Control of Pecan Aphids with an Organosilicone Surfactant

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Abstract. Aphids cause major annual economic losses to the U.S. pecan [*Carya illinoensis* (Wangenh.) K. Koch] industry and are becoming harder to control with standard pesticides. An evaluation of efforts by certain growers to suppress aphid populations using air-blast sprays of 0.05% Silwet L-77, a non-ionic super-wetting organosilicone surfactant, indicated that: 1) reductions in blackmargined aphid [*Monellia caryella* (Fitch)] levels were mostly attributable to the air-blast spray effect rather than to the Silwet L-77 component; 2) a 0.05% solution of Silwet L-77 reduced net photosynthesis (A) of foliage by 5% for at least 14 days post-treatment; and 3) the efficacy of 0.05% Silwet L-77 sprays is not substantially increased by doubling the volume of spray per tree (1868 L·ha⁻¹). However, higher Silwet L-77 concentrations were highly effective in killing aphids, although there was little or no residual activity. A response curve indicated that air-blast sprays of orchard trees with 0.30% (v/v) Silwet L-77 (at 934 L·ha⁻¹) are capable of reducing yellow pecan aphid (*Monelliopsis pecan* Bissell) populations by at least 84% while only reducing A by ≤10%. Chemical names used: silicone-polyether copolymer (Silwet L-77).

Three species of foliar feeding aphids cause major economic losses to pecan (Dutcher et al., 1984; Tedders and Wood, 1985; Wood et al., 1987). These are the blackmargined aphid, yellow pecan aphid, and black pecan aphid [*Melanocallis caryaefoliae* (Davis)]. Control strategies using standard synthetic aphicides generally intensify aphid-associated problems by either inducing resistance or by suppressing natural control agents such as predators and parasitoids. An alternate strategy has been the conjunctive use of KNO₃ and detergent sprays (Wood et al., 1995). While this strategy can suppress orchard populations of aphids, improved methods are needed because of expense and often insufficient aphid control.

The ability of surfactants, such as soaps and detergents, to suppress aphid populations raises the possibility that super-surfactants, such as the organosilicones (Harvey, 1992), could substantially suppress orchard populations of aphids. These organosilicone-based surfactants confer exceptionally low surface tensions (Loveland Industries, 1993), thus greatly enhancing wetting of plant and, potentially, insect surfaces. One of these, Silwet L-

77 [a non-ionic silicone-polyether copolymer (Loveland Industries, Greeley, Colo.)], may be useful in controlling aphids on pecan trees. The present study examines the efficacy of air-blast sprays of Silwet L-77 on pecan aphid populations within orchards and its effect on gas exchange characteristics of pecan foliage.

Materials and Methods

Expt. 1. Effect of concentration of Silwet L-77. The efficacy of applying Silwet L-77 to control pecan aphids was evaluated in a 15-year-old commercial orchard of 'Cheyenne' pecan trees growing at a 9 × 9-m spacing. Trees were managed according to commercial standards for irrigation, nutrition, and diseases (Crocker, 1995), but had not received insecticide sprays during the study period (1995 and 1996). Test trees were selected that possessed an increasing aphid population. This was judged by the relative abundance of 1st to 4th instar nymphs vs. winged adults. Twenty-one trees were then grouped by aphid population levels into seven blocks (ranging from 27 to 274 aphids per terminal) containing three trees, each of which received a different spray treatment. The experimental design was a randomized complete block with one tree per Silwet L-77 concentration [0% (an air-blast + water control), 0.025%, 0.050% (v/v)]. Silwet L-77 was applied at 934 L·ha⁻¹ using a commercial air-blast sprayer with a volute. Treatments were applied within 4 h after counting aphids on five mid-canopy terminal shoots per tree. Aphids were recounted on these same five terminal shoots 24 h after spraying to assess survival. Aphids were identified as either blackmargined adults, black aphid adults, or

total nymphs of both species. Essentially no yellow pecan aphids were present at the time of spraying. Data were analyzed by ANOVA (SAS-PC) as a continuous variable utilizing linear and quadratic regression to assess dose response (SAS, 1990).

Expt. 2. Effects of air-blast application and volume of water applied. A second Silwet L-77 study was initiated to evaluate the effect of the air-blast spray and amount of water sprayed on aphid populations. Experimental protocol was similar to the above described study except that the aphid population complex consisted almost entirely of the yellow pecan aphid. Trees were blocked and treated as described above. Most terminals had 30 to 50 aphids at the time of spraying. The five treatments were: unsprayed, water at 8 L per tree (934 L·ha⁻¹), or 16 L per tree (1868 L·ha⁻¹), Silwet L-77 (0.05% v/v) at 8 L per tree, or at 16 L per tree. All applications were made with an air-blast sprayer. Results were assessed by indexing aphid populations ≈24 h after spraying with populations on the same terminal immediately before spraying. Data were analyzed as discrete variables using Tukey's standardized range test to compare treatment means.

Expt. 3. Comparison of a range of concentrations of Silwet L-77. A third study evaluated the efficacy of Silwet L-77 at concentrations much higher than those typically used (0.05% v/v). Blackmargined aphid populations were counted on terminals just before spraying (at 934 L·ha⁻¹) the same day; aphids per terminal ranged from 55 to 160. Treatments were: unsprayed, a water control, and Silwet L-77 at 0.05%, 0.1%, 0.2%, 0.4%, 0.8%, and 1.2% (v/v). Sprays were applied using a hand-held sprayer. Aphids were counted about 24 h after spraying. Experimental design was a randomized complete block with 20 single-tree blocks made up of eight treatments positioned within the tree so as to avoid cross contamination by spray drift. Data were analyzed by ANOVA and regression (SAS-PC). A subjective evaluation of the impact of Silwet L-77 treatments on beneficial insects, such as lady beetles and lace wings, was made by examining the bare ground beneath treated trees for dead or dying arthropods.

Expt. 4. Residual activity of Silwet L-77 on aphid populations. Residual activity was evaluated in vitro using a water agar leaf disc method developed by Reilly and Tedders (1990). Fully expanded foliage of seedlings was sprayed to runoff with test solutions using a hand sprayer. Upon drying, leaf sections (4 × 4 cm) were placed on water agar in petri dishes. Spray treatments were: water control, Pydrin 2.4 E [Cyano (3-phenoxyphenyl) methyl-4-chloro- α -(1-methylethyl) benzeneacetate (Shell Chemical Co., Houston)] at 0.35 g·L⁻¹, and Silwet L-77 at 0.01%, 0.03%, and 0.06% (v/v). Five fourth-instar yellow pecan aphids were collected from the same trees as were the leaf discs and placed on the leaf section in each petri dish 1, 2, and 4 days post-treatment. Aphid survival was then evaluated to determine residual activity. Experimental design was a randomized complete

Received for publication 12 Nov. 1996. Accepted for publication 10 Feb. 1997. Chemical names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval or disapproval of the product to the exclusion of others that may also be suitable. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

Table 1. Mean number of blackmargined and black pecan aphids per terminal shoot 1 day after an application of Silwet L-77 at 0.05% (v/v), with a carrier volume of 934 L·ha⁻¹.

Silwet L-77 (%)	Blackmargined aphids (Adults)	Black aphids (Adults)	All aphids (Nymphs)
0 (Unsprayed)	35	14	168
0.025	28	7	98
0.050	28	14	105
Significance ^a	L	NS	L,Q

^aLinear and quadratic orthogonal contrasts were performed to test the trend of different concentrations of Silwet: NS = nonsignificant; L, linear at $\alpha \leq 0.05$ level; and Q, quadratic at $\alpha \leq 0.05$ level.

Table 2. Effect of Silwet L-77 (0.05%) and volume of water applied on yellow pecan aphid populations in pecan trees.

Silwet L-77	Water applied (L/tree)	Aphids/terminal (% of pretreatment level)
Unsprayed control	0	152 a ^z
-	8	86 b
-	16	109 b
+	8	138 b
+	16	83 b

^zMean separation by Tukey's standardized range test, $\alpha \leq 0.10$.

block containing six blocks with one leaf section per experimental unit.

Expt. 5. Influence of Silwet L-77 on gas exchange rates. Foliar sprays of Silwet L-77 were assessed for impact on gas exchange of orchard trees. Branches of individual 'Desirable' pecan trees were treated with one of 11 concentrations [0%, 0.015%, 0.031%, 0.061%, 0.125%, 0.25%, 0.5%, 1.0%, 2.0%, 4.0%, and 8.0% (v/v)] of Silwet L-77. Experimental design was a randomized complete block using eight blocks (trees), with Silwet L-77 applied to runoff to branches within the tree using a backpack-type sprayer. Gas exchange was measured immediately before application and again 1, 8, and 14 days post-treatment. These post-treatment readings were indexed to their pretreatment levels. Net photosynthesis (*A*) and stomatal conductance (*g_{sw}*) were determined on apical leaflets using a LI-COR 6200 portable photosynthetic system with a 0.25 L leaf chamber (LI-COR, Lincoln, Neb.). Gas exchange measurements were taken from apical leaflets that were fully exposed to the sun between 9:30 AM until about solar noon at light levels $>1200 \mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ and at ambient atmospheric CO₂ levels (about 340–380 mg·L⁻¹). Leaf temperature typically increased $<0.2^\circ\text{C}$ during the measurement period, while relative humidity and CO₂ levels dropped $<2\%$ and 40 mg·L⁻¹, respectively, within the leaf chamber.

Results

Expt. 1. Efficacy of Silwet L-77 on aphids. Both concentrations of Silwet L-77 at 934 L·ha⁻¹ reduced the population of adult blackmargined aphids by 20% (Table 1). Although the lower rate suppressed adult black aphid populations about 50%, the higher rate had no effect. Suppression of nymphs was about 40% at both concentrations. Treatments did not appear to selectively kill nymphs over adults.

Expt. 2. Effects of air blast application and volume of water applied. Air-blast sprays of either 8 or 16 L of water per tree, alone or with Silwet at 0.05%, suppressed yellow pecan

aphid populations in comparison with the unsprayed control ($\alpha \leq 0.10$; Table 2). However, Silwet L-77 was no more effective than water alone.

Expt. 3. Comparison of a range of concentrations of Silwet L-77. When Silwet L-77 was applied at substantially higher rates as an air-blast spray at 934 L·ha⁻¹, the response curve for aphid population suppression was sigmoidal, with the population being greatly reduced at $\geq 0.8\%$ (Fig. 1). Silwet at 0.05% reduced aphids by only 4% compared with the water control at 8 or 16 L per tree. However, a 0.10% concentration reduced the population 35%. Suppression of the aphid population by $>95\%$ required Silwet concentrations $>0.04\%$. Under the conditions of this study, air-blast spraying with water alone suppressed aphid populations by 8% as compared to the unsprayed check. Inspection of the orchard floor beneath sprayed trees shortly after spraying and again the next day revealed no dead or dying lady beetles or lacewings, although these insects were found within the canopy of treated trees. Silwet L-77 therefore appears to have little or no adverse effects on adults or larvae of these important insects.

Expt. 4. Residual activity of Silwet L-77 on

Discussion

The "super wetter," Silwet L-77, a non-ionic organosilicone surfactant, suppresses surface tensions far below that achieved by conventional surfactants (Loveland Industries, 1993). Since it is capable of entering the stomatal cavity of foliage (Field and Bishop, 1988), this characteristic may be involved in the observed suppression of gas exchange rates on pecan. Although they tested no organosilicones, Lownds and Bukovac (1989) observed an increase in ethylene production from apple and sour cherry foliage when evaluating non-ionic surfactants. Since ethylene can suppress photosynthesis, it may also be linked to the suppression observed in the present study.

These data indicate that the use of Silwet L-77 for pecan aphid control at the 0.05% rate occasionally used in commercial orchards appears to provide only a slight level of suppression of aphid populations above that provided by the water alone. Doubling the volume of water being applied per tree did not overcome the low efficacy at this concentration. These data indicate that air-blast sprays of 0.05% Silwet L-77 are likely to be of little

Fig. 1. Efficacy of Silwet L-77, a non-ionic organosilicone surfactant, against yellow pecan aphid populations on orchard trees. Trees were treated with air-blast sprays of surfactant (v/v) mixed with water (934 L·ha⁻¹) and rated for aphid survival 24 h later. The sigmoid response curve ($r^2 = 0.94$) was: $y = a + b/(1 + \exp(-(x-c)/d))$, where $a = 6.40$, $b = 1141$, $c = -0.47$, and $d = -0.16$. Means of the unsprayed control and the air-blast + water control differed at the $\alpha \leq 0.001$ level.

Table 3. Mean percentage of yellow pecan aphids surviving on leaf discs following application of Pydrin or Silwet L-77.^a

Chemical treatment	Concn	Percentage of yellow pecan aphids		
		1 day	2 days	4 days
None (unsprayed control)	---	95 a ^z	98 a	95 a
Pydrin 2.4 E	0.35 g L ⁻¹	5 b	0 b	0 b
Silwet L-77	0.01%	93 a	100 a	97 a
Silwet L-77	0.03%	95 a	95 a	100 a
Silwet L-77	0.06%	90 a	100 a	97 a

^aMean separation by Tukey's Standardized Range Test, $\alpha \leq 0.001$.

practical benefit for controlling aphids in pecan orchards, while imparting up to a 5% suppression in A and g_{sw} .

Conversely, these data indicate that air-blast sprays of 0.10% Silwet L-77 would likely suppress aphid populations to about 76% of the unsprayed population within 1 day post-treatment, whereas a 92% reduction would be achieved using the 0.80% solution. Silwet L-77 did not appear to exhibit residual activity on aphid survival. It appears that death results from contact with the surfactant at the time of spraying or before drying of the spray. Since aphids are not particularly mobile, spray coverage will play a major role in the ability of Silwet L-77 to suppress aphid populations. Since both the 0.10% or 0.80% levels appear to suppress photosynthesis about 10% up to at least 14 days post-treatment, usage at these concentrations may adversely affect physiological processes and ultimately nut yields. Return flowering is highly sensitive to dormant season carbohydrate reserves (Worley, 1979); therefore, the suppression of gas ex-

change could possibly be yield limiting if trees are repeatedly sprayed with Silwet L-77 during the growing season. The sigmoid dose-response curve indicates that a concentration of about 0.30% would be nearly as effective against aphids as would much higher levels and would have less negative impact on gas exchange than higher levels. However, these data indicate that air-blast sprays of Silwet L-77 at about 0.3% (v/v) delivered at 934 L ha⁻¹ substantially suppress blackmargined and yellow pecan aphid populations (and probably black pecan aphids). This strategy could unfortunately reduce A and g_{sw} up to about 10% for 1 to 7 days post-treatment; therefore, extensive repetitive applications might adversely affect nut yields. While this reduction in gas exchange is undesirable, usage of most standard pesticides to control pecan aphids typically results in an equal or greater decline in gas exchange (Wood and Payne, 1986); hence, the decline caused by Silwet L-77 may not be of much practical concern.

Since leaf surface structure can influence leaf wetting by surfactants (Wirth et al., 1991) and since pecan surface structures vary with cultivar type (Grauke et al., 1987; Wetzstein and Sparks, 1983), efficacy against aphid pests may vary depending upon type of surface structure. For example, cultivars possessing rough surfaces with epicuticular wax crystals are difficult to wet (Wirth et al., 1991); therefore, aphid contact with the surfactant solution may vary and subsequently influence aphid mortality.

The exceptionally low surface tension of this agent and its ability to penetrate minute cavities, such as stomata, raises the possibility of using low concentrations of Silwet L-77 to aid the infection of aphid populations with biological control agents (i.e., bacterial, viral, fungal, etc.). Similar strategies have been considered concerning biological weed control (Zidack et al., 1992) and may also have potential in the control of pecan aphids.

Usage of Silwet L-77 at the 0.3% level would appear to be merited in many commercial operations when aphid levels are rapidly increasing and there is need for suppression without resorting to traditional pesticides. Such agents typically cause adverse and harsh side-effects on the orchard ecosystem. While Silwet L-77 suppresses aphids, its effects on beneficial arthropods are not yet clear and therefore merit further investigation. Subjective obser-

vations indicated that Silwet L-77 sprays <2% had little or no influence on adults and larvae of lady beetles or green lacewings, both types of insects being of substantial potential importance in the biological control of aphids.

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Fig. 2. Influence of different concentrations of an organosilicone surfactant, Silwet L-77, on net photosynthesis (A) and stomatal conductance (B) of mature pecan foliage 1, 8, and 14 days after a single spray application. Application was by a backpack sprayer until runoff.