EFFECTS OF OIL AND OIL-SURFACTANT COMBINATIONS ON SILVERLEAF WHITEFLY NYMPHS (HOMOPTERA: ALEYROIDIDAE) ON COLLARDS

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ABSTRACT

Collards, *Brassica oleracea* L., treated with SunSpray Ultra-Fine® oil with and without silicon-based oil surfactants were evaluated for effects on nymphs of *Bemisia argentifolii* Bellows & Perring. Synchronously developing populations of eggs, small nymphs and pupae on collards were sprayed to run-off. The rate of egg hatch was not affected by oil treatments. Treated nymphs, pupae, and crawlers emerging from treated eggs, were affected by all oil treatments. Of those nymphs that were affected by the oil, approximately 50% to 75% were killed outright. Over 90% of those that remained alive developed abnormally, remaining small and failing to molt into the next stage. Adults failed to emerge from approximately 94% to 99% of treated pupae. Oil surfactants did not significantly alter whitefly mortality when used with paraffinic oil.

Key Words: insecta, *Bemisia argentifolii*, whitefly, surfactant, oil

RESUMEN

Se evaluó *Brassica oleracea* L. tratada con el aceite SunSpray Ultra-Fine® con y sin un surfactante de aceite en una base de silicón para ver los efectos en ninfas de *Bemisia argentifolii* Bellows & Perring. Poblaciones en desarrollo y sincronizadas de huevos, pequeñas ninfas y pupas en *Brassica oleracea* se rociaron al punto de que chorreaban. El tratamiento de aceite no afectó la eclosión de los huevos. Las ninfas, pupas, y larvas emergiendo de los huevos fueron afectadas por todos los tratamientos de aceite. De las ninfas que fueron afectadas por el aceite, aproximadamente del 50% al 75% murieron al momento. Más del 90% de aquellas que quedaron vivas se desarrollaron anormalmente, manteniéndose pequeñas y no haciendo la muda a la próxima etapa. Adultos no emergieron aproximadamente del 94% al 99% de las pupas tratadas. La mortalidad de las moscas blancas no fue afectada significativamente cuando se usaron en combinación surfactantes de aceite con aceite parafínico.

Whiteflies have been linked to tomato irregular ripening (Schuster et al. 1990) and squash silver leaf (Schuster et al. 1991). Oils have been shown to be toxic and repel-

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lent to adult whiteflies (Liu & Stansly 1995a, Butler & Henneberry 1991a, Butler et al. 1989, Puri et al. 1994), to deter oviposition (Liu & Stansly 1995a, b), to reduce the numbers of nymphs that develop from eggs laid after treatment (Butler & Henneberry 1991a), and to kill treated nymphs (Butler et al. 1993, Puri et al. 1994). Oil, as a control of whiteflies, has the advantages of low toxicity to animals and no restrictions on when sprays can be applied. The disadvantages include the need for repeated treatments (Butler & Henneberry 1991a), crucial need for good coverage (Liu & Stansly 1995b) and potential phytotoxicity (Butler & Henneberry 1991b). Water miscible surfactants are widely used to increase the coverage of insecticidal sprays or to kill insects outright (Chandler 1994). Chemicals that have been added to oil in an attempt to increase repellency, but that had no effect, are trans-cinnamaldehyde, cineole, and citronello (Butler et al. 1989). Oil surfactants are siloxanes that can increase oil spread. We studied paraffinic oil and oil/surfactant combinations for their effects on whiteflies. SunSpray Ultra-Fine® oil was used at 1% as this concentration was previously found to control whiteflies (Liu & Stansly 1995a).

Materials and Methods

The colony of *Bemisia argentifolii* was maintained on collards and tomatoes. To obtain immature whiteflies, 4-wk-old greenhouse-grown collard plants grown in a whitefly-free screened cage were trimmed to three fully expanded leaves and were transferred to the whitefly colony for 48 h. Adults were then aspirated from the plants, and the plants were placed in a separate cage. The synchronously-developing, uniformly-aged whitefly populations were then held until they developed to the appropriate stage. There were approximately 100 to 500 developing immature whiteflies on all of the plants used.

The plants were treated with water (control), 1% SunSpray Ultra-fine paraffinic oil, and 1% SunSpray emulsions with the following silicone-based oil surfactants as 5% of the oil: Silwet 560, Tegoprene 3130, and Tegoprene 6814. The plants were sprayed to run-off with 1.5-l pressurized sprayers. All experiments were done in screened plexiglass cages in a temperature controlled room at 30°C, 50% RH, and 12:12 L:D photoperiod.

Egg Mortality and Attachment of Crawlers

Immediately after the adult whiteflies were aspirated from the plants, the plants were sprayed. There were six replicates (plants) for each of the four treatments. Eight days after treatment, the unhatched eggs and newly emerged nymphs were counted and the percent hatch calculated. The experiment was repeated and the eggs were allowed to develop for 10 d after treatment. Live nymphs, dead attached nymphs and dead nymphs that emerged and did not attach were counted. The percent attachment of newly emerged nymphs and the percentage of nymphs that died after emergence were calculated to determine if attachment affected mortality after hatching.

Early Stage Nymphal Mortality

Eight days after infestation, when first instar nymphs had emerged and attached to the leaf, the plants were sprayed as before. There were 13 replicates (plants) per treatment. Ten days after treatment, the numbers of dead nymphs, large, normally developing nymphs, and small, abnormally developing nymphs were counted and the percentage of each was calculated.

Late Stage Pupal Mortality

Fourteen days after infestation, when most nymphs were in the red-eye stage, the plants were sprayed as before. There were six replicates (plants). Seven days after treatment, when most of the pupae had emerged from control plants, the numbers of empty pupal cases and pupae that failed to emerge were counted and the percent of emergence was calculated.

Arcsin-transformed data were analyzed by ANOVA and means were separated by Student-Newman-Keuls multiple-range test (Gabriel 1964).

RESULTS

Over 90% of the eggs hatched and nymphs were able to emerge, regardless of treatment and no significant differences were detected (Table 1). However, once the nymphs had emerged, they were adversely affected by the oil treatments. Crawlers that hatched from treated eggs attached at a low rate, often dying on empty egg shells. The nymphs that did attach, attached only partially with the posterior abdomen in the air, or died shortly after attaching to the leaf. Mortality of nymphs emerging from eggs that had been treated approached 100%. The differences in attachment or mortality were not affected by the addition of silicon surfactants to the oil.

The percentage of early stage nymphs that developed normally ranged from 1% to 4% for oil treatments compared to 98% for the control (Table 2). Of those remaining, 50% to 76% of oil-treated nymphs were killed outright, and 23% to 44% developed abnormally. Applications of SunSpray oil combined with Silwet 560 had the highest levels of abnormally developing nymphs.

Over 90% of treated pupae failed to complete development to adult emergence (Table 3). The oil appeared to interfere with the ability to emerge into adults. There were no differences among any of the oil and oil-oil surfactant mixtures. Of the pupae that did not complete development at seven days after treatment, some were still alive.

DISCUSSION

Oil is important in the control of whiteflies. It does not prevent neonates from eclosion, but does prevent attachment of first stage nymphs to leaves, and kills those that do attach. Butler et al. (1988) also studied the effect of oil on treated eggs and inter-

TABLE 1. PERCENT EGGS HATCHED, NYMPHS ATTACHED, AND NYMPHS DEAD AFTER EMERGENCE.

Treatment	% Eggs hatched	% Nymphs attached	% Nymphs dead after emergence
Control	95.0 a	—	0.5 a
1% SunSpray Oil®	92.9 a	10.0 a	98.5 b
Silwet 560	93.1 a	25.6 a	99.6 b
Tegoprene 3130	94.0 a	7.8 a	99.6 b
Tegoprene 6814	93.1 a	14.6 a	99.5 b

Arcsin-transformed data were analyzed by ANOVA and the means were separated by Student-Newman-Keuls multiple range test. Means followed by the same letter are not significant ($P = 0.05$).

TABLE 2. PERCENT NORMAL AND ABNORMAL NYMPHAL DEVELOPMENT AND MORTALITY.

Treatment	% Normal	% Abnormal	% Dead
Control	97.9 a	0.1 a	2.0 a
1% SunSpray	4.4 b	29.3 b	66.3 bc
Silwet 560	2.3 b	44.5 c	53.1 b
Tegoprene 3130	1.0 b	23.2 b	75.8 c
Tegoprene 6814	2.0 b	26.6 b	71.4 c

Arcsin-transformed data were analyzed by ANOVA and the means were separated by Student-Newman-Keuls multiple range test. Means followed by the same letter are not significant ($P = 0.05$).

TABLE 3. PERCENT ADULT EMERGENCE.

Treatment	% Emergence
Control	87.7 a
SunSpray	6.0 b
Silwet 560	2.4 b
Tegoprene 3130	1.9 b
Tegoprene 6814	0.7 b

Arcsin-transformed data were analyzed by ANOVA and the means were separated by Student-Newman-Keuls multiple range test. Means followed by the same letter are not significant ($P = 0.05$).

preted a reduction in the numbers of nymphs and pupae as a reduction in egg hatch. Lack of egg mortality from oil treatments was consistent with that observed by Larew and Locke (1990) with SunSpray-treated *T. vaporariorum* eggs. They observed that larvae died in the process of emergence, we noted that death occurred in the emergence process, inability to attach to treated surfaces, or shortly after attachment.

Oil is most effective when applied on eggs for control of first stage nymphs. When first stage nymphs are treated, they are prevented from developing normally by oil treatments with or without the addition of oil surfactants. Some of the nymphs do not die and are not able to molt and grow normally. They appear very rounded, as if they need to, but are not able to molt. This has implications for development of symptoms of tomato irregular ripening, if nymphs are able to continue to live on the plant for long time intervals. Costa et al. (1993) associated whitefly nymphs with the induction of symptoms of squash silverleaf. Oil treatments also prevent the emergence of adults from treated pupae. Again, of the ones that do not emerge, not all are killed outright. Control with paraffinic oil is not affected by the addition of oil surfactants except to impact whether or not the treated nymphs continue to live in an abnormal state or are killed by the oil.

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