Whitefly Update

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Whiteflies are small insects with piercing-sucking mouthparts related to aphids and scales. They are principally tropical and subtropical in distribution. Adults have four wings covered with waxy scales and resemble tiny moths. Females attach eggs to the undersides of leaves by a short stalk. Upon hatching, the first instar young or crawler actively seeks a suitable feeding site close by. Subsequent immature stages are legless, sessile (non-moving), and resemble scales. Both adults and immatures feed on plant sap from the underside of the leaf by inserting the proboscis into the phloem. By excreting a sugary honeydew they concentrate sufficient amino acids in their gut to meet their nutritional requirements.

Three species of whitefly are known to transmit geminiviruses, the greenhouse whitefly Trialeurodes vaporariorum (Westwood) the banded wing whitefly, T. abutilonea (Haldeman) and the sweetpotato whitefly, (SPWF) Bemisia tabaci (Gennadius). All three occur in Florida and all three have a wide host range of herbaceous broadleaf plants which includes tomato. The pupae of both Trialeurodes species can be distinguished from SPWF by the presence of a marginal fringe and the banded wing whitefly pupa is much darker in color than either of the other two. The adults can be distinguished by the dark wing bands of T. abutilonea, and the habit of the smaller SPWF of holding its wings rooflike over the body rather than vertically as do the larger Trialeurodes species. The greenhouse whitefly is usually confined to greenhouses and the banded wing whitefly is rare on tomato.

SPWF on Tomato in Florida

SPWF is native to the old world, possibly the Middle East, but has been introduced along with its many crop and ornamental hosts into all the warm regions of the world. In Florida it was first reported in 1900 but was not an economic pest until late fall of 1987. In southern tomato production areas large populations caused yield reductions, fruit contaminated with sooty mold from honeydew secretions, and annoyed pickers. However, the most serious economic losses occurred when an irregular or blotchy ripening condition of the fruit led to rejection of many shipments in northern markets (Maynard & Cantliffe 1989).

Intensified chemical control of SPWF largely eliminated these initial problems but not the widespread appearance of severe virus symptoms in tomato in the fall of 1989. The disorder was determined to be a geminivirus (Hiebert 1990, Brown 1990) transmittable by SPWF (Kring et al. 1990). Field trials during spring 1990 at the SWFREC in Immokalee have shown that populations as low a 1 adult SPWF per leaf were enough to spread geminivirus effectively from a nearby inoculum source of infected tomato. Therefore, whitefly numbers must be kept low when infected plants are present, especially early in the crop cycle when geminivirus causes greatest yield losses Figures 1 and 2 (also Vavrina 1990 and Csizinszky et al. 1990).

Vector - Virus Relationships

All geminiviruses known so far are persistent in their whitefly vectors, meaning they remain infective for at least several days. Acquisition of the virus usually requires at least an hour of feeding and a latent period is necessary before transmission can be effected. An example is chino del tomate (CDT), a geminivirus from Mexico which causes symptoms in tomato similar to those of the Florida geminivirus. SPWF acquires the virus at low efficiency after an hour of feeding, whereas a 4 hour feeding results in almost 100% acquisition. At least two hours of feeding are necessary before the SPWF can transmit CDT following a 17 hour latent period (Brown and Nelson 1988).

Chemical Control

The relatively long periods necessary for acquisition, latency and inoculation of geminiviruses compared to many aphid-transmitted viruses implies that chemical control of the whitefly vector can be an effective means of slowing the spread of the disease. However, adequate chemical control of SPWF is difficult, in part because the sessile stages (eggs, nymphs and pupae) occur on the undersides of leaves where coverage is difficult at best. Furthermore, heavy insecticide use will undoubtedly select for resistant strains as it has in the cotton producing regions of the Sudan where resistance factors as high as 660 times for Monitor and 350 times for deltamethrin have been reported (Dittrich et al. 1990). Preliminary tests from around the state made by C. E. Mantilla and G. L. Leibee at the CFREC at Sanford have already detected the beginnings of pyrethroid resistance in a population from Gainesville heavily sprayed for only a year (Table 1). The problem of resistance is compounded by the tendency of insecticides to eliminate natural enemies of the whitefly such as lacewings, predaceous mites and parasitic wasps.

Complete reliance on chemical insecticides as the only method of pest management would be suicidal, but it is unlikely that their use can be entirely eliminated in the near future and still maintain high standards of quality. Therefore, IFAS entomologists continue testing new products in hopes of staying ahead of resistance and finding alternatives that are less destructive to beneficials. Field trials were carried out at GCREC last fall and this spring to test materials of different formulations, combinations and rates for management of the SPWF, irregular ripening, and virus on tomato (Tables 2-6).

A field trial at SWFREC in fall 1989 compared two formulations of Lorsban alone and mixed with Asana to a grower check alternating Asana and Thiodan (Tables 7 and 8). Significant differences among treatments in counts of whitefly immatures occurred on the second of 3 post-treatment evaluations when plots treated with Lorsban had fewest pupae and mixtures or alternations including Asana XL had fewest nymphs (Table 7). There were no significant differences in virus incidence or yield value among treatments, but irregular ripening at second pick followed a pattern similar to nymphal counts.

In the spring of 1990, a trial was conducted at SWFREC to control SPWF and delay geminivirus transmission through the use of JMS Stylet Oil or synthetic pyrethroids (Asana XL or Brigade at two rates). The plots were 9 rows wide and located south and adjacent to 3 beds of 100% geminivirus- infected tomato planted the previous November and partially protected from the Christmas freeze.

Whitefly populations were low throughout March and increased throughout April. All stages were generally highest in the control plots, lowest in the insecticide plots, and intermediate in the oil plots (Fig. 3a and b). For the overall analyses, differences between controls and the remaining treatments were statistically significant for all life stages but crawlers. There were significantly fewer large nymphs and adults (avg. of 11 dates) in plots sprayed with pyrethroids compared to oil plots (Tables 9 and 10). Virus symptoms appeared first and early in the center section of the northernmost row (closest to the old, infected rows) and spread in all directions, rapidly at first, then more slowly commensurate with low whitefly populations. Visible evidence of infection remained largely confined to the northern 3 rows. The presence of geminivirus in a sample of symptomatic plants was confirmed by observation of inclusion bodies in phloem. Statistical analysis indicated a random distribution of infected plants over treatments except for the last observation period (March 26 to April 4) when a significantly greater number of plants showed symptoms in the control plots compared to the oil and insecticide plots (Table 11).

Other Control Methods

Plant Houses. It is important that transplants be as free from whiteflies (and virus) as possible. Reliance on insecticides to clean up transplants has the disadvantage of prolonging the selection period for resistance. An alternative is exclusion of whiteflies from transplant houses with plastic screen. Studies at GCREC showed that fabric with a 350 u hole (0.014 in) excluded penetration of all whiteflies, although preventing movement forced by airflow requires smaller mesh (Price et al. 1990).

Biological Control. Whiteflies are attacked by numerous natural enemies including insect predators, insect parasites, and fungal pathogens. The combined effects of these agents may well be at least partially responsible for maintaining the low populations of SPWF seen on weeds not adjacent to cultivated fields. Considerable research effort on the part of IFAS and USDA scientists in Florida is aimed at determining the impact of natural enemies of SPWF with the ultimate goal of incorporating the most useful elements into our management systems (Osborne et al. 1990).

Paecilomyces fumosoroseus, is a fungal pathogen specific to insects which often attacks SPWF in Florida greenhouses. Studies at Central Florida Research and Education Center at Sanford have demonstrated the virulence of the fungus and the feasibility of its use as a biological control agent (Osborn et al. 1990). Development and commercialization of P. fumosoroseus is being pursued through a cooperative agreement between the University of Florida and the W.R. Grace Company.

Another effort is being directed toward investigating the potential for biological control with insect parasites. The first phase of this project is to identify the species of tiny wasps which occur in Florida and to evaluate their impact on SPWF. Three species have been reared consistently from SPWF collected throughout the southern part of the state on 30 different plants, 18 of them weeds. Parasitism has been as high as 100% in some samples (Table 12), indicating the high efficiency of these wasps under certain conditions. Now that the local parasite fauna is known, the impact of any promising new parasites introduced subsequently can be better assessed.

The large and diverse group of insects which prey on SPWF is only beginning to be appreciated. This is partly because, unlike parasites and pathogens, predators leave little evidence of their activity. Osborne et al. (1990) have reported the ability of a tiny ladybeetle, Delphastus pusilius, to reduce heavy populations of SPWF in Florida greenhouses. Studies are in progress at GCREC to evaluate the potential of lacewing larvae to manage SPWF populations.

Colored Mulches. Any means of delaying the onset of virus symptoms would reduce the deleterious effect on yield. Colored mulches continue to show promise as a means of slowing virus movement into the field. However, the mulches themselves influence plant growth through effects on soil and leaf temperature by selectively transmitting certain wavelengths of light and reflecting others. In field trials conducted at GCREC, virus symptoms appeared on aluminum mulches after either yellow or orange mulches, but tomatoes on orange mulch yielded more than either yellow or aluminum mulches (Csizinszky et al. 1990).

Scouting. Due to the multiplicity of complicating factors and our lack of knowledge about the pest, the disorders it causes, and the viruses it vectors, there is not yet a generally accepted "threshold" density, below which risk to production can be considered minimal. Each grower's situation will be different, depending on environmental and economic factors and the cultural practices employed. Certainly if populations remain low and stable as the crop matures, spray programs can be reduced. Scouting remains the basic tool of tomato pest management, and research continues on more efficient sampling methods. In one study at SWFREC during the fall of 1989 it was determined that the number of nymphs per terminal 3 leaflets was approximately the same for the 6th, 7th, or 8th leaf, counting down from the top, although there were significantly more pupae on the lower leaves (Table 13). For sampling adults a comparison was made between direct counts on the third leaflet from the top (n=3/plot) and suction samples (N = .36) taken on two sample dates with a modified portable vacuum cleaner. A good correlation (R = 0.79) was found between these two types of samples. Future studies will compare sticky card samples with the other two methods.

Postharvest Control. The successive planting of adjacent fields which is common practice throughout Florida often leads to large scale movement of SPWF and geminivirus inoculum from old fields to young fields. Harvested fields may be treated with defoliants to kill eggs and nymphs, but adults and pupae escape harm. The addition of insecticides to the defoliant may eliminate part of the adult population but not pupae. One alternative might be to incinerate the plant and associated whiteflies immediately after harvest with propane burners used for string removal. Results from a preliminary trial at CMC Farms of Collier County showed that mortality was virtually 100% on leaf tissue wilted by the burn.

The longer the summer fallow period is free of virus and whitefly hosts, the fewer problems there will be in the fall. Timely and thorough post-harvest clean-up of fields and destruction of volunteers by disking, herbicide treatment, and cover crop maintenance will benefit everyone.

References

Brown, J. K. and M. R. Nelson. 1988. Transmission, host range, and virus-vector relationships of chino del tomate virus, a whitefly-transmitted geminivirus from Sinaloa, Mexico. Plant Disease 72:866-869.

Brown, J. K. 1990. Whitefly-transmitted geminiviruses of tomato and pepper in Mexico and Arizona and their relationship to geminiviruses of tomato in Florida. In R. K. Yokomi, Y. Narayanan and D. J. Schuster, Eds. Proceedings of the Workshop on the Sweetpotato Whitefly-Mediated Vegetable Disorders of Florida. Univ. of Fla., IFAS, Gainesville. In press.

Csizinszky, A. A., D. J. Schuster, and J. B. Kring. 1990. Use of color mulches for tomato production. Fla. Grower & Rancher. In press.

Dittrich, V., S. Uk, and G. H. Ernst. 1990. Chemical control and insecticide resistance of whiteflies. In Whiteflies: Their Bionocs, Pest Status and Management. Dan Gerling, Ed. Intercept Ltd. Andover. 348 pp.

Hiebert, E. 1990. Preliminary characterization of the tomato geminivirus in Florida. In R. K. Yokomi, Y. Narayanan and D. J. Schuster, Eds. Proceedings of the Workshop on the Sweetpotato Whitefly-Mediated Vegetable Disorders of Florida. Univ. of Fla., IFAS, Gainesville. In press.

Kring, J. B., D. J. Schuster, J. F. Price, and G. W. Simone. 1990. Sweetpotato whitefly transmission studies of Florida tomato disorders. In R. K. Yokomi, Y. Narayanan and D. J. Schuster, Eds. Proceedings of the Workshop on the Sweetpotato Whitefly-Mediated Vegetable Disorders of Florida. Univ. of Fla., IFAS, Gainesville. In press.

Maynard, D. N. and D. J. Cantliffe. Squash silverleaf and tomato irregular ripening: new vegetable disorders in Florida. Vegetable Crops Fact Sheet VC-37. IFAS, Gainesville.

Osborne, L., S. K. Hoelmer, and D. Gerling. 1990. Prospects for biological control of Bemisia tabaci. SROP/WPRS Bull. 13: 153-160.

Price, J. F., D. J. Schuster, and J. B. Kring. 1990. Exclusion of sweetpotato whitefly for greenhouse grown tomatoes. In R. K. Yokomi Y. Narayanan and D. J. Schuster, Eds. Proceedings of the Workshop on the Sweetpotato Whitefly-Mediated Vegetable Disorders of Florida. Univ. of Fla., IFAS, Gainesville. In press.

Vavrina, C. S. 1990. Virus complex strikes Florida tomatoes. American Vegetable Grower 38(2): 61-64.

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Table 1. Probit analysis of Florida populations of the SPWF treated with fenvalerate on sticky tapes.

Population:	N	LC 50 (95% c.l.)	Slope +-S.E.	
Gainesville	586	0.89 (0.67 - 1.09)	1.95	0.2
Homestead	512	0.28 (0.08 - 0.48)	1.60	0.3
Immokalee	487	0.65 (0.30 - 0.90)	3.00	0.3
Sanford	499	0.55 (0.30 - 0.80)	2.56	0.3

Table 2. Field trial for control of SPWF on tomato at GCREC, Fall 1990.

Insecticide	Rate lb (AI)/100 gal	No./10 leaflets Sessile nymphs 8 Nov	Sessile nymphs 7 Dec	Pupae 8 Nov	Pupae 7 Dec	Fruit/10 plants No.	Fruit/10 plants Wt (lb)	Wt (lb)/ Fruit	% Irregular Ripening
Ambush 2 EC	0.125	6.8 a	3.2 a	0.8 a	0.2 a	109.8 a	28.5 b	0.26 a	0.5 a
Ammo 2.5 EC	0.10	1.0 a	1.2 a	0.8 a	0.0 a	102.0 a	33.7 ab	0.30 a	0.0 a
Asana XL 0.66 EC	0.03	8.5 a	5.5 a	1.2 a	0.0 a	143.0 a	42.7 a	0.30 a	0.0 a
Brigade 10 WP	0.06	1.5 a	0.5 a	0.0 a	0.0 a	139.5 a	41.5 a	0.31 a	0.0 a
Karate 1 EC	0.03	1.2 a	1.5 a	0.5 a	0.0 a	146.8 a	45.2 a	0.30 a	0.0 a
Karate 1 EC	0.025	7.5 a	0.5 a	1.2 a	0.5 a	137.0 a	42.6 a	0.31 a	0.0 a
Karate 1 EC	0.02	3.8 a	1.2 a	1.5 a	0.0 a	134.0 a	41.5 ab	0.30 a	0.5 a
Lorsban 50 WP	1.0	3.8 a	1.0 a	0.0 a	0.0 a	116.2 a	35.4 ab	0.30 a	2.4 a
Lorsban 4 EC	1.0	6.2 a	2.2 a	1.2 a	0.2 a	122.2 a	35.8 ab	0.29 a	0.0 a
Check	-	32.8 b	37.0 b	9.5 b	4.2 b	143.8 a	46.0 a	0.32 a	2.5 a

On 8 Sept, transplants were set 18 inches covered with white polyethylene mulch. Plots consisted of 3-2 ft long rows on 5 ft centers. Treatments were applied with a tractor-mounted sprayer on 2, 10, 16, 23, 30 Oct, 6, 13, 20, 27 Nov and 4 Dec. The sprayer delivered 50 gpa the first three sprays (4 nozzles/row, 130 psi, D-4 disks, #25 cores), 85 gpa the next three sprays (6 nozzles, 200 psi, D-3 disks, #25 cores), and 100 gpa for the remaining sprays (8 nozzles, 200 psi, D-3 disks, #23 cores). The terminal leaflet was collected from the 7th or 8th leaf (counting from the top) of each of ten stems from the middle row of each plot on 8 Nov and 7 Dec. The numbers of sessile nymphs and pupae of the sweetpotato whitefly were counted. All fruit of marketable size were harvested on 8 Dec and the fruit counted and weighed. Samples of 50 fruit from each plot were held at room temperature in paper bags and the number of fruit exhibiting external symptoms of irregular ripening (IRR) determined as the fruit ripened.* Means within a column followed by the same letter are not significantly different at the P = 0.05 level, Duncan's multiple range test.

Table 3. Evaluation of pyrethroid insecticides alone and combined with organophosphate insecticides for control of the sweetpotato whitefly on tomato, GCREC, Spring 1990.

	No. sweetpotato whitefly immatures/10 leaflets				Irregular ripening	
Treatment and lb (AI)/acre	Eggs	Crawlers	Sessile Nymphs	Pupae	Rating	% Un-marketable
Ambush 2EC 0.125	19.5b	26.2b	45.8c	2.5b	2.16ab	12.3abc
Ambush 2EC 0.10 + Monitor 4EC 0.75	6.0a	16.5ab	25.5bc	0.0a	2.12ab	9.6abc
Asana XL 0.66EC 0.05	8.5ab	17.2ab	24.0bc	1.0ab	2.04a	3.8a
Asana XL 0.66EC 0.038 + Monitor 4EC 0.75	7.2ab	8.2ab	6.0ab	0.0a	2.04a	3.3a
Danitol 2.4EC 0.2	8.2ab	14.5ab	12.8ab	0.0a	2.07a	6.4a
Danitol 2.4EC 0.1	8.0ab	17.5ab	15.2abc	0.8ab	2.12ab	9.5abc
Danitol 2.4EC 0.2 + Monitor 4EC 0.75	1.5a	11.2ab	4.0a	0.0a	2.11ab	9.1abc
Danitol 2.4EC 0.1 + Monitor 4EC 0.75	5.0ab	23.2ab	5.5ab	0.2a	2.27bc	22.7bc
Danitol 2.4EC 0.2 + Orthene 75SP 1.0	1.2a	5.0a	2.0a	0.0a	2.08a	6.7ab
Danitol 2.4EC 0.1 + Orthene 75SP 1.0	2.8ab	6.0ab	4.0a	0.2a	2.11ab	8.9abc
Check (water)	19.5b	81.2c	103.2d	6.8c	2.35c	25.3c

Transplants of 'Sunny' were set March 20 into plots consisting of 3-20 ft long rows. Treatments were replicated 4 times. Listed treatments were alternated weekly with Thiodan 3EC at 0.94 lb AI/acre. Beginning with Thiodan, treatments were applied with a high clearance, self-propelled sprayer on April 20, 26, May 4, 11, 16, 23, 30, June 5-6 and 18. Ten leaflets were collected from each plot on June 11 and the numbers of whitefly immatures were counted. Fruit were harvested June 14 and 27 and were rated 1-4 for increasing severity of symptoms of irregular ripening. Fruit rated 3 or 4 were considered unmarketable. Means within a column followed by the same letter are not significantly different at $P<0.05$ level, Duncan's multiple range test.

Table 4. Evaluation of insecticides applied for control of immature lifestages of the sweetpotato whitefly on tomato, GCREC, Spring 1990.

	% dead				No. live pupae	
	Crawlers		Sessile nymphs			
Treatment and lb (AI)/100 gal	0 DAT	2 DAT	0 DAT	2 DAT	0 DAT	2 DAT
Agri-Mek 0.15EC 0.01	2.3a	55.1a-c	1.5a	33.3ab	2.0a	26.0ab
Agri-Mek 0.15EC 0.005 + Sunspray Ultrafine Oil 1 gal	3.3a	50.7a-c	1.9a	41.3a	2.0a	30.5a-d
Ambush 25WP 0.125	1.4a	40.0b-d	1.5a	25.2ab	3.0a	33.0a-d
Ambush 25WP 0.0625 + Monitor 4EC 0.50	3.9a	51.8a-c	1.3a	24.9ab	2.0a	18.0a
Ambush 25WP 0.0625 + Safer Insecticidal Soap 1 gal	11.7a	49.6a-c	0.9a	37.0ab	4.0a	59.0cd
Brigade 10WP 0.10	6.3a	60.6ab	3.5a	35.4ab	5.2a	11.5a
Brigade 10WP 0.05	6.5a	63.9ab	1.3a	35.8ab	3.2a	28.5a-c
Bromosept 0.04	2.3a	30.2cd	0.5a	21.3b	2.5a	36.5a-d
Bromosept 0.02	1.8a	35.5b-d	0.7a	19.6b	1.5a	21.2a
Karate 1EC 0.030	2.7a	72.9a	3.0a	32.2ab	3.8a	18.2a
Karate 1EC 0.025	4.6a	64.1ab	2.2a	27.9ab	2.2a	24.8ab
Lorsban 50WP 1.0	4.8a	71.2a	1.8a	37.7ab	6.8a	37.0a-d
Lorsban 50WP 0.5 + Ambush 25WP 0.0625	3.5a	69.1a	2.4a	37.9ab	1.8a	37.8a-d
Safer Insecticidal Soap 2 gal	3.7a	56.2a-c	1.8a	35.9ab	1.8a	55.5b-d
Sunspray Ultrafine Oil 2 gal	2.1a	68.9a	4.0a	43.9a	2.0a	29.0a-c
Check (water)	1.9a	22.6d	1.8a	24.6ab	4.0a	60.5d

Transplants of 'Sunny' were set March 20 into plots consisting of 3-20 fot long rows. Treatments were replicated 4 times and were applied with a high clearance, self-propelled sprayer on 7-8 and 12-13 June. Ten leaflets were collected from each plot on June 5 (0 DAT) before the first spray and again on June 14-15 (2 DAT) two days after the last spray and the numbers of whitefly immatures were counted. Means within a column followed by the same letter are not significantly different at the $P<0.05$ level, Duncan's multiple range test.

Table 5. Comparison of insect growth regulators and other insecticides for management of the sweetpotato whitefly on tomato, GCREC, Spring 1990.

	No. sweetpotato whitefly immatures/10 leaflets				Irregular ripening	
Treatment and lb (AI)/100 gal	Eggs	Crawlers	Sessile Nymphs	Pupae	Rating	% Un-marketable
Ambush 25WP 0.0625 + Monitor 4EC 0.375	132.7a*	262.3c	136.7d	3.0ab	2.82b	54.0b
Ambush 25WP 0.0625 + Thiodan 3EC 0.5	77.7a	120.3ab	70.3a-c	0.7ab	2.81b	49.8b
Andalin 1EC 0.25	241.3ab	181.7a-c	120.0b-d	8.3b	2.84b	52.2b
CME 13411 100 gm EC 0.06	248.0ab	171.7a-c	50.3a	4.3ab	2.43a	29.4a
Incite 8EC 0.5	161.0a	202.0bc	63.7ab	1.7ab	2.88b	53.9b
SN 85292 400 gm/L 0.375	387.3bc	177.0a-c	66.7ab	3.3ab	2.27a	21.9a
SN 85292 400 gm/L 0.25	252.5ab	60.0a	21.5a	0.0a	2.38a	29.3a
Thiodan 3EC 1.0	128.7a	114.0ab	43.3a	5.7ab	2.84b	53.8b
Thiodan 3EC 0.5	112.3a	136.7a-c	29.0a	4.3ab	2.78b	49.1b
Thiodan 3EC 1.0 + Incite 8EC 0.5	124.7a	117.3ab	52.7a	1.7ab	2.80b	51.4b
Thiodan 3EC 0.5 + Incite 8EC 0.5	109.0a	152.0a-c	74.0a-c	4.7ab	2.88b	54.4b
Check (water)	463.3c	201.0bc	125.7d	5.7ab	2.88b	56.3b

Transplants of 'Sunny' were set March 20 into plots consisting of 3-20 ft long rows. Treatments were replicated 4 times and were applied with a high clearance, self-propelled sprayer on April 23, May 9, 17, 24, 31, June 14-15 and 20. Ten leaflets were collected from each plot on May 21 and the numbers of whitefly immatures counted. Fruit were harvested June 13 and 26 and were rated 1-4 for increasing severity of external symptoms of irregular ripening. Fruit rated 3 or 4 were considered unmarketable. Means within a column followed by the same letter are not significantly different at the $P<0.05$ level, Duncan's multiple range test.

Table 6. Evaluation of petroleum oils for control of the sweetpotato whitefly, irregular ripening and geminivirus on tomato, GCREC, Spring 1990.

Treatment and amount/100 gal	Application Pressure (psi)	No. sweetpotato whitefly immatures: Eggs	Crawlers	Sessile Nymphs	Irregular ripening: Rating	% Un-marketable	No. virus infected plants
JMS Stylet Oil 0.5 gal	400	99.0a	90.3ab	153.0a	2.93a	58.8a	3.2a
JMS Stylet Oil 0.5 gal	200	120.7a	84.7ab	89.3a	3.03a	66.8a	9.5a
Saf-T-Side Oil 2 gal	200	263.5ab	10.5a	194.5a	2.83a	51.9a	3.0a
Sunspray Ultrafine Oil 1 gal	400	345.0b	123.5ab	136.5a	3.08a	66.1a	6.0a
Sunspray Ultrafine Oil 1 gal	200	247.3ab	208.3b	208.7a	2.80a	52.7a	6.2a
Super Savol Oil 0.25 gal	200	178.5ab	15.5a	281.5a	2.98a	61.1a	12.8a
Check (water)	200	183.7ab	172.0b	300.3a	3.05a	65.3a	7.5a

Transplants of 'Sunny' were set March 20 into plots consisting of 3-20 ft long rows. Treatments were replicated 4 times and were applied with a tractor-pulled sprayer on April 6, 12, 17, May 2, 8, 16, 30, June 5, 11 and 18. Ten leaflets were collected from each plot on June 27 and the numbers of whitefly immatures counted. The number of plants with symptoms of geminivirus were counted on June 22. Fruit were harvested on June 12 and 25 and were rated 1-4 for increasing severity of external symptoms of irregular ripening. Fruit rated 3 or 4 were considered to be unmarketable. Means within a column followed by the same letter are not significantly different at the $P<0.05$ level, Duncan's multiple range test.

Table 7. Results of field trials for control of SPWF on tomato, SWFREC, Fall 1989.

Insecticide	Rate lb (AI)/A	No./27 leaflets 19 Oct	1 Nov	15 Nov
		Sessile Nymphs		
Lorsban 4E	1.0	76.5 A	22.8 AB	63.3 A
Lorsban 50W	1.0	58.3 A	25.8 AB	46.3 A
Lorsban 4E+ Asana XL 0.66 EC	0.5 + 0.018	63.3 A	11.3 B	30.0 A
Thiodan 3E or Asana XL 0.66 EC	0.5 0.036	54.5 A	15.3 B	45.8 A
Untreated Check	-----	99.4 A	42.3 A	74.9 A
		Pupae		
Lorsban 4E	1.0	38.8 A	11.0 B	8.8 A
Lorsban 50W	1.0	31.8 A	12.0 B	14.3 A
Lorsban 4E + Asana XL 0.66 EC	0.5 + 0.018	30.0 A	11.3 B	7.3 A
Thiodan 3E or Asana XL 0.66 EC	0.5 0.036	42.0 A	25.3 A	7.3 A
Untreated Check	-----	59.4 A	29.4 A	18.9 A

Tomatoes spaced at 18 in were transplanted on 7 Aug in 3-row plots 24 ft long on 3 raised soil beds (6 ft. centers) which were fumigated with Vorlex and covered with plastic mulch. Manzate 200 (1.5 lb/ac) and Tri-Basic Copper (3 lb/ac) were applied weekly, and Javelin SC at 1.2 qt/ac was applied twice to control Spodoptera spp. Insecticide applications began 13 Oct and continued weekly for 6 weeks using a tractor mounted boom sprayer delivering 150-200 lbs/in^2 to 4 drop lines with a maximum of 24 T-jet hollow cone nozzles fitted with brass TLX-3 80° tips and 100 mesh stainless steel strainers with check valves. Induce at 1pt/100 gal) was applied as an adjuvant with all treatments including the control. Whitefly immatures were counted on the terminal leaflet of the 6th, 7th and 8th leaf from the top on 9 randomly selected plants per plot.

Table 8. Effects on virus, of insecticide treatments for control of SPWF on geminivirus incidence, irregular ripening, and yield.

Insecticide	Rate lb (AI)/A	Yield Value ($/A)*	% Irregular ripening		
			21 Nov.	4 Dec.	% Virus Incidence
Lorsban 4E	1.0	24,265 A	26.5 A	19.8 B	7.8 A
Lorsban 50W	1.0	22,091 A	23.0 A	23.7 B	6.5 A
Lorsban 4E + Asana XL .66EC	0.5+ 0.018	22,239 A	21.0 A	9.8 C	7.8 A
Thiodan 3E or Asana XL 0.66 EC	0.036 or 0.5	26,264 A	18.8 A	10.8 C	8.5 A
Untreated Check	----	22,489 A	24.9 A	34.8 A	6.3 A

Plants affected by geminivirus were marked as symptoms appeared. All fruit of commercial size was harvested on 21 Nov and 4 Dec, graded for quality and size and weighed. Fruit held for 4 days in ethylene, and sorted according to degree of ripeness. Fruit that were still between 10% and 50% green were considered "irregular" in ripeness. Yield value was assessed according to 8 Dec 1989 prices irrespective of irregular ripening.

Table 9. Mean number of immature whiteflies on 9 tomato leaves in plots at SWFREC averaged over 11 sample dates.

	Whitefly Stage					
		------Nymphs------				
TREATMENT	EGGS	CRAWLERS	SMALL	LARGE	PUPAE	TOTAL
Control	1.9 A*	0.14 A	4.4 A	3.3 A	1.6 A	11.3 A
Oil	0.78 A	0.12 A	2.2 A	0.86 B	0.18 B	4.1 B
Asana	0.23 B	0.0 B	0.14 B	0.21 C	0.11 B	0.48 C
Brigade Low	0.16 B	0.0 B	0.45 B	0.91 C	0.23 B	0.32 C
Brigade High	0.02 B	0.0 B	0.25 B	0.27 C	0.45 B	0.52 C

Table 10. Number of adult whiteflies on three tomato leaves in plots at SWFREC, last 4 observation dates and average over 11 observation dates.

	Sample Date				
TREATMENT	8 APR	16 APR	23 APR	30 APR	AVERAGE OF 11 DATES
Control	4.4 A*	7.8 A	15.7 A	35.3 A	6.2 A
Oil	2.6 AB	5.5 AB	6.9 B	9.5 B	2.5 B
Asana XL	2.3 B	1.3 BC	2.0 BC	3.5 BC	1.1 C
Brigade Low	1.0 B	2.0 BC	1.0 C	1.8 C	0.8 C
Brigade High	1.3 B	0.3 C	0.8 C	1.8 C	0.6 C

Table 11. Average number of tomato plants per 60-plant plot initiating virus symptoms between the indicated observation dates.

	Observation Period					
TREATMENT	PRE-MAR 2	MAR 3-MAR 8	MAR 9-MAR 16	MAR 17-MAR 25	MAR 26-APR 4	TOTAL
Control	1.10 A*	1.00 A	1.5 A	2.1 A	1.50 A	7.0 A
Stylet Oil	1.00 A	0.86 A	1.5 A	2.0 A	0.50 B	6.1 A
Insecticide	0.25 A	0.36 A	1.5 A	1.6 A	0.38 B	4.1 A

Table 12. Number and (%) of SPWF and hymenopterous parasite adults reared from whitefly pupae on foliage of selected wild and cultivated host plants (unpublished data of F. D. Bennett, D. J. Schuster, J. F. Price, and J. B. Kring).

Host plant	*Bemisia tabaci*	*Eretmocerus californicus*	*Encarsia nigricephala*	*Encarsia tabacivora*
Ambrosia	4(8.0)	17(34.0)	0(0.0)	29(58.0)
Bidens	95(43.8)	11(5.1)	42(19.4)	69(31.8)
Cassia	24(42.9)	17(30.4)	7(12.4)	8(14.3)
Crotolaria	8(25.8)	3(9.7)	9(29.0)	11(35.5)
Emilia	25(19.2)	2(1.5)	60(46.1)	43(33.1)
Euphorbia spp.	20(21.3)	22(23.4)	32(34.0)	20(21.3)
Fleabane	4(7.3)	6(10.9)	0(0.0)	45(81.8)
Indigofera	36(18.2)	44(22.2)	31(15.7)	87(43.9)
Ipomea	20(5.1)	293(75.1)	28(7.2)	49(12.6)
Lambsquarters	13(52.0)	3(12.0)	2(8.0)	7(28.0)
Ludwigia	36(14.3)	93(37.1)	56(22.3)	66(26.3)
Macroptilium	31(22.8)	22(16.2)	73(53.7)	10(7.4)
Physalis	42(29.0)	20(13.8)	68(46.9)	15(10.3)
Polygonum	1(2.6)	20(52.6)	9(23.7)	8(21.0)
Sida	0(0.0)	13(54.2)	4(16.7)	7(29.2)
Solanum	31(17.3)	47(26.3)	46(25.7)	55(30.7)
Sonchus spp.	64(30.8)	12(5.8)	12(5.8)	120(57.7)
Urena	0(0.0)	25(26.3)	18(18.9)	52(54.7)
Basil	3(14.3)	0(0.0)	18(85.7)	0(0.0)
Broccoli	491(94.6)	3(0.6)	0(0.0)	25(4.8)
Cabbage	159(70.3)	2(0.9)	0(0.0)	65(28.8)
Cantaloupe	147(83.0)	3(1.7)	0(0.0)	27(15.3)
Collard	566(37.8)	576(38.4)	175(11.7)	181(12.1)
Cucumber	232(81.4)	41(14.4)	11(3.9)	1(0.4)
Eggplant	157(63.6)	11(4.5)	0(0.0)	79(32.0)
Poinsettia	1722(96.8)	27(1.5)	30(1.7)	0(0.0)
Potato	9(24.3)	0(0.0)	3(8.1)	25(67.6)
Squash	93(36.7)	0(0.0)	105(41.5)	55(21.7)
Tomato	197(63.8)	10(3.2)	13(4.2)	89(28.8)
Watermelon	93(57.4)	0(0.0)	1(0.6)	68(42.0)

Table 13. Number of SPWF nymphs and pupae on trifoliates of the 6th, 7th and 8th leaf, counting from the top. Cumulative average of 72 trifoliates from each level on each of 5 sample dates at SWFREC, fall 1990.

Leaf	Nymphs	Pupae
6th	18.7 A*	4.2 A
7th	21.2 A	8.2 B
8th	16.6 A	12.5 C

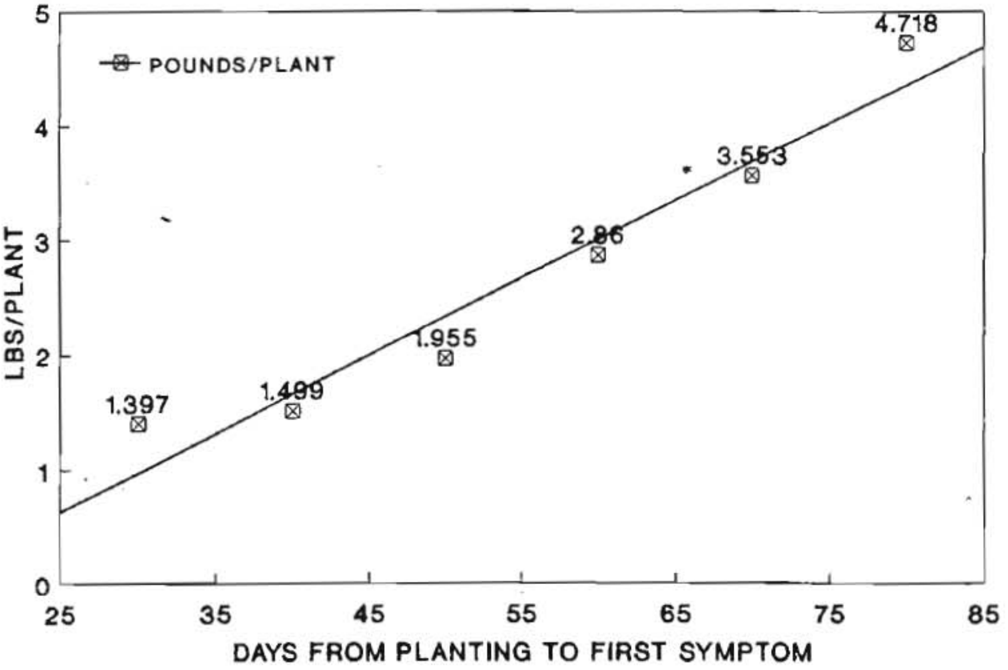

Figure 1. Relationship of yield to first detection of geminivirus on tomato plants grown in the spring 1990 at SWFREC. Cumulative yields are from three harvests of 10 to 31 plants depending on the date of first symptoms.

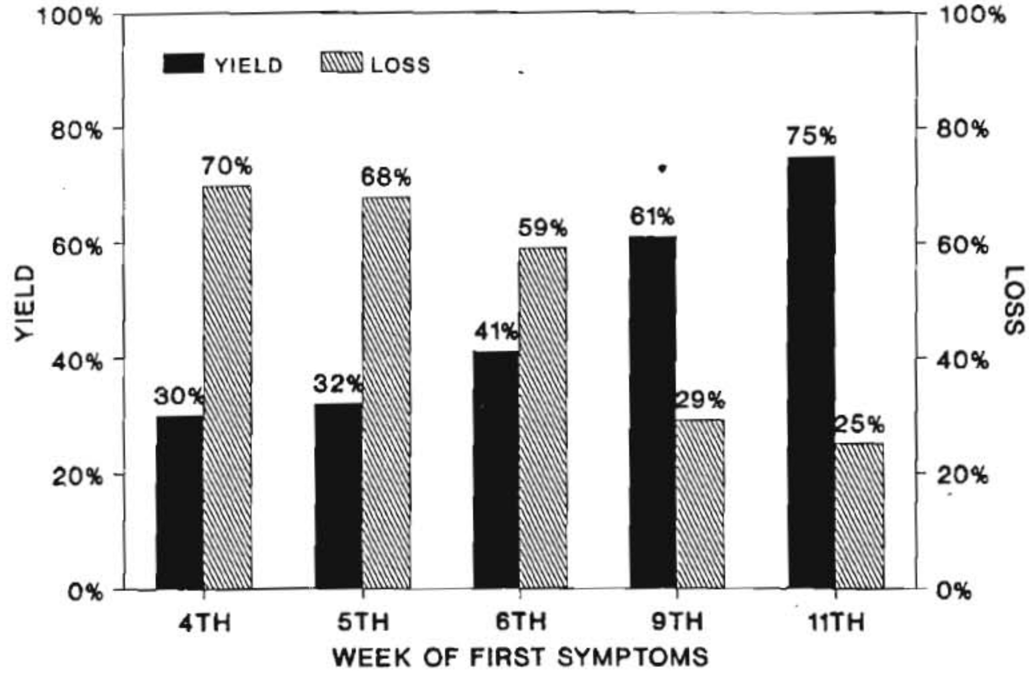

Figure 2. Percent yield loss by geminivirus infection in tomato as a function of time of first symptom appearance in the spring of 1990 at SWFREC.

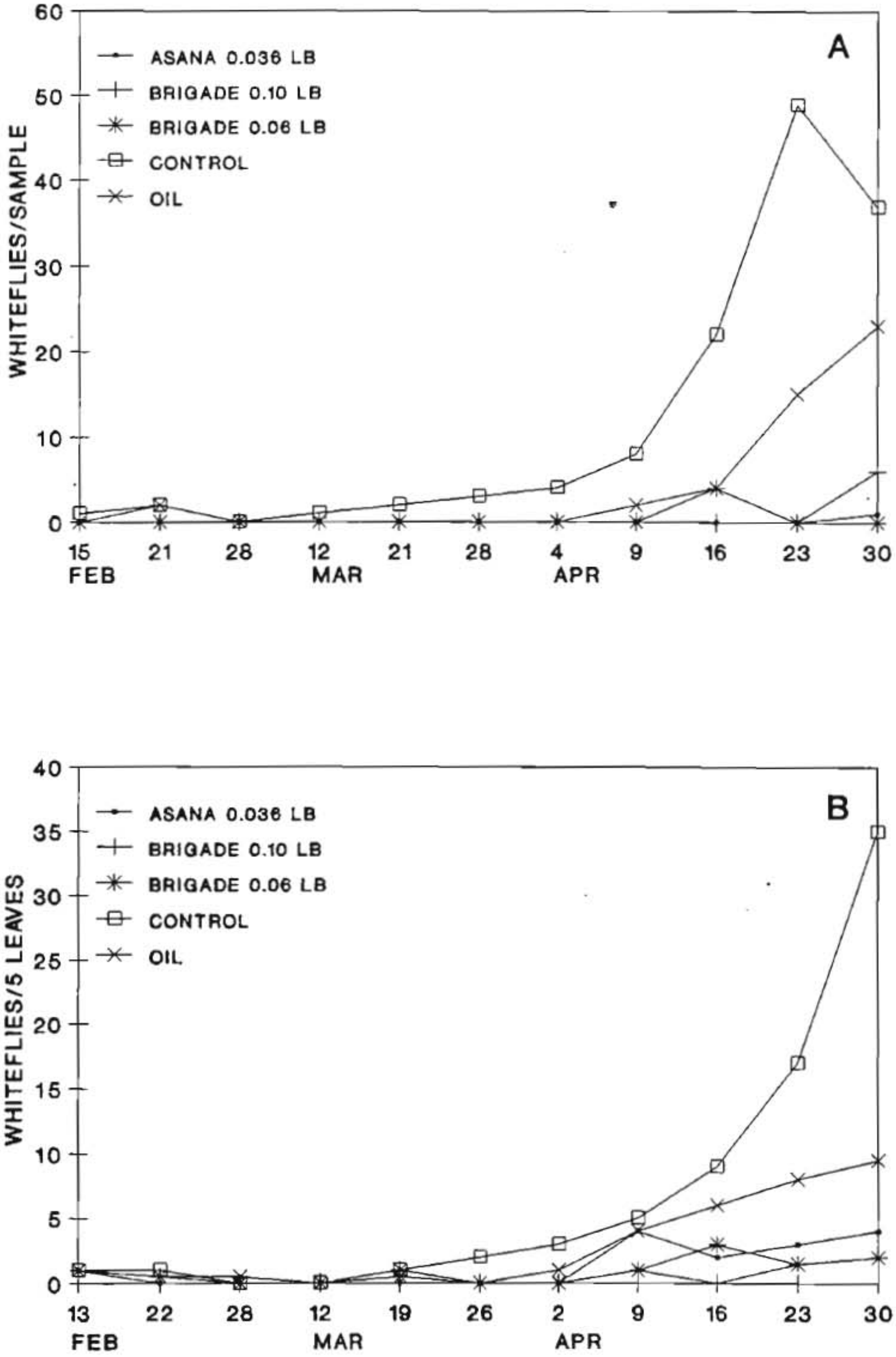

Figure 3. Numbers of sweetpotato whitefly adults or immatures in tomato sprayed with insecticide during the spring of 1990 at SWFREC: A. Number of immatures on 9 trifoliates per plot, N = 36. B. Number of adults from 5 leaves per plot.