce the primary spread of TSW. One such tactic which is showing a great deal of promise is use of highly reflective (metalized) mulches. These metalized mulches have a thin layer of aluminum applied to a polyethylene mulch with reflectance levels usually greater than 75 %.

From 1996 through 2001, UV-reflective mulches have consistently reduced WFT numbers by as much as least 50% in tomato flowers. An example of the effect of mulch reflectance on WFT populations is shown in **Figure 1**. When the number of thrips is reduced, the primary spread of TSW is reduced. For example, in 1997, nearly 40% of plants in black mulch were infected, while only 20-25% of plants in UV-reflective mulch were infected with TSW (**Figure 2**).

In 1998 through 2001, experiments were conducted with UV-mulch as well as SpinTor and Monitor to investigate the combined effects of UV-mulch and insecticides. The insecticides were applied weekly from early May through mid June. SpinTor was more effective in reducing adults and larvae of the WFT than Monitor, although it has a short time of residual activity. Reductions in populations of WFT with UV-reflective mulch was most dramatic in the untreated tomato plots, but early in the season (until approximately May 15), fewer thrips were observed in UV-reflective mulch plots in all insecticide treatments. Both insecticides effectively reduced late-season secondary spread of TSW compared to untreated tomato in both black and UV-reflective mulch treatments (**Figure 3**).

For the past couple of years we have been evaluating the effect of Actigard on incidence of TSW. In our small plots we have been able to show a consistent reduction in TSW of about 10 % or more. Figure 4 shows disease curves of TSW for spring 2002 trial. These plots received no insecticides to control thrips so curves show both primary and secondary infection.

The metalized mulch was also evaluated for its effect on tomato yields in both spring and fall crops. In the spring of 1998, with >FL 47' tomatoes, the black mulch produced significantly higher yield on a per plant basis than those on the metalized mulch beds (data not shown), however, on a per acre basis there were no differences in yields between the two mulch systems (**Table 1**). One reason for this per plant decrease is that the metalized mulch is much cooler than the black mulch due to the reflection of sunlight back up away from the beds. Early season growth on the metalized mulch is mulch slower, thus the reduction in yield on a per plant basis. However, the overall yields with the metalized mulch were equal to those produced on the black mulch due to the reduction of TSW with the metalized mulch.

In the spring of 1999, from a late March planting, yields were not affected by mulch type (**Table 1**). Early production season of 1999 was warmer than 1998 negating early growth differences. In the spring 2001 crop the tomatoes on the metalized mulch produced higher yields that those on black mulch due to the high incidence of TSW on the black mulch compared to the metalized mulch. Because of the potential cooling effect on soils we do not recommend use of metalized mulches for late February or early March planting in the north Florida/ south Georgia production area. The metalized mulch has also been compared to a white on black mulch for fall production. There has been no effect of mulch types during fall production (**Table 2**).

Grower Trials

Large scale grower trials were initiated in early April of 1998. Approximately 1 acre of a 15 acre tomato field had metalized mulch applied. Early growth was slower than the black mulch due to the cooling effect of the metalized mulch. As temperatures increased the growers remarked that the plants on the metalized beds caught up with the plants on the black mulch and by the end of the season the plants on the metalized beds were larger than those on the black mulch. The 1 acre block was scouted separately from the rest of the field. By harvest time the incidence of TSW was only 10 % in the metalized area compared to 19 % in the black mulch area. In the spring of 2000 these same growers had a field of 30 acres where the metalized mulch was used next to a field of black mulch for tomato production. At final scouting date (6/18/00), the metalized field had a TSW incidence of 11 % compared to 45 % in the black mulched area, a 75 % reduction in virus. During the spring season of 2002 these same growers had about 100 acres on metalized mulch next to about 20 acres on black mulch. Disease incidence at end of season was about 23 % in black mulch area and only about 4 % in metalized mulch area. We are finding that the larger area treated with metalized mulch the more effect we seem to have on incidence of TSW. Growers have observed that in the large fields with metalized mulch, most of the TSW incidence is on the outer edges. Growers have started using the metalized mulch during the fall season, even though TSW has not showed up in the fall for many years. Stand establishment is much higher on the metalized mulch (98 %) versus the white on black mulch (70 %). These number are average of eleven 100 plant stand counts on both mulches taken on 23 July, 2002.

Summary

The use of metalized mulches in tomato production for suppression of WFT numbers and incidence of TSW has shown great promise. Our research has shown that use of the metalized mulch can result in a reduction in TSW even greater than currently labeled insecticides when compared to unsprayed controls. Costs of the metalized mulch are about twice that of standard black mulches but equal to white or white on black mulches currently used in tomato production, but large scale field trials have shown that the extra costs are justified due to the suppression of TSW.

At this time we do not recommend their use for early spring plantings due to their cooling effect on the beds. In some grower trials, we have looked at using metalized strips in the drive rows during early plantings and have shown reduction in TSW in the rows next to the metalized strip. Also evaluation of a narrow strip of black down the middle of the metalized beds to look at the effect on early plantings for yields, thrips and TSW control is underway. The metalized mulches are difficult for the field crews to work around due to their blinding effect and growers have had to provide sunglasses to their field help.

Table 1. Effect of mulch type on yield of 'FL 47' tomatoes, spring crop. NFREC, Quincy, FL.

Mulch	Yield (boxes/a)		
	1998	1999	2001
Metalized	1311	2257	1522
Black	1277	2189	1289
P level	ns	ns	0.01

Table 2. Effect of mulch type on yield 'Equinox' tomatoes, fall crop. NFREC, Quincy, FL.

Mulch	Yield (boxes/a)	
	1998	2000
Metalized	1488	1825
White/black	1468	1679
	ns	ns

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

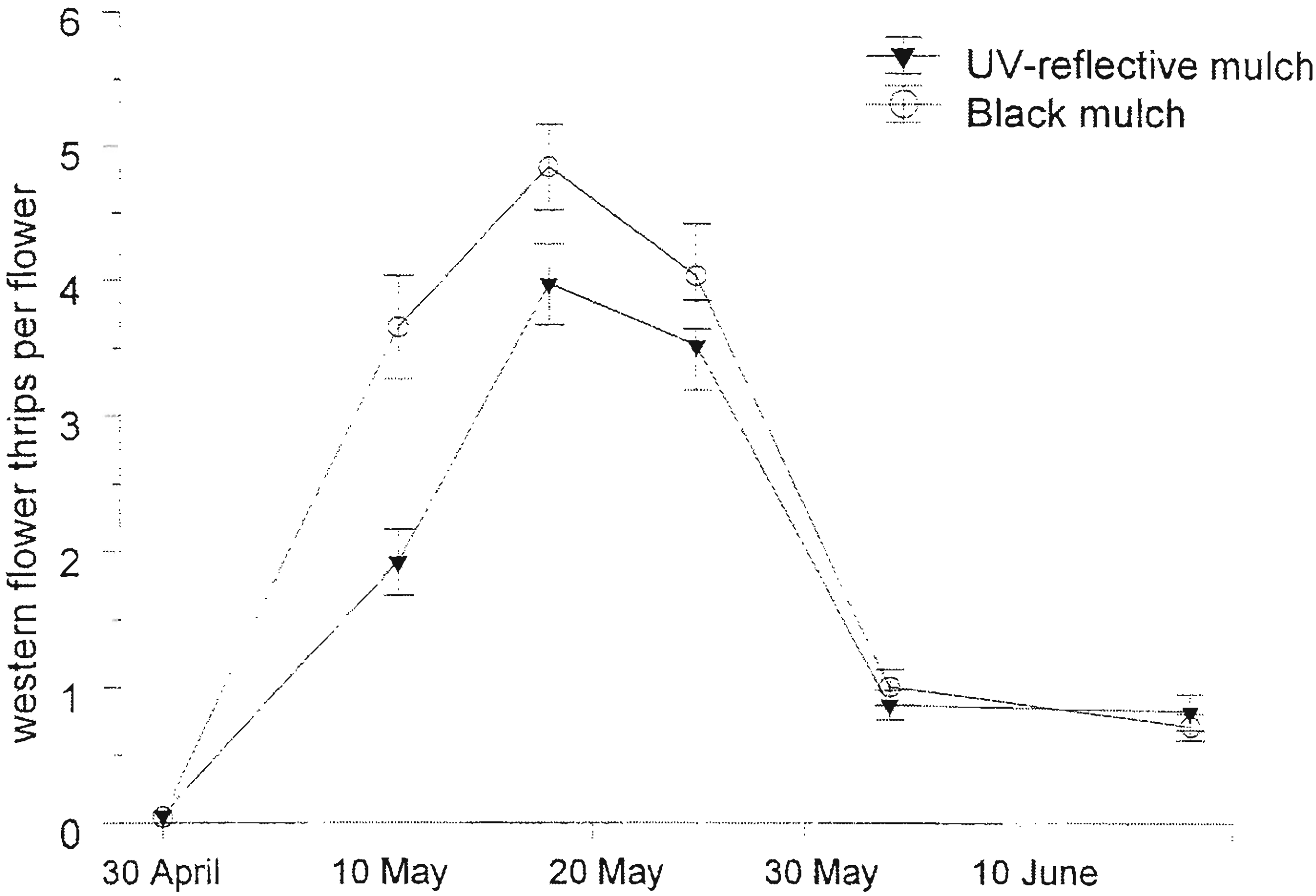


Figure 2. Incidence of TSWV in tomato in the spring of 1997.

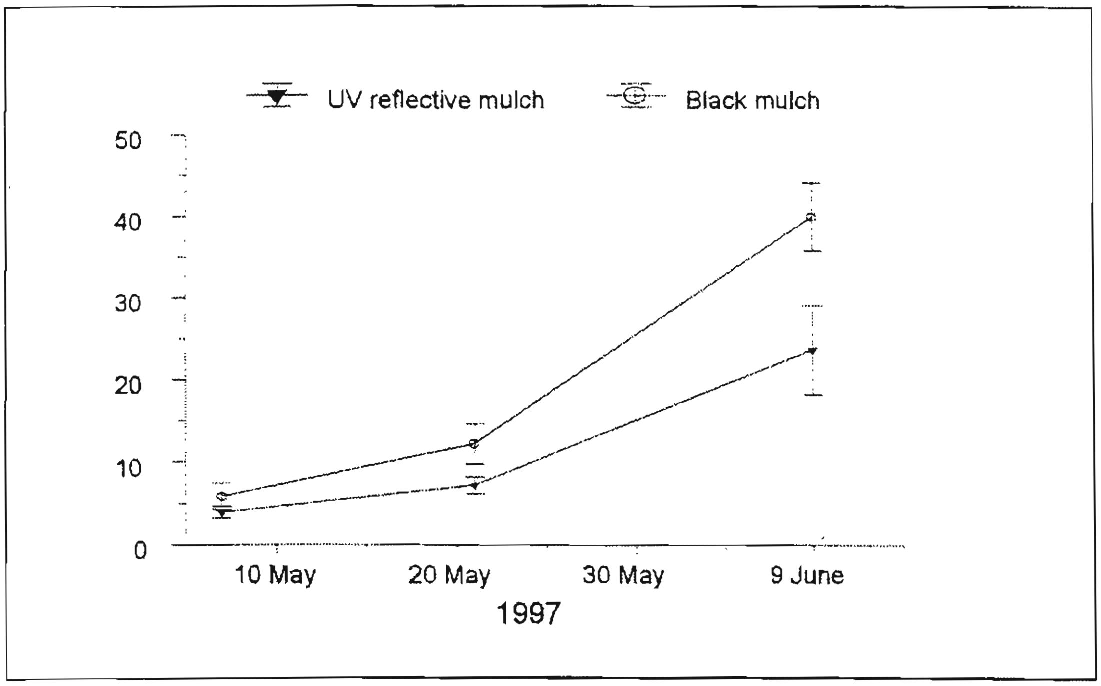


Figure 3. Interactions of insecticide treatments and mulches on incidence of Tomato Spotted Wilt.

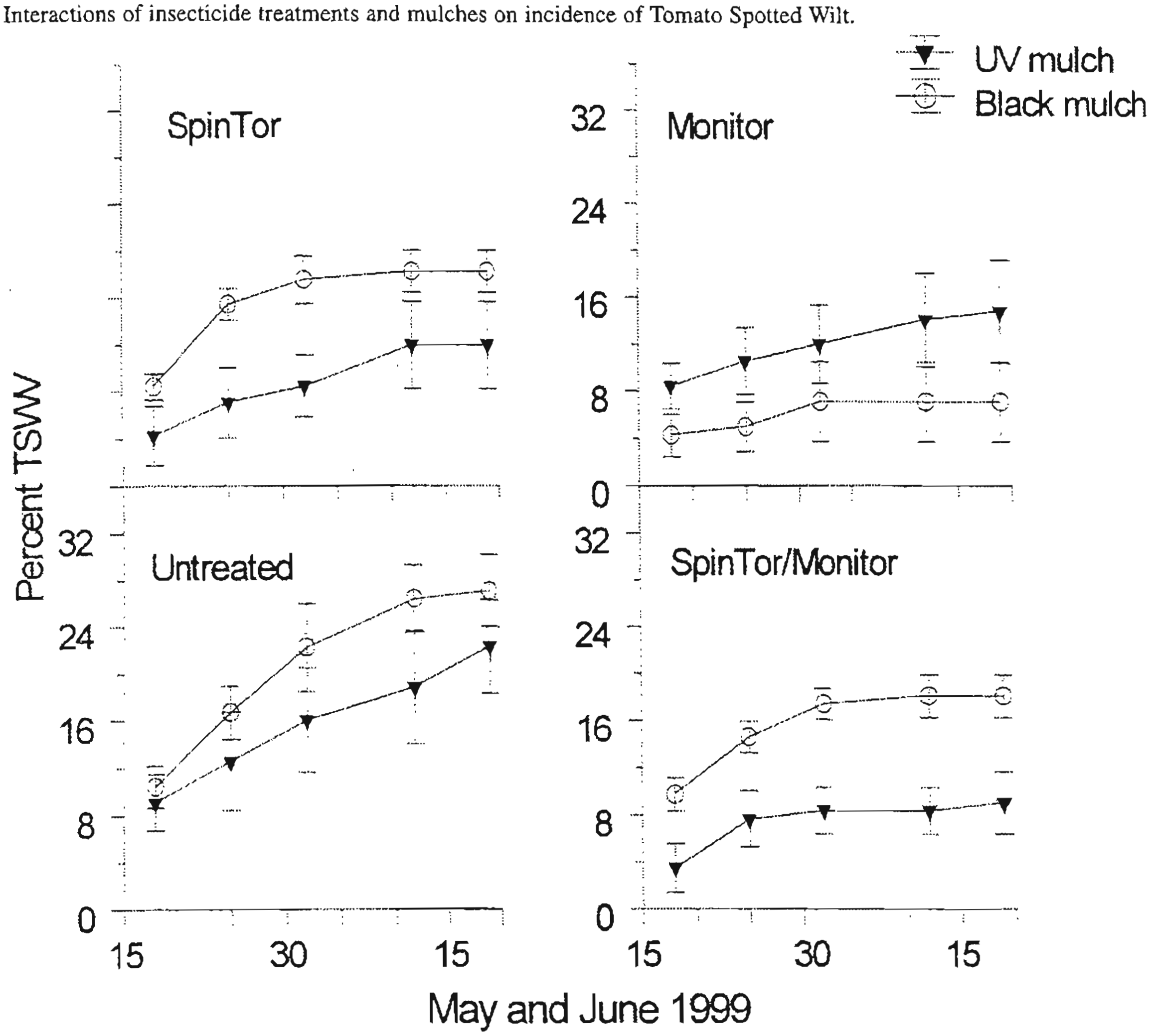
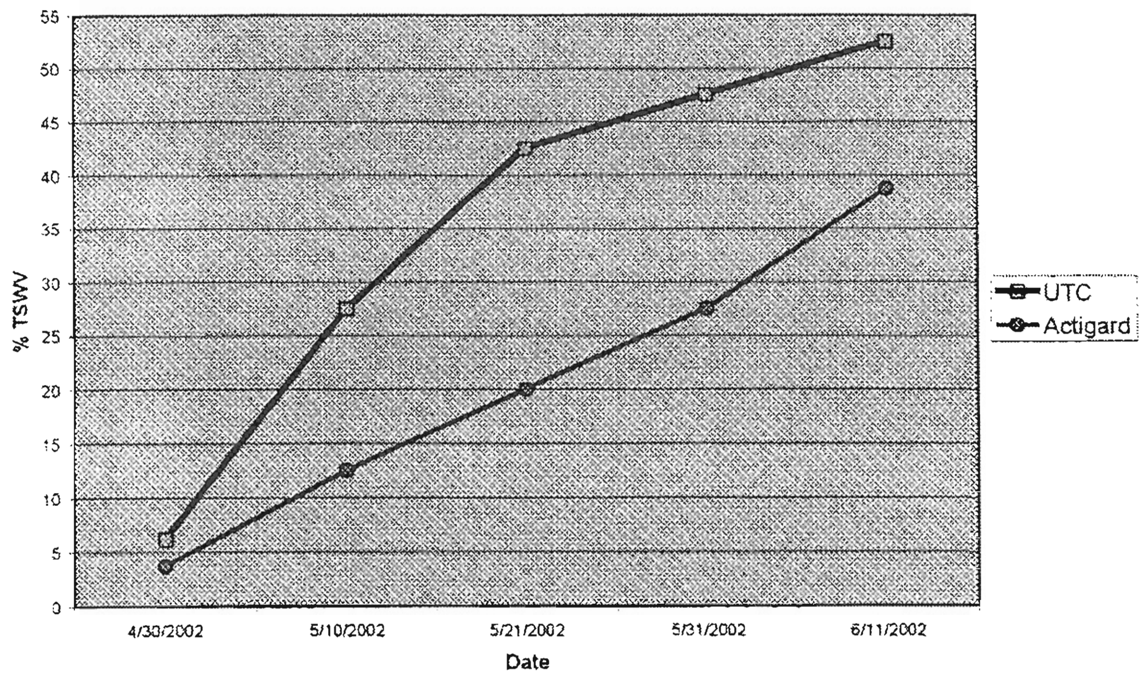


Figure 4. Disease Curve for Industry Tomato Test, Spring 2002



Integrated Management of Bacterial Spot on Tomato

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Bacterial spot of tomato caused by *Xanthomonas campestris* pv. *vesicatoria* (Xcv) was first observed in 1914 in South Africa (Doidge, 1920). This disease is present wherever tomatoes and peppers are grown, but is especially severe in Florida and the southeastern US when weather conditions (high temperature, high humidity, and rain) become conducive for disease development. Antibiotics are not covered in this review due to their uncertain future in US and previous problems of antibiotic-resistant Xcv strains in Florida and elsewhere.

Symptoms

Disease symptoms can be seen on all above ground plant parts. Spots which are generally dark brown and circular on the leaves, stems, and fruit spurs **(Fig 1)** usually start on the lower leaves, and are more visible initially on the under side of the leaves. Spots rarely develop to more than 3 mm in diameter. In some cases, in an area with race T3 of the bacterium, shot holes develop at the center of the spots. On leaflets the spots can easily be confused with early blight, gray leaf spot, or target spot. Bacterial spot lesions form an ooze when cut in half. This ooze is visible under a microscope **(Fig 2)**, but lesions of fungal diseases do not ooze. Early blight and target spot lesions have concentric zones. Gray leaf spot lesions are lighter in color and are more uniformly distributed than bacterial spot lesions. When conditions are optimal for disease development, spots coalesce to form irregular shape lesions. A general yellowing and blighting may occur on leaflets with many lesions. Often the dead foliage remains on the plant, giving it a scorched appearance. Fruit lesions begin as small, slightly raised blisters. As spots increase in size, they become dark brown, scablike, and slightly raised. However, they may also be raised around the margins and sunken in the middle. A developing lesion may have a faint prominent halo, which eventually disappears (Jones, 1991).

Causal Organism

Xanthomonas campestris pv. *vesicatoria* is a motile bacterium, strictly aerobic, gram negative rod which possesses a single polar flagellum. On nutrient agar it grows relatively slowly, and the colonies are circular, wet, shining, yellow, and whole.

On tomato, this pathogen has four races. Tomato race 1 (T1) was commonly found in Florida until T3 became dominant since its appearance in Florida. Recently T4 was discovered in Florida, however, its distribution is limited in some areas. T2 is common in Ohio and other mid-western states (Jones, 1991)

Disease Cycle and Epidemiology

The organism is able to survive on tomato volunteers and diseased plant debris. Seeds may also serve as a medium for the survival and dissemination of the bacterium. Disease development is favored by temperatures of 24-30 C and by high humidity and rain. The dissemination of the bacterium within fields occurs by wind-driven rain droplets and aerosols, and some cultural practices. The bacterium enters through natural openings (i.e, stomates and hydathodes) and wounds created by wind-driven sand, insect punctures, or mechanical means (Jones, 1991).

Disease Management

Cultural Practices

Crop rotation should be used in an attempt to avoid carry-over on volunteers and crop residue (tomato and pepper). Use disease and pathogen-free transplants. Avoid cull piles near field operations. Do not spray, tie, harvest, or handle plants while plants are wet. Eliminate solanaceaous weeds such as ground cherry and nightshade in and around tomato fields (Kucharek, 1994).

Biological Control

Biological control of the bacterial spot caused by race T1 has been achieved by using Xcv race T3 (T3 strains antagonize the T1s) (Jones et al., 1998, Hert, 2001;) and with other antagonistic bacteria such as *Pseudomonas putida* B56 and *Pseudomonas syringae* Cit7 (Wilson et al, 1997).

Bacteriophages (phages) (known as Agriphage, AgriPhi Inc, UT) have been found as an effective biocontrol agent for the management of bacterial spot on tomato (Flaherty et al, 2000). Phages are viruses that infect bacteria. In order to minimize the development of phage resistant bacterial strains, phages were applied as a mixture of several different phages. Coupled with this was the use of host-range mutant phages (h-mutants) to reduce cross-resistance within bacterium (Jones et al., 2002). Recently, protective formulations were developed to increase longevity of phages on plant surfaces in the field conditions (Balogh et al, 2002). Newly formulated phages performed better than the copper-mancozeb treatment and UTC in the field. A 'Powdered Skim milk' formulation may be recommended for field application because it is easy to prepare and apply.

Evening (before sunset) applications of phages resulted in better bacterial spot control compared to morning applications. Based on recent results, formulated phages could be applied twice a week at sunset for the management of bacterial spot. Labeled product is Agriphage (AgriPhi, Inc). During the past several years, Jones et al. tested bacteriophages for control of the bacterial spot pathogen on tomato. In a field study in which tomato plants were treated with phage, copper-mancozeb or untreated, bacterial spot severity was significantly reduced compared to the copper-mancozeb treatment and the control. Yield was also affected with an increase between 17 and 25% over the other two treatments (Flaherty et al, 2000). Recently, research on bacteriophages has focused on improving the formulation in order to increase survival of the bacteriophage on the leaf surface (Balogh et al, 2002). We have developed new formulations for phage longevity in the field conditions and modified the timing of applications to increase bacteriophage efficacy.

Chemical approach

Copper. Copper as a fungicide has been used in agriculture in Bordeaux mixture since 1885. Soluble copper ions are known to bind tightly to sulfhydryl groups, therefore they contain biocidal properties. Free copper ions can penetrate through plant cuticles and cause severe phytotoxicity. Water-insoluble copper salt ("fixed copper") is the solution to this problem. Since then, "fixed copper" materials have become the major chemical group for bacterial disease control. Some disadvantages of copper materials are phytotoxicity, reduced copper sensitivity by Xcv strains (in some areas), and environmental impact. Copper ions are not degraded in soil and can accumulate to high levels at locations with a history of intensive copper application (Koller, 1998)

Copper materials are also protectants. They only affect bacteria on plant surfaces. For bacterial diseases, copper materials are used as part of an integrated management program. But until recently for bacterial spot control on tomato there were very limited options to integrate with copper. Chemical control originally relied on the application of streptomycin, an antibiotic, and also copper compounds. However, streptomycin lost its effectiveness due to the emergence of resistant strains in the 1960s (Thayer and Stall, 1961) and by the 1980s copper resistant strains emerged as well (Marco and Stall, 1983). Eventually, the copper bactericides also became ineffective in some tomato production areas when used alone (Marco and Stall, 1983); however, it was discovered that the addition of maneb or mancozeb fungicides to the copper bactericides enhanced their efficacy (Marco and Stall, 1983). The management of bacterial spot is a challenge in commercial production in Florida due to limited efficacy of fixed copper bactericides and the presence of copper-tolerant strains. Since then, these copper-mancozeb mixtures have been in use for controlling bacterial spot, although complete control cannot be achieved solely with them. In a fall crop, south Florida growers may apply copper plus mancozeb two or more times per week in an attempt to manage this disease. Control, based on fixed copper bactericides, is not acceptable when weather conditions are optimal for disease development

SAR inducers. Recently, alternative chemical control approaches have been investigated in which chemicals are applied that activate plant defense responses. Systemic acquired resistance (SAR) is a biochemical state of the plant in which the plant develops greater resistance to a pathogen by previous infection by that pathogen or a different pathogen (Sticher et al., 1997). Several substances that specifically induce SAR, such as acibenzolar-S-methyl (ASM) (known as Actigard, Syngenta, NC) and harpin (Messenger, Eden Bioscience, WA) have been investigated. ASM has shown activity against bacterial spot in tomato (Louws et al., 2001) in Florida, Alabama, North Carolina, Ohio and Ontario, Canada. Recent modifications on phages and its integration with Actigard have resulted in significant increases in disease control compared to the standard bacteriophage and copper-mancozeb treatments (Balogh et al, 2002; Obradovic et al., 2002).

New materials. We are currently investigating new SAR materials such as a beta 1-3 glucan (extracted from a brown alga, *Laminaria digitata* (VacciPlant, Agrimar) and a plant extract (94-815, HeadsUp Plant Protectants, Kamsack, SK, Canada), and bactericides and/or fungicides such as, new formulation of Basic Copper Sulfate (Cuprofix Disperss, Cerexagri), Mancozeb /Zoxamide (Gavel, Dow AgroSciences) plus copper, Famoxate (Dupont) plus copper or mancozeb, Famoxate plus Cymoxanil (Tanos, Dupont), against bacterial spot in tomato. Results from these trials will be presented and discussed.

Integrated Management

An integrated management program against bacterial spot is a key factor for a successful tomato production. There are two important approaches to reduce severity and incidence of bacterial spot on tomato in the field: reducing inoculum and minimizing plant susceptibility. Recently, new environmentally friendly technologies have emerged that could be utilized in IPM programs as alternative management tools for bacterial spot. These include the following: a compound (Actigard) which induces systemic acquired resistance (SAR) (ie. increasing natural defense mechanism of the existing commercial cultivars or minimizing susceptibility) and uses phages specific to the target bacterium (i.e., reducing inoculum on leaf and fruit surfaces).

Since fall of 1999, we initiated a new research and extension program in north Florida to fine tune the use of Actigard and phage and reduce copper usage for tomato production in Florida. In the meantime, we are investigating many new potential materials for integration to tomato health management programs that could ensure economically and environmentally sustainable tomato production in Florida. Based on our intensive research programs on bacterial spot in Quincy and Gainesville (total of 29 field and greenhouse experiments) the following current recommendations have been made for bacterial spot management for fresh market tomato production in Florida:

- •Use Actigard every 14 days. The first application needs to start as early as possible after transplanting. This will help to reduce copper application per season. Mancozeb may be still needed for some foliar fungal disease control. Actigard label cautioned yield reduction in some cases. In north Florida and south Georgia yield reduction due to Actigard have not been observed since1999.

•Use an Actigard-AgriPhage combination. This combination might help to eliminate or reduce copper significantly for the management of bacterial spot. In this program, use Actigard every 14 days. Use phage twice a week, apply before sunset, especially before expected rains and/or immediately after. Use powdered skim milk as a protective for phages.

•If you never used Actigard and/or AgriPhage in your production, try it only in limited areas (to gain experience). Read all label information carefully.

•Always use the cultural practices mentioned above as a backbone of your integrated program.

Bacterial spot causes serious problems every year on tomatoes in Florida. Results derived from our research program are being used to design an effective IPM program that aims to reduce copper use on Florida tomatoes while maximizing bacterial spot control with environmentally sound disease management practices. Also by reducing the use of copper based bactericides, the amount of copper that enters the soil system will be diminished.

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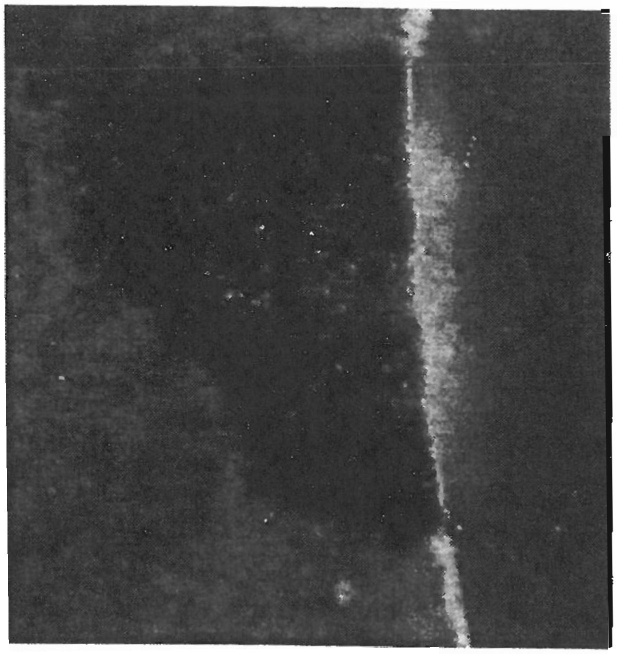
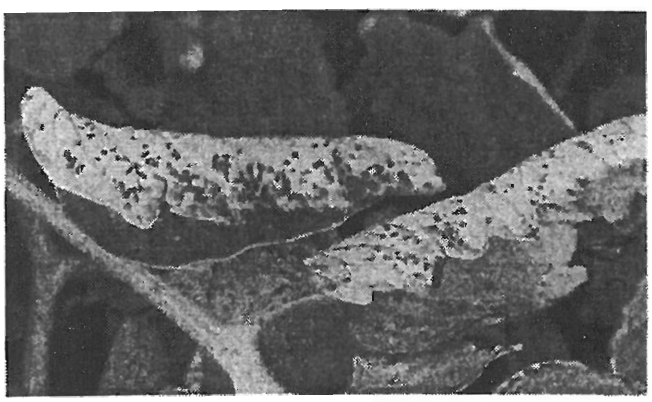


(credits: Hank Dankers)

Fig. 2. View of diseased tissue under micrfoscope test



(credits: Hank Dankers)

Fig. 1. Leaf spots on tomato leaves

Perspectives on a Decade of Late Blight in Florida Tomatoes (and Potatoes)

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The 2002 growing season marked the tenth season that Florida tomato and potato growers have had to deal with the modern or new strains of the late blight pathogen *Phytophtora infestans.* The first observation of a new strain of *P. infestans* in Florida (i.e. US-6) was made from a single Lee County tomato sample collected in 1991. It was not until two years later, however, during the 1993 season that the first statewide late blight epidemic resulting from one of the new strains of *P.*infestans occurred in the state. Since the initial Florida 1993 late blight epidemics in both tomato and potato, the disease has been a problem in either or both crops, somewhere in the state each year. We hope in this short report to summarize in general terms what we have learned about late blight in Florida since 1993 and to assess the impact of the new strains on the tomato and potato industries in the state.

Background

Prior to the 1970's and 80's Phytophthora and late blight researchers relied on morphological, cytological and pathogenic tools to identify strains of *P. infestans.* Spore types, attachments of spores, growth on selective media, number and type of chromosomes, and ability to cause disease on R-gene differential potato clones were some of the tools used. Although these methods are still being used, advances in molecular biology during the 1970's and 80's provided pathologists with powerful new tools to differentiate among different strains of pathogens. Allozyme and DNA fingerprint analyses in particular have revolutionized our ability detect and monitor changes in the population makeup of the late blight pathogen. Use of mating tests and assessment of resistance to metalaxyl are also used.

The use of molecular methods coupled with more traditional tools has greatly enhanced our understanding of the origins of P. *infestans* and the dynamics of late blight epidemics. There are currently two hypotheses regarding the evolutionary origin of *P. infestans.* One school of thought regards the Peruvian Andes as the source whereas the other, and more widely accepted hypothesis, considers the highlands of central Mexico as the center of origin for P. *infestans.* It is also widely accepted that until the 1970's, aside from Mexico, worldwide populations of P. *infestans* consisted mainly of a single clonal or asexually reproducing lineage which had a single mating type designated as A1. The opposite mating type or A2 existed only in Mexico and populations of *P. infestans* in Mexico were more diverse than elsewhere. It is also widely accepted that the populations of *P. infestans* outside of Mexico had changed relatively little since the migration leading to the Irish Potato Famine of the mid 1840's. The genotype or strain of the predominate clonal lineage existing outside of Mexico was named US-1. The first evidence for changes in the existing population structure of the late blight pathogen came from Europe during the early 1980's with the discovery of the A2 mating type. A similar report came from North America in 1991.

A clonal lineage of *P. infestans* is a population of the pathogen that is reproducing asexually from a single strain or genotype. The historic genotype of *P. infestans*, US-1 is believed to be a clonal lineage dating back to the mid 1840's. Even though certain of the new genotypes of *P. infestans* which migrated into North American agriculture since the 1970's consisted of A2 mating types and were apparently resistant to metalaxyl, those identified during the early 1990's (i.e. US-6, US-7, and US-8) were also clonal or asexual lineages. These three clonal lineages rapidly replaced the historic US-1 genotype because they had greater pathogenic fitness. The factors contributing to this greater fitness include resistance to metalaxyl (all three), superior aggressiveness on tomato (US-6 and US-7), superior aggressiveness on potato (US-8), enhanced pathogenicity to potato tubers and foliage (US-8). Rapid tentative diagnosis of the US-1, 6, 7, and 8 has been possible using allozyme analysis of the single Gpi locus because these four genotypes have distinct banding patterns at this locus.

Late Blight in Florida

Late blight has been a problem in Florida potatoes as long as the crop has been cultivated in the state. The disease was first reported in tomatoes about 50 years later during the mid 1940's. Although severe outbreaks of late blight have been rare after the introduction of the EBDC fungicides during the 1940's, the disease generally occurred someplace in Florida nearly every season either in tomato or potato. Late blight was rarely seen in Florida tomatoes or potatoes between 1983 and 1993 following the release of metalaxyl in the early 1980's. Since the statewide late blight epidemics of 1993 and the introduction of new genotypes, late blight has again been a problem somewhere in the state each year.

Development of late blight, as is the case for all plant diseases, requires a susceptible host, a favorable environment, and a source of inoculum. Most existing commercially acceptable varieties of tomato and potato are highly susceptible to late blight. Also, for most of the production season, weather conditions in Florida, especially in south Florida, are generally favorable for development of late blight. Historically, weather conditions in north Florida tend to moderate late blight epidemics. Cold nighttime temperatures coupled with low relative humidity and relatively short durations of leaf wetness when the potato crop is emerging during January and February often deter epidemics; and high daytime temperatures coupled with intense radiant energy between blossoming and harvest impede late season late blight disease progress in north Florida potatoes. Late blight is most severe in north Florida when nighttime temperatures are above normal during January and February because these temperature conditions generally result in fog and/or heavy precipitation of dew. Unfortunately, average daily temperatures and nighttime durations of leaf wettness in south Florida are usually optimum for late blight development during most of the tomato and potato production seasons.

The source(s) of inoculum for late blight in Florida tomato and potato crops was for many years considered to be seed tubers imported from northern states and Canadian provinces. Many tomato producers also considered potato to be the most important source of inoculum for late blight in commercial tomatoes. Allozyme analyses and other tools have helped shed light on development of late blight epidemics in Florida tomato and potato crops. Seed tubers are indeed an important source of inoculum during some seasons. The genotypes of *P. infestans* observed in Florida potato fields during the early 1990's matched those of the states from which the seed was purchased. Potato seed tubers, however, were not the only source because the genotypes in tomato fields sometimes differed from those in nearby potato fields. Genotype analyses also revealed that inoculum for late blight epidemics in some potato fields likely came from tomato. It is therefore important to realize the late blight is indeed a community disease and that both tomato and potato are a part of this community.

Prior to the introduction of the A2 mating type from Mexico, the late blight pathogen required living tissue for its survival from one season to the next. In addition to infected potato seed tubers, there are a number of other potential sources of inoculum: potato and tomato culls, volunteer tomato and potato plants, infected tomato transplants, and alternative hosts. Survival of P. *infestans* as oospores is theoretically possible if A1 and A2 strains mate and form oospores. Allozyme and DNA fingerprint analyses of *P. infestans* populations can help determine if sexual recombination has occurred. In absence of other data, however, these methods cannot always determine where and when the recombination took place.

We have in recent seasons observed late blight in volunteer potato plants, home gardens, and fall potatoes during the planting and emerging period of the Hastings potato crop. Inoculum for the 1997 epidemic in Hastings area potatoes clearly came from either or both a home garden and fall planted potatoes. There have also been anecdotal reports of late blight in potato cull piles in late October. Therefore seed tubers, although still important, are no longer considered to be the sole source of late blight inoculum in the Hastings potato region.

We have been following late blight epidemics in both potato and tomato throughout the state since 1993. Work in our laboratory has included among other things, partial characterization of *P. infestans* isolates collected throughout the state, comparisons of pathogenicity among different *P. infestans* genotypes, assessment of potential alternative hosts, evaluations of cultivar resistance, and fungicide efficacy in potato. We also participated in the National Late Blight Fungicide Trials and the National Late Blight Resistance Program.

Changes in Florida *P. infestans* Populations

We have analyzed 893 isolates of *P. infestans* since 1993. During that period we detected seven (US-1, US-6, US-7, US-8, US-10, US-11, and US-17) different genotypes, and possibly an eighth, in Florida. As summarized in **Table 1**, the mix of genotypes detected has changed through time. The "historic" genotype, US-1, has essentially disappeared from the Florida scene, as have US-6 and US-7 which were the bad guys back in the early 1990's **(Table 2)**. Meanwhile US-8 has become the culprit of record in Florida potato production, as it has in other potato regions. Tomato, on the other hand, has had US-11 and US-17 to deal with. The relative frequencies of the genotypes observed in tomato and potato are summarized in **Table 3** and the frequencies are tabulated by year in **Table 4**.

It is clear from these data that the dynamics of late blight epidemics in north and south Florida are quite different. With the exception of a US-1 observation in 1997 and a single US-10 (which has not been fully confirmed) in 2000, US-8 has been the only genotype observed in the Hastings region since 1996. During this same period of time US-7, US-8, US-10, US-11, and US-17 have been recorded in south Florida. There also have been south Florida epidemics associated with US-8 in potato and tomato, and US-11 and US-17 in tomato.

The reasons for the difference in the population structures of *P. infestans* between south and north Florida are not fully understood, however, are likely due to differences in the sources of inoculum or in the differences in cropping practices between the two regions. Both tomato and potato are grown in south Florida whereas only potato is grown in the Hastings region.

Many US observers consider Florida as an inoculum source for northern late blight epidemics. There has also been some concern that sexual recombination has occurred within Florida populations of *P. infestans*. The only genotypes found in Florida, which may have arisen due to sexual recombination, are US-10, US-11, and US-17 **(Table 2)**. Each of these genotypes, including US-17, were found in other states before they were observed in Florida. US-10 was reported from samples collected in Wisconsin in 1993, US-11 in Washington in 1994, and US-17 was identified in tomato samples from several states three to four months before it was found in Florida. Coincident with our detection of US-17 in south Florida during 1997, we also identified this genotype on tomato samples from Gainesville area home gardens, presumably planted with nursery store transplants. Since this was the only finding of US-17 outside of south Florida, movement of the pathogen in tomato garden transplants was strongly indicated. Available data therefore suggest that these genotypes developed elsewhere and were introduced into Florida.

Our data suggest that there are two distinct late blight pathosystems in the state...one in potato and one in tomato. The genotypes predominating in each pathosytem are for the most part unique to the particular crop. The tomato and potato pathosystems in south Florida tend to overlap resulting in potato genotypes infecting tomato and tomato genotypes occurring in potato. It seems likely that the host rather than the geographic region is the most important component distinguishing the two pathosystems, however, additional pathogenicity studies are needed to confirm this hypothesis.

Pathogenicity of Different Genotypes in Tomato and Potato

The relative aggressiveness of US-8 isolated from tomato and potato, US-10 from potato and US-17 from tomato were compared on both excised leaves and whole plants of tomato and potato. Disease severity, sporangia development, and the length of latent period (time between inoculation and lesion development) were assessed. All three genotypes caused disease in both tomato and potato. Based on disease severity, all three genotypes were aggressive on tomato **(Fig. 1)**; however, US-17 was less aggressive on potato than were US-8 and US-10. Both US-8 and US-10 produced considerably more sporangia/ area of leaf tissue on potato than did US-17. All three genotypes produced equivalent numbers of sporangia on tomato. Both US-8 and US-17 produced fewer sporangia/leaf area on tomato than they did on potato. US-17 produced more sporangia on tomato than potato; however, production on potato was very low. In these tests US-8 and US-10 were equally aggressive on potato and tomato whereas US-17 was more aggressive on tomato. Field scouts on the other hand have reported that US-17 and US-8 tend to be more aggressive on, respectively, tomato and potato when observed in the field. When all data are considered, tomato growers need to be especially diligent with spray programs when US-17 is present whereas potato growers need to be most observant for US-8.

Alternative Hosts

Potato and tomato are both members of the tomato plant family Solanaceae. Erwin and Ribeiro in their comprehensive review of Phytophthora diseases list 90 different plant species, 47 of these being in the potato genus Solanum, as hosts of *P. infestans*. Many of the reports on nonsolanaceous hosts are based on artificially inoculated hosts; and most of the solanaceous hosts are close relatives of potato found in Latin America. Recently, however, *P. infestans* has been reported in hairy nightshade (*Solanum sarachioides)* and petunia (*Petunia hybrida*) in other regions of North America. Hairy nightshade has been rarely observed in Florida whereas petunia is widely sold in nursery stores as a bedding plant.

A wide range of solanaceous plants are found in Florida and we were interested in determining whether some of these were potential alternative hosts for *P. infestans* even though the pathogen had not been observed on these plants in Florida. Tropical soda apple and American black nightshade were of particular interest. Tropical soda apple because it is a recent introduction and widely distributed in south Florida; and American black nightshade because it is extremely common along ditch banks in south Florida potato and tomato fields.

We completed seven inoculation studies since 1997 to assess the potential of several solanaceous plants to serve as over seasoning or alternative hosts for *P. infestans.* The species used in our studies were bell pepper (*Capsicum annum*), petunia, eggplant (*S. melongena*), cut leaf ground cherry (*Physalis angulata)*, American black nightshade (*S. americanum)*, tropical soda apple (*S. viarum)*, jimsonweed (*Datura stramonium)*, morning glory (Ipomea sp.), tomato (*Lycopersicon esculentum)*, and potato (*S.tuberosum*). The criteria used for selecting the species included literature reports of host status, presence in tomato/potato production areas of Florida, and availability of seed or transplants. Isolates of US-1, US-8, US-10, US-11, and US-17 were used in one of more of the experiments.

We completed two series of alternative host studies. The first series included several experiments performed during 1999 in temperature control rooms and included pepper, petunia, eggplant, potato, and tomato whole plants and/or excised leaves or leaflets which were inoculated with Florida isolates of US-8 and US-17. Late blight symptoms and sporangia developed on both potato and tomato in these studies, however, all other plant species were totally free of disease symptoms or signs of infection.

In several subsequent trials completed by the junior author four *P. infestans* genotypes were used to inoculate excised leaves or leaflets of ten different potential hosts. Sporangia were produced on, in addition to tomato and potato, six different plant species (petunia, eggplant, American black nightshade, jimson weed, and cutleaf ground cherry **(Table 5**). Sporulation was sparce on all six plant species except American black nightshade (ABNS). Isolates of the pathogen from ABNS (except US-17 which was from tomato) were used to inoculate the same ten hosts to test pathogenicity of the isolates. The length of time between inoculation and visible signs of infection, called the latent period, is often used as a measure of a pathogen's aggressiveness. The latent period was used to assess the pathogenicity of the isolates on the various hosts in this study. As summarized in Table 6, aside from tomato and potato, signs of infection were observed only on petunia, ABNS, and Jimson weed. The shortest latent periods for US-8, 11, and 17 were generally in tomato and potato.

It is difficult to fully assess the importance of the alternative host data without additional studies. Although petunia has been reported as a host of *P. infestans* in other regions of the US and Canada, late blight or its pathogen have not been observed in Florida on petunia or any of the other plant species used in our studies. Petunias are grown mainly as bedding plants during the winter and spring in Florida and its primary importance as an alternate host would most likely be to introduce inoculum on imported transplants. The role of ABNS is a particular enigma because it is widely distributed and in some cases extremely abundant in tomato and potato producing areas of south Florida. Nonetheless, *P. infestans* has not been found naturally in this host and its implication as a potential over seasoning host for the late blight pathogen at this point is speculative. The data from these experiments, however, does implicate its potential and additional testing and surveys should be completed.

Concluding Comments

The late blight picture in Florida tomato and potato productions is much clearer today than it was ten years ago, however, we still do not have a full picture of how inoculum for the disease is either introduced or maintained in the state. Potato seed tubers have been and will be an important source of inoculum, not only in Florida, but wherever the crop is grown. Both tomato and potato cull piles and, if susceptible hosts are nearby, plants in the surrounding ditch banks and unplanted areas adjacent to packing areas where late blight infected plant material may have been discarded are also potential sources. Alternative hosts remain a possibility, however, natural infection of hosts other than tomato and potato with *P. infestans* has not been observed in Florida. Volunteer tomato and potato plants in Florida also constitute inoculum sources and in recent years late blight has been observed in volunteers of both crops. Every effort should be made to eliminate volunteers.

Movement of late blight inoculum and new genotypes in tomato remains unsolved. It is clear from our data and from the data of others that more genotypes found are in North American tomato than potato. There has also been a trend for new tomato genotypes to show up in many different areas of the country within a relatively short period of time. This pattern strongly suggests movement of inoculum in transplants, diseased fruit or some other man- aided means.

North Florida and south Florida, most likely because of the geographic distance between the production areas, constitute two distinct late blight pathosystems. Although the issue is still not fully resolved, genotype data and the temporal development of late blight epidemics in south Florida strongly suggest that most tomato and potato production areas in the southern part of the state are interrelated. It is highly likely that *P. infestans* can "leap frog" from one potato or tomato production area to another in south Florida because the geographic distance is not great. Nonetheless, epidemics in south Florida tomato and potato are often distinct, but can "trespass" into the others turf. Again, our data are fragmentary, however, and additional observations are needed to draw more quantitative conclusions.

So far the good news is that we as yet have no evidence of sexually reproducing populations of *P. infestans* in Florida. We also have no evidence that it is surviving as oospores from one season to the next. We have found A1 and A2 mating types in the same area, however, we have not found them on the same plants, nor have we found oospores on or in host tissue.

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Table 1. Summary of *Phytophthora infestans* genotypes and the years they were observed in Florida during the period 1993 to 2002.

Genotype	Years observed
US-1	1993, 1995, 1997
US-6	1991*, 1993
US-7	1993, 1996, 1996
US-8	1994, 1995, 1996, 1997,1998, 1999, 2000, 2001
US-10	1999**, 2000**
US-11	1998, 2001***, 2002
US-17	1997***, 1998, 1999, 2000, 2002***

* A single lesion was found in a Lee County tomato field.
** Single isolates were collected each year from fields heavily infected with US-8.
*** Epidemic in tomato fields.

Table 2. Description of *Phytophthora infestans* genotypes identified in Florida between 1993 and 2002*.

Genotype	Mating type	Gpi allozyme genotype	Additional information
US-1	A1	86/100	Historic genotype since 1840's. Last found in Florida during 1997.
US-6	A1	100/100	Introduced into California in 1979. Found in Lee County tomatoes in 1991. Last observation in Florida during 1993.
US-7	A2	100/111	Introduced from Mexico. Predominant genotype in 1993 Florida epidemics in both potato and tomato. Last found in Florida during 1996.
US-8	A2	100/111/122	Introduced from NW Mexico. First found in Florida in 1994. Predominant genotype in US potato production, including Florida.
US-10	A2	111/122	Either a sexual recombinant or a recent migrant from Mexico. Single isolates found, respectively, during 1999 and 2000 in south and north Florida potato fields heavily infected with US-8.*
US-11	A1	100/100/111	Possible sexual recombinant. First found in western Washington in 1994 and California and New York during 1995. First observation in south Florida in 1998. Predominant genotype in Florida tomatoes during 2001.
US-17	A1	100/122	Probable sexual recombinant between US-6 and US-8. Found in tomatoes during 1996, respectively, in New York (Aug. and Oct.), Alabama (Oct.), New Jersey (Sept.), and Florida (Dec.). Predominant strain in Florida tomatoes during 1997 and 2002 (?).

*Isolates of US-10 have not been fully collaborated with DNA fingerprinting. Florida isolates tested are resistant to metalaxyl whereas previously the reported isolate of US-10 was sensitive.

Adapted from Goodwin, *et.al.* 1998. Phytopathology 88:939-949.

Table 5. Number of leaves or leaflets with sporangia following inoculation with four different genotypes of *Phytophthora infestans*.

	Genotype			
Plant species	US-1	US-8	US-11	US-17
Potato	4	4	4	4
Tomato	4	4	4	4
Petunia	2	2	0	0
Eggplant	1	1	1	0
Pepper	0	1	0	0
American black nightshade	3	4	4	3
Jimson weed	1	1	0	0
Cutleaf ground cherry	0	1	2	0
Tropical soda apple	0	0	0	0
Morning glory	0	0	0	0

Table 6. Number of days from inoculation to sporangia development (i.e. latent period)on potential alternative hosts of four different genotypes of *Phytophthora infestans* isolated from inoculated American black nightshade

	Genotype[1]			
Plant species	US-1	US-8	US-11	US-17
Potato	8.5*	2****	3.75****	3*
Tomato	8****	2****	3.25****	4****
Petunia	8.3***	7***	8****	9.25****
Eggplant	-	-	-	-
Pepper	-	-	-	-
American black nightshade	9*	7.5****	8*	14*
Jimsonweed	14*	9**	8***	9*
Cutleaf ground cherry	-	-	-	-
Tropical soda apple	-	-	-	-
Morning glory	-	-	-	-

One, two, three, or four (*) signify that data are from average of one, two, three, or four replications, respectively, and that no sporangia were observed in the other replications. A (–) signifies that no sporangia developed. US-17 isolates used in this study were from tomato.

Figure 1. Severity of late blight in potato and tomato following inoculation with different P. infestans genotypes

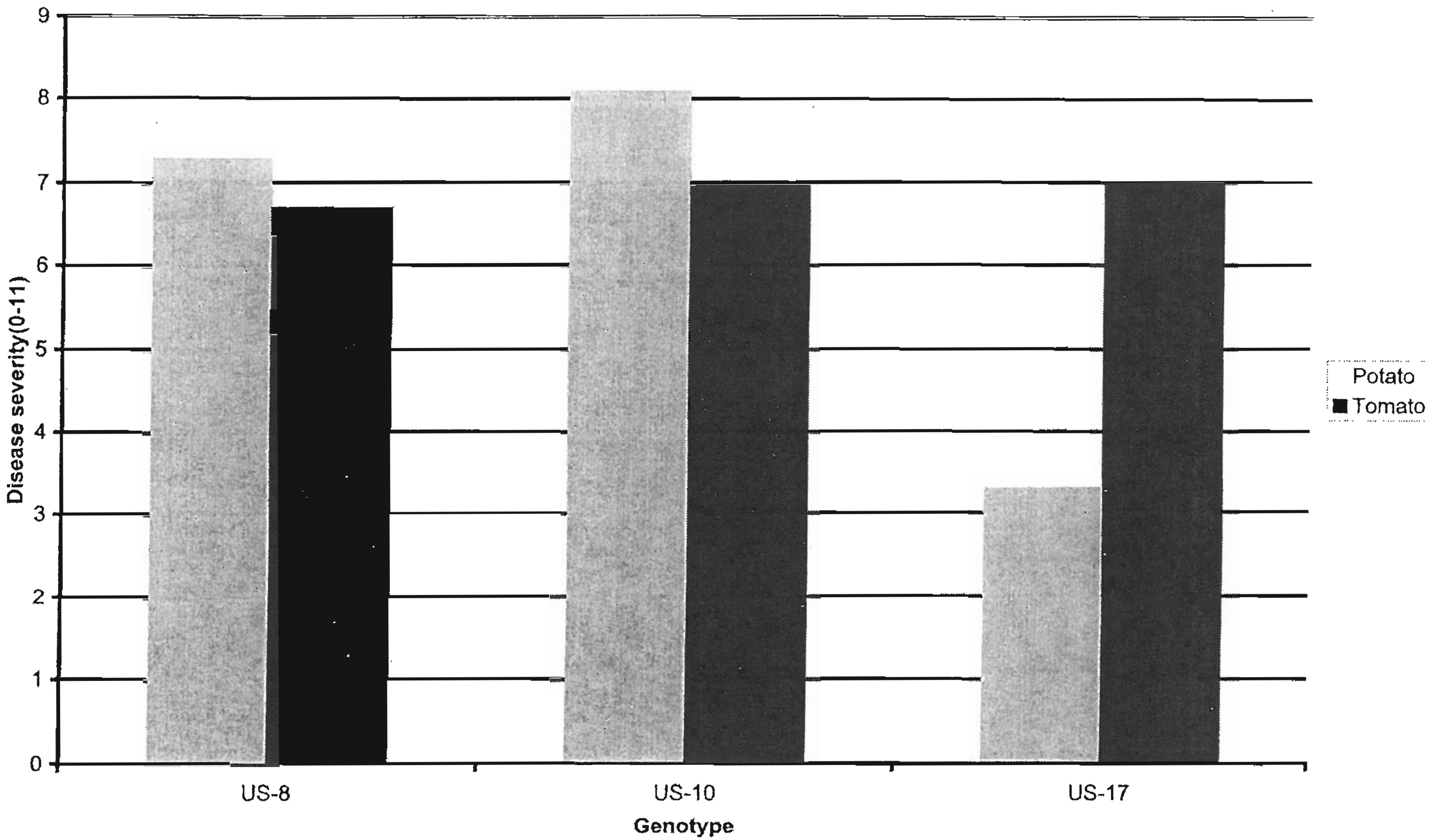
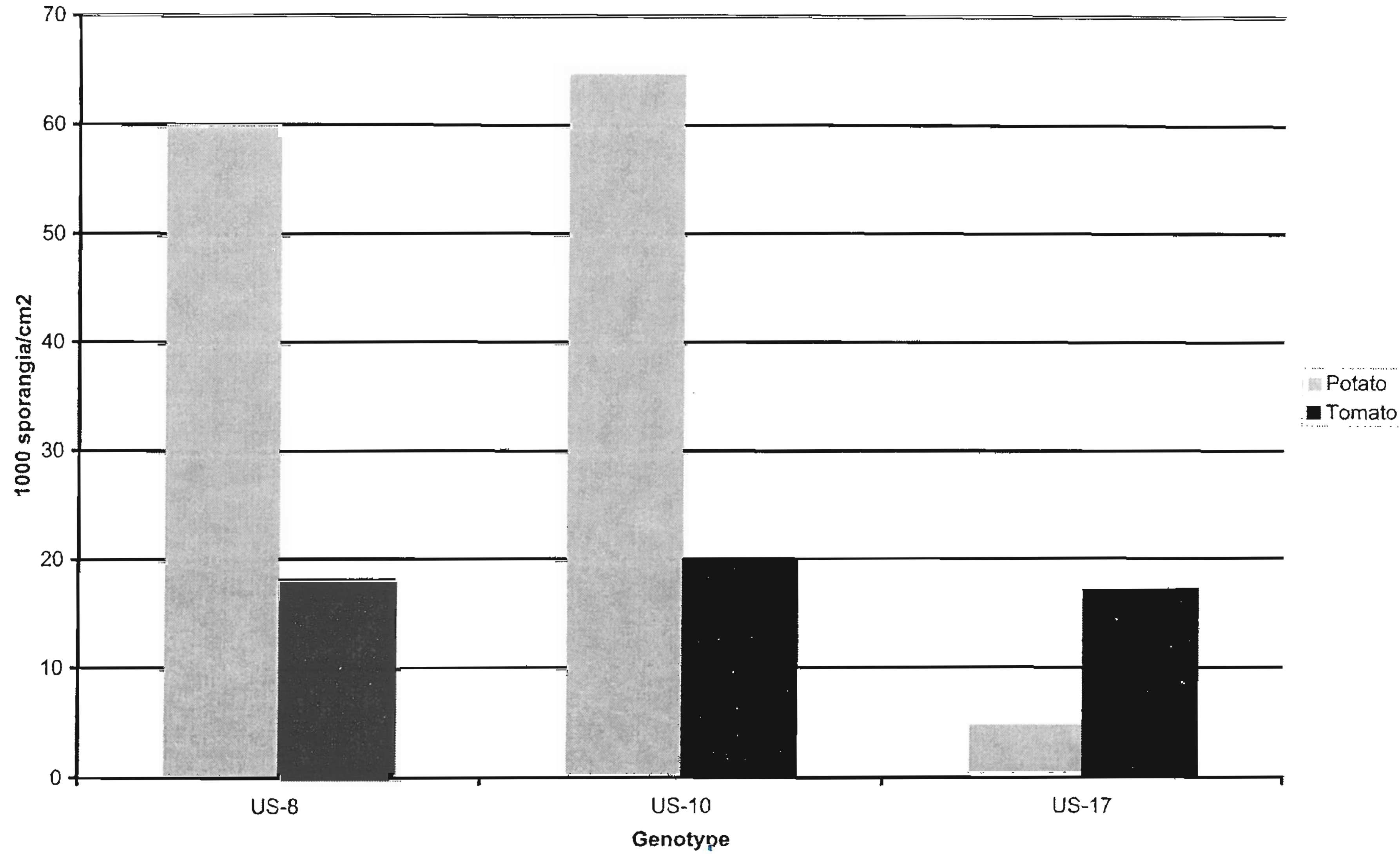


Figure 2. Sporangía produced by P. infestans genotypes on potato and tomato



Bts Celebrate 100 Years

Bacillus thuringiensis (Bt) bioinsecticides are celebrating a birthday of sorts. Roughly a century ago, in 1901 Japan, a bacteriologist discovered the Bt bacterium. Field tests for the first commercial Bt product began in the late 1920s and ever since Bts have played a role in agricultural pest management.

"It is surprising," H. Charles Mellinger, Ph.D. says. "Bts have lasted a unique length of time."

Some classes of synthetic chemical pesticides have come and gone, largely due to overuse and resistance, safety concerns or adverse environmental impact. But a full century after it was first discovered and 75 years after it was first used in the field, Bt still predominates the global biopesticide market, accounting for more than 90 percent of the $60 million in biopesticide sales in the U.S. alone.

Advances in Bt genetics, strain selection, fermentation media and formulation over the past 20 years have resulted in more potent, stable Bt spray products with more consistent performance against a broader array of insect pests. Because it has little or no impact on nontarget organisms and offers an alternative mode of action for delaying insecticide resistance in pests, Bt remains a key tool for Integrated Pest Management (IPM), especially in forestry, row crops, tree fruits, vines, nuts and vegetables.

In the U.S., Florida tomato growers are the largest users of Bt bioinsecticides. Up to 90 percent of the 40,000-acre tomato crop receive five to six Bt sprays per season to control Southern armyworm, beet armyworm, loopers, tomato fruitworm and cutworm.

"Bts are still the backbone of the worm control complex," says Dr. Mellinger who is director of technical services for Glades Crop Care, Inc. of Jupiter, FL, the largest independent crop consulting and research firm in the state. (www.gladescropcare.com)

> *"Bts are nuggets...and they still are so effective."*
>
> —Dr. Charles Mellinger

"Bts are still efficacious, they are still economical, and they are still soft on beneficials," he says. And, although

(continued on reverse)

Bt History Timeline

- 1901: Eureka! The rod-shaped, spore-forming bacterium is discovered
- 1915: Bt gets its formal scientific name: *Bacillus thuringiensis*
- 1920s: Bt is first tested in the field as a biopesticide
- 1938: Sporeine, the first Bt product, is registered in France
- 1940s: Bt begins to attract the attention of the modern crop protection industry
- 1957: Thuricide, the first large-scale Bt product, is introduced in the USA by Sandoz
- 1960s: USDA/industry standardize production and quality
- 1970s: New subspecies of Bt are found that control mosquitoes, beetles
- 1981: The first Bt toxin gene is cloned, leading the way to Bt transgenic crops
- 1990s: Mergers and acquisitions alter the number of Bt manufacturers
- 2000: Certis USA is established and becomes a primary Bt supplier worldwide

Bt Birthday *(continued from reverse)*

new chemistries with some characteristics that cannot be matched by Bts have been available for the last several years, Bts are still the workhorses of Florida tomato production.

At Glades Crop Care, Dr. Mellinger says the company's consultants start the fall tomato production season with Bt products, because they are "generally the most economical." Then, as the season moves into Florida's rainy period, Glades Crop Care recommends the rotation of Bts with one of the highly rainfast worm control materials tebufenozide or indoxacarb. "We usually hold spinosad for later in the season when we need leafminer control," Dr. Mellinger says. In the spring, the consultants recommend a return to the economical Bt-reliant program until circumstances again dictate the rotation of another material.

Also, Dr. Mellinger says, "By maintaining a soft larvicide program, which you can do with the Bts, we can preserve populations of the wasp that parasitizes leafminer larvae." Glades Crop Care advocates the use of softer products like the Bts to retain and build up the wasp population through the fall. "That way the wasps will control the early developing populations of leafminer and save the grower one or two applications of abamectin or cyromazine, and that's good," he says.

"Bts are nuggets that have been with us for so long, and they still are so effective," Dr. Mellinger says. "That's the gem of the deal, right there."

Common Bt Products

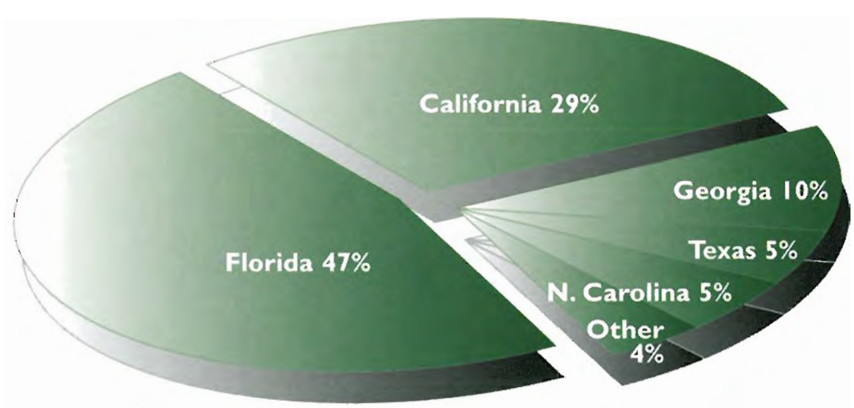
Product	Manufacturer	Subspecies
Agree®	Certis USA	*Bt aizawai* (Transconjugant)
BioBit®	Valent U.S.A.	*Bt kurstaki* (Non-modified)
Condor®	Certis USA	*Bt kurstaki* (Transconjugant)
CryMax®	Certis USA	*Bt kurstaki* (Recombinant)
Cutlass®	Certis USA	*Bt kurstaki* (Transconjugant)
Deliver®	Certis USA	*Bt kurstaki* (Non-modified)
DiPel®	Valent U.S.A.	*Bt kurstaki* (Non-modified)
Foil®	Certis USA	*Bt kurstaki* (Transconjugant)
Foray®	Valent U.S.A.	*Bt kurstaki* (Non-modified)
Javelin®	Certis USA	*Bt kurstaki* (Non-modified)
Lepinox®	Certis USA	*Bt kurstaki* (Recombinant)
Mattch®	Dow AgroSciences	Not *Bt* (Recombinant*)
MVP®	Dow AgroSciences	Not *Bt* (Recombinant*)
Novodor®	Valent U.S.A.	*Bt tenebrionis* (Non-modified)
Raven®	Certis USA	*Bt kurstaki* (Recombinant)
Thuricide®	Certis USA	*Bt kurstaki* (Non-modified)
XenTari®	Valent U.S.A.	*Bt aizawai* (Non-modified)

*Note: Mattch and MVP are recombinant *Pseudomonas fluorescens* expressing cry genes from *Bt*

Bt Usage on US Vegetable Crops in 2000

Percentage by State ■ *Source:* USDA-NASS July 2001

Total reported Bt usage: 990,570 acre treatments



Certis USA
Product List

	The Pest	The Certis USA Solution	
INSECTICIDES	**Bt Bioinsecticides**		
	Lepidoptera (caterpillar) pests	Agree®	*Bt aizawai/kurstaki* (Transconjugant)
		Condor®	*Bt kurstaki* (Transconjugant)
		CryMax®	*Bt kurstaki* (Recombinant)
		Deliver®	*Bt kurstaki*
		Javelin®	*Bt kurstaki*
		Lepinox®	*Bt kurstaki* (Recombinant)
		Thuricide®	*Bt kurstaki*
	Coleoptera	Raven®	*Bt kurstaki/tenebrionis* (Recombinant)
	Mosquito, blackfly	Teknar®	*Bt israelensis*
	Insect Growth Regulators		
	Whitefly, leafminer, aphid	Neemix®	Azadirachtin
	Insecticidal Fungi		
	Whitefly, aphid, spider mites	PFR	*Paecilomyces fumosoroseus*
	Insecticidal Nematodes		
	Diaprepes root weevil, blue-green weevil, mole cricket	BioVector® 355	*Steinernema riobrave*
	Flea (immature), sod web-worm, blackvine weevil	Millenium® BioVector® 25	*Steinernema carpocapsae*
	Insecticidal Viruses		
	Bollworms, tobacco budworm, corn earworm	GemStar®	*Helicoverpa zea nucleopolyhedrosis virus* (HzNPV)
	Beet armyworm	SPOD-X®	*Spodoptera exigua nucleopolyhedrosis virus* (SeNPV)
MITICIDES	**Miticides** (Acaricides)		
	Spider, broad and rust mites	Trilogy®	Clarified neem oil
PHEROMONES	**Pheromones** (Mating Disruption)		
	Codling moth	3M MEC-CM	CM Pheromone
	Leafroller	3M MEC-LRX	LRX Pheromone
	Oriental fruit moth	3M MEC-OFM	OFM Pheromone
	Grape berry moth	3M MEC-GBM	GBM Pheromone
FUNGICIDES	**Biofungicides**		
	Powdery mildew, *Alternaria*, greasy spot, postbloom fruit drop	Trilogy® Triact®	Clarified neem oil
	Damping-off and other soil-borne diseases	SoilGard®	*Gliocladium virens*

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Update on Insecticides for Whitefly and Leafminer Control

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The silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring (SLWF) {also know as the B strain of the sweetpotato whitefly, *B. tabaci* (Gennadius)}, and the leafminer, *Liriomyza trifolii* (Burgess), are considered serious pests of tomatoes in Florida (Schuster et al. 1996a). *B. argentifolii* causes losses by inducing the irregular ripening (IRR) disorder of tomato fruit and by transmitting the geminiviruses tomato mottle virus (ToMoV) and tomato yellow leaf curl virus (TYLCV) (Schuster et al. 1996b). The larval feeding of *L. trifolii* within the leaves causes serpentine mines and can result in significant defoliation of plants, particularly when secondary microorganisms invade the mines (Musgrave et al. 1975).

To avoid the losses due to ToMoV and TYLCV, nearly 100% of the tomato transplant producers are applying the nicotinoid Admire 2F® (imidacloprid; Bayer CropScience., Kansas City, MO) at least once seven to 10 days prior to transplanting. This application is made to help assure that the plants are protected against *B. argentifolii* for up to three weeks after transplanting. Another soil application of either Admire or Platinum® (thiamethoxam; Syngenta Crop Protection, Inc., Greensboro, NC), another nicotinoid, is made either at transplanting or up to three weeks after transplanting. These applications provide whitefly and TYLCV control for three to 12 weeks, depending upon location and season (Schuster and Morris 2002).

Applications of insecticides other than the nicotinoids, such as the insect growth regulators Courier® (buprofezin; Nichino America, Inc., Wilmington, DE) and Knack® (pyriproxyfen; Valent U.S.A. Corp., Walnut Creek, CA) are recommended for control of whitefly nymphs as the effects of Admire or Platinum diminish (Schuster 2002). Because of the continued threat of TYLCV, growers are applying additional insecticides including Fulfill® (pymetrozene; Syngenta Crop Protection, Inc., Greensboro, NC), pyrethroids, organochlorines and soap for control of adults, even during the period after transplanting when soil applications of nicotinoids are still effective. Some of these compounds, particularly the pyrethroids and organochlorines, are no longer as effective against adults as they once were. Some growers have begun to make foliar applications of nicotinoids including Provado® (imidacloprid; Bayer CropScience., Kansas City, MO) and Actara® (thiamethoxam; Syngenta Crop Protection, Inc., Greensboro, NC), even if they previously have made soil applications of either Admire or Platinum. This practice will encourage the development of resistance to these insecticides (Elbert and Nauen 2000) and, possibly, to the whole nicotinoid class. Recently, another nicotinoid, Assail® (acetamiprid; Aventis CropScience, Research Triangle Park, NC), has been registered for whitefly control as foliar applications and will only increase the potential of multiple applications of nicotinoids to a tomato crop.

To manage *L. trifolii*, growers apply insecticides including Agri-Mek® (abamectin; Syngenta Crop Protection, Inc., Greensboro, NC), Trigard® (cyromazine; Syngenta Crop Protection, Inc., Greensboro, NC) and SpinTor® (spinosad; Dow AgroSciences, Indianapolis, IN), usually on demand. However, growers, scouts and others have expressed the opinion that these products are declining in efficacy against the leafminer on tomato.

This past spring many tomato growers observed that the level of leafminer damage and the incidence of plants with TYLCV symptoms were more severe than in recent years. With the concern of increased pest pressure and the concern for possible decreases in efficacy of some insecticides, there is a need for additional insecticidal products to maintain a high level of control and to incorporate into rotations as part of a resistance management program. Therefore, the objectives of the present investigations were to continue monitoring the susceptibility of the SLWF in Florida to Admire and to compare the efficacy of newer insecticides against whiteflies and leafminers with that of older insecticides.

Materials and Methods

Monitoring Whitefly Susceptibility to Admire

A cut leaf petiole method was developed to compare the susceptibility of field populations of the SLWF to Admire with that of a highly susceptible laboratory colony (Schuster and Thompson 2001). The method was used to evaluate the relative susceptibility of SLWF populations from three Admire-treated tomato fields in the spring of 2000, nine fields in the spring of 2001, and 13 fields in the spring of 2002. Some of the sites sampled in 2002 were the same as those sampled in 2001. Bioassays were conducted using adults reared from foliage infested with nymphs that had been collected from each tomato field. The progeny of adults that survived the bioassay from the Duette site in 2001 were reared for 8 wk (about 4 generations) on tomato in the laboratory and then bioassayed again. At the Immokalee1 and Ruskin sites in 2001, whitefly-free, greenhouse-grown tomato plants were placed on the field perimeters about 4 wk after the crop had been destroyed. One week later, the plants were returned to the laboratory and held 4-5 wk (about 2-3 generations) and the progeny bioassayed. Standard probit analyses was used to estimate the LC_{50} values (the concentration estimated to kill 50% of the population) for the laboratory colony and for each field population (SAS Institute 1989). The relative susceptibility (RS_{50}) of each field population compared to the laboratory colony was calculated by dividing the LC_{50} values of the field populations by the LC_{50} value of the laboratory colony. Increasing values greater than one suggest decreasing susceptibility in the field population.

Evaluating Insecticide Field Efficacy

Three trials were conducted during the spring of 2002 at the Gulf Coast Research & Education Center (GCREC), Bradenton, three at commercial tomato farms in west central Florida, and one at the Southwest Florida Research & Education Center (SWFREC). In the first GCREC experiment, transplants were set 18 inches apart on March 7 on raised beds of EauGallie fine sand covered with black polyethylene mulch. Plots were three, 21 ft long rows on 5 ft centers and were irrigated by a seepage sub-irrigation system. Treatments were replicated four times in a randomized complete block design. Admire and V-10112 (chemistry not identified; Valent U.S.A. Corp., Walnut Creek, CA) were applied on March 7 to each plant in 4 ozs of water. MT-02-2 (chemistry not identified) , novaluron (Crompton Uniroyal Chemical, Raleigh, NC) and MT-02-3 (chemistry not identified) were applied at the predetermined density of 5 whitefly sessile nymphs and/or pupae per 10 leaflets. Thus, MT-02-2 was applied on May 8 and 29; novaluron on May 8, 21, 29, and June 13; and MT-02-3 on May 8 and June 13. Foliar applications were made with a high clearance, self-propelled sprayer operated at 200 psi and 3.4 mph. It was fitted with eight Albuz orange nozzles per row and delivered 90 (six nozzles open) gpa on May 8 and 21 or 120 (eight nozzles open) gpa for remaining dates. The number of plants in each plot with definite symptoms of whitefly-vectored geminivirus, primarily TYLCV, were recorded weekly. The numbers of sessile nymphs (2nd and 3rd instars) and pupae (4th instar or red eye nymphs) of the silverleaf whitefly were counted on the terminal leaflet from the 7th - 8th leaf counting from the top of each of ten plants in the center row of each plot on April 29, May 6, 13, 20, 28, June 3, 10, 17 and 24.

In the second GCREC experiment, transplants were set March 7, 18 inches apart on 8-inch-high beds of EauGallie fine sand covered with black polyethylene mulch. Each plot consisted of a single 18 ft row with rows on 5 ft centers. Treatments were replicated four times in a randomized complete block design and were applied with a 2.5 gal, hand-held CO_2-powered sprayer on April 1. The sprayer was operated at 60 psi and delivered 60 gpa using a single nozzle fitted with a D-5 disk and #25 core. The number of leafmines were counted during a 2 minute search of each plot on April 17, 24 and May 1.

In the last experiment at GCREC and the three experiments on commercial farms, transplants were set March 12 at the GCREC and on February 18, March 1 and 7 at farms near Ruskin, Lorraine and Duette, respectively. Transplants at all locations were grown commercially and, with the exception of those set at GCREC, were treated with Admire in the plant house prior to delivery. Plots consisted of two rows of 15 plants each and treatments were replicated three times in randomized complete block designs. Plant spacing ranged from 18 to 24 inches and row spacing was 5 or 6 ft with resulting plant numbers/acre of 5,808, 4,356, 3,960 and 3,630 for GCREC, Ruskin, Lorraine and Duette respectively. Admire 2F was applied at 16 ozs/acre and Platinum 2SC was applied at 8 ozs/acre in at least 1.7 ozs of water as a drench to the base of each plant at transplanting. All plants in each plot were examined weekly for definite symptoms of TYLCV and 10 plants of one row of each plot were sampled weekly for whitefly sessile nymphs as in the first experiment. The numbers of *Liriomyza* leafmines per plot were counted weekly during a one min search of one row of each plot by one person. The data were averaged over all locations for analyses.

In the experiment at SWFREC, seedlings were planted March 25 at 18-inch spacing on two sets of three, drip irrigated beds, 240 ft long on 6 ft centers. The middle row of each three-bed set was left untreated to serve as a source of whiteflies while the outer two beds of each set were divided into eight plots, each 30 ft long and assigned to treatments in a randomized complete block design with 4 replications. Admire 2F and Platinum 2SC were applied as soil drenches on March 27 in 0.7 oz of water per plant. The remaining products were applied beginning April 10 in three weekly foliar applications at a rate of 44 gpa using a high clearance sprayer driven by a hydraulic pump operating at 200 psi and delivering the spray through two drop booms each equipped with two yellow hollow cone ceramic Albuz® nozzles. On May 1, an additional nozzle was added to each drop for an output of 66 gpa for three additional weekly applications. Assessments of whitefly immature lifestages were monitored from one leaf removed from the 6th node of 10 centrally located plants in each plot. Large whitefly nymphs and pupae were counted that appeared in a 2.2 cm ring placed four times on the terminal leaflet from each leaf collected. Live leaf miner larvae also were noted on the same leaflets on three sampling dates. Plants were monitored weekly for symptoms of TYLCV.

Results and Discussion

Monitoring Whitefly Susceptibility to Admire

Over all three years, nearly 80% of the RS_{50} values of whiteflies collected from the Admire-treated fields were 8 or less (**Table 1**). While values approaching 8 could indicate decreasing susceptibility of the whiteflies, such variability is not unexpected when comparing field-collected insects with susceptible, laboratory-reared insects. The laboratory colony used as a susceptible standard in this study has been in continuous culture since the late 1980's without the introduction of whiteflies collected from the field and, therefore, would be anticipated to be particularly susceptible to insecticides. In both 2001 and 2002 whiteflies from three populations had RS_{50} values of 10 or greater, which were sufficiently high to draw attention. This was particularly true of the SWFREC and Duette sites in 2002. Because monitoring for susceptibility to Admire has only been conducted for three years, it is not known whether these six fields represent the higher points in the natural susceptibility range, a trend toward increasing tolerance or whether such events have occurred in the past and that observed increased tolerance will disappear or decrease between cropping seasons. The RS_{50} value of the 4th generation progeny of the bioassay survivors from the Duette site in 2001 was about 2 compared to 8 for the 1st generation (**Table 2**). Furthermore, the RS_{50} values for whitefly populations collected 4 wk after the end of the crops at the Immokaleel and Ruskin sites in 2001 were both about 2 compared to 15 and 5, respectively, during the season. In addition, the RS_{50} value for a whitefly population collected at the SWFREC site from tomato plants that had not been treated with Admire dropped from about 13 to about 6 after having been reared in the laboratory for only one generation (data not presented). Therefore, the high RS_{50} values in 2001 and 2002 may represent either the high end of natural levels of variability or may represent unstable shifts in reduced susceptibility, i.e. Admire tolerance may increase at some sites during the season but dissipate or disappear during the off-season. The fact that densities of whitefly nymphs on the tomatoes at the SWFREC (**Fig. 3**) and Duette (Schuster and Morris 2002) sites in 2002 were not especially high and the fact that none of the whitefly populations in sampled fields, including the six with higher RS_{50} values, were out of control also might suggest variability in the populations or in the bioassay itself. Nevertheless, the high level of some RS_{50} values at some sites, especially in 2002, should be of sufficient concern to growers to encourage them to redouble their efforts in implementing a nicotinoid resistance management program as outlined by Schuster and Thompson (2001).

Nicotinoid Resistance Management Recommendations

Reduce overall whitefly populations by strictly adhering to cultural practices including:

•Plant whitefly-free transplants;

•Delay planting new crops as long as possible and destroy old crops immediately after harvest to create or lengthen a tomato-free period;

•Do not plant new crops near or adjacent to infested weeds or crops, abandoned fields awaiting destruction or areas with volunteer plants;

•Use UV-reflective (aluminum) plastic soil mulch

•Control weeds on field edges if scouting indicates whiteflies are present and natural enemies are absent;
•Manage weeds within crops to minimize interference with spraying;
•Avoid u-pick or pin-hooking operations unless effective control measures are continued;
•Do not use a nicotinoid like Admire on transplants or apply only once 7-10 days before transplanting; use other products in other chemical classes, including Fulfill, before this time;
•Apply a nicotinoid like Admire (16 ozs/acre) or Platinum (8ozs/acre) at transplanting and use products of other chemical classes (such as the insect growth regulators Knack® or Courier®) as the control with the nicotinoid diminishes;
•Never follow an application (soil or foliar) of a nicotinoid with another application (soil or foliar) of the same or different nicotinoid on the same crop or in the same field within the same season (i.e. do not treat a double crop with a nicotinoid if the main crop had been treated previously);
•Save applications of nicotinoids for crops threatened by whitefly-transmitted plant viruses or whitefly-inflicted disorders (i.e. tomato, beans or squash) and consider the use of chemicals of other classes for whitefly control on other crops.

Evaluating Insecticide Field Efficacy

The whitefly population in the first trial at GCREC was low until the ninth week after transplanting, when nymphal densities in the check first reached the threshold of 5 nymphs/10 leaflets (Fig. 1A). Nevertheless, the numbers of nymphs on foliage from treated plots were significantly different from that on foliage from the check plots on all sampling dates after and including May 13 (week 10), except for novaluron and MT-02-3 on May 13. Single applications of MT-02-2 generally resulted in nymphal densities below the threshold of 5 nymphs/10 leaflets for two to three weeks while a single application of MT-02-3 provided similar control for up to four weeks. The soil application of V-10112 resulted in control that was statistically similar to that of the soil application of Admire, although plants treated with Admire reached threshold two weeks sooner than did those treated with V-10112. While applications of novaluron resulted in significant reductions in the number of whitefly nymphs, densities did not drop below the threshold until after four applications. While the percentage of plants with symptoms of TYLCV were lowest on plots treated with V-10112, Admire and MT-02-2, differences from the check were not significant (Fig. 1B).

In the second experiment at GCREC, the leafminer population was very low. Nevertheless, a single application of each of the treatments including Avaunt, which is registered on tomato but not for leafminers, generally resulted in significantly fewer *Liriomyza* leafmines relative to the check for three weeks after treatment. **(Fig.2)** Agri-Mek treated plants still had significantly fewer leafmines compared to the check four weeks after treatment.

In the experiments comparing soil drenches of Admire and Platinum at GCREC and three commercial farms, whitefly populations generally were low, with the density in the check averaged over all four locations not reaching the threshold of 5 nymphs/10 leaflets until the eighth week after transplanting (Fig. 3A). In general, both Admire and Platinum resulted in reductions in nymphal densities relative to the check and were not different from each other. The incidence of plants with symptoms of TYLCV also was low with no significant effect of either Admire or Platinum compared to the check (Fig. 3B). The *L. trifolii* populations were low to moderate for a spring season (Fig. 3C). Both Admire and Platinum resulted in fewer leafmines relative to the check, at least on some dates, although control was greater and more consistent with Platinum. Neither product provided control after five weeks following treatment.

In the experiment at SWFREC, densities of whitefly nymphs were significantly lower with all treatments, both soil and foliar, from the fourth through the seventh week of sampling (Fig. 4A). By the seventh week, densities were significantly lower with the foliar applications of either MT-02-3 or Assail than with either Admire or Platinum. Although the percentage of plants with symptoms of TYLCV were lower than the check, particularly with Platinum and Admire five and six weeks after transplanting, the differences were not significant (Fig. 4B). A large number of whitefly adults carrying the virus evidently migrated into the plots during the fourth week after transplanting (data not shown) with the result of a steep increase in the percentage of plants with TYLCV symptoms two weeks later. Significantly fewer leafminer larvae relative to the check were found only for Assail and Platinum and only on the fifth week after transplanting(Fig. 4C).

Results of the field efficacy experiments identified new insecticides that will be useful for managing whiteflies and leafminers in the future. Some of these products are of chemistries already registered for use on tomatoes such as Avaunt and the nicotinoids Platinum and Assail. Avaunt, which is registered for control of lepidopterous pests of tomatoes, may offer an alternative when both armyworms and leafminers are present at potentially damaging levels. Platinum and Assail, which are registered for control of whiteflies and other pests on tomato, may offer alternatives to growers when control of both whiteflies and leafminers is needed; however, as outlined in the resistance management program above, these products should not be applied if another nicotinoid has already been applied to any given tomato crop. Other products of new chemistries that are not yet registered, such as MT-02-2 and MT-02-3, provided excellent control of the SLWF and are potential alternatives for future control of this pest. The availability of all of the above products will be valuable for rotating with existing products in resistance management programs and will help ensure continued, long-term management of two of the most important insect pests of tomatoes in Florida.

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

County/Site	Date	RS_{50}[1]
	2000	
Manatee/GCREC, Field	June	6.0
Manatee/Rye	June	2.8
Manatee/Myakka City	June	2.3
	2001	
Hendry/Devil's Garden	April	3.1
Collier/Immokalee1, Field 1	April	8.0
Collier/Immokalee1, Field 2	May	14.6
Collier/Immokalee2	May	5.1
Manatee/Duette1	May	10.6
Manatee/Duette1	June	8.0
Hillsborough/Ruskin	June	4.6
Manatee/Ft. Hamer	June	13.1
Manatee/GCREC, Field	June	2.6
Hillsborough/Riverview	July	4.5
	2002	
Collier/Immokalee1, Field 1	April	7.3
Palm Beach/Boynton Beach	April	2.6
Collier/Immokalee3	April	5.6
Collier/Immokalee4	April	2.9
Collier/Immokalee1, Field 2	May	3.9
Dade/Homestead	May	7.3
Collier/SWFREC	May	21.9
Manatee/Duette	June	35.2
Manatee/Ft. Hamer	June	5.7
Hillsborough/Ruskin	June	3.4
Manatee/GCREC, Field 1	June	14.8
Manatee/GCREC, Field 2	June	5.9
Manatee/Lorraine	June	1.2

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

Table 2. Changes in relative Admire susceptibility (RS_{50}) of silverleaf whitefly adults evaluated two to four generations following collection in the field, 2001.

Site	Date: Collected	Date: Evaluated	Estimated no. generations in lab	RS_{50}[1]
Immokalee 1	8 May	18 May	1	14.6
Immokalee 1	6-13 July[2]	18 Aug	2-3	2.2
Ruskin	13 June	21 June	1	4.6
Ruskin	19-26 July[2]	25 Aug	2	1.5
Duette	13 June	21 June	1	8.0
Duette	13 June[3]	16 Aug[4]	4	1.5

[1]Ratio of the LC_{50} of the field population to the LC_{50} of the lab colony. Increasing values greater than one indicate decreasing susceptibility to Admire relative to the laboratory colony.
[2]Collected as adults on whitefly-free tomato plants placed in the field about 4 wk after crop destruction.
[3]Survivors of the 21 June bioassay were reared on tomato without selection in the lab for 8 wk.

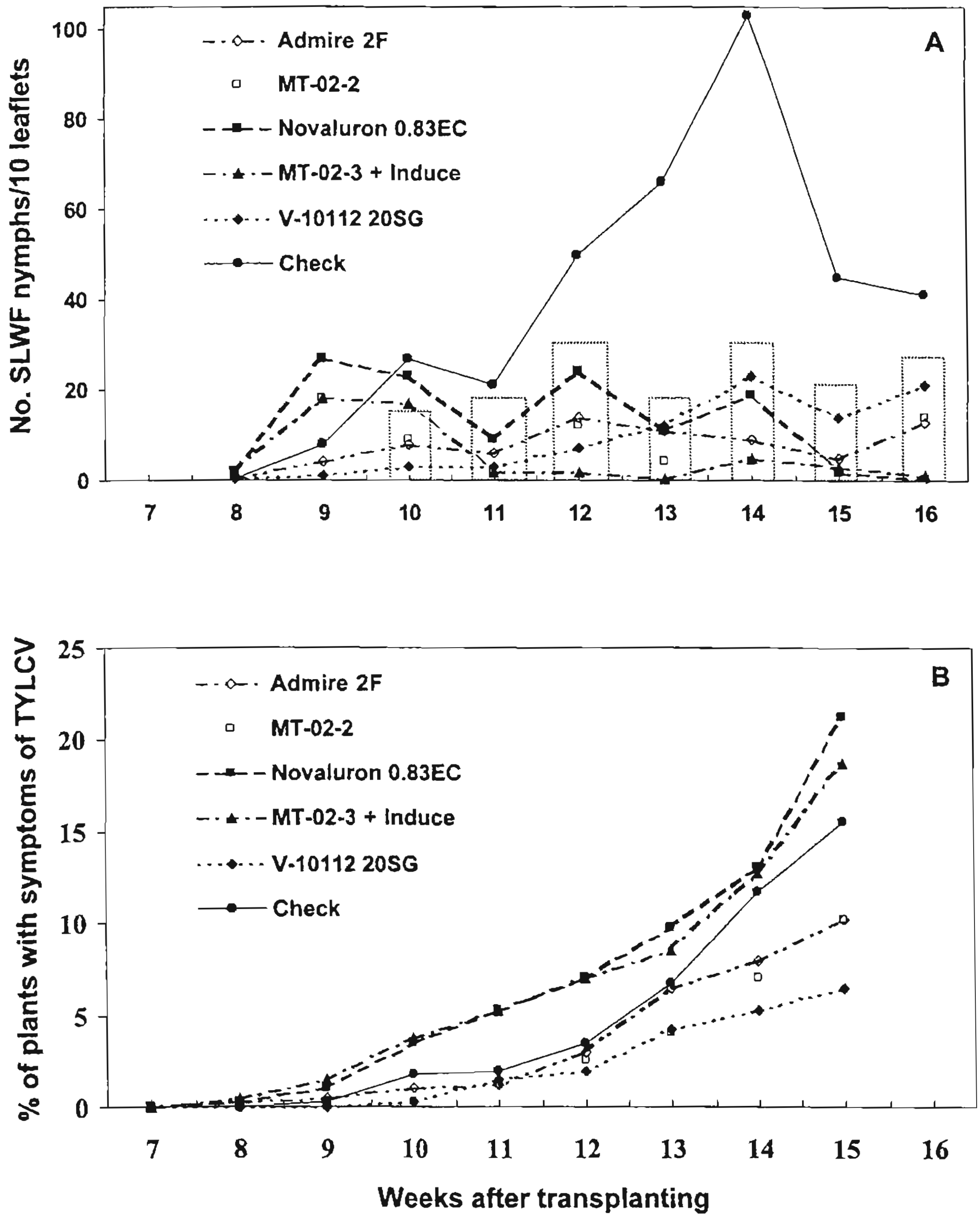

Fig. 1. The density of whitefly nymphs (A) and the incidence of plants with symptoms of tomato yellow leaf curl virus (TYLCV) (B) on tomato plants treated with insecticides at GCREC, Spring 2002. Data points within boxes are significantly different from the check.

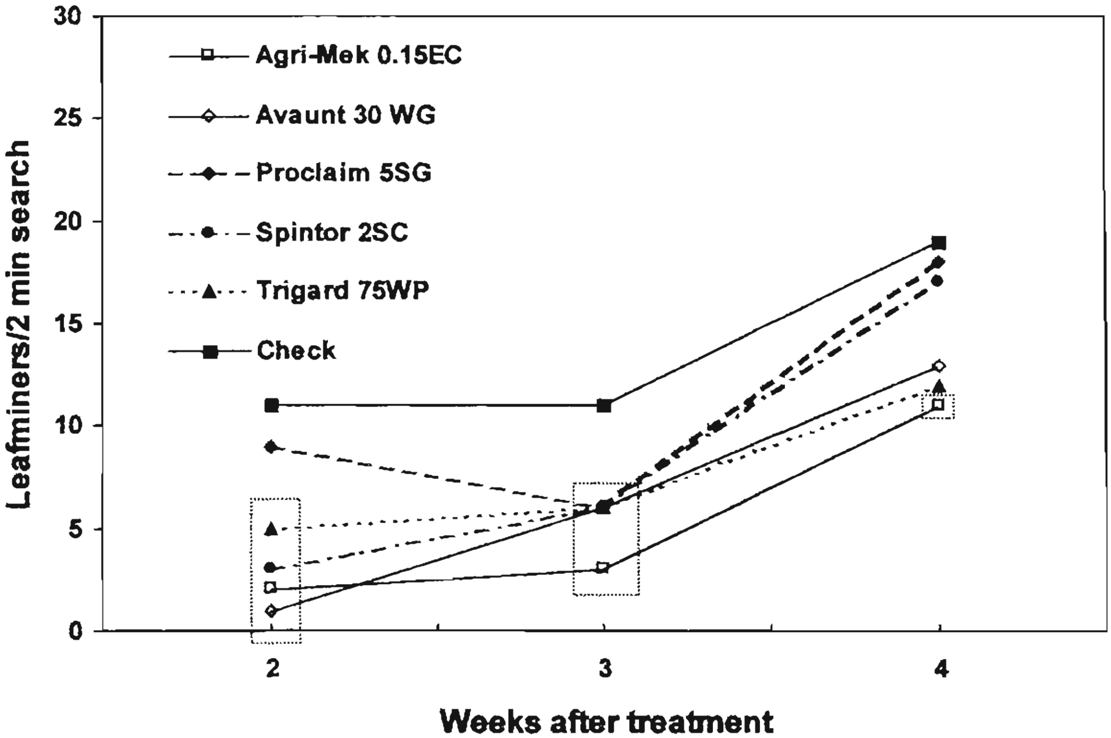

Fig. 2. The density of *Liriomyza* leafmines following a single application of insecticide on tomato at GCREC, Spring 2002. Data points within boxes are significantly different from the check.

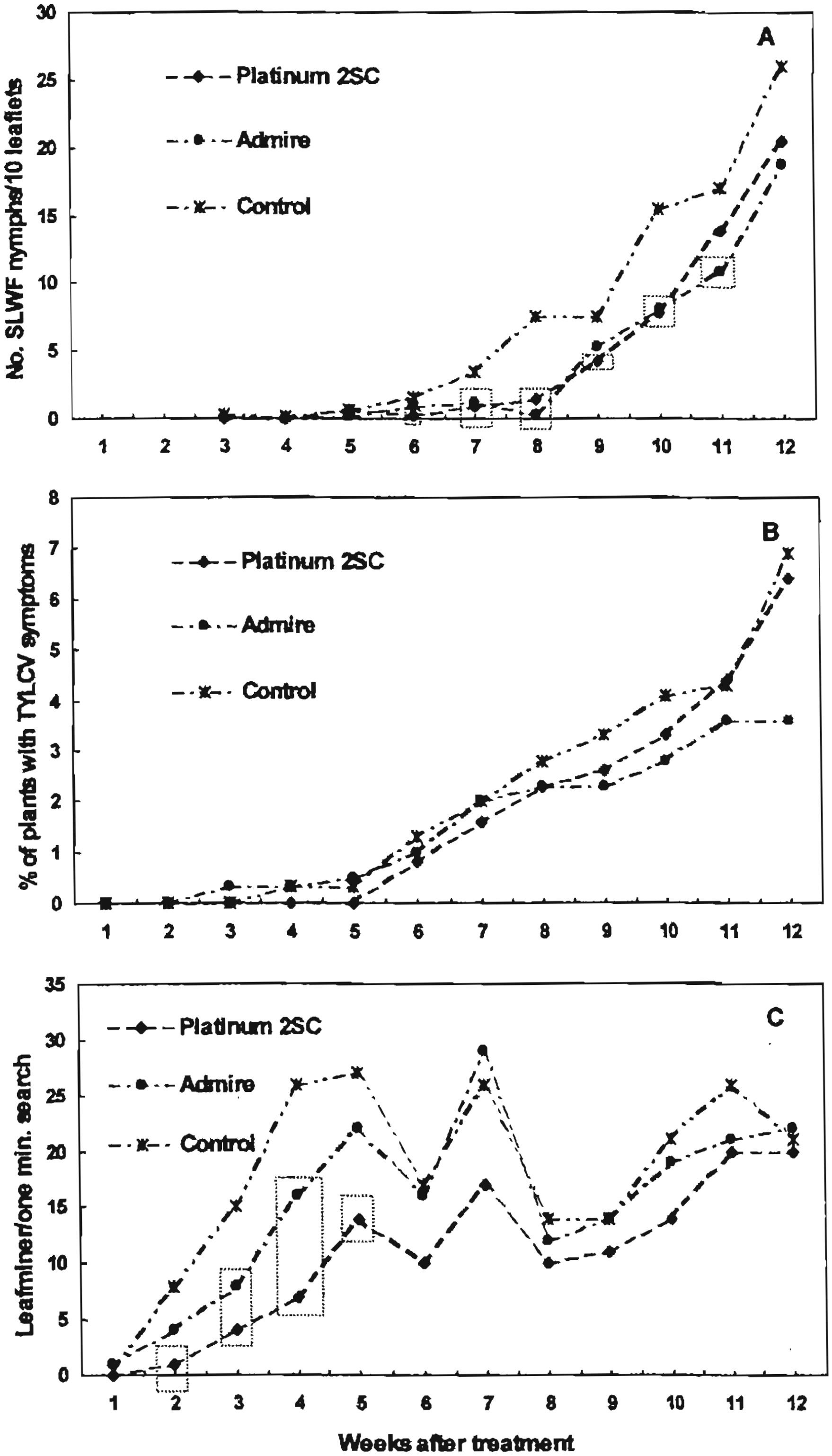

Fig. 3. Density of whitefly nymphs (A), incidence of plants with symptoms of tomato yellow leaf curl virus (TYLCV) (B), and density of *Liriomyza* leafmines on tomato drenched at transplanting with nicotinoid insecticides (C), Spring 2002. Data averaged over four locations. Data points within boxes are significantly different from the check.

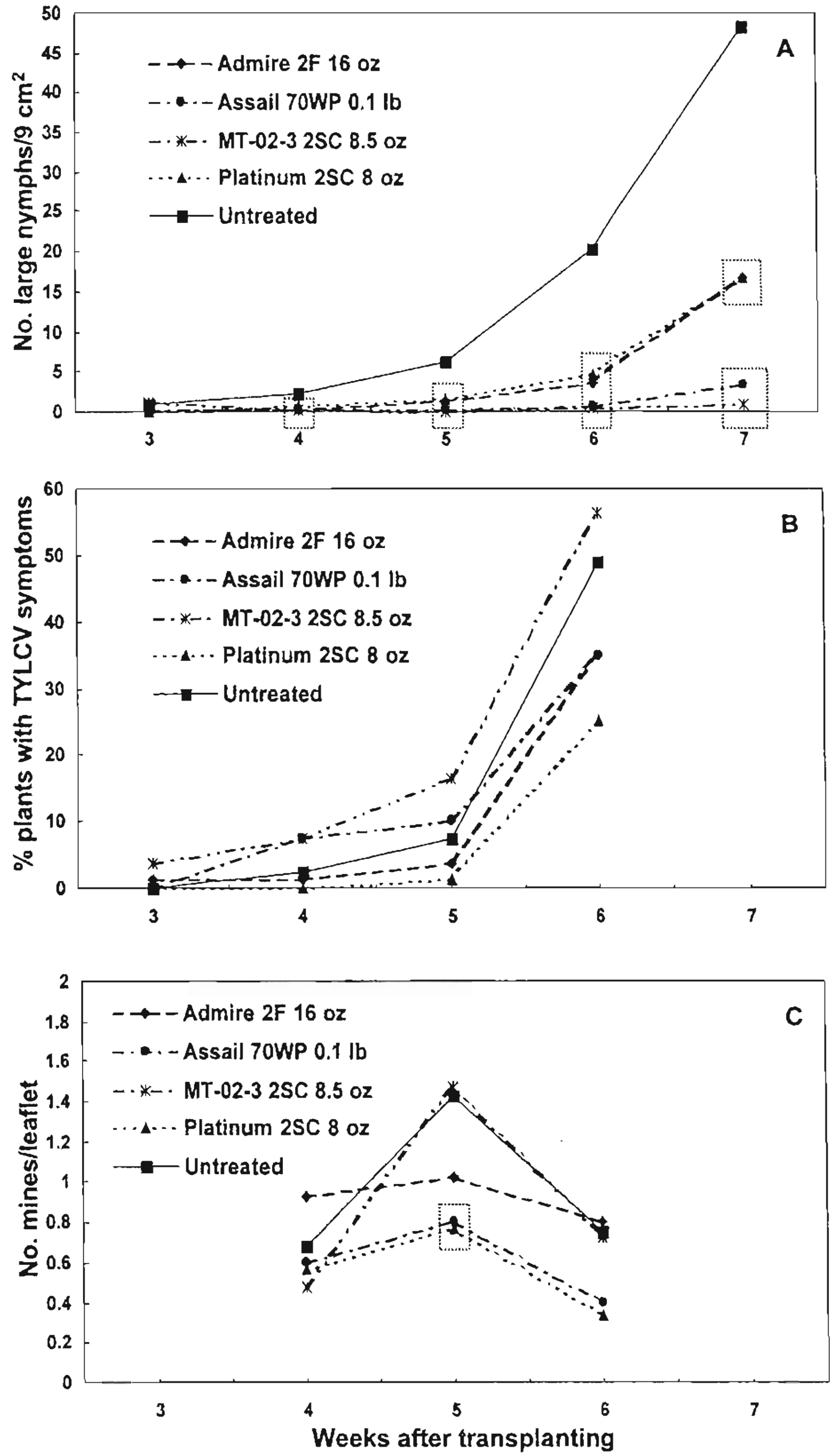

Fig. 4. The density of whitefly nymphs (A), the incidence of plants with symptoms of tomato yellow leaf curl virus (TYLCV) (B), and the density of *Liriomyza* leafmines (C) on tomato plants treated with insecticides at SWFREC, Spring 2002. Data points within boxes are significantly different from the check.

Water Management for Tomato

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Approximately 43,800 acres of tomatoes were harvested in Florida during the 2000-2001 growing season. The value of the fresh-market tomato crop that year was estimated at slightly above $588 million (Florida Agricultural Statistics, Vegetable Summary). The main areas of production are Gadsden county (Quincy), Manatee County (Palmetto-Ruskin), Hendry county (southeast cost), Palm Beach county (southwest coast), and Dade county (Homestead). Most of the tomato acreage today uses plasticulture (raised beds, polyethylene mulch and drip irrigation) Some tomatoes are still grown with polyethylene mulch and overhead or seepage irrigation.

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

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

A wide range of irrigation scheduling methods is used in Florida, with corresponding levels of water managements (**Table 1**). The recommended method to schedule irrigation for tomato is to use together a measurement of soil water status and the tomato crop water requirement method that takes into account plant stage of growth (water management level 5 in **Table 1**).

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

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

SWT can also be measured with GMS. They are made of two concentric metal conductors that are embedded in a sand-like matrix (hence the term granular). The electrical conductivity between the two metal parts depends on the moisture content of the granular matrix. A slow dissolving calcium sulfate pellet is included in the unit, so that changes in soluble salts in the soil solution do not affect the reading. As the GMS is buried into the soil, moisture content inside th GMS becomes in equilibrium with that of the soil. GMS cost approximately $35 each, and require a $260 reader. GMS can be used for approximately 5 to 8 years. While some theoretical valid concerns have been made regarding the accuracy of the GMS readings, they have proven to be potentially useful field devices to schedule irrigation. GMS should be used for tomato production on a trial basis only.

Times domain reflectometry (TDR) is not a new method for measuring soil moisture. However, the recent availability of inexpensive equipment ($1,200 to $1,500/unit) has increased the potential of this method to become practical. TDR actually determines percent soil moisture. A soil water release curve has to be used to convert soil moisture in to SWT. The advantage of TDR is that probes need not being buried permanently, and readings are available within seconds. This means that, unlike the tensiometer and the GMS, TDR can be used as a hand-tool. As the potential use of TDR as an on-farm tool for scheduling irrigation for vegetables is currently under evaluation, it should be used on an experimental basis only.

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

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

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

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

Eq. [1]
Crop water requirement = Crop coefficient x Reference evapotranspiration

$$ETc = Kc \times ETo$$

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

Eq. [2]
Irrigation requirement = Crop water requirement / Application efficiency

$$IR = ETc/Ea$$

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

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

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

1. In the 2-acre field, there are 14,520 feet of bed (2 x 45,560/6). Because of the alleys, only 6/8 of the field is actually planted. So, the field actually contains 10,890 feet of bed (14,520x 6/8).
2. A 0.20 acre-inch irrigation corresponds to 5,430 gallons applied to 7,260 feet of row, which is equivalent to 75gallons/100feet (5,430/72.6).
3. The drip tape flow rate is 0.30 gallons/hr/emitter which is equivalent to 30 gallons/hr/100feet. It will take 1 hour to apply 30 gallons/100ft, 2 hours to apply 60gallons/100ft, and 2 ? hours to apply 75 gallons. The total volume applied will be 8,168 gallons/2-acre (75 x 108.9).

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

Level	Water Management Rating	Irrigation scheduling method
0	None	Guessing (irrigate whenever)
1	Very low	Using the 'feel and see' method
2	Low	Using systematic irrigation (example: 2 hrs every day)
3	Intermediate	Using a soil water tension measuring tool to start irrigation
4	Advanced	Using a soil water tension measuring tool to schedule irrigation and apply amounts based on a budgeting procedure
5	Recommended	Adjusting irrigation to plant water use, and using a dynamic water balance based on a budgeting procedure and plant stage of growth, together with using a soil water tension measuring tool

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

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

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

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

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

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

Fertilizer and Nutrient Management for Tomato

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

Calibrated Soil Test: Taking the Guessing Out of Fertilization

Prior to each cropping season, soil tests should be conducted to determine fertilizer needs and eventual pH adjustments. Obtain an IFAS soil sample kit from the local agricultural Extension agent for this purpose. Commercial soil testing laboratories also are available, however, be sure the commercial lab uses methodologies calibrated for, and extractants suitable to Florida soils. When used with the percent sufficiency philosophy, routine soil testing helps adjust fertilizer applications to plant needs and target yields. In addition, the use of the routine calibrated soil test reduces the risk of over-fertilization. Over fertilization reduces fertilizer efficiency and increases the risk of groundwater pollution. Systematic use of fertilizer without a soil test may also result in crop damage from salt injury.

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

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

Liming

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

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

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

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

Fertilizer-related Physiological Disorders

Blossom-End Rot. At certain times, growers have problems with blossom-end-rot, especially on the first one or two fruit clusters. Blossom-end rot (BER) is basically a Ca deficiency in the fruit, but is often more related to plant water stress than to Ca concentrations in the soil. This is because Ca movement in the plant occurs with the water (transpiration) stream. Thus, Ca moves preferentially to the leaves. As an enlarging fruit is not a transpiring organ, most of the Ca is deposited during early fruit growth.

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

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

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

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

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

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

Fertilizer Application

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

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

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

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

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

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

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

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

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

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

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

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

Additional nutrients can be supplied through drip irrigation if deficiencies occur during the growing season.

Sources of N-P_2O_5-K_2O

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

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

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

All sources of potassium can be used for tomatoes. Potassium sulfate, sodium-potassium nitrate, potassium nitrate, potassium chloride, monopotassium phosphate, and potassium-magnesium sulfate are all good K sources. If the soil test predicted amounts of K_2O are applied, then there should be no concern for the K source or its associated salt index.

Sap Test and Tissue Analyses

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

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

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

Levels of Nutrient Management for Tomato Production

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

Suggested Literature

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

		Nutrient requirements	Supplemental applications[1]	
Soil type	Number of expected harvests	lbs/A[2] N-P_2O_5-K_2O	lbs/A N-P_2O_5-K_2O	Number of applications
Mineral	2-3	200-150-225	30-0-20	0-2

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

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

Crop development		Injection (lb/A/day)[z]	
stage	weeks	N	K_2O
1	2	1.5	1.5
2	2	2.0	2.0
3	7	2.5	3.0
4	1	2.0	2.0
5	1	1.5	1.5

[z] Total nutrients applied are 200 lb N and 225 lb K_2O per acre (7,260 linear bed feet). These injection programs assume no N or K preplant. If 20% of N and K are applied preplant in the bed, then first two weeks of injection can be reduced.

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

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

[z]MRM=Most recently matured leaf.

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

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

Table 5. Progressive levels of nutrient management for tomato production

Nutrient Mgt. Level	Description
0	Guessing
1	Soil testing and still guessing
2	Soil testing and implementing 'a' recommendation
3	Soil testing, understanding IFAS recommendations, and correctly implementing them
4	Soil testing, understanding IFAS recommendations, correctly implementing them, and monitoring crop nutritional status
5	Soil testing, understanding IFAS recommendations, correctly implementing them, monitoring crop nutritional status, and practice year-round nutrient management and/or following BMPs

Chemical Control Guide for Diseases of Tomatoes

Dr. Tom Kucharek, Plant Pathology Dept., University of Florida

Crop	Chemical	Maximum Rate Per Acre Per Application	Maximum Rate Per Acre Per Season	Min. Days To Harvest	Pertinent Diseases	Remarks
Tomato	****For best possible chemical control of bacterial spot with copper fungicides, maneb or mancozeb must be added to the tank mix.**					
	Ridomil Gold 4 EC	2 pts./trtd. acre	3 pts./trtd./ acre		Pythium diseases	See label for use at & after planting.
	Nu-Cop, Kocide 101, Blue Shield, KOP Hydroxide or Champion 77 WPs	4 lbs.		2	Bacterial spot	3 lbs. maximum for Nu-Cop
	Blue Shield 3 L, Nu-Cop, Kocide LF, or KOP Hydroxide, 3-lb Copper Flowable FLs	5⅓pts.		2	Bacterial spot	
	Kocide 4.5 LF	2 2/3 pts		1	Bacterial spot	
	Kocide 2000 53.8 DF	3 lbs.		1	Bacterial spot	
	Champ 4.6 FL	2 2/3 pts.		1	Bacterial spot	
	Basicop or Basic Copper 53 WPs	4 lbs.		1	Bacterial spot	
	Manex 4 F	2.4 qts.	16.8 qts.	5	Early & late blight, Gray leaf spot, Bacterial spot[1]	Field & Greenhouse use
	Dithane, Manzate or Penncozeb 75 DFs	3 lbs.	22.4 lbs.	5	Same as Manex 4 F	
	Nu-Cop 50, Kocide 61.4 or Blueshield 61.4 DFs	4 lbs.		1	Bacterial spot	
	Maneb 80 WP	3 lbs	21 lbs.	5	Same as Manex 4 F	Field & Greenhouse use
	Dithane F 45 or Manex II 4 FLs	2.4 pts.	16.8 qts.	5	Same as Manex 4 F	
	Dithane M-45, Penncozeb 80, or Manzate 80 WPs	3 lbs.	21 lbs.	5	Same as Manex 4 F	
	Equus 720[4], Echo 720, or Chloronil 720 6 Fls	3 pts. or 2.88 pts.	20.1 pts.	2	Early & late blight, Gray leaf spot, Target spot	Use higher rates at fruit set & lower rates before fruit set.
Tomato (continued)	Maneb 75 DF	3 lbs.	22.4 lbs.	5	Same as Manex 4 F	Field & Greenhouse Use.

Crop	Chemical	Maximum Rate Per Acre Per Application	Season	Min. Days To Harvest	Pertinent Diseases	Remarks
Tomato (continued)	Quadris 2.08 FL	6.2 fl.ozs.	37.2 fl.ozs.	0	Early Blight Late Blight Sclerotinia Powdery mildew Target spot Buckeye rot	Do not make more than 2 sequential applications with Quadris. Do not make more than 6 appl. or alternate or tank mix with fungicides for which resistance to a pathogen exists. For soilborne diseases see onions section.
	Echo 90 DF	2.3 lbs.		2	Early & late blight, Gray leaf spot, Target spot	Use higher rates at fruit set & lower rates before fruit set.
	Bravo 500, Echo 500, or GK Chloro Gold 4.17 FLs	4 pts.		2	Early & late blight, Gray leaf spot, Target spot	Use higher rates at fruit set & lower rates before fruit set.
	Ridomil Gold Bravo 76.4 W	3 lbs.		14	Early & late blight, Gray leaf spot, Target spot	Limit is 4 appl./crop
	Ridomil MZ 68 WP[2]	2.5 lbs.	7.5 lbs.	5	Late blight	Limit is 3 appl./crop
	JMS Stylet Oil	3 qts.		NTL	Potato Virus Y Tobacco Etch Virus	See label for specific info on appl. technique (e.g. use of 400 psi spray pressure)
	Ridomil Gold Copper 64.8 W	2 lbs.[3]	6 lbs.	14	Late blight	Limit is 3 appl./crop. Tank mix with a maneb or mancozeb fungicide
	Sulfur (many brands)			1	Powdery mildew	
	Aliette 80 WDG	5 lbs.	20 lbs.	14	Phytophthora root rot	Using potassium carbonate or Diammonium phosphate, the spray of Aliette should be raised to a pH of 6.0 or above when applied prior to or after copper fungicides.
	Bravo Ultrex 82.5 WDG	2.75 lbs.		2	Early & Late blights, Gray leafspot, Target spot, Botrytis, Rhizoctonia fruit rot	Use higher rates at fruit set.
Tomato (continued)	Bravo Weather Stik 6 FL	3 pts.		2	Same as Bravo Ultrex	Use higher rates at fruit set.

Crop	Chemical	Maximum Rate Per Acre Per Application	Season	Min. Days To Harvest	Pertinent Diseases	Remarks
Tomato (continued)	Botran 75 W	1 lb.	4 lbs.	10	Botrytis	Greenhouse tomato only. Limit is 4 applications. Seedlings or newly set transplants may be injured.
	Nova 40 W	4 ozs.	1.25 lbs.	0	Powdery mildew	Note that a 30 day plant back restriction exists.
	Actigard 50 WG	1/3-3/4 oz[5]	4 ozs.	14	Bacterial spot Bacterial speck	Do not use highest labeled rate in early sprays to avoid a delayed onset of harvest. Begin with 1/3 oz. rate and progressively increase the rate as instructed on the label. Limit is 6 appl./crop/ season. Do not exceed a concentration of 3/4 oz.100 gal. of spray mix. Begin spray program before occurrence of disease.
	Exotherm Termil	1 can/1000 sq.ft.		2	Botrytis, Leaf mold, Late & Early blights, Gray leaf spot	Greenhouse use only. Allow can to remain overnight & then ventilate. Do not use when greenhouse temperature is above 75F
	ManKocide 61.1 DF	5.3 lbs.	112 lbs.	5	Bacterial spot Bacterial speck Late blight Early blight Gray leaf spot	
	Basic Copper Sulfate 98 WP	4 lbs.			Bacterial spot	Reeenter when sprays are dried
	Cuprofix Disperss 36.9 WP	6 lbs.		1	Bacterial spot Bacterial speck	
	KOP 300 FL	1/2 gal.		12 hrs.	Bacterial spot	

[1]When tank mixed with a copper fungicide
[2]Do not exceed limits of mancozeb active ingredient as indicated for Dithane, Penncozeb, Manex II or Manzate products.
[3]Maximum crop is 3.0 lbs. a.i. of mefenoxam from Ridomil-containing products
[4]Do not tank mix with Copper Count N.
[5]Label indicates 1/3, 1/2, & 3/4 oz. for 30-50, 60-70, and 70-100 gpa of water.

NEMATICIDES REGISTERED FOR USE ON FLORIDA TOMATO

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

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

[2] The manufacturer of Telone II, Telone C-17, and Telone C-35 has restricted use only on soils that have a relatively shallow hard pan or soil layer restrictive to downward water movement (such as a spodic horizon) within six feet of the ground surface and are capable of supporting seepage irrigation regardless of irrigation method employed. Higher label application rates are possible for fields with cyst-forming nematodes. Consult manufacturers label for other use restrictions which might apply.

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

[4] Rate/acre estimated for row treatments to help determine the approximate amounts of chemical needed per acre of field. If rows are closer, more chemical will be needed per acre; if wider, less.

Rates are believed to be correct for products listed when applied to mineral soils. Higher rates may be required for muck (organic) soils. Growers have the final responsibility to guarantee that each product is used in a manner consistent with the label. The information was compiled by the author as of July 27, 2002 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.

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Weed Control in Tomato

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

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

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

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

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

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

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

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

Postharvest Vine Dessication

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

The importance of rapid vine destruction can not be 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	Labeled Crops	Time of Application to Crop	Rate (lbs. AI./Acre) Mineral	Rate (lbs. AI./Acre) Muck
Clethodem (Select 2 EC)	Tomatoes	Postemergence	0.9-.125	---
Remarks: Postemergence control of actively growing annual grasses. Apply at 6-8 fl oz/acre. Use high rate under heavy grass pressure and/or when grasses are at maximum height. Always use a crop oil concentrate at 1% v/v in the finished spray volume. Do not apply within 20 days of tomato harvest.				
DCPA (Dacthal W-75)	Established Tomatoes	Posttransplanting after crop establishment (non-mulched)	6.0-8.0	—
Remarks: Controls germinating annuals. Apply to weed-free soil 6 to 8 weeks after crop is established and growing rapidly or to moist soil in row middles after crop establishment. Note label precautions of replanting non-registered crops within 8 months.				
Diquat (Reglone)	Tomato Vine Burndown	After final harvest	0.375	---
Remarks: Special Local Needs (24c) label for use for burndown of tomato vines after final harvest. Applications of 1.5 pts. material per acre in 60 to 120 gals. of water is labelled. Add 16 to 32 ozs. of Valent X-77 spreader per 100 gals. of spray mix. Thorough coverage of vines is required to insure maximum burndown.				
Diquat dibromide (Reglone)	Tomato	Pretransplant Postemergence directed-shielded in row middles	0.5	---
Remarks: Diquat can be applied as a post-directed application to row middles either prior to transplanting or as a post-directed hooded spray application to row middles when transplants are well established. Apply 1 qt of Diquat in 20-50 gallons of water per treated acre when weeds are 2-4 inches in height. Do not exceed 25 psi spray pressure. A maximum of 2 applications can be made during the growing season. Add 2 pts non-ionic surfactant per 100 gals spray mix. Diquat will be inactivated if muddy or dirty water is used in spray mix. A 30 day PHI is in effect. Label is a special local needs label for Florida only.				
MCDS (Enquik)	Tomatoes	Postemergence directed/shielded in row middle	5 - 8 gals.	---
Remarks: Controls many emerged broadleaf weeds. Weak on grasses. Apply 5 to 8 gallons of Enquik in 20 to 50 gallons of total spray volume per treated acre. A non-ionic surfactant should be added at 1 to 2 pints per 100 gallons. Enquik is severely corrosive to nylon. Non-nylon plastic and 316-L stainless steel are recommended for application equipment. Read the precautionary statements before use. Follow all restrictions on the label.				
Metribuzin (Sencor DF) (Sencor 4)	Tomatoes	Postemergence Posttransplanting after establishment	0.25 - 0.5	---
Remarks: Controls small emerged weeds after transplants are established direct-seeded plants reach 5 to 6 true leaf stage. Apply in single or multiple applications with a minimum of 14 days between treatments and a maximum of 1.0 lb ai/acre within a crop season. Avoid applications for 3 days following cool, wet or cloudy weather to reduce possible crop injury.				

Table 1. Chemical weed controls: tomatoes.

Herbicide	Labeled Crops	Time of Application to Crop	Rate (lbs. AI./Acre)	
			Mineral	Muck
Metribuzin (Sencor DF) (Sencor 4)	Tomatoes	Directed spray in row middles	0.25 - 1.0	---
Remarks: Apply in single or multiple applications with a minimum of 14 days between treatments and maximum of 1.0 lb ai/acre within crop season. Avoid applications for 3 days following cool, wet or cloudy weather to reduce possible crop injury. Label states control of many annual grasses and broadleaf weeds including, lambsquarter, fall panicum, amaranthus sp., Florida pusley, common ragweed, sicklepod, and spotted spurge.				
Napropamid (Devrinol 50DF)	Tomatoes	Preplant incorporated	1.0 - 2.0	---
Remarks: Apply to well worked soil that is dry enough to permit thorough incorporation to a depth of 1 to 2 inches. Incorporate same day as applied. For direct-seeded or transplanted tomatoes.				
Napropamid (Devrinol 50DF)	Tomatoes	Surface treatment	2.0	---
Remarks: Controls germinating annuals. Apply to bed tops after bedding but before plastic application. Rainfall or overhead-irrigate sufficient to wet soil 1 inch in depth should follow treatment within 24 hours. May be applied to row middles between mulched beds. A special Local Needs 24(c) Label for Florida. Label states control of weeds including Texas panicum, pigweed, purslane, Florida pusley, and signalgrass.				
Paraquat (Gramoxone Extra) (Boa)	Tomatoes	Premergence; Pretransplant	0.62 - 0.94	---
Remarks: Controls emerged weeds. Use a non-ionic spreader and thoroughly wet weed foliage.				
Paraquat (Gramoxone Extra) (Boa)	Tomatoes	Post directed spray in row middle	0.47	---
Remarks: Controls emerged weeds. Direct spray over emerged weeds 1 to 6 inches tall in row middles between mulched beds. Use a non-ionic spreader. Use low pressure and shields to control drift. Do not apply more than 3 times per season.				
Paraquat (Gramoxone Extra) (Boa)	Tomato	Postharvest dessication	0.62-0.93 0.46-0.62	
Remarks: Broadcast spry over the top of plants after last harvest. Label for Boa states use of 1.5-2.0 pts while Gramoxone label is from 2-3 pts. Use a nonionic surfactant at 1 pt/100 gals to 1 qt/100 gals spray solution. Thorough coverage is required to ensure maximum herbicide burndown. Do not use treated crop for human or animal consumption.				
Pebulate (Tillam 6E)	Tomato	Pretransplant Incorporated Directed	4 6	--- ---

Table 1. Chemical weed controls: tomatoes.

Herbicide	Labeled Crops	Time of Application to Crop	Rate (lbs. AI./Acre) Mineral	Muck
Remarks: Do not use on seeded tomatoes. Has supplemental labeling for use in transplanted tomatoes grown under polyethylene mulch and in combination with Telone C-17 or C-35. Transplants may be set by hand if chemical resistant gloves are worn. Consult label for incorporation methods recommended. May be applied post transplanting as a directed spray to clean cultivated soil. There is a 8 day PHI. Product is volatile and not persistent in soil. Susceptible weeds germinating late in the season may not be controlled.				
Pelargonic Acid (Scythe)	Fruiting Vegetable (tomato)	Preplant Preemergence Directed-Shielded	3-10% v/v	---
Remarks: Product is a contact, nonselective, foliar applied herbicide. There is no residual control. May be tank mixed with several soil residual compounds. Consult the label for rates. Has a greenhouse and growth structure label.				
Sethoxydim (Poast)	Tomatoes	Postemergence	0.188 - 0.28	---
Remarks: Controls actively growing grass weeds. A total of 4_ pts. product per acre may be applied in one season. Do not apply within 20 days of harvest. Apply in 5 to 20 gallons of water adding 2 pts. of oil concentrate per acre. Unsatisfactory results may occur if applied to grasses under stress. Use 0.188 lb ai (1 pt.) to seedling grasses and up to 0.28 lb ai (1_ pts.) to perennial grasses emerging from rhizomes etc. Consult label for grass species and growth stage for best control.				
Trifluralin (Treflan HFP) (Treflan TR-10) (Trilin) (Trilin 10G) (Trifluralin 480) (Trifluralin 4EC) (Trifluralin HF)	Tomatoes (except Dade County)	Pretransplant incorporated	0.5	---
Remarks: Controls germinating annuals. Incorporate 4 inches or less within 8 hours of application. Results in Florida are erratic on soils with low organic matter and clay contents. Note label precautions of planting non-registered crops within 5 months. Do not apply after transplanting.				
Trifluralin (Treflan HFP) (Treflan TR-10) (Trilin) (Trilin 10G) (Trifluralin 480) (Trifluralin 4EC) (Trifluralin HF)	Direct-Seeded tomatoes (except Dade County)	Post directed	0.5	---
Remarks: For direct-seeded tomatoes, apply at blocking or thinning as a directed spray to the soil between the rows and incorporate.				

Section 18 Labels

Herbicide	Labeled Crops	Time of Application to Crop	Rate (lbs. AI./Acre) Mineral
Carfentrazone (AIM 2EC)	Fruiting Vegetables	Row Middles	0.016 - 0.031
Remarks: Apply to control emerged paraquat resistant nightshade and other broadleaf weeds. Apply row middles with ground applicator equipped with sprayhoods. Use 1 to 2 fluid oz of formulated product per application. A total of 6 fl oz may be applied per acre per year. Allow 14 days between applications. A 1 day PHI will be observed. Section 18 expires May 30, 2003.			
Halosulfuron (Sandea)	Tomatoes	Pre-transplant Postemergence	0.024 - 0.036
Remarks: A total of 2 applications of Sandea my be applied as either one pre-transplant soil surface treatment at 0.5 - 0.75 ounces product; one over-the-top application 14 days after transplanting at 0.5 - 0.75 oz product; and/or postemergence application(s) of up to 1 oz product (0.047 lb ai) to row middles. A 30-day PHI will be observed. The section 18 is for the control of yellow and purple nutsedges in tomato. The Section 18 expiration date is June 3, 2003.			

Tomato Varieties for Florida

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

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

•**Yield** - The variety selected should have the potential to produce crops at least equivalent to varieties already grown. The average yield in Florida is currently about 1400 25-pound cartons per acre. The potential yield of varieties in use should be much higher than average.

•**Disease Resistance** - Varieties selected for use in Florida must have resistance to Fusarium wilt, race 1, race 2 and in some areas race 3 ; Verticillium wilt (race 1); gray leaf spot; and some tolerance to bacterial soft rot. Available resistance to other diseases may be important in certain situations, such as Tomato Spotted Wilt resistance in northwest Florida.

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

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

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

Current Variety Situation

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

Tomato Variety Trial Results

Summary results listing the five highest yielding and the five largest fruited varieties from trials conducted at the University of Florida's Gulf Coast Research and Education Center, Bradenton and North Florida Research and Education Center, Quincy for the Spring 2001 season are shown in Table 1. High total yields and large fruit size were produced by BHN 543 at both Bradenton and at Quincy. Large fruit size was produced by PS 150535 at both locations. The same entries were not included at both locations.

Summary of results listing the five highest yielding and five largest fruited entries from trials at the University of Florida's Indian River Research and Education Center, Ft. Pierce; and the North Florida Research and Education Center, Quincy for the fall 2001 season are shown in Table 2. High total yields and large fruit size were produced by Fla. 7943 at Bradenton; Fla. 7943, Florida 91 and Sanibel at Fort Pierce; and by BHN 189 and BHN 537 at Quincy. Fla. 7943, Sanibel and Solar Set produced high yields at two of three locations and Florida 91 and RFT 0418 produced large fruit at two of three locations. Not all entries were included at both locations.

Tomato Varieties for Commercial Production

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

Large Fruited Varieties

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

BHN-444. Early-midseason maturity. Fruit are globe shape but tend to slightly elongate, and green shouldered. Not for fall planting. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), gray leaf spot, and Tomato Spotted Wilt. **For Trial.** (BHN).

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

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

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

PS 150535. Midseason, determinate, jointed hybrid. Fruit are oblate and uniform-green shouldered. Recommended for situations where tomato yellow leaf curl virus is expected to be a problem. Resistant: TYLCV, Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), Alternaria stem canker, gray leaf spot. (Seminis).

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

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

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

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

Plum Type Varieites

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

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

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

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

Veronica. Tall determinate hybrid. Smooth plum type fruit are uniform ripening. Good performance in all production seasons. Resistant: Verticillium wilt. (Sakata).

Cherry Type Varieties

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

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

Reference

This information was gathered from results of tomato variety trials conducted during 2001 at locations specified in each table. Tomato variety evaluations were conducted in 2000 by the following University of Florida faculty:

H. H. Bryan,Tropical Research & Education Center, Homestead

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

S. M. Olson.,North Florida Research & Education Center, Quincy

P. J. Stoffella. Indian River Research & Education Center, Fort Pierce.

Table 1. Summary of University of Florida tomato variety trial results. Spring 2001.

Location	Variety	Total yield (ctn/acre)	Variety	Average fruit wt. (oz)
Bradenton	ASX 013	2821	Florida 47	7.8
	BHN 543	2796	RFT 0252	7.6
	Fla. 7973	2681	BHN 543	7.3
	Sunguard	2619	PS 150535	7.2
	ASX 911	2558 [1]	Florida 91	7.1 [2]
Quincy	BHN 543	2475	BHN 543	8.0
	BHN 575	2358	HA 3027	8.0
	Fla. 7973	2350	PS 150535	7.8
	Florida 91	2339	Sanibel	7.7
	RFT 0417	2326 [3]	HA 3028	7.6 [4]

[1]22 other entries had yields similar to ASX 911.
[2]21 other entries had fruit weight similar to Florida 91.
[3]21 other entries had yields similar to RFT 0417.
[4]17 other entries had fruit weight similar to HA 3028.

Seed Sources:

Agrisales: ASX 013, ASX 911.
BHN: BHN 543, BHN 575.
Hazera: HA 3027, HA 3028.
Seminis: Florida 47, Florida 91, Sanibel, Sunguard, PS 150535.
Sygenta: RFT 0252, RFT 0417
University of Florida: Fla. 7973.
Agrisales:BHN: BHN 189, BHN 444, BHN 537, BHN 555, BHN 563.
Agriset 761, Agriset 911.
Hazera: HA 3057

Table 2. Summary of University of Florida tomato variety trial results. Fall 2001.

Location	Variety	Total yield (ctn/acre)	Variety	Average fruit wt. (oz)
Bradenton	NC 99405	3268	Fla. 7943	6.9
	Sanibel	3092	RFT 0418	6.8
	HA 3057	2973	RFT 0442	6.7
	Fla. 7943	2463	Florida 47	6.8
	Agriset 911	2731 [1]	EX 1405037	6.6 [2]
Fort Pierce	Fla. 7943	2463	Florida 47	6.8
	Agriset 761	2355	Fla. 7973	6.6
	Florida 91	2343	Florida 91	6.3
	Solar Set	2229	Floralina	6.2
	Sanibel	2229 [3]	Sanibel	6.0 [4]
Quincy	BHN 537	3029	BHN 537	6.2
	BHN 563	2678	Florida 91	6.1
	BHN 189	2634	BHN 189	5.9
	Solar Set	2558	RFT 0418	5.8
	BHN 555	2554 [5]	BHN 444	5.8 [6]

[1]21 other entries had yields similar to Agriset 911.
[2]17 other entries had fruit weight similar to EX 1405037.
[3]5 other entries had yields similar to Sanibel.
[4]5 other entries had fruit weight similar to Sanibel.
[5]14 other entries had yields similar to BHN 555.
[6]14 other entries had fruit weight similar to BHN 444.

Seed Sources:

Agrisales: Agriset 761, Agriset 911
BHN: BHN 189, BHN 444, BHN 537, BHN 555, BHN 563
Hazera: HA 3057
North Carloina State: NC 99405
Seminis: Florida 47, Florida 91, Floralina, Sanibel, Solar Set, EX 1405037
University of Florida: Fla. 7943, Fla. 7973

Selected insecticides approved for use on insects attacking tomatoes. S.E. Webb, P. A. Stansly, D. J. Schuster and J. E. Funderburk*

Chemical Name	REI (hours)	Days to Harvest	Insects	Notes
Actara (thiamethoxam)	12	0	Aphids, Colorado potato beetle, flea beetles, stink bugs, whiteflies	Do not exceed a total of 0.125 lb ai per acre per season. Allow at least 5 applications.
Admire 2 (imidacloprid)	12	21	aphids, Colorado potato beetle, flea beetles, thrips, whiteflies	
***Agrimek 0.15EC** (abamectin)	12	7	Colorado potato beetle, *Liriomyza* leafminers, spider mite, tomato pinworms, tomato russet mite	Do not make more than 2 sequential applications.
***Ambush 2EC, 25W** (permethrin)	12	Up to day of harvest	beet armyworm, cabbage looper, Colorado potato beetle, granulate cutworms, hornworms, southern armyworm, tomato fruitworm, tomato pinworm, vegetable leafminer	Do not apply more than 1.2 lb active ingredient per acre per season.
***Asana XL 0.66EC** (esfenvalerate)	12	1	beet armyworm (aids in control), cabbage looper, Colorado potato beetle, cutworms, flea beetles, grasshoppers, hornworms, potato aphid, southern armyworm, tomato fruitworm, tomato pinworm, whiteflies, yellowstriped armyworm	Not recommended for control of vegetable leafminer in Florida.
Assail (acetamiprid)	12	7	Aphids, Colorado potato beetle, whiteflies	Begin applications for whiteflies when first adults are noticed. Do not apply more than 4 times per season or apply more often than every 7 day.
Avaunt (indoxacarb)	12	3	beet armyworm, hornworms, loopers, southern armyworm, tomato fruitworm, tomato pinworm	Do not apply more than 14 ounces of product per acre per crop. Minimum spray interval is 5 days.
Azatin XL (azadirachtin)	4	0	aphids (suppression), armyworms, beetles, caterpillars, cutworms, leafhoppers, leafminers, loopers, thrips, whiteflies	Use with oil for leafminers.
Bt (*Bacillus thuringiensis*) Agree, Biobit Hp, Dipel DF, Javelin WG, Ketch DF, Lepinox WDG, Xentari	4^{12} (most)	See label	armyworms, cabbage looper, corn earworm, cutworms, hornworms, loopers, tomato fruitworm	

Chemical Name	REI (hours)	Days to Harvest	Insects	Notes
***Baythroid 2** (cyfluthrin)	12	0	beet armyworm (1), cabbage looper, Colorado potato beetle, dipterouus leafminers, European corn borer, flea beetles, hornworms, potato aphid, southern armyworm (1), stink bugs, tomato fruitworm, tomato pinworm, variegated cutworm, western flower thrips, whitefly (2)	(1) Ist and 2nd instars only (2) suppression Do not apply more than 0.26 lb ai per acre per season.
Checkmate TPW (pheromone)	0	0	tomato pinworm	
Confirm 2F (tebufenozide)	4	7	armyworms, black cutworm, hornworms, loopers	
Courier (buprofezin)	12	7	whiteflies	No more than 2 applications per season. Allow at least 28 days between applications. Do not plant food crops except those on the label (cucumbers, lettuce, melons, pumpkins, and squash) within 120 days following application.
***Danitol 2.4 EC** (fenpropathrin)	24	3 days, or 7 if mixed with Monitor 4	beet armyworm, cabbage looper, fruitworms, potato aphid, silverleaf whitefly, stink bugs, thrips, tomato pinworm, twospotted spider mites, yellowstriped armyworm	Use alone for control of fruitworms, stink bugs, twospotted spider mites, and yellowstriped armyworms. Tank-mix with Monitor 4 for all others.
Dimethoate 4 EC, 2.67 EC (dimethoate)	48	7	aphids, leafhoppers, leafminers	
***D.z.n.; AG-500, 4 EC** (diazinon)	24	1	**foliar application:** aphids, beet armyworm, banded cucumber beetle, *Drosophila*, fall armyworm, dipterous leafminers, southern armyworm **soil application at planting:** cutworms, mole crickets, wireworms	Will not control organophosphate-resistant leafminers.
Extinguish ((S)-methoprene)	4	0	Fire ants	Slow-acting IGR (Insect growth regulator). Best applied early spring and fall where crop will be grown. Colonies will be reduced after three weeks and eliminated after 8 to 10 weeks. This is the only fire ant bait labeled for use on cropland. May be applied by ground equipment or aerially.
Fulfill (pymetrozine)	12	14	green peach aphid, potato aphid, suppression of whiteflies	Do not apply by air.

Chemical Name	REI (hours)	Days to Harvest	Insects	Notes
***Fury** (zeta-cypermethrin)	12	1	beet armyworm, cabbage looper, Colorado potato beetle, cutworms, fall armyworm, flea beetles, grasshoppers, green and brown stink bugs. hornworms, leafminers, leafhoppers, lygus bugs, plant bugs, southern armyworm, tobacco budworm, tomato fruitworm, tomato pinworm, true armyworm, yellowstriped armyworm; Aides in control of aphids, thrips and whiteflies	Not recommended for vegetable leafminer in Florida. Do not make applications less than 7 days apart. Do not apply more than 0.3 lb ai per acre per season.
Kelthane MF (dicofol)	12	2	Mites	Do not apply more than twice a year.
Knack IGR (pyriproxyfen)	12	14	immature whiteflies	Apply when first nymphs appear.
Kryocide 96 WP; Prokil Cryolite 96 (cryolite)	12	14	blister beetle, cabbage looper, Colorado potato beetle larvae, flea beetles, hornworms, tomato fruitworm, tomato pinworm	Minimum of 7 days between applications.
***Lannate LV, SP** (methomyl)	48	1	aphids, armyworms, beet armyworm, fall armyworm, hornworms, loopers, southern armyworm, tomato fruitworm, tomato pinworm, variegated cutworm	
Malathion 5 EC, 57 EC, 8 EC (malathion)	12	3 (5EC) 1 (57EC, 8EC)	aphids, *Drosophila*, mites	
***Monitor 4EC** (methamidophos) [24(C) labels]	48	7	tomato pinworm (1), thrips (North Florida only), whiteflies (2)	(1) Suppression of pinworms (2) Use as tank mix with a pyrethroid for whitefly control. Do not apply more than 10 pts per acre.
M-Pede 49% EC (Soap, insecticidal)	12	0	aphids, leafhoppers, mites, plant bugs, thrips, whiteflies	
Neemix .25 (azadirachtin) **Neemix 4.5**	4 12	0 0	aphids, armyworms, hornworms, psyllids, Colorado potato beetle, cutworms, leafminers, loopers, thrips, tomato fruitworm (corn earworm), tomato pinworm, whiteflies	
NoMate MEC TPW (pheromone)			tomato pinworm	
Novodor FC (*Bacillus thuringiensis* subspecies *tenebrionis*)	4	0	Colorado potato beetle - larval stage	Most effective against 1st and 2nd instar larvae. Death occurs 2 to 5 days after ingestion of treated leaves.

Chemical Name	REI (hours)	Days to Harvest	Insects	Notes
Platinum (thiamethoxam)	12	30	Aphids, Colorado potato beetle, flea beetles, whiteflies	Soil application. See label for rotational restrictions.
***Pounce 3.2 EC** (permethrin)	12	0	beet armyworm, cabbage looper, Colorado potato beetle, dipterous leafminers, granulate cutworm, hornworms, southern armyworm, tomato fruitworm, tomato pinworm	Do not apply to cherry or grape tomatoes (fruit less than 1 inch in diameter).
Provado 1.6E (imidacloprid)	12	0 - foliar	aphids, Colorado potato beetle, whiteflies	Do not apply to crop that has been treated with Admire.
Pyrellin EC (pyrethrin + rotenone)	12	12 hours	aphids, Colorado potato beetle, cucumber beetles, European corn borer, flea beetles, flea hoppers, leafhoppers, leafminers, loopers, mites, plant bugs, stink bugs, thrips, vegetable weevil, whiteflies	
Py-Rin 60-6 EC (pyrethrin + piperonyl butoxide)	12	0	aphids, armyworms, cabbage looper, Colorado potato beetle, corn earworm, crickets, cucumber beetles, *Drosophila*, flea beetles, leafhoppers, psyllids, thrips, whiteflies	
Sevin 80S (WP); XLR; 4F (carbaryl)	12	3	Colorado potato beetle, cutworms, European corn borer, fall armyworm, flea beetles, lace bugs, leafhoppers, plant bugs, stink bugs**, thrips**, tomato fruitworm, tomato hornworm, tomato pinworm, sowbugs	**suppression
Sevin 5 Bait (carbaryl)	12	3	ants, crickets, cutworms, grasshoppers, sowbugs	
SpinTor 2SC (spinosad)	4	1	armyworms, Colorado potato beetle, European corn borer, flower thrips, hornworms, *Liriomyza* leafminers, loopers, *Thrips palmi*, tomato fruitworm, tomato pinworm	Do not apply to seedlings grown for transplant within a greehouse or shadehouse.
Spod-X LC (beet armyworm muclear polyhedrosis virus)	4	0	Beet armyworm	Treat when larvae are young (1st and 2nd instar). Follow label instructions for mixing. Use only non-chlorinated water at a pH near 7 for mixing.
Sulfur	24	See label	tomato russet mite	
***Telone C-35** (dichloropropene)	5 days (See label)	Preplant	garden centipedes (symphylans), wireworms	See supplemental label for restrictions in certain Florida counties.
Thiodan 3EC, Phaser (endosulfan)	24	2	aphids, blister beetle, cabbage looper, Colorado potato beetle, flea beetles, hornworms, stink bugs, tomato fruitworm, tomato russet mite, whiteflies, yellowstriped armyworm	Do not exceed a maximum of 3.0 lb active ingredient per acre per year or apply more than 6 times.
Trigard (cyromazine)	12	0	Colorado potato beetle (suppression of), leafminers	No more than 6 applications per crop.
Ultra Fine Oil	4	0	Aphids, beetle larvae, leafhoppers, leafminers, mites,	Do not exceed four applications per

Chemical Name	REI (hours)	Days to Harvest	Insects	Notes
(oil, insecticidal)			thrips, whiteflies	season.
***Vydate L 2EC** (oxamyl)	48	3	aphids, Colorado potato beetle, leafminers (except *Liriomyza trifolii*), whiteflies**	**suppression Do not apply more than 32 pts per acre per season.
***Warrior** (lambda-cyhalothrin)	24	5	aphids (2), beet armyworm (1), cabbage looper, Colorado potato beetle, cutworms, European corn borer, fall armyworm (1), flea beetles, grasshoppers, hornworms, leafhoppers, leafminers (2), plant bugs, southern armyworm (1), stink bugs, tomato fruitworm, tomato pinworm, whiteflies (2), yellowstriped armyworm (1)	Do not use on cherry or grape tomatoes. (1) for control 1st and 2nd instars only. (2) suppression only Do not apply more than 0.36 lb ai per acre per season.
The pesticide information presented in this table was current with federal and state regulations at the time of revision. The user is responsible for determining the intended use is consistent with the label of the product being used. Use pesticides safely. Read and follow label instructions.				
*** Restricted Use Only**				

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