Insecticidal activity of surfactants and oils against silverleaf whitefly (*Bemisia argentifolii*) nymphs (Homoptera: Aleyrodidae) on collards and tomato

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Abstract: The insecticidal activities of four surfactants (Cide-kick, Silwet L-77, M-Pede and APSA-80), a dishwashing detergent (New Day), a mineral oil (Sunspray oil), a cotton seed oil and a vegetable oil, alone or in combination, were tested against nymphs of *Bemisia argentifolii* Bellows & Perring on collards and tomato. Silwet L-77 was more effective (>95% mortality) than Cide-Kick or APSA-80 at rates from 0.25–1.00 g AI litre^{-1} but caused severe phytotoxicity to tender tomato leaves at all but the lowest rate. New Day dish detergent at 2.0 ml litre^{-1} caused mortality (95%) comparable to M-Pede insecticide soap at 10-fold greater concentration. A New Day ingredient, cocamide DEA, was considerably more active than the other ingredients or the commercial mixture. Additional surfactants added to Sunspray oil increased efficacy in some treatments, but not others. Toxic responses of 2nd- and 3rd- instar whiteflies to vegetable oil and cotton seed oil at 5.0 and 10.0 ml litre^{-1} plus 0.4 g AI litre^{-1} APSA-80 ranged from 22.1 to 79.9% and 66.3–88.7% mortality, respectively. Whitefly mortality was greater on tomato than on collard in six of seven instances when differences between host plants were significant. Our results indicate that the these surfactants and oils have good potential for controlling *B argentifolii*.

Keywords: silverleaf whitefly; sweetpotato whitefly; mineral oils; vegetable oils; surfactants

1 INTRODUCTION

The silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring, formerly known as 'Biotype B' of the sweet potato whitefly, *B tabaci* (Gennadius) (Hemiptera: Aleyrodidae), is a serious insect pest of many food and fiber crops in the southern USA and elsewhere. Perring *et al*[1] estimated that crop damage caused by the whitefly in the USA. exceeded one-half billion dollars in 1991 alone. In an effort to limit these losses, use of broad-spectrum insecticides reached high levels. For instance, an average 7.6 kg AI ha^{-1} of the two most-used insecticides (endosulfan and chlorpyrifos) was applied to tomato in 1994, mostly to control *B argentifolii* (Stansly PA, unpublished). In response, the whitefly has developed resistance to almost all classes of commercially available insecticides.[2]

Oils and surfactants may provide safe alternatives to chemical insecticides and are less prone to selection for resistance.[3,4] Surfactants have long been used as wetting, spreading, emulsifying and sticking agents to improve the effectiveness and coverage of many pesticides.[5] Many surfactants, however, exhibit insecticidal effects themselves[6–11] and could be used as an alternative to current insecticides.

Oils were among the first chemicals used to control various pests, and their applications on vegetables have increased because newer formulations have lower phytotoxicity than earlier formulations.[6,12] Although oils have been replaced in many of their uses by synthetic organic compounds, they remain a viable alternative due to several advantages over conventional insecticides, including: (1) safety to human and environmental health, (2) apparent lack of resistance mechanisms among insects and mites, presumably due to action by suffocation, (3) reliable efficacy and, (4) relatively low cost.[6,13] In addition, oils as adjuvants mixed with other insecticides reduce evaporation, especially in tropical and sub-tropical areas, and can reduce washing off of insecticides during rainy seasons.[7] Emulsions of cotton seed oil and mineral

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oils provided effective control of *B argentifolii* on cotton in Israel[14] and India[15], and on cotton and vegetables in the US[3,15–21] when good coverage on the lower leaf surface was obtained.[22] Oils with surfactants or other adjuvants as emulsifiers can increase spreading, and have been shown to be effective against whiteflies and other pests.[16]

The objectives of this study were to evaluate the insecticidal effects of some commonly used mineral and botanical oils and some wetting and spreading surfactants against *B argentifolii* nymphs. If these surfactants and oils prove to be effective, they could replace some more toxic agents for whitefly management. Of particular interest was the interaction of oils and surfactants with each other and with waxy versus non-waxy leaf surfaces.

2 MATERIALS AND METHODS

2.1 Whitefly culture and host plants

Bemisia argentifolii were cultured in an air-conditioned greenhouse on potted tomato (*Lycopersicum esculentum* Miller, cv 'Lanai'), collard (*Brassica oleracea* L var *acephala*, cv 'Georgia LS'), salvia (*Salvia spelendis* L), eggplant (*Solanum melongena* L, cv 'Black Beauty'), hibiscus (*Hibiscus rosa-sinensis* L), and sweet potato (*Ipomoea batatas* L) plants (one per 15-cm pot) using Metro-Mix 300 growing medium (Grace Sierra, Hort Products Co, Milpitas, CA). Plants were watered and fertilized with 4 g litre^{-1} of Stern's Miracle-Gro with a 14-30-15 N-P-K solution (Port Washington, NY) as needed.

Tomato (three nodes, 7–9 leaves, 45–50 cm high) and collards (6–7 leaves, 35–40 cm high) were used as host plants for the whiteflies in the tests. Before whitefly infestation, all except the top 3–4 fully expanded leaves for both tomato and collard plants were removed. *B argentifolii* eggs were collected from a greenhouse culture by exposing plants for a 24-h oviposition period. Plants bearing whitefly eggs were removed from the greenhouse, and disinfested of whitefly adults using a vacuum (BioQuip, Gardena, CA). The plants were confined in $60 \times 60 \times 60$ cm large screen cages, and whitefly eggs were allowed to develop for 8–9 days for 2nd-instars, and 10–11 days for 3rd-instars. All tests were conducted in an air-conditioned insectary in a laboratory where the temperature was set at 25 ($\pm$2) °C, 60 ($\pm$5)% RH, and a photoperiod of 14:10 h L:D.

2.2 Surfactants

Eight surfactants were evaluated: Silwet L-77 (100% silicone-polyester copolymer, Loveland Industries, Inc, Greeley, CO); Cide-Kick (100% D-limonene and selected emulsifiers, JLB International Chem, Vero Beach, FL); APSA-80 (80% alkyl aryl alkoxylate, free fatty acids, 20% inert ingredient, Amway Co, Ada, MI); M-Pede (49% potassium salt of a naturally derived fatty acid, Mycogen Corp, San Diego, CA); and New Day detergent (Peck Products Co, St Louis, MO) containing 27% active ingredients (dodecylbenzene sulfonic acid, cocamide DEA, and sodium laurylether sulfate) which were also tested individually.

2.3 Oils

A mineral oil, Sunspray Ultra-Fine Spray Oil (68 s viscosity, 212 °C [414 °F] 50% distillation point, 94.0% unsulfonated residue, Safer Incorporated, Newton, MA), and two botanical oils, a cotton seed oil and a vegetable oil provided by Garden Alive (Lawrenceburg, IN), were used, and water as a control.

2.4 Bioassays

Three bioassays were performed, surfactants only, surfactants and Sunspray oil, and cotton seed oil and vegetable oil plus surfactants.

2.4.1 Surfactants alone

Cide-Kick, APSA-80, and Silwet L-77 were evaluated at 1.00, 0.50, and 0.25 g AI litre^{-1} with de-ionized water as a control. Detached tomato leaves (trifoliage) bearing whitefly nymphs (46–78 per leaflet) were dipped in each dilution for 5 s, and air-dried for 1 h. Treated leaves were placed petiole down in water-filled 20-ml vials and incubated in the insectary for 5–7 days. Dead and live nymphs were recorded 6 days later. Nymphs were considered dead if they were shriveled, discolored or dried. Each treatment had 10 replications (leaves).

In a separate bioassay, New Day, and its three major active ingredients, dodecylbenzene sulfonic acid, cocamide DEA, and sodium laurylether sulfate, all at 27% active ingredient and M-Pede (49% active ingredient) were evaluated at 2.5, 5.0 and 10.0 ml litre^{-1} each. Tomato leaves bearing 1st- and 2nd-instars were dipped in appropriate solutions for 5 s, and air-dried for 1 h. The leaves were kept in a 20-ml glass vial with petiole down for 3–5 days in the insectary. Mortality was recorded under a dissection microscope. Each treatment had eight replicates (leaves).

2.4.2 Sunspray oil and surfactants

Seven treatments were evaluated including three surfactants and Sunspray oil alone, and each surfactant mixed with Sunspray oil. These treatments are: (1) APSA-80 (0.4 g AI litre^{-1}), (2) Silwet L-77 (0.10 g AI litre^{-1}), (3) M-Pede (0.4 ml litre^{-1}), (4) Sunspray oil (5.0 ml litre^{-1}) + APSA-80 (0.4 g AI litre^{-1}), (5) Sunspray oil (5.0 ml litre^{-1}) + Silwet L-77 (0.1 g AI litre^{-1}), (6) Sunspray oil (5.0 ml litre^{-1}) + M-Pede (0.4 ml litre^{-1}), and (7) purified water as control. Detached tomato leaves (trifoliates) and collard leaves bearing an average of 120 whitefly nymphs per leaf (range: 34–254) were removed from the plants and placed abaxial side up in the bottom of a Potter Spray Tower (Burkard Manufacturing Co, Rickmansworth, Hertfordshire, England). The tower was operated at 68.95 kPa and delivered a volume of

Table 1. Percentage mortality of 2nd-instar nymphs of *Bemisia argentifolii* on tomato leaves treated with three surfactants

	Mortality (% ± SE)[a]				
Rate (g AI litre^{-1})	*Cide-Kick*	*Silwet L-77*	*APSA-80*	*F*	*P*
1.00	76.4 (±3.4)aC	99.7 (±0.1)aA	87.7 (±5.5)aB	11.75	0.0004
0.50	57.2 (±5.3)bB	98.8 (±0.1)aA	56.8 (±5.0)bB	36.55	0.0001
0.25	47.4 (±8.1)bB	95.7 (±3.8)aA	33.1 (±8.9)cB	22.29	0.0001
0.00 (control)	3.8 (±1.4)cA	4.7 (±2.3)bA	3.7 (±1.9)dA	0.09	0.9179
F	26.3	41.3	88.5		
P	0.0001	0.0001	0.0001		

[a] Mean percentage mortalities in the same column followed by the same lower case letters, and in the same row followed by the same upper letters are not significantly different ($P = 0.05$).

3 ml. Treated and dried leaves were placed petiole down in water-filled 20-ml vials and incubated for 5–7 days. Dead and live nymphs were recorded 6 days later. Each treatment had 16 replications (leaves).

2.4.3 Vegetable and cotton seed oils plus surfactant

The cotton seed oil, vegetable oil and Sunspray oil were used in this test, and 5 ml APSA-80 (0.4 g litre^{-1} rate) was added to each of the oil. De-ionized water was used as a control. The mixture was shaken using a Vortex shaker (Fisher, Philadelphia, PA) for about 1 min. Dilutions of 5.0 and 10.0 ml litre^{-1} were made by adding the correct amount of each mixture drop by drop to a 500-ml beaker filled with de-ionized water while stirring on a magnetic stirring plate. The resulting emulsions were stirred for an additional 2–3 min for a total stirring time of 5–10 min. Detached tomato and collard leaves bearing whitefly nymphs (28–74 nymphs per leaflet) were dipped in the emulsions for 5 s, and air-dried for 1 h. The leaves were individually inserted with petiole down into a 20-ml water-filled glass vial. The vials were fixed on the bottom to plastic trays using double sticky tape. Dead and live nymphs were recorded 6 days later. Each treatment had 16 replications (leaves). Two tests were conducted, second-instar *B argentifolii* were used in the first, and third-instars were used in the second. Mortalities of whitefly nymphs were recorded 5 days after treatment.

All treated plant leaves treated with surfactants or oils were evaluated for phytotoxicity at the time whitefly mortalities were recorded. The degrees of phytotoxicity for all treated leaves were estimated based on the following six categories: 0, no damage; 1, minor (1% leaf area damaged); 2, minor–moderate (2–5% leaf area damaged); 3, moderate (6–10% leaf area damaged); 4, moderate–heavy (11–30% leaf area damaged); and 5, heavy (>30% leaf area damaged).

2.5 Data analysis

Proportional mortalities of whitefly nymphs were transformed to the arc sine square root [arsine (proportion killed)$^{1/2}$] before analysis of variance (ANOVA) to stabilize error variance,[23] although untransformed mean percentage mortalities (±SE) are reported. Means were separated using the least significant difference (LSD) test following a significant *F* test.[24]

3 RESULTS

3.1 Surfactants alone

In the first test, percentage mortalities of whitefly nymphs among the surfactants and rates varied greatly among the surfactants ($F = 64.37$; df = 2, 79; $P = 0.0001$), among the rates ($F = 221.20$; df = 3, 79; $P = 0.0001$), and surfactant × rates ($F = 11.74$; df = 3, 79; $P = 0.0001$) (Table 1). Percentage mortalities of whitefly nymphs did not show a dose response to different concentrations of Silwet L-77, but did with Cide-Kick and APSA-80. At the same rates, Silwet L-77 gave the greatest percentage mortalities. These results showed that >90% whitefly nymph mortality could be achieved even at lower rates. Percentage mortalities caused by Cide-Kick and APSA-80 were significantly lower than with Silwet L-77, with only 47.4% and 33.1% at the lowest concentration (0.25 g AI litre^{-1}).

Percentage mortalities of nymphs treated with New Day at concentrations ≤10.0 ml litre^{-1} were significantly greater than these of M-Pede, while these in the 20.0 and 30.0 ml litre^{-1} between the two materials were not significantly different (Table 2). M-Pede was ineffective at 5.0 and 2.0 ml litre^{-1} while >95% mortality was observed from treatment with New

Table 2. Percentage mortalities of 2nd-instar *Bemisia argentifolii* on tomato treated with New Day and M-Pede

	Mortality (% ± SE)[a]			
Rate (ml litre^{-1})	*New Day*	*M-Pede*	*F*	*P*
30	99.0(±1.4)a	96.6(±3.9)a	0.03	0.7857
20	99.7(±0.8)a	91.1(±10.5)a	0.98	0.6581
10	98.6(±1.7)a	72.1(±9.7)b	4.68	0.0045
5	95.6(±18.5)a	18.5(±9.2)c	45.12	0.0001
2	95.1(±4.9)a	19.9(±7.8)c	33.47	0.0001
0 (water)	3.0(±3.2)b	3.0(±3.2)d	—	—
F	47.32	31.25		
P	0.0001	0.0001		

[a] Mean percentage mortalities in the same column followed by the same letters are not significantly different ($P = 0.05$).

Table 3. Effects of New Day and its active ingredients to 1st- and 2nd-instar *Bemisia argentifolii* on tomato

	Mortality (% ± SE)[a]					
Rate (ml litre^{-1})	*New Day*	*Dodecylbenzene sulfonic acid*	*Cocamide-DEA*	*Sodium laurylether sulfate*	*F*	*P*
10.0	81.5 (±4.2)bA	64.1 (±5.6)cA	95.5 (±1.5)aA	49.3 (±6.1)dA	18.56	0.0001
5.0	85.3 (±2.1)bA	60.9 (±9.8)cA	92.7 (±2.6)aA	49.7 (±2.7)dA	25.43	0.0001
2.5	72.9 (±4.0)bB	44.7 (±7.0)cB	89.6 (±2.7)aA	40.8 (±3.2)cA	21.04	0.0001
0.0 (water)	1.0 (±0.6)aC	1.0 (±0.6)aC	1.0 (±0.6)aB	1.0 (±0.6)aC	—	—
F	75.32	15.68	124.18	65.71		
P	0.0001	0.0002	0.0001	0.0001		

[a] Mean percentage mortalities in the same row followed by the same lower case letters and in the same column followed by the same upper case letters are not significantly different ($P = 0.05$).

Day at these rates. Phytotoxicity (necrotic leaf tissue) was observed from APSA-80 at 1.0 g AI litre^{-1}, Silwet L-77 and Cide-Kick at 0.5 and 1.0 g AI litre^{-1} and New Day at 20.0 and 30.0 ml litre^{-1}. No phytotoxicity was apparent on tomato leaves in any other treatments.

All three major active ingredients of New Day caused significant mortalities to *B argentifolii* nymphs (ingredients: $F = 221.20$; df = 3, 136; $P = 0.0001$; rates: $F = 221.20$; df = 3, 136; $P = 0.0001$; and ingredients × rates: $F = 221.20$; df = 9, 136; $P = 0.0001$) (Table 3). Cocamide DEA was one of the most effective ingredient against young *B argentifolii* nymphs (90–96% mortality) at the three concentrations, whereas dodecylbenzene sulfonic acid, and sodium laurylether sulfate gave relatively low whitefly mortality.

3.2 Sunspray oil and surfactants

The efficacies of Sunspray oil, surfactants and their mixtures varied among the treatments ($F = 65.13$; df = 7, 240; $P = 0.0001$), between the plants ($F = 3.75$; df = 1, 240; $P = 0.0475$), and the interaction of treatments and plants ($F = 3.43$; df = 7, 240; $P = 0.0016$). On collard, Sunspray oil alone at 5.0 ml litre^{-1} caused higher percentage mortality than APSA-80 at 0.4 g AI litre^{-1} or Silwet L-77 at 0.1 g AI litre^{-1} (Table 4). Additional surfactant did not increase the performance of Sunspray oil by itself on collard. However, the addition of M-Pede actually decreased the performance of Sunspray oil on tomato. This and another mixture (Sunspray oil + Silwet L-77) produced significantly less whitefly mortality on collard compared with those on tomato, and did M-Pede alone.

3.3 Vegetable and cotton seed oils and surfactants

In this test, APSA-80 at 0.4 g AI litre^{-1} caused only 47.6% mortality to 2nd-instars on collard, although mortality on tomato was significantly higher (Table 5). The addition of any of the three oils at either 5.0 or 10.0 ml litre^{-1} significantly increased mortality of 2nd-instars on collard. All three oils with APSA-80 (0.4 g AI litre^{-1}) performed better at 10.0 ml litre^{-1} on tomato, although there was no significant improvement with any of the oils tested at 5.0 ml litre^{-1}. Whitefly mortality on collard with any oil at 5.0 ml litre^{-1} plus surfactant was in the range 53.1–68.6%, whereas mortality on tomato varied from 65.2 to 80.6%. There were no differences among the cotton seed oil and the vegetable oil at the 10.0 ml litre^{-1}, although 10.0 ml litre^{-1} cotton seed oil appeared to give best results on tomato. Whitefly mortality was greater on tomato for all treatments ($F = 16.27$; df = 1, 124; $P = 0.0001$), and significantly so for three of the seven treatments tested.

Of the three oils, Sunspray oil and cotton seed oil provided greater mortalities of 3rd-instar *B argentifolii*

Table 4. Percentage mortalities of 2nd-instar *Bemisia argentifolii* treated with Sunspray oil and surfactants

	Mortality (% ± SE)[a]			
Treatments and rates	*Collards*	*Tomato*	*F*	*P*
Sunspray oil, 5 ml litre^{-1}	76.7 (±3.8)a	74.7 (±3.0)ab	0.28	0.5981
M-Pede, 0.4 ml litre^{-1}	70.6 (±1.4)a	66.5 (±2.5)bc	8.73	0.0060
APSA-80, 0.4 g AI litre^{-1}	63.0 (±5.8)b	74.5 (±4.3)ab	2.21	0.1473
Silwet L-77, 0.1 g AI litre^{-1}	57.9 (±7.9)b	53.2 (±7.0)d	0.21	0.6510
Sunspray oil, 5 ml + M-Pede 0.4 ml litre^{-1}	85.3 (±2.0)a	62.0 (±5.5)cd	16.25	0.004
Sunspray oil, 5 ml + APSA-80 0.4 g AI litre^{-1}	75.2 (±4.9)a	81.5 (±4.1)a	0.66	0.4246
Sunspray oil, 5 ml + Silwet L-77 0.1 g AI litre^{-1}	81.9 (±2.8)a	70.3 (±2.4)abc	10.25	0.0032
Control (water)	5.1 (±1.0)c	7.4 (±0.9)e	3.69	0.0643
F	35.8	32.6		
P	0.0001	0.0001		

[a] Mean percentage mortalities in the same column followed by the same letters are not significantly different ($P = 0.05$).

Table 5. Percentage mortality of 2nd-instar nymphs of *Bemisia argentifolii* on collard and tomato dipped in dilutions of some insecticidal oils with surfactants

Vegetable/treatment	*Rates and mortality (% ± SE)*[a] *10 ml litre^{-1}*	*5 ml litre^{-1}*	*APAS-80 (0.4 g AI litre^{-1})*	*Water*
Collard				
Vegetable oil + APSA-80	79.9 (±2.6)aA	65.8 (±6.4)aA	47.6 (±6.8)aB	7.1 (±1.7)aC
Cotton seed oil + APSA-80	74.6 (±4.5)aA*	68.6 (±6.8)aA*	47.6 (±6.8)aB	7.1 (±1.7)aC
Sunspray oil + APSA-80	60.5 (±9.8)bA	53.1 (±4.7)bA*	47.6 (±6.8)aA	7.1 (±1.7)aC
Tomato				
Vegetable oil + APSA-80	85.8 (±1.7)aA	69.1 (±4.3)bB	60.5 (±5.7)aB	5.9 (±1.1)aC
Cotton seed oil + APSA-80	88.7 (±2.7)aA*	80.6 (±3.6)aB*	60.5 (±5.7)aB	5.9 (±1.1)aC
Sunspray oil + APSA-80	74.4 (±4.2)bA	65.2 (±2.9)bAB*	60.5 (±5.7)aB	5.9 (±1.1)aC

[a] Mean percentages in the same column followed by the lower case letters and in the same row followed by the same upper letters are not significantly different ($P = 0.05$).

* indicates the mean percentage is significantly different from the corresponding mean percentage at the same rate of the same oil on different host plants ($P = 0.05$).

than the vegetable oil (Table 6). Percentage mortalities were generally lower than those of 2nd-instars on both collard and tomato, with the exception of Sunspray and cotton seed oil. There was a tendency for higher mortality on tomato than on collard ($F = 11.47$; df = 1,124; $P = 0.0001$), and the differences were still apparent in two of three significant comparisons. With one exception (vegetable oil at 5.0 ml litre^{-1} + 0.4 g AI litre^{-1} APSA-80), mortality was less than with the APSA-80 at 0.4 g AI litre^{-1} control, Dose responses were consistent throughout both tests. No phytotoxicity was observed.

4 DISCUSSION

The surfactants proved to be generally more active than oils at similar rates although more prone to cause phytotoxicity. The one exception was the insecticidal soap M-Pede, which did not cause >90% mortality until the rate was increased to 20.0 ml litre^{-1} (*c* 1.0 g AI litre^{-1}), but also did not cause phytotoxicity even at 30.0 ml litre^{-1}. In contrast, percentage mortality from the lowest tested rate (2.0 ml litre^{-1} or *c* 0.5 g AI litre^{-1}) of New Day exceeded 95%, only 1/10 of the rate at which phytotoxicity was observed. Therefore, New Day appeared to be highly active and relatively safe for whitefly control. This class of detergent, particularly the main active ingredients, cocamide DEA and dodecylbenzene sulphonic acid, deserves further attention as an insecticide. Silwet L-77 proved most active against whiteflies, although the margin of safety was only a factor of two between the lowest rates tested (0.25 g AI litre^{-1}) and the phytotoxic rate (0.5 g AI litre^{-1}) although this rate may not cause phytotoxicity when it was sprayed in the field (TX Liu, unpublished data).

We were not able to improve on the commercial formulation of Sunspray oil for whitefly control with additional surfactants. However, our tests indicate that cotton seed oil and vegetable oil can perform as well as or better than the mineral oils and may deserve further consideration for pest control. The interaction with the two foliar surfaces tested provided an interesting contrast. Possibly the aqueous emulsions tested did not spread as well on the waxy surface of collard leaves. Leaf pubescence may have also been a factor, either directly or through its effect on whiteflies. It is known, for instance, that body thickness and setae of *B*

Table 6. Percentage mortality of 3rd-instar nymphs of *Bemisia argentifolii* on collard and tomato dipped in dilutions of some insecticidal oils with surfactants

Vegetable/treatment	*Rates and mortality (% ± SE)*[a] *10 ml litre^{-1}*	*5 ml litre^{-1}*	*APAS-80 (0.4 g AI litre^{-1})*	*Water*
Collard				
Vegetable oil + APSA-80	49.8 (±6.8)bA	22.1 (±3.7)cA*	53.8 (±3.9)aB*	2.3 (±0.5)aC
Cotton seed oil + APSA-80	83.8 (±3.7)aA	74.2 (±4.7)bA*	53.8 (±3.9)aB	2.3 (±0.5)aC
Sunspray oil + APSA-80	87.0 (±4.9)aA	86.8 (±4.8)aA	53.8 (±3.9)aB	2.3 (±0.5)aC
Tomato				
Vegetable oil + APSA-80	55.7 (±7.8)bA	33.1 (±3.4)cB*	27.9 (±3.6)aB*	2.1 (±0.5)aC
Cotton seed oil + APSA-80	80.0 (±7.7)aA	66.3 (±3.5)bB*	27.9 (±3.6)aC	2.1 (±0.5)aD
Sunspray oil + APSA-80	88.0 (±3.2)aA	82.5 (±4.4)aA	27.9 (±3.6)aB	2.1 (±0.5)aC

[a] Mean percentages in the same column followed by the lower case letters and in the same row followed by the same upper letters are not significantly different at $P = 0.05$.

* indicates the mean percentage is significantly different from the corresponding mean percentage at the same rate of the same oil on different host plants ($P = 0.05$).

argentifolii nymphs are positively correlated with leaf pubescence.[25] Therefore, greater pubescence of the tomato leaf could have predisposed the nymph to greater susceptibility. Conversely, the glabrous collard leaf produces a flat smooth nymph that may be less susceptible to the emulsified oil.

Our results demonstrate good insecticidal activity of surfactants and oils, comparable with some conventional insecticides.[19,20] Nevertheless, these results are based on excellent to perfect coverage obtained with the spray tower or by leaf dips. The contact activity of these materials requires thorough and complete coverage on the lower leaf surface where whiteflies are located to obtain effective control.[6,18,20,22] In addition, surfactants are only active while wet and become ineffective under drying conditions.[18,20] Therefore, successful use of these materials requires appropriate application methods and environmental conditions.

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