Use of "Soft" Pesticides in a Pest Management Program for Tomatoes and Peppers

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What Is a "Soft" Pesticide?

The use of "soft" in reference to pesticides is meant to imply selectivity: death to pests while leaving unscathed all beneficial insects, mites, and other non-targets including people. A better term might be "reduced risk" or "smart" in analogy to "smart" weaponry intended to limit collateral damage. The term "soft" might also imply that the price for selectivity may be reduced efficacy compared to the older "hard" or broad-spectrum pesticides that kill everything. Another assumption sometimes made is that being "soft" on humans necessarily means soft on beneficials. Not surprisingly, there are exceptions to all these generalizations.

The history of modern insecticides begins with the first use of DDT during the WW2 years, followed quickly by additional chlorinated hydrocarbons (dieldron, toxaphene, chlordane), organophosphates (parathion, malathion), carbamates (carbaryl, methomyl) and eventually pyrethroids. These constitute the principal groups of broad-spectrum insecticides compared to which all pesticides are selective = "soft". These latter include the insect growth regulators (IGRs): juvenile hormone mimics such as pyriproxyfen (Knack®), chitinase inhibitors such as buprofezin and diflubenzuron (Courier, Dimilin) and ecdysone agonists like tebufenozide and methoxyfenozide (Confirm and Intrepid). There are also the neonicotinoids such as imidacloprid, thiamethoxam and acetamiprid (Admire, Platinum) that are most selective when taken up by the roots thereby avoiding contact exposure of insects on the foliage. There remains a large group of insecticides that defies easy classification and includes bacterial products (B.t. abamectin, spinosad), indoxacarb (Avaunt), pymetrozine (Fulfill), oils and surfactants (soaps and detergents). In addition, there are a number of miticides that all tend to be relatively selective.

Soaps and Oils

True soaps are anionic surfactants consisting of sodium or potassium salts of fatty acids. Commercially available insecticidal soaps are potassium salts of fatty acids, particularly oelic acid that has an 18-carbon chain backbone with one (unsaturated) double bond and was supposedly chosen to optimize the balance between insecticidal activity and phytotoxicity. However, any true soap has the disadvantage of precipitating out in hard water due to the insolubility of its calcium or magnesium salts. Detergents have largely replaced soaps for most cleaning tasks because they precipitate less or not at all in hard water.

Phytotoxicity of both soaps and oils is a function of concentration, plant type, environmental conditions and chemical characteristics of the material. We lab-tested in Immokalee one household liquid detergent widely used on tomato in Florida and composed principally of the anionic surfactants sodium laureth sulfate and sodium dodecyl benzene sulfonate. We found it to be about 4 times more active against whitefly than insecticidal soap. However, it was also more phytotoxic, causing measurable reductions in yield at first pick at rates as low as 0.5% v/v sprayed twice a week, although the effect on yield at this concentration was not significant at once a week intervals **(Fig. 1).**

Horticultural mineral oils (HMOs) are the mainstay of pest management in Florida citrus but are still regarded with suspicion by vegetable growers for fear of phytotoxicity. However, the purity and therefore safety of the best HMOs continues to improve. The optimal oil for killing bugs has 21 carbons in a straight (paraffinic) chain and would boil at about 435°F. However, commercial oils are mixtures of hydrocarbons of different sizes and shapes with different boiling points, so a sort of average or mid-boiling point is used, the temperature at which half the oil boils off. Lighter oils are less volatile and thus shorter acting, whereas heavier oils hang around longer and so are more phytotoxic. The narrower the temperature range between which 10% to 90% of the oil boils off the better, preferably not more than 70F. Another factor affecting phytotoxicity is unsufonated residues (UR), that inert fraction of the oil that will not react with concentrated sulfuric acid. The reactive fraction of unsaturated and aromatic hydrocarbons can cause plant injury and should not constitute more than 8% (UR > 92%). Medicinal paraffinic oil has greater than 99% UR.

Sunspray Ultrafine ® (mid boiling point 415 °F, BP range 65 °F, UR > 92%, 1.2% emulsifier) has always been considered a safe oil for vegetables. We found it could be sprayed twice a week on pepper with or without copper and Manzate® at up to 2% v/v without damage or loss of yield, although we saw problems at 4% **(Fig. 2).**

Advantages and Selectivity of "Soft" Pesticides

Under advantages of selective insecticides we could include conservation of natural enemies and consequently reduced pesticide use resulting in lower production costs and less rapid selection for insecticide resistance. Another advantage for many "soft" pesticides would be reduced preharvest intervals (PHIs) and re-entry intervals (REIs). Most are not restricted use, reducing paperwork and aggravation. Some, such as soaps, oils and Bt, are relatively inexpensive. On the negative side, selective pesticides may not control all pests present, may be slower acting and may be more expensive that older chemistries.

How selective are the "soft" insecticides? Not surprisingly, this depends on the non-target being considered. EPA regulations require evaluation of pesticide toxicity against a number of non-target organisms including mammals, birds, fish, freshwater crustacia and honeybees. The toxic effects of ingestion are expressed in terms of the LD-50, the amount of material per unit weight of the test organism (milligrams/kilogram) lethal to 50% of the test population. It is understandably difficult to find human volunteers for such testing, so rats are used instead. As a point of reference, the LD-50 for common table salt, NaCl, is considered to be about 3000 mg/kg, or about ½ lb for a 150 lb person. Many active ingredients such as tebufenozide, pyriproxyfen, cyromazine, pymetrozine and of course the Bts have higher LD-50s and are thus less toxic than salt **(Table 1).** Most broad-spectrum insecticides are considerably more toxic to rats, humans.

Toxicity of pesticides to insects and mites is usually expressed in a similar but distinct unit, the LC-50 (LC-90) or lethal *concentration* necessary to kill 50% (90%) of the population. This is because we usually know what the insect was exposed to but not how much it actually ingested. LC-50s usually vary with the age of the insect and the means by which it was exposed, so it is not always evident from laboratory results the impact of a field application.

One convenient guide to non-target effects on biological control agents is the Koppert "Side Effects Guide" (www.koppert.com) that summarizes published and unpublished laboratory results and field experience with augmentative biological control. While by no means complete, the Guide lists effects of most insecticides, acaricides and fungicides on 22 beneficial arthropods sold by the company for biological control. Three numbers are given for many of these arthropod/pesticide combinations: ratings of effects on mature stages, on immature stages, and weeks of residual effect. Summing these three numbers gives an overall rating given for some pesticides used in Florida tomatoes on the predaceous lacewing *Crysoperla carnea* and the whitefly parasitic wasp *Encarsia formosa* in **Table 1**. We can see that soap is actually less compatible with these beneficial insects than some other pesticides such as pymetrozine (Fulfill®), although much more so than the broad-spectrum insecticides bifenthrin or methomyl.

Effectiveness of Surfactants and Oils for Whitefly Control

Surfactants (including true soaps and detergents) and oils are among the least expensive of insecticides, so can be applied frequently at relatively low cost. It is widely believed that surfactants act by dissolving cell membranes, but there is evidence that they kill by reducing surface tension and allowing water to invade the tracheae, drowning the insect. Oils probably act by sealing the integument, including the spiracles, preventing gas exchange and causing asphyxiation. While many types of surfactants might be used to control insects, petroleum oils appropriate for application to vegetables are restricted to a narrow set of specifications as explained above.

When applied to whitefly nymphs as a leaf dip in the laboratory at field rates or below, the efficacy of soaps or oils is comparable to a pyrethroid **(Fig. 3)**. However, the effectiveness of soaps and especially oils drops off rapidly with decreasing coverage **(Fig. 4)**. In Immokalee, we obtained better coverage and thus better control in the field using a low volume, air assisted sprayer compared to a hydraulic sprayer **(Fig. 5)**. In another trial on eggplant, control of whitefly using air-assisted, motorized back-pack sprayers was better with oil than with endosulfan **(Fig. 6)**.

Last season in Immokalee we began testing a new oil product from Petro-Canada, BioCover LS, a 435°F oil with very high (99%) unsulfonated residue in a 98% emulsifiable concentrate. The plan was to see if an extra measure of pest protection could be provided by adding the oil to the weekly spray of whatever. We intentionally tested a sufficient rate (2%) to cause phytoxicity when applied to 2-week-old seedlings in September that also increased incidence of bacterial spot, although we also saw good whitefly control **(Fig. 6)**. At the 0.5% rate we still had whitefly control without the plant injury and no measurable decrease in yield **(Figs. 7, 8)**.

We repeated the experiment in a late spring trial planted March 31 with rates from 0.25% to 1% sprayed weekly on plants treated with 16 oz of Admire. These were compared to Admire alone and 2 oil treatments at 1% without Admire, BioCover and Sunspray Ultrafine. Whitefly and virus pressure was intense, and by mid May all plants were showing symptoms of TYLCV. However, symptoms were delayed in plants sprayed with BioCover though less so with Ultrafine **(Fig. 9)**. Differences in yield were not significant except between the best and worst treatments **(Fig. 10)**.

We also tested rates up to 2% in Jalapeño pepper without Admire, applied as a tankmix with Actara ® (two applications) or Vydate ® in rotation. We saw significant suppression of whitefly adults **(Fig. 11)** and nymphs **(Fig. 12)** with the BioCover tankmix that increased with rate, though less with Ultrafine. There was no evidence of phytotoxicity at even the highest rate. The big surprise was evidence of enhanced pepper weevil control with the addition of oil. Less fruit infestation was seen on plants sprayed with tank mixes of Actara or Vydate with oil compared to Actara or Vydate alone, and most marketable fruit harvested from plants receiving the 0.5% rate of BioCover **(Fig.13)**.

In a trial conducted on tomato in Spring 2002 in Bradenton, the whitefly population was low early in the season but increased to a moderate level by about 9 weeks after transplanting. The standard in this trial was Admire 2F (16 oz; a registered nicotinoid insecticide) applied as a soil drench one day after transplanting followed by foliar sprays of Courier 70W (0.5 lb; a registered insect growth regulator) and then Knack 0.86EC (8.9 oz; a different registered insect growth regulator) when a threshold of 5 nymphs/10 leaflets was reached (one application each). Experimental insecticides Diamond 0.86EC (8 oz; a new insect growth regulator) and Oberon 240SC (8.5 oz; new insecticidal chemical class) were each applied twice foliarly based upon the above threshold following a soil application of Admire 2F @ 16 oz **(Table 2)**. Fewer whiteflies were seen on plants sprayed with either the Courier/Knack rotation, Diamond or Oberon compared to unsprayed plants, and were below the threshold about 10 days after the first application (Table 3). Plants sprayed eight times weekly with Endosulfan 3EC (21.4 oz; a registered organochlorine insecticide) or a combination of Ecozin 3%EC (8 oz; a registered neem product), Ultrafine Oil (0.5% v/v; a registered paraffinic oil), and Endosulfan 3EC (21.4 oz) had fewer nymphs than the check 9 weeks after transplanting and thereafter, although the numbers generally were not below the threshold. Counts of nymphs on plots sprayed with a Ecozin/Ultrafine Oil combination, PF-2000 (1% v/v; a detergent) or PREV-AM (0.8% v/v; an orange oil-based product) were statistically lower than those of non-treated plots on at least some dates, 8 weeks after transplanting, although counts were not below the threshold. Counts tended to be lower on PREV-AM treated plots, especially 11 and 12 weeks after transplanting.

In conclusion, we have seen that pesticides considered as "soft" actually vary greatly in selectivity to different groups of pest and beneficial insects and mites. Surfactants (primarily soaps and detergents) and high quality horticultural oils are effective against whitefly and other pests, although their efficacy depends greatly on coverage. However, they are inexpensive and so can be sprayed frequently. However, phytotoxicity could be a problem with frequent applications at rates of 1% or above, especially when temperatures are high (oil). Weekly applications at 0.5% have not caused significant phytotoxicity and have provided significant whitefly control, delayed onset of TYLCV in tomato, and reduced damage from pepper weevil in Jalapeño pepper.

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Table 1. LD-50 for rats and toxicity rating (0 to 16) of pesticides used in Florida tomato production to the lacewing *Crysopa carnea* and parasitic wasp *Encarsia formosa* (www.koppert.com).

Broad-Spectrum	LD-50 (mg/kg)	Crysopa	Encarsia
Capture (bifenthrin)	54	16	16
Lannate (methomyl)	17	16	14
IGRs			
Confirm (tebufenozide)	5,000	0	*
Courier (buprofezin)	2,198	*	1.5
Knack (pyriproxyfen)	3,773	0	4
Neem (azadirachtin)	5,000	1	2
Trigard (cyromazine)	3,387	6	0
Neonicotinoids			
Actara, Provado, Assail	1563,424,126	10	8
Platinum, Admire	1563,424	0	0
Miscellaneous			
B.t.	5,000	0	0
Oil (BioCover)	15,000	0	0
Soap (M-Pede)	16,900	6	4
Acramite (bifenazate)	5,000	0	0
Agri-Mek (abamectin)	10	3	6
Fulfill (pymetrozine)	5,820	0	0
SpinTor (spinosad)	3,783	5	*
Salt (NaCl)	3,000	*	*

*information not available

Table 2. Application schedule for insecticides applied to control the silverleaf whitefly on tomato, Fall 2003, GCREC-Bradenton.

Treatment/ formulation*	Rate Amount/ acre	Soil application 11 Sep	Date of application: 60 gpa 8 Oct	60 gpa 14 Oct	90 gpa 21 Oct	90 gpa 29 Oct	90 gpa 6 Nov	120 gpa 12 Nov	120 gpa 20 Nov	120 gpa 3 Dec
Admire 2F	16.0 oz	X								
then Courier 70W	0.5 lb								X	
then Knack 0.86EC	8.9 oz									X
Admire 2F	16.0 oz	X								
then Diamond 0.86EC	8.0 oz								X	X
Admire 2F	16.0 oz	X								
then Oberon 240SC	8.5 oz								X	X
Ecozin 3% EC	8.0 oz									
+ Ultrafine Oil	0.5% v/v		X	X	X	X	X	X	X	X
Ecozin 3% EC	8.0 oz									
+ Ultrafine Oil	0.5% v/v									
+ Endosulfan 3EC	21.4 oz		X	X	X	X	X	X	X	X
Endosulfan 3EC	21.4 oz		X	X	X	X	X	X	X	X
PF-2000	1.0% v/v		X	X	X	X	X	X	X	X
PREV-AM	0.8% v/v		X	X	X	X	X	X	X	X
Check	----									

* A "+" indicates that the products were combined.

Table 3. Control of the silverleaf whitely on tomato following soil and foliar applications of insecticides, Fall 2003, GCREC-Bradentor

Treatment/ formulation*	Amount/ acre	No. silverleaf whitefly nymphs/10 leaflets									
		13 Oct	20 Oct	27 Oct	3 Nov	11 Nov	17 Nov	24 Nov	1 Dec	8 Dec	Avg
Admire 2F then Courier 70W then Knack 0.86EC	16.0 oz 0.5 lb		2	<1	1	3	5	4	3	1	2
Admire 2F then Diamond 0.86EC	16.0 oz 8.0 oz	0	<1	<1	<1	1	6	6	4	4	2
Admire 2F then Oberon 240SC	16.0 oz 8.5 oz	0	2	2	<1	8	9	8	2	3	4
Ecozin 3% EC + Ultrafine Oil	8.0 oz 0.5% v/v	3	4	1	4	6	20	13	13	20	9
Ecozin 3% EC + Ultrafine Oil + Endosulfan 3EC	8.0 oz 0.5% v/v 21.4 oz	3	3	2	<1	3	7	7	6	12	5
Endosulfan 3EC	21.4 oz	2	1	1	1	4	5	9	3	11	4
PF-2000	1.0% v/v	8	5	2	9	11	23	16	14	14	10
PREV-AM	0.8% v/v	3	4	1	<1	5	28	13	6	9	7
Check	----	1	6	5	4	8	40	19	31	33	15
LSD $P = 0.05$	----	5	5	3	4	6	14	8	9	14	4

*A "+" indicates that products were combined.

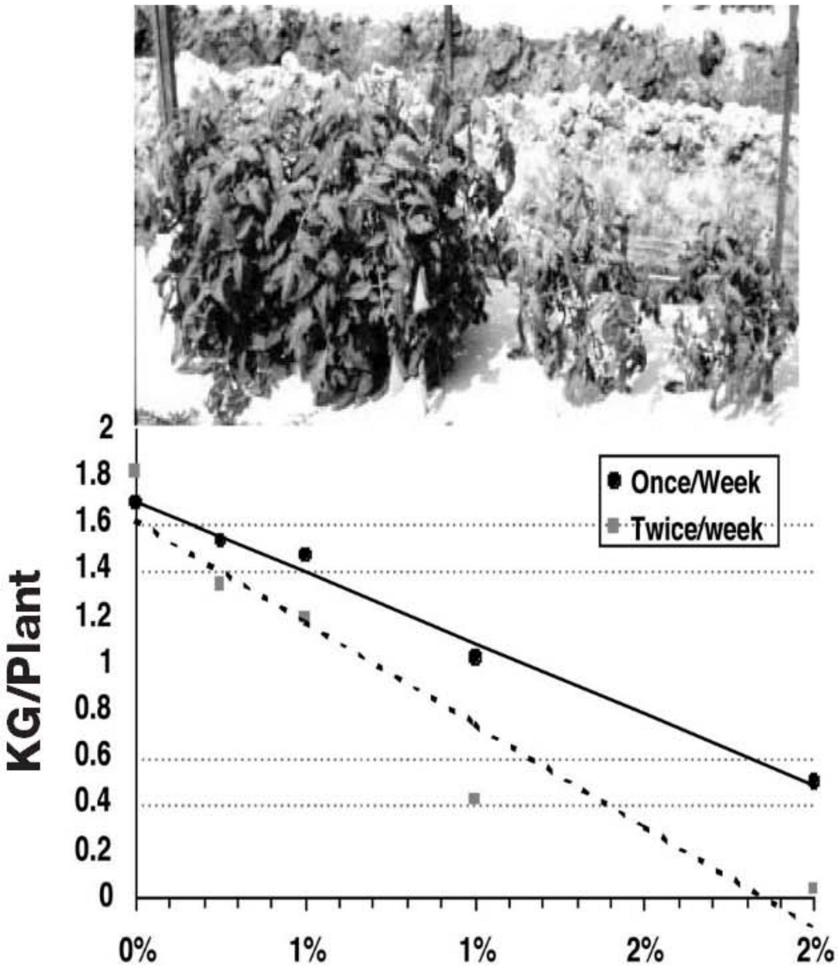


Fig.1. Effect of detergent sprays on tomato. A. Plants sprayed with water (left) or 2% v/v New Day Dish Detergent (right). B. Regression of yield at first harvest against rate of New Day.

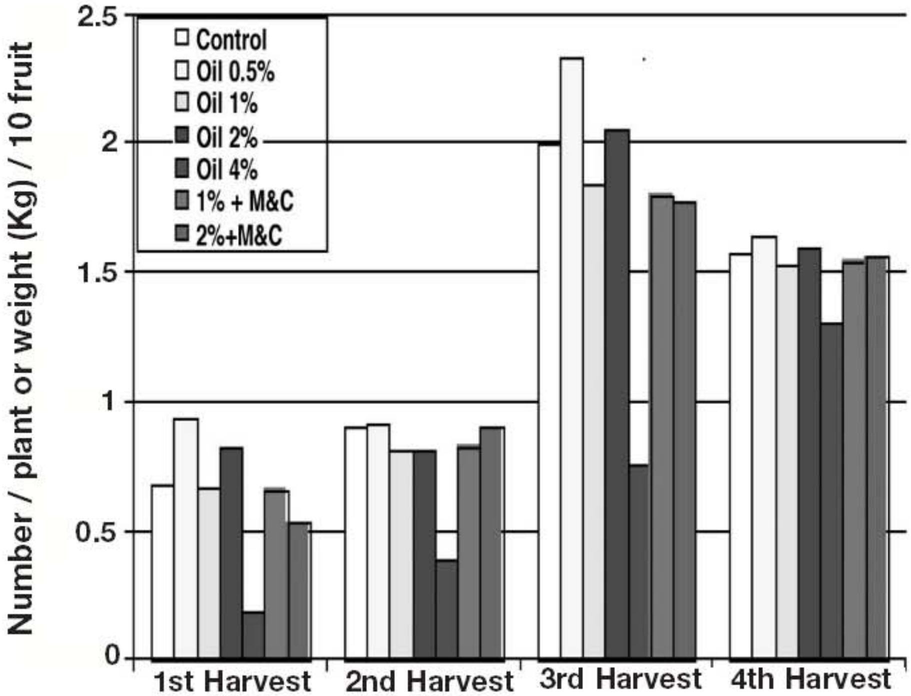


Fig. 2. Effect of Sunspray UltraFine Spray Oil alone or with Manzate and copper on yield of Bell pepper, (Vavrina, 1994)

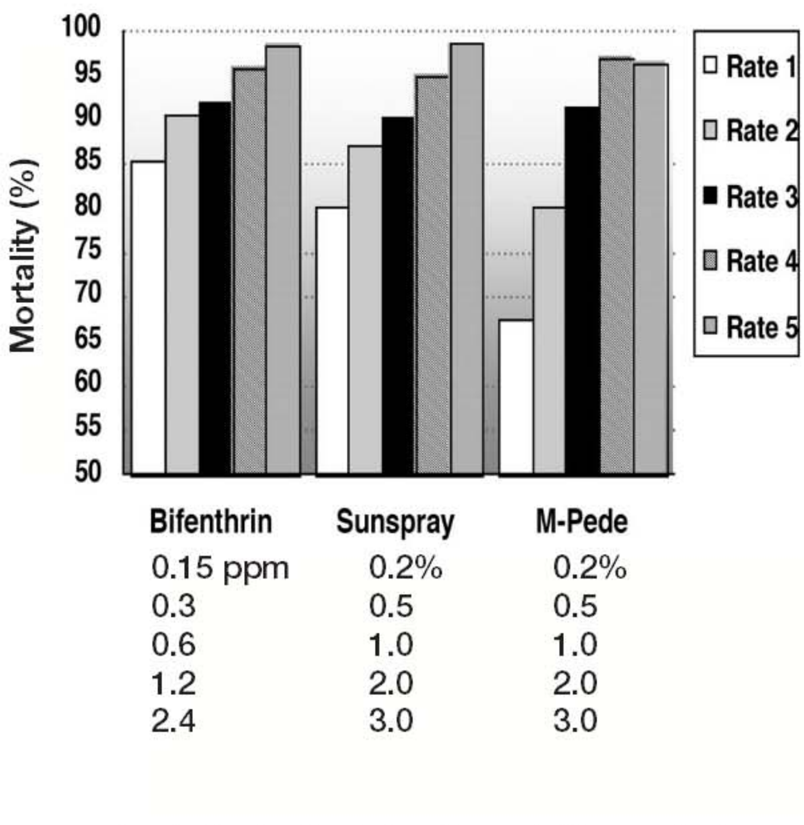


Fig. 3. Contact toxicity of insecticides applied as a leaf dip to young nymphs of *B. tabaci*

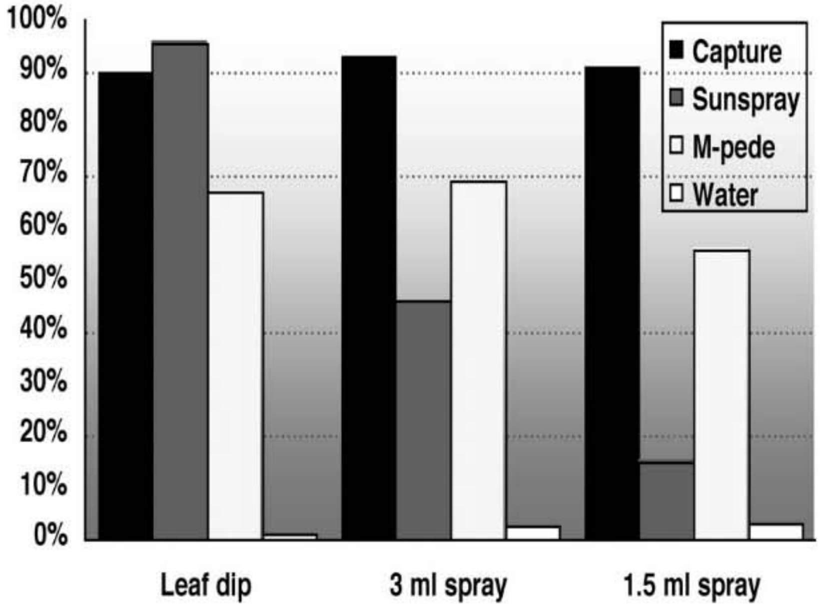
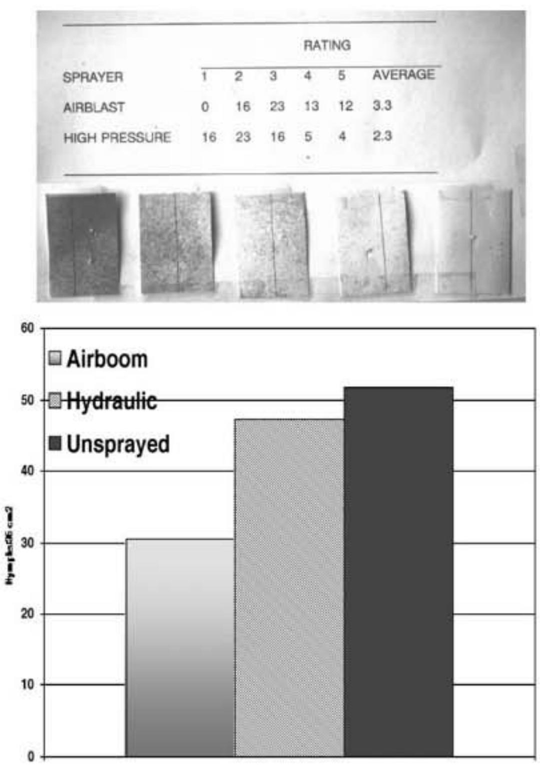


Fig. 4. Mortality to 1st Instar SLWF nymphs from pesticides applied by leaf-dip and Potter Tower spray in 3 ml or 1.5 ml volume, Capture @ 32 oz./100 gal, Sunspray and M-Pede @ 0.5%



	RATING					
SPRAYER	1	2	3	4	5	AVERAGE
AIRBLAST	0	16	23	13	12	3.3
HIGH PRESSURE	16	23	16	5	4	2.3

Fig. 5. Effect of sprayer type on coverage of water sensitive paper pinned to tomato leaf underside and whitefly control

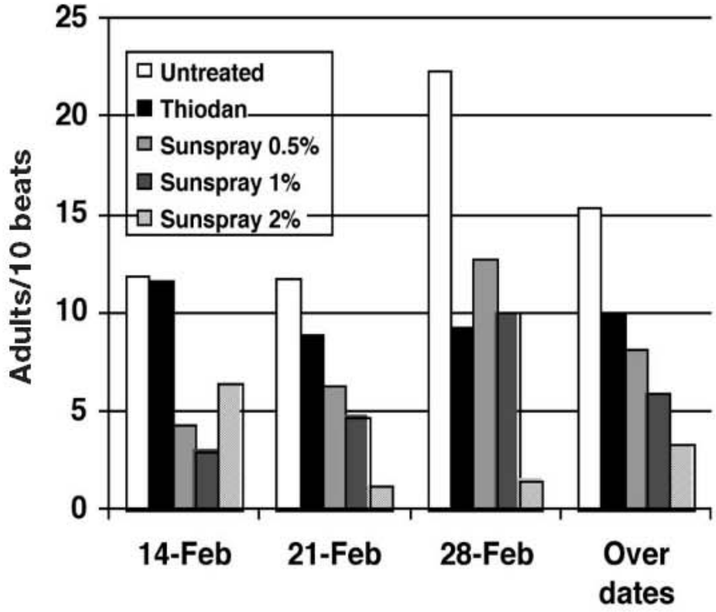


Fig. 6. Control of SLWF on commercial eggplant, Sinaloa, Mexico, 1997. Applications made with motorized air assisted backpack sprayers.

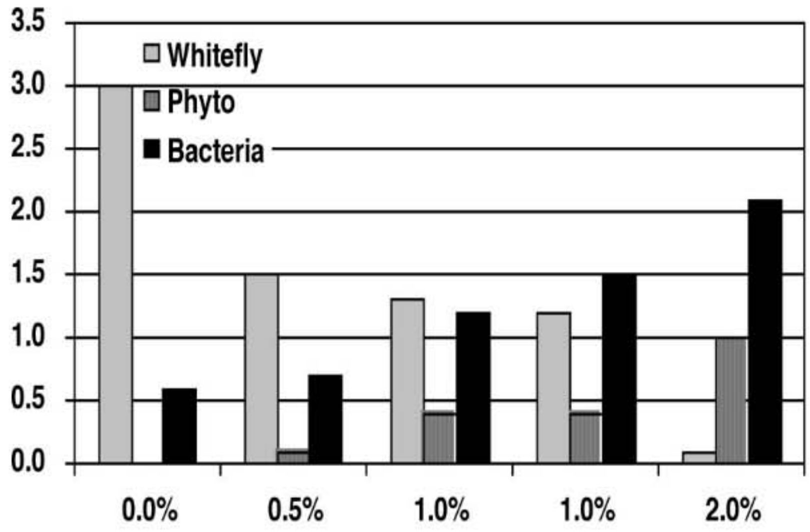


Fig. 7. Effect of BioCover oil concentration applied weekly alone or in combinationwith standard pesticides on incidence of SLWF, phytotoxicity rating and bacterial spot, Fall 2003. All treatments included Admire except for 2nd 1% oil.

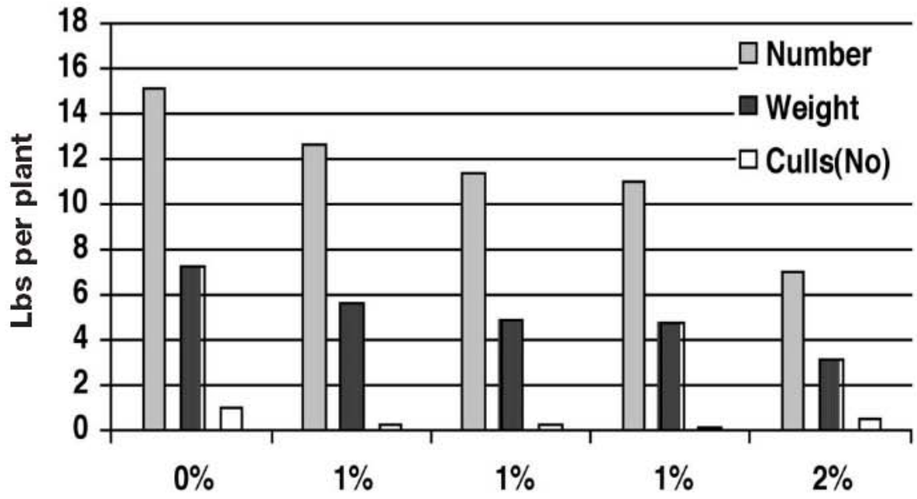


Fig. 8. Effect of concentration of BioCover Oil applied weekly alone or in combination with other pesticides on tomato yield, fall 2000.

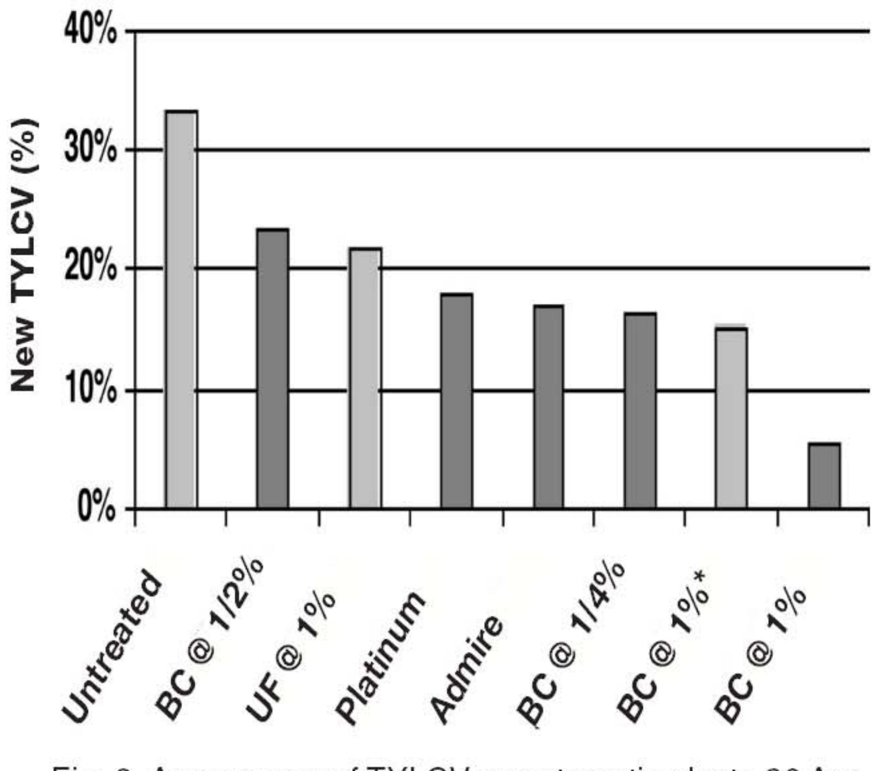


Fig. 9. Appearance of TYLCV symptomatic plants 26 Apr - 5 May, 5 weeks after transplanting. Solid bars indicate plants were drenched with neonicotinoid 1 day after planting. Plants sprayed weekly with BioCover or Sunspray Ultrafine as indicated.

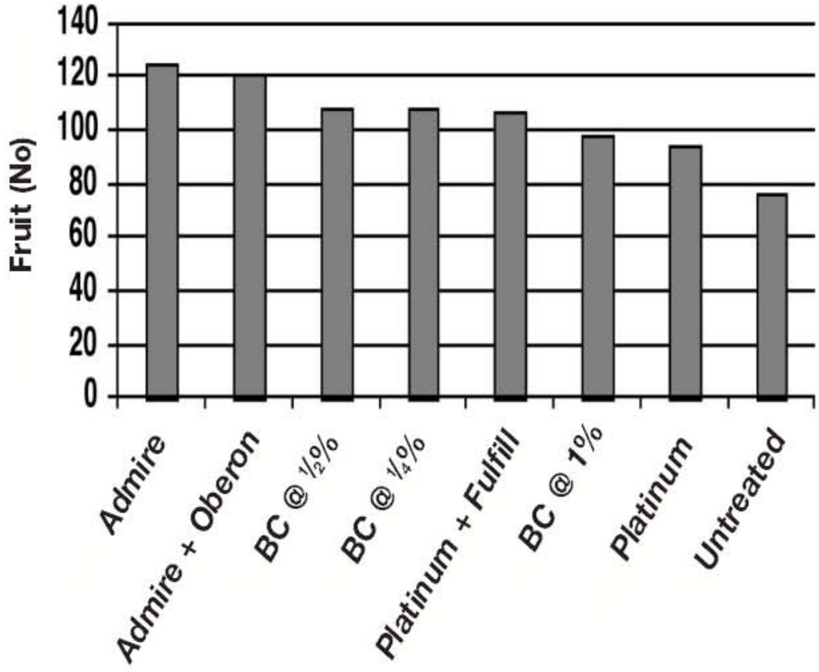


Fig. 10. Yield (fruit number per 20 tomato plants), spring 2004. All plants but control drenched with neonicotinoid 1 day after planting. Plants sprayed weekly with BioCover or Sunspray Ultrafine as indicated.

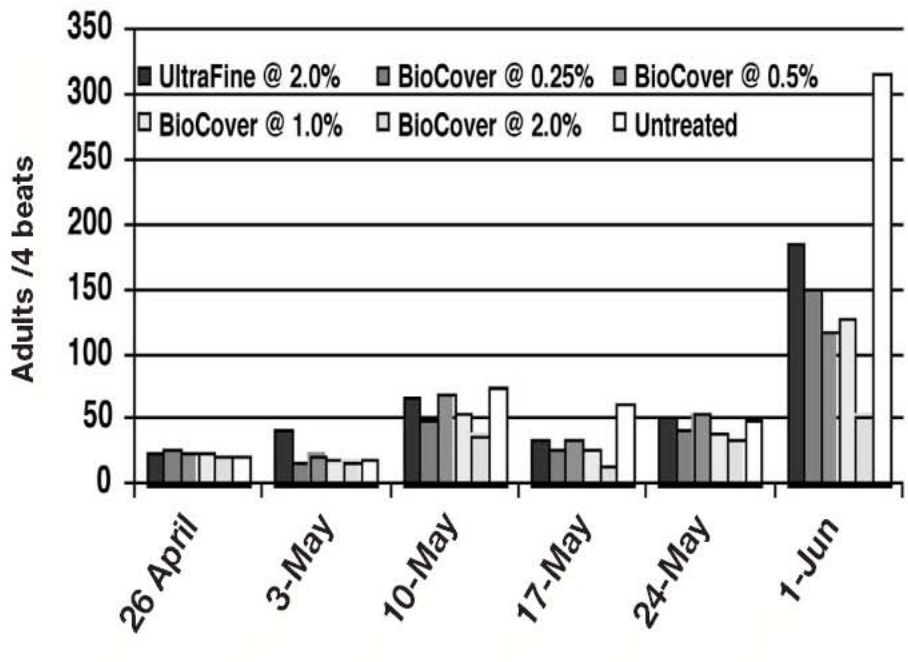


Fig. 11. Effect of weekly sprays of BioCover or UltraFine Oil tankmixed with a standard rotation of Actara (2 sprays) and Vydate (4 sprays) on adult SLWF. Jalapeño Pepper - spring 2004.

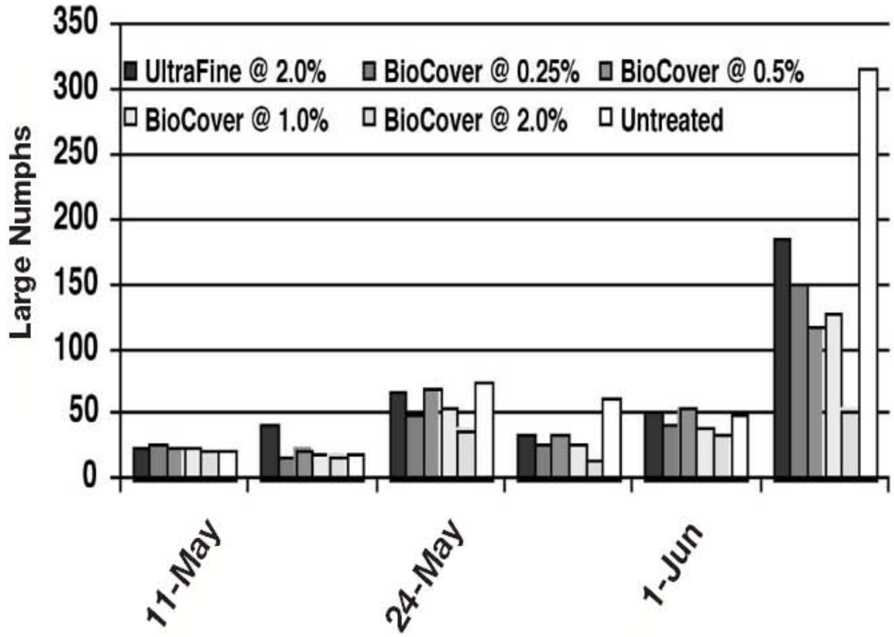


Fig. 12. Effect of weekly sprays of BioCover or UltraFine Oil on large nymph SLWF, Jalapeño Pepper - spring 2004.

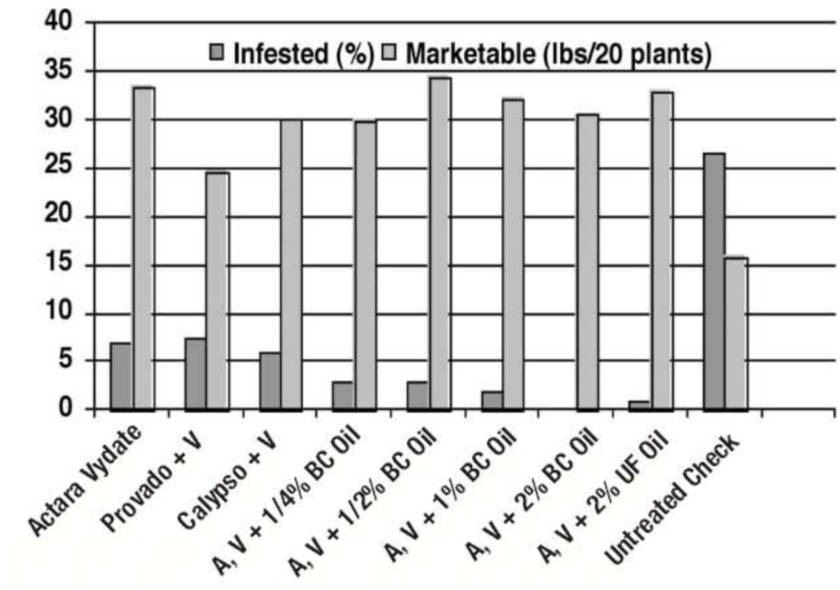


Fig. 13. Effect of weekly sprays of BioCover or UltraFine Oil on weevil infestation and yield in Jalapeño Pepper - spring 2004.