Synergism: Potential new approach to whitefly control

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Sweetpotato whitefly feeding on cotton leaves produce sticky honeydew that reduces cotton quality and value.

Combining a defoliant with an insecticide gave superior control of sweetpotato whitefly in cotton

The sweetpotato whitefly (SPWF) has become an increasingly important pest of cotton and vegetable crops in the desert regions of southern California and western Arizona. The primary damage to cotton results from honeydew deposits on the leaves during feeding by the immature life forms. On cotton lint, the sticky honeydew may interfere with ginning and spinning, and it promotes the development of sooty molds that stain the lint, reducing its quality and value. Where abundant, sweetpotato whitefly, *Bemisia tabaci* (Gennadius), may reduce cotton photosynthesis and overall crop vigor and production.

Feeding by SPWF adults may also transmit virus diseases to other crops. One of the most important of these, lettuce infectious yellows virus (LIYV) has caused severe infections in cucurbits, lettuce, and sugarbeets throughout the Imperial and Palo Verde valleys (*California Agriculture*, November-December 1982). Cotton has not been shown to harbor the virus, but it contributes to the disease cycle by serving as an alternative host of SPWF. When cotton is defoliated in the fall, large numbers of SPWF adults migrate from cotton to nearby plantings of lettuce and other host crops.

Repeated applications of conventional insecticides are ineffective in suppressing sweetpotato whitefly populations on cotton during the season because of problems with coverage and insecticide resistance. Coverage does not usually extend below the upper canopy in cotton, because most insecticides are applied by air. Problems with coverage also stem from the fact that the immature SPWF stages (nymphs and pupae) secrete a protective waxy covering and live primarily on the undersides of leaves. SPWF resistance is broad-based, spanning at least four classes of insecticides—organochlorines, organophosphates, carbamates, and pyrethroids.

Use of synergism

One way to conserve the effectiveness of available insecticides is to use combinations of chemicals that have different modes of action, are detoxified by different pathways, or work better together than separately (synergism). The value of synergists in managing resistance has been demonstrated in the laboratory, especially for cases in which the insect does not have alternative pathways of detoxification. For example, in mosquitoes, in which the only known mechanism for organophosphate resistance is detoxification via esterase enzymes, the use of the synergist *S, S, S* - tributyl phosphorotrithioate (DEF) with an organophosphate has inhibited the evolution of resistance.

In addition to being an inhibitor of insecticide-metabolizing esterase enzymes in insects, DEF is widely used as a cotton defoliant in preparation for harvest. Sweetpotato whitefly is known to have relatively high concentrations of such enzymes. We hypothesized, therefore, that SPWF densities might be substantially reduced in the fall by incorporation of an insecticide (that is synergized by DEF) with the regular DEF application on cotton.

Laboratory bioassay

Our initial objective was to test for synergism among several commonly used insecticides on cotton. Cotton leaf disks were dipped in solutions of formulated material for 10 seconds, allowed to air-dry for one hour, and placed in a petri dish. Immobilized SPWF adults were gently shaken onto the treated leaf and the covered petri dishes were then transferred to a temperature cabinet. The mortality of both sexes was determined after 24 hours. Five concentrations were used for most tests; the data were subjected to probit analysis.

We assayed two SPWF strains: a susceptible (S) strain that had been reared in a greenhouse on cotton plants, and a field (F) strain collected from a cotton field in the Imperial Valley, near Brawley, in September 1986.

Repeated tests have shown that adult female SPWFs are considerably less sensitive to insecticides than adult males. For that reason, only the results on adult females are reported here.

S-strain females were highly susceptible to permethrin and cypermethrin

TABLE 1. Synergism of various insecticides by DEF on sweetpotato whitefly females

	Susceptible (S) strain			Field (F) strain		
Materials	Ratio	LC_{50}*	ST†	LC_{50}	SR	RR‡
		ppm AI		*ppm AI*		
Cypermethrin	1:0	75.0		270		3.6
+ DEF	1:1	2.4	31.2	17	15.9	
Permethrin	1:0	19.0		1,200		63.2
+ DEF	1:1	3.2	5.9	37	32.4	
+ DEF	1:5	1.2	15.8			
Sulprofos	1:0	300		4,000		13.3
+ DEF	1:0.1			1,400	2.9	
Methyl parathion	1:0	1,900		2,800		1.5
+ DEF	1:0.1			640	4.4	

* Values in terms of parts per million active ingredient (ppm AI) of insectiide. LC_{50} = concentration lethal to 50 percent of the test population.
† Synergism ratio = LC_{50} insecticide in absence of DEF ÷ LC_{50} insecticide in presence of DEF.
‡ Resistance ratio = LC_{50} F strain ÷ LC_{50} S strain.

(based on the LC_{50}, table 1), but were less susceptible to the organophosphates sulprofos and methyl parathion. In contrast, F-strain females exhibited a 63.2-fold level of resistance to permethrin (LC_{50} of 1,200 ppm), and a more moderate resistance to sulprofos (13.3-fold). These results may reflect the insecticide exposure histories of the F strain, since other resistance studies involving sweetpotato whitefly in the Imperial Valley have reported similar findings for permethrin.

As indicated by the synergism ratios (SR) in table 1, combinations of DEF with cypermethrin or permethrin exhibited a high degree of synergism (15.9- and 32.4-fold, respectively); combinations of DEF with sulprofos or methyl parathion displayed low synergism (2.4- and 4.4-fold) The high degree of pyrethroid synergism by DEF in our laboratory study suggests that esterases are involved in pyrethroid resistance in SPWF. Based on these results, we conducted tests in the field to better evaluate the effects of different combinations of DEF and pyrethroids.

Field trials

Experiments were conducted in eight fields in the Imperial Valley near Brawley and one field in the Palo Verde Valley near Blythe in 1986. All fields were in commercial production and ranged in size from 70 to 120 acres.

Cylindrical yellow sticky traps, placed flush with the cotton canopy, were used to sample weekly population trends of SPWF from August 5 through September 19 in the Imperial Valley. The traps were located about 60 feet within each cotton field and were replaced weekly with new traps.

Because attraction of adult SPWFs from nearby nondefoliated fields might inflate estimates of SPWF densities on traps in defoliated cotton fields, we made direct counts of adults on the two most newly expanded leaves of the cotton terminal (20 terminals per treatment) and D-vac suction samples taken from the midsection of the canopy (100 per treatment). This sampling was conducted in one of the eight test fields near Brawley and in the field near Blythe.

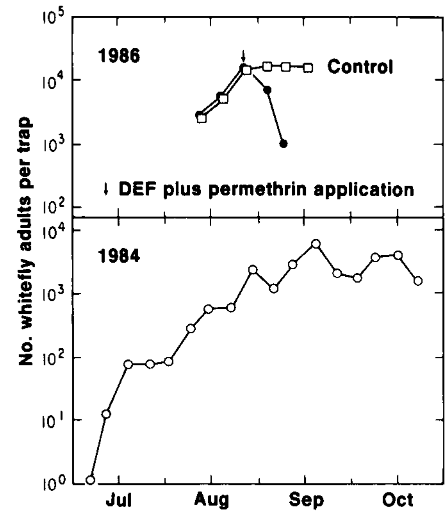

Fig. 1. Top: one application of DEF plus permethrin (arrow) sharply reduced SPWF numbers in cotton compared with control fields treated only with DEF. Bottom: typical adult SPWF population trend in Imperial Valley.

TABLE 2. Mean number of sweetpotato whitefly adults (both sexes from the two most newly expanded leaves on the cotton terminal (20 terminals per treatment)

Site, date, treatment*	Rate	Pre-treatment counts	Post-treatment counts	Percent mortality†
	lb AI/acre			
Brawley, 9/5/86:				
DEF +	1.87			
cypermethrin	0.08	2,495	143	94.3 a
DEF +	1.87			
permethrin	0.15	2,515	557	77.8 b
DEF	1.87	3,444	783	77.3 b
Blythe, 9/30/86:				
DEF +	2.25			
cypermethrin	0.1	2,127	16	99.2 a
DEF +	2.25			
permethrin	0.2	1,439	76	94.7 b
DEF	2.25	2,544	481	81.1 c
Sodium chlorate +	4.0			
cypermethrin	0.1	2,412	1,100	54.4 d

* Trade names and formulations for DEF, cypermethrin, permethrin, and sodium chlorate are DEF 6EC, Ammo 2.5 EC, Pounce 3.2EC, and Leafex 3EC, respectively.

† Treatments followed by the same letter are not statistically different at the 1% level of significance (chi-square test of two-way frequency tables.)

TABLE 3. Mean number of sweetpotato whitefly adults from 100 D-vac samples per treatment in cotton near Blythe, September 1986

Materials	Rate	Pretreatment counts	Posttreatment counts	Percent Mortality†
	lb AI/acre			
DEF +	2.25			
cypermethrin	0.1	11,937	1,045	91.2 a
DEF +	2.25			
permethrin	0.2	11,425	3,002	73.7 b
DEF	2.25	13,748	5,892	57.1 c
Sodium chlorate +	4.0			
cypermethrin	0.1	19,753	15,725	20.4 d

† See footnote (†), table 2.

Treatments consisted of DEF alone and DEF plus the pyrethroids cypermethrin or permethrin. An application of sodium chlorate (a defoliant) plus cypermethrin also was included in the test field near Blythe. All materials were applied by air at recommended field rates. Because these trials were conducted in commercial fields, it was necessary to apply DEF (as well as sodium chlorate) at rates that would cause the required degree of defoliation to prepare the crop for harvest. It was not possible to include an untreated check along with the other treatments.

Despite numerous insecticide applications from July through September, high densities of sweetpotato whitefly developed on cotton in the Imperial Valley. For purposes of comparison, figure 1 (bottom) presents a typical population trend of SPWF adults monitored on sticky yellow traps during 1984 in the Imperial Valley; densities increased from the middle of June to the beginning of September. Figure 1 (top) also shows the effects of a single application (arrow) of DEF plus permethrin on cotton near Brawley in 1986. Although SPWF densities remained high in the control field, adult counts declined sharply from about 15,000 to fewer than 1,000 adults per trap by the second week after treatment.

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with nut clusters. Among these 14, OBLR larvae had webbed together several nuts in the cluster and then fed on the stem and hull tissue. Stems were consumed at the point of nut attachment to the extent that larvae entered the mature pistachio shell cavity and fed on the nut meats. Additional random counts of nuts in July and August 1984 showed 19 of 1,053 clusters (1.8 percent) infested to some degree. Most nuts in infested clusters were not extensively damaged, however, leading to an estimate that less than 0.1 percent of all nuts sampled were lost.

Conclusions

At present, it is unclear what the potential of obliquebanded leafroller may be as a pest on pistachios. Earlier work has indicated that this leafroller is not common in the arid southwestern states, but the area in Madera County known to be infested is generally hot and dry during most of the year, with an annual rainfall of 10.7 inches and maximum temperatures routinely over 100°F from June through September. Cultural practices in the infested Madera orchards, primarily low-angle sprinkler irrigation and permanent clover ground cover, which would tend to cool the orchard, may have contributed to the development of obliquebanded leafroller in this location. Economic populations of OBLR are reported relatively slow to develop on filberts in Oregon. Thus, a decision on the potential of OBLR as a pest on pistachios should be deferred until additional observations can be made.

Examination of OBLR nests in pistachios during this study revealed the presence of two parasitic wasps. These parasites were identified as *Macrocentrus iridescens* French (Hymenoptera: Braconidae) and *Pteromalus* (*Habrocytus*) sp. (Hymenoptera: Pteromalidae). The effect of these and perhaps other parasites and predators, such as *Brochymena sulcata* and *Phytocoris* spp., on OBLR is undetermined.

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associated sediments. Many algae and bacteria can accumulate many times their dry weight in selenium, and the resulting concentration in their cells may be over a hundred times greater than background water levels.

Biomagnification, the uptake of selenium by way of the diet and food chain, has been questioned by some researchers, at least as far as selenium is concerned. In biomagnification, the chemical is accumulated at lower levels of the food chain and is passed up the chain as higher organisms feed on the lower forms. Due to the constant need for nourishment and the inefficiency of the energy transfer from one level to the next higher level, an organism consumes more food than its own mass. This leads to a greater concentration of the toxicant with each subsequent step in the food chain. Conflicting evidence complicates the picture; some links in the food chain result in higher concentrations in the consumer while others do not. In general, field observations, especially in small ecosystems, support the concept of biomagnification, but it has yet to be substantiated by laboratory experiments.

Seeking solutions

Numerous possibilities for dealing with excess selenium are under investigation, including oceanic or estuarine disposal. An important consideration in any proposal involving transport of selenium from one system to another, however, is whether such a solution would merely spread the problem. Obtaining more concrete knowledge of the selenium cycle is one key to planning the best time, place, and method for removal of excess selenium from a system. Unless it can be shown that selenium is not as harmful as we suspect, dealing with excess selenium will become vital for maintaining the quality of aquatic environments in the Central Valley.

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More significantly, samples of cotton terminals collected 24 hours after treatment revealed high adult mortality levels associated with combinations of DEF plus pyrethroids in Blythe, and with DEF plus cypermethrin in Brawley (table 2). Overall, DEF plus cypermethrin was the most effective treatment, in which 99.2 percent mortality was recorded in Blythe. Although 94.7 percent mortality was recorded in the DEF-plus-permethrin treatment in Blythe, a distinctly lower mortality level of 77.8 percent was recorded in this same treatment in Brawley. This discrepancy between the two locations for this treatment may be the result of the lower rates used in the Brawley trial. In addition, DEF alone caused relatively high adult mortalities of 77.3 and 81.1 percent in both locations.

The treatment associated with the lowest adult mortality overall was sodium chlorate plus cypermethrin. This was not surprising, since sodium chlorate is not known to have insecticidal or synergistic properties at the dosage used.

In general, the results obtained with the D-vac sampling method were in good agreement with those of the cotton terminal method (table 3). There were significant ($P = 0.01$) differences among all four treatments, with the highest mortality of 91.2 percent occurring in the DEF-plus-cypermethrin treatment.

Conclusion

High toxicity of DEF in combination with cypermethrin or permethrin was demonstrated in both laboratory and field trials. In the field trials, a single application of DEF plus cypermethrin also resulted in superior control of sweetpotato whitefly adults on cotton before harvest. After further evaluation, the use of DEF with pyrethroids, along with other cultural control methods, may prove useful in reducing the threat of SPWF populations to fall plantings of cucurbit and lettuce crops.

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