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Author(s): Christopher Tipping, Veronique Bikoba, Gabriel J. Chander, and Elizabeth J. Mitcham

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Efficacy of Silwet L-77 Against Several Arthropod Pests of Table Grape

CHRISTOPHER TIPPING,¹ VERONIQUE BIKOBA,¹ GABRIEL J. CHANDER,² AND
ELIZABETH J. MITCHAM¹

Department of Pomology, University of California—Davis, One Shields Avenue, Davis, CA 95616

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ABSTRACT Silwet L-77, an organosilicone surfactant, was applied to several arthropod pests of California table grapes. Eggs of grape mealybug, *Pseudococcus maritimus* (Ehrhorn), and omnivorous leafroller, *Platynota stultana* Walsingham, were tolerant to 0.1, 0.25, and 0.5% treatment solutions; however, eggs of Pacific spider mite, *Tetranychus pacificus* McGregor, were highly susceptible with mortality >99.4% (0.1% Silwet L-77). Mortality of immature and adult stages of cotton aphid (*Aphis gossypii* Glover), Western flower thrips (*Frankliniella occidentalis* Pergande), and Pacific spider mite (*Tetranychus pacificus* McGregor) was ≥ 93.8 , ≥ 98.5 , and $\geq 99.4\%$ for 0.1, 0.25, and 0.5% Silwet L-77, respectively. Grape mealybug crawlers had 100% mortality when treated with 0.5 and 1.0% Silwet L-77 solutions; however, mortality was only 6.7% when 0.1% Silwet L-77 was applied. ‘Thompson Seedless’ table grapes were not damaged when treated with up to 1% Silwet L-77; however, grapes treated with the 0.5 and 1.0% solutions appeared wet after removal from cold storage because of the effect of the surfactant spreading the water condensation. Grapes dried with the normal bloom on the berries when they reached room temperature.

KEY WORDS *Aphis gossypii*, *Frankliniella occidentalis*, organosilicones, *Platynota stultana*, *Pseudococcus maritimus*, *Tetranychus pacificus*

SURFACTANTS ARE OFTEN USED in conjunction with many classes of pesticides as adjuvants to facilitate the spread or wetting of active ingredients (Coupland et al. 1989, Foy 1989, Zidack et al. 1992). Although the exact nature of the toxic effects of surfactants has not been adequately determined, insecticidal and acaricidal effects of soaps and oils as surfactant were first described more than 80 yr ago (Wilcoxon and Hartzell 1931). Dills and Mensan (1935) stated that soap solutions penetrated aphid tracheae, implying mortality was a result of suffocation. Puritch (1981) reported that soaps were insecticidal because of their disruption of the lipoprotein matrix of intercellular membranes. Mosquito larvae associated with an air/water interface have been shown to be adversely affected by surfactants (Levy et al. 1980, Corbet et al. 1995). One possible mode of action for this observed effect in mosquito larvae and pupae is a change in the hydrophobic lining of the spiracles and trachea leading to flooding of the tracheal system and subsequent drowning of the insect (Murray 1936).

The organosilicones represent a relatively new chemistry as surfactants for agricultural applications (Knoche 1994). In addition, to their insecticidal properties, they enhance herbicide, foliar nutrient, growth

regulator, and fungicide efficacy (Stevens 1993). This class of surfactants has low mammalian toxicity and is commonly used in foods, drugs, and cosmetics (Purcell and Schroeder 1996). Silwet L-77 is one such surfactant and has been shown to kill insects and mites (Cowles et al. 2000, Imai et al. 1995a, Purcell and Schroeder 1996, Wood and Tedders 1997). Silwet L-77 has been approved by the United States Environmental Protection Agency (EPA) for postharvest applications including increased calcium infiltration for ‘Golden Delicious’ apples (Saftner et al. 1997). Silwet L-77 has also been evaluated as a thrips disinfestation treatment on harvested asparagus grown in New Zealand (Rohitha et al. 1992). Silwet L-77 is registered for use as an adjuvant with herbicides, desiccants, defoliant, insecticides, acaricides, fungicides, plant growth regulators, and foliar nutrients, and for turf applications and soil wetting (Loveland Industries, Greeley, CO). Suggested rates are 3 to 16 fluid ounces of Silwet L-77 per 100 gallons of spray mixture. Silwet L-77 is not currently registered as a pesticide.

California table grapes, *Vitis vinifera* L., are host to a number of arthropod pests including grape mealybug, *Pseudococcus maritimus* (Ehrhorn) (Homoptera: Pseudococcidae), western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae), Pacific spider mite, *Tetranychus pacificus* (McGregor) (Acari: Tetranychidae), cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae), and omnivorous leaf roller, *Platynota stultana* (Walsingham) (Lepidoptera:

¹ Department of Pomology, University of California, Davis, One Shields Avenue, Davis, CA 95616 (e-mail: ejmitcham@ucdavis.edu).

² Department of Statistics, University of California, Davis, One Shields Avenue, Davis, CA 95616.

Tortricidae) (Flaherty et al. 1992). Here we report the effects of Silwet L-77 on several life stages of these arthropod pests and on 'Thompson Seedless' grapes.

Materials and Methods

Arthropods. Pacific spider mite life stages were selected from a laboratory culture reared on cotton seedlings (*Gossypium hirsutum* L.), maintained at 25°C (45% RH), under continuous light. Eggs were obtained from infested cotton leaves by rinsing with distilled water into 60-ml plastic cups. Excess water was removed from the cups with thin strips of filter paper. Western flower thrips life stages were selected from a culture maintained on green bean pods (*Phaseolus vulgaris* L.) in 500-ml clear plastic deli containers covered with nylon screen and maintained at 25°C (30% RH) with a 12:12 (L:D) h photoperiod. Omnivorous leaf roller eggs were selected from a culture reared on a modified lima bean diet (Yokoyama et al. 1987) with a photoperiod of 16:8 (L:D) h at 27°C. The eggs were laid on a wax paper lid covering the top of a cardboard container that was used to rear adults. Wax paper on the adult cage was changed daily and eggs used were <24 h old at the time of treatment. Female grape mealybugs were collected from the field and held in 60-ml plastic test cups covered with screen at 24°C (>90% RH) until initiation of ovi-sacs. Females were then removed from the ovi-sacs and the eggs inside ovi-sacs were used for treatments. Additionally, other ovi-sacs were held at 24°C (>90% RH) until eclosion to obtain individuals in the crawler stage. Cotton aphid life stages were selected from a culture maintained on cotton seedlings in a greenhouse at an average of 27°C, 55% RH. Before application of all treatment solutions, cotton leaves infested with mixed stages of Pacific spider mites or cotton aphids were examined with a stereoscope at 80× to remove dead or injured individuals.

Silwet L-77 Applications. A glass chromatography atomizer (PGC Scientifics, Gaithersburg, MD) was used to apply ≈0.15 g of distilled water (dH₂O) or Silwet L-77 solutions of 0.1, 0.25, 0.5, or 1.0% (vol:vol, pH 7) to immature and adult stages of western flower thrips, grape mealybug, Pacific spider mite, and cotton aphid, as well as the egg stage of Pacific spider mite, omnivorous leaf roller, and grape mealybug. The mixed immature and adult stages of cotton aphid and Pacific spider mite were treated while on excised cotton seedling cotyledons. Other arthropods or eggs were treated naked and were not provided with food after treatment. Treatment amounts were sufficient to wet leaf, arthropod, and cup surfaces without creating excess run off that could potentially affect mortality of test subjects.

All arthropod life stages were treated at 25°C while in 60-ml plastic cups. Untreated controls were handled in the same manner, but without application of dH₂O or Silwet L-77 solution. Three replications of two cups per treatment were performed with sample sizes summed from both cups. After treatment, cups with larval or adult stages were covered with nylon screen

and transferred to 24°C, >90% RH for 24 h before evaluation of mortality. Life stages were examined for mortality under a stereomicroscope (80×) by gently touching with a dissection needle; lack of movement indicating mortality. Cups that contained eggs were examined daily under a stereomicroscope (80×) daily for eclosion. Neonates were removed each day until all viable eggs had hatched.

Effects on 'Thompson Seedless' Grapes. 'Thompson Seedless' grapes were obtained locally and were sprayed with dH₂O, 0.1, 0.5, and 1.0% Silwet L-77 solutions until berries were visibly wet. Grapes were then placed in cold storage (0°C, >90% RH) in unsealed plastic bags before evaluation at 0, 1, 7, and 14 d after treatment. Each treatment was replicated three times with entire bunches. Grapes were visually inspected for damage to berries, rachis (collection of small stems that attach the berries to the main stems) and stems, and rated in comparison to untreated controls. In addition, grapes were examined for berry shatter (detachment of berries from the rachis).

Statistical Analysis. The effects of Silwet L-77 solutions on the proportion mortality of the arthropods were analyzed using logistic regression, treating concentration as categorical. There were three replications and a completely random design. Pair-wise comparisons of treatment levels were accomplished via a Bonferroni procedure to maintain an overall alpha level of 0.05 (SAS Institute 1999). Significance between treatments was determined by comparing point estimates for the parameters from the logistic regression model. Because percent mortality is a more intuitive measure of treatment efficacy, percent mortality, not estimates based on the logit scale, is presented.

Results

Mortality of grape mealybug eggs treated with 0 to 0.5% of Silwet L-77 was not significantly different from the untreated controls or dH₂O (Table 1). Omnivorous leafroller eggs were also tolerant to Silwet L-77. In contrast, eggs of Pacific spider mite were highly susceptible to Silwet L-77 (Table 1), with mortality levels between 99.4 and 100% for the Silwet L-77 concentrations tested. Mortality for Silwet L-77 treatments was significantly higher than mortality for the untreated control and dH₂O treatments ($P < 0.5$), but not significantly different from each other.

The grape mealybug crawlers were completely controlled with 0.5 and 1.0% Silwet L-77 (Table 2). However, mortality of crawlers treated with 0.1% Silwet L-77 was significantly lower. Mixed larval and adult stages of omnivorous leafroller were completely controlled with ≥0.5% Silwet L-77. Cotton aphids were similarly sensitive to Silwet L-77, and larval and adult mortality increased with higher concentrations of Silwet L-77—99.4% at 0.5% (Table 3). Mortality of mixed larval and adult stages of Pacific spider mite was >96% after treatment with 0.1% Silwet L-77 (Table 3); however complete mortality was not achieved, even with 0.5%.

Table 1. Mortality (mean ± SE) of eggs of grape mealybug, omnivorous leafroller, and Pacific spider mite after application of Silwet L-77

Treatment	% Mortality ^a					
	Grape mealybug	n ^b	Pacific spider mite	n	Omnivorous leafroller	n
Control	1.7 ± 0.02a	133	8.5 ± 0.02a	328	2.0 ± 0.01b	495
dH ₂ O	1.6 ± 0.04a	201	4.7 ± 0.01a	464	5.1 ± 0.1b	256
0.1%	1.1 ± 0.03a	111	99.4 ± 0.03b	490	3.9 ± 0.01b	433
0.25%	1.6 ± 0.03a	165	100.0 ± 0.0b	295	1.1 ± 0.01a	520
0.5%	1.4 ± 0.03a	221	99.5 ± 0.03b	407	4.7 ± 0.01b	472

^a Means based on three replications. Means within columns followed by the same letter are not significantly different (*P* < 0.05).
^b n = total number of arthropods treated.

‘Thompson Seedless’ grapes treated with solutions of Silwet L-77 were not visibly different from untreated controls after 0, 7, 14, and 21 d of cold storage. Grapes treated with 0.1% Silwet L-77 did not show any surfactant effects, but grapes treated with ≥0.5% Silwet L-77 had a wet appearance on removal from cold storage, because of surfactant effects on condensation. After the grapes reached room temperature, they were indistinguishable from untreated controls. Rachis and stems were not discolored nor was there an increase in berry shatter for any of the treatments in comparison to the untreated controls (data not shown).

Discussion

The application of soaps and surfactants against a variety of arthropods has yielded mixed results (van der Meulen and van Leeuwen 1929, Levy et al. 1984, Butler and Henneberry 1990, Larew and Locke 1990, Wood and Payne 1995). Efficacy of 0.1% Silwet L-77 against *Myzus persicae* (Homoptera: Aphididae) was reported by Imai et al. (1995a) to be enhanced when applied at a relative humidity of 90% compared with lower humidities. The humidity in the atmosphere surrounding packaged fruit is generally high because of moisture evaporating from the fruit collecting in a closed package, potentially aiding the efficacy of Silwet L-77. All treatments in our tests were with >90% RH.

Cotton aphid, omnivorous leafroller and Pacific spider mite adult and immature mortality was ≥93.8% with 0.1% Silwet L-77, and increasing the concentra-

Table 2. Mortality (mean ± SE) of grape mealybug crawlers after treatment with Silwet L-77

Treatment	% Mortality ^a	n ^b
Control	0.0 ± 0.00c	94
dH ₂ O	0.0 ± 0.00c	227
0.1%	6.7 ± 0.03b	222
0.5%	100.0 ± 0.00a	301
1.0%	100.0 ± 0.00a	195

^a Means based on three replications. Means within columns followed by the same letter are not significantly different (*P* < 0.05).
^b n = total number of arthropods treated.

Table 3. Mortality (mean ± SE) of mixed immature and adult stages of Western flower thrips, Pacific spider mite, and cotton aphid after treatment with Silwet L-77

Treatment	% Mortality ^a					
	Western flower thrips	n ^b	Pacific spider mite	n	Cotton aphid	n
Control	11.0 ± 0.01b	1652	7.4 ± 0.01a	616	2.6 ± 0.00a	2726
dH ₂ O	3.8 ± 0.00a	2017	6.4 ± 0.01a	603	8.3 ± 0.01b	2065
0.1%	94.0 ± 0.01c	1698	96.4 ± 0.01b	802	93.8 ± 0.00c	3212
0.25%	99.9 ± 0.00d	1937	99.0 ± 0.00c	702	98.5 ± 0.00d	2349
0.5%	100.0 ± 0.00d	1815	96.7 ± 0.01b	722	99.4 ± 0.00e	3346

^a Means based on three replications. Means within columns followed by the same letter are not significantly different (*P* < 0.05).
^b n = total number of arthropods treated.

tion to 0.5% increased mortality to 99.4, 100, and 96.7%, respectively. These data may indicate that coverage was an important factor in treatment efficacy because mortality remained close to but just under 100% over a broad range of treatment concentrations. Lui and Stansly (2000) report >95% mortality of silverleaf whitefly (*Bemisia argentifolii*) (Homoptera: Aleyrodidae) nymphs treated with Silwet L-77. However, they reported that mortality was lower when Silwet L-77 was applied under drying conditions, or when complete coverage was not achieved. Both cotton aphid and Pacific spider mite were treated while infesting cotton seedlings, which could provide small regions of refuge. An immersion treatment could provide better arthropod control than a spray treatment, but would not be feasible for a crop like California table grapes, which are not wetted after harvest.

The egg stage for two species tested in our study, grape mealybug and omnivorous leafroller, was tolerant to Silwet L-77 treatment, while Pacific spider mite eggs were highly susceptible with nearly 100% mortality after treatment with as little as 0.1% Silwet L-77, indicating significant differences in tolerance between species. These data also indicate that Silwet L-77 would not be a stand-alone treatment for control of all lifestages of omnivorous leafrollers or grape mealybugs. All grape mealybug crawlers that emerged from eggs treated with 0.25 and 0.5% Silwet L-77 died within 24 h of eclosion (data not shown). Dying crawlers were unable to initiate the powdery wax coating that is normally exuded from the cuticular pores of healthy individuals. Neonates of omnivorous leafroller that emerged from treated eggs were found to be healthy 24 h after treatment with Silwet L-77.

Tetranychid spider mites have been shown to be susceptible to surfactants (Cowles et al. 2000). The carmine mite (*T. cinnabarinus* Boisduval) had 100% mortality when treated with 1.0% solutions of several anhydrosorbital surfactants (Otsuji 1985). The commercial organosilicone, Pulse, killed ≥99% of diapausing two-spotted spider mites (*T. urticae* Koch) (Dentener and Peetz 1992) when applied using the standardized FAO slide-dip method 10a (Busvine 1980). Our results show the effectiveness of organosilicone surfactants against the eggs of Pacific spider

mite, indicating that this could be an effective treatment to control all lifestages of Pacific spider mites on produce.

The mode of action of surfactants on arthropods remains largely unknown. Terrestrial arthropods have high surface to volume ratios, and are therefore susceptible to materials that affect the physical properties of water. Because organosilicones have superior wetting properties, they might disrupt a variety of arthropod systems that depend on specific water relationships including cuticular and respiratory functions (Imai et al. 1995b). Puritch (1981) reported a potential mode of action of surfactants as disrupters of cellular membrane integrity. Puritch and de L'Arme (1974) stated that soft-bodied insects such as aphids, mealybugs, and pear psylla are more susceptible to topical treatment with soaps than Lepidopteran larvae. Our data supports this assertion. Microscopic examination of the outer chorion of the eggs of insects and mites could provide important information in determining the mode of action of Silwet L-77.

Surfactants have been used successfully in postharvest disinfestation research for apples infested with two-spotted spider mites (Peetz and Dentener 1992) and asparagus infested with an unidentified thrips sp. (Rohitha et al. 1992). Otherwise, the application of organosilicones as postharvest pesticides has been largely unexplored. Our study indicates no effect on table grape quality from the Silwet L-77 treatment, but more extensive testing should be completed. Further investigations are required into the toxicological effects of Silwet L-77, as well as its potential as a postharvest disinfestation treatment for other commodities. Silwet L-77 must be registered for insect control before it could be recommended for such purpose.

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