SILWET L-77 IMPROVES THE EFFICACY OF HORTICULTRAL OILS FOR CONTROL OF BOISDUVAL SCALE *DIASPIS BOISDUVALII* (HEMIPTERA: DIASPIDIDAE) AND THE FLAT MITE *TENUIPALPUS PACIFICUS* (ARACHNIDA: ACARI: TENUIPALPIDAE) ON ORCHIDS

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ABSTRACT

Pest management of insects and mites on orchids has been based on the use of synthetic organic pesticides. However, less-toxic chemical control is needed by hobbyists and small growers. Orchids from 8 genera were treated with Silwet L-77 alone and no evidence of phytotoxicity was seen. Subsequently, 3 petroleum oils in combination with Silwet L-77 were tested to determine efficacy in suppressing Boisduval scale *Diaspis boisduvalii* Signoret (Hemiptera: Diaspididae) and the flat mite *Tenuipalpus pacificus* Baker (Arachnida: Acari: Tenuipalpidae). The results indicate Silwet L-77 increased toxicity of the oils and increased removal of the scales and mites from foliage over oil alone, yet no phytotoxicity was observed in any of the plants treated. Petroleum oil + Silwet L-77 is considered low-toxic, may be less expensive than some pesticides, and may conserve natural enemies, making it a potential addition to an integrated pest management program for orchids.

Key Words: Silwet L-77, petroleum oils, orchids, *Diaspis boisduvalii, Tenuipalpus pacificus,* pest management

RESUMEN

Manejo de plagas de insectos y ácaros en orquídeas ha sido basado en el uso de pesticidas organicos sintéticos. Sin embargo, los pequeños agricultores y los aficionados necesitan químicos de control menos tóxicos. Las orquídeas de 8 diferentes géneros fueron tratadas con solamente Silwet L-77 y ningúna evidencia de fitotóxicidad fue observada. Subsiguientemente, 3 clases de aceite de petroleo en combinación con Silwet L-77 fueron probados para determiner su eficacia en suprimir la escama, *Diaspis boisduvalii* Signoret (Hemiptera: Diaspididae), y el ácaro plano, *Tenuipalpus pacificus* Baker (Arachnida: Acari: Tenuipalpidae). Los resultados indican que Silwet L-77 aumentó la toxicidad de los aceites y la eliminación de escamas y acaros del follaje en comparición con el uso solo de aceite, además no fitotóxicidad fue observada en ninguna de las plantas tratadas. El aceite de petroleo + Silwet L-77 es considerado menos tóxico, y posiblemente menos costoso que algunos pesticidas, y puede conservar los enemigos naturales, esto crea una adición potencial para un programa de manejo de plagas integrado para las orquídeas.

The Orchidaceae is believed to be the largest family of flowering plants (Bechtel et al. 1992; Dressler 1993; Tsavkelova et al. 2008) with approximately 19,000 named species (Atwood 1986; Dressler 1993). Orchids are the second most economically important flowering plant produced in the United States and sales continue to grow (Jerardo 2006). As orchid popularity continues to grow, so will the desire for pest and disease information, as illustrated in the question and answer section of *Orchids* magazine published by the American Orchid Society, which frequently contains questions submitted by hobbyists and commercial growers concerning the identification and control of orchid pests and diseases. Common arthropod pests of orchids that can be difficult to control include the Boisduval scale *Diaspis boisduvalii* Signoret (Hemiptera: Diaspididae) and several species of mites.

Boisduval scale is one the most important orchid pests and can be difficult to control with traditional chemical methods because females possess a hard covering (Hamon 2002; Johnson 2009). Boisduval scale is commonly introduced into an orchid collection on an infected plant and scales can move quickly to a variety of orchids (Johnson 2009). Mites also can be a major problem on cultivated orchids (Johnson 2008). Mite species that are known pests of orchids include the two-spotted spider mite (*Tetranychus urticae* Koch, Arachnida: Acari: Tetranychidae) and several flat mites (Tenuipalpidae) such as the orchid mite (*Tenuipalpus orchidarum* Parfitt), the phalaenopsis mite (*Tenuipalpus pacificus* Baker), and the oncidium mite (*Brevipalpus oncidii* Baker) (Johnson 2008).

Synthetic organic pesticides historically have been the primary tactic used in pest control on orchids, but many orchids, some of which are highly valuable or rare, exhibit phytotoxicity when treated with pesticides (Johnson 2008). Therefore, alternatives to traditional pesticides are desirable, especially for hobbyists and smaller orchid producers. In order to preserve as many natural enemies as possible and have the least impact on the environment and human health, more alternatives to traditional pesticides are needed. One alternative to traditional pesticides is Silwet L-77, an organosilicone surfactant.

Surfactants commonly are used in agriculture to increase the wettability and spread of herbicides or pesticides on plants, and thus improve control of the target pest or weed (Tu et al. 2001). Silwet L-77 has been shown to increase the effectiveness of limonene for the control of mealybugs (*Pseudococcus longispinus* Targioni-Tozzetti) by reducing the surface tension around their wax-covered bodies (Hollingsworth 2005). Tipping et al. (2003) demonstrated that Silwet L-77 alone is toxic to Pacific spider mite eggs (*Tetranychus pacificus* McGregor), grape mealybug crawlers (*Pseudococcus maritimus* Ehrhorn), western flower thrips (*Frankliniella occidentalis* Pergande), and cotton aphid (*Aphis gossypii* Glover). In addition, Silwet L-77 alone is toxic to nymphs of the Asian citrus psyllid (*Diaphorina citri* Kuwayama) and can significantly increase mortality of *D. citri* eggs when applied with one-fourth the label rates of imidacloprid or abamectin and mortality of adults when applied using one-fourth or one-half the label rate of imidacloprid (Srinivasan et al. 2008). Silwet L-77 also can increase the efficacy of fungicides. Silwet L-77 or another surfactant (Kinetic) improved the activity of the protectant fungicide maneb using potato early blight or dry bean rust as model systems (Gent et al. 2003). Thus, the addition of Silwet L-77 as an adjuvant to chemical pesticides has been shown to increase their efficacy, even at lower-than-label rates.

The objectives of this study were to (1) determine if Silwet L-77 can be used without causing phytotoxicity to 8 commonly cultivated orchid genera, and (2) determine if Silwet L-77 can increase the effectiveness of 3 horticultural oils against Boisduval scale (*Diaspis boisduvalii)* and the flat mite (*Tenuipalpus pacificus*) on orchids.

Materials and Methods

Phytotoxicity Study

Representatives of 7 commonly cultivated orchid genera obtained from commercial orchid growers in south Florida were used: *Doritaenopsis* Luchia Lip 'Sog. F714' X Han-Ben 'Girl RL' in 10.2-cm pots, *Cymbidium* Golden Elf in 15.2-cm pots, *Dendrobium* cultivars Blue Sampran, Burana Stripe, Lady Pink, Lena Pink, Pegasus, and Salaya Fancy, all in 10.2-cm pots, *Epidendrum* mericlones in 10.2-cm pots, *Oncidium* KBR in 10.2-cm pots, *Paphiopedilum* Maudiae types in 10.2-cm pots, and *Cattleya* mericlones in 10.2-cm pots. Plants received pre- and post-spray ratings based on overall vigor, color, and presence/absence of spots or necrotic areas on leaves, stems, flowers, or flower buds. Plants received a quality rating on a scale from 1 to 10, with 10 being undamaged and 1 being so severely damaged that the plant could not be sold. Plants were watered and fertilized as per commercial practice for each type of orchid.

Plants were treated within 1 h of the pre-spray assessment. Treatments consisted of a water control or Silwet L-77 (99.5% polyalkyleneoxide modified heptamethyltrisiloxane, Helena Chemical Co.) at 0.05% (v:v) and the number of replicates of each orchid type is shown in Table 1. Plants, including inflorescences, were sprayed twice at 7-d intervals with hand sprayers until completely covered and assessed for phytotoxicity damage 1 week after the second spray. Plants (pre- and post-spray) were kept in a greenhouse at the Department of Entomology and Nematology, University of Florida, Gainesville, FL at temperatures ranging from 21.0 to 35.0°C and 45 to 95% RH and 16L:8D photoperiod from the time the plants were obtained until the end of the experiment. Statistical analysis was performed with the PROC GLM procedure in SAS (SAS Institute 2002) to compare the pre-spray rating with the control, and the post-spray rating with the control. Levene's test for homogeneity of variance was performed (Hill & Lewicki 2006).

Silwet + Oil Efficacy Trial (Boisduval Scale)

A commercial *Cattleya* orchid grower in central Florida with a heavy Boisduval scale infestation participated in the efficacy trial. Thirty *Cattleya* orchid hybrids and mericlones in 15.2-cm pots were selected based on size and severity of scale infestation (200+ female scales per plant and nymphs and males were so abundant that much of the foliage appeared white). Pre- and post-spray assessments were performed 2 ways: (1) The density of female scales present was estimated according to the following scale: 0: 0 scales; 1: 1-20 scales; 2: 21-40 scales; 3: 41-60 scales; 4: 61-80 scales; 5: 81-100 scales; 6: 101-120 scales; 7: 121-140 scales; 8: 141-160 scales; 9: 161-180 scales, 10: 181-200+ scales. (2) Mortality was calculated by examining 10 randomly chosen female scales remaining on each plant after the post-spray assessment. Each scale was examined with

TABLE 1. PRE-SPRAY AND POST-SPRAY QUALITY RATINGS (RANGE = 1-10) OF ORCHIDS USED IN THE PHYTOTOXICITY STUDY.

Orchid genera tested	Treatment	*N*	Mean pre-spray quality rating ±SE[a]	*P*	Mean post-spray quality rating ±SE[a]	*P*
Dendrobium hybrids						
	Water	10	7.9 ± 0.4	0.27	8.1 ± 0.3	0.74
	Silwet	10	7.3 ± 0.4		7.9 ± 0.2	
Oncidium KBR 456						
	Water	10	8.1 ± 0.2	0.55	8.3 ± 0.2	0.66
	Silwet	10	8.3 ± 0.2		8.4 ± 0.2	
Doritaenopsis hybrids						
	Water	10	7.2 ± 0.1	0.78	8.0 ± 0	1.00
	Silwet	7	7.1 ± 0.1		8.0 ± 0	
Paphiopedilum maudiae type						
	Water	7	5.6 ± 0.3	0.16	6.0 ± 0.4	0.84
	Silwet	8	6.1 ± 0.2		6.0 ± 0.3	
Epidendrum MC						
	Water	10	6.5 ± 0.3	0.88	7.2 ± 0.2	0.28
	Silwet	7	6.5 ± 0.2		6.7 ± 0.2	
Cymbidium Golden Elf						
	Water	10	7.8 ± 0.1	0.63	7.9 ± 0.1	1.00
	Silwet	10	7.7 ± 0.2		7.9 ± 0.1	
Cattleya MC						
	Water	3	6.3 ± 0.3	0.37	6.7 ± 0.8	0.12
	Silwet	3	6.0 ± 0		6.0 ± 0	

[a]Means were analyzed with the PROC GLM procedure of the SAS software program. Levene's test for homogeneity of variances showed equal variances within each orchid genus. Plant received a quality rating on a scale from 1 to 10, with 10 being undamaged and 1 being so severely damaged that the plant could not be sold.

a hand lens to determine if it was alive or dead. Female scales were used in both assessments because males tend to cluster, making them difficult to count.

Two separate trials were conducted. In the first trial, 2% (v:v) petroleum oil 435 (Growers 435, Growers Fertilizer Co., Lake Alfred, FL) was used and in the second trial 1% (v:v) Prescription Treatment Ultra-Fine Oil (Whitmire Micro-Gen Research Laboratories, Inc., St. Louis, MO) was used. Thirty *Cattleya* orchids were selected as described above and used in each trial (10 water controls, 10 oil treatments and 10 oil + 0.05% (v:v) Silwet treatments). Because Silwet L-77 is not labeled for use as a pesticide, it was only used in combination with petroleum oil. Plants were sprayed to run-off using a 3.8-L pump sprayer (H. D. Hudson Manufacturing Company, Hastings, MN). Plants were treated within 1 h of the pre-spray assessment. Plants were kept in a greenhouse at 18.0 to 27.0°C and 60-80% RH. Plants in each trial were treated once a week for 2 weeks and the post-spray assessment was done 1 week after the second treatment. Each trial was performed twice.

Silwet + Oil Efficacy Trial (Flat Mite)

Two types of orchids (*Grammatophyllum* and *Dendrobium)* that were infested with flat mites were obtained from 2 commercial orchid growers in south Florida. Samples were sent to the Florida Division of Plant Industry, Gainesville, Florida for species identification and were confirmed to be *Tenuipalpus pacificus*. Pre-spray assessments of mite densities were performed by randomly selecting a single leaf of each plant and counting the number of adult mites present. The leaf was marked and the same leaf was used in the post-spray assessment.

Nine *Grammatophyllum* orchids in 15.2-cm baskets or 9 *Dendrobium* orchids in 10.2-cm pots were used in the efficacy trial and consisted of 3 water controls, 3 oil treatments (Prescription Treatment Ultra-pure Oil, Whitmire Micro-Gen Research Laboratories, Inc., St. Louis, MO) and 3 oil (Prescription Treatment Ultra-pure) + 0.05% (v:v) Silwet treatments. Plants were sprayed to run-off with a 3.8-L pump sprayer (H. D. Hudson Manufacturing Company). Plants were treated within 1 h of the pre-spray assessment.

Plants (pre- and post-spray) were kept in a greenhouse at the Tropical Research and Education Center, University of Florida, Homestead, FL, under 50% shade with temperatures ranging from 18 to 30.5°C and 45-80% RH. Post-spray assessment was performed 24 h after spraying. The *Dendrobium* trial was repeated once but, due to a lack of infested plants, the *Grammatophyllum* trial was not repeated.

Statistical analysis for the Boisduval trial and the flat mite trial was performed by the PROC GLM procedure in SAS (SAS Institute, 2002) and treatment means were separated with Fisher's LSD test. Levene's test for homogeneity of variance was performed (Hill & Lewicki 2006).

Results

Phytotoxicity Study

No evidence of phytotoxicity (burning, chlorosis, spots, or other types of lesions) was observed on any of the 7 orchid genera tested in this study including leaves, stems, inflorescences or roots and there was no significant difference between the pre- and post-spray quality ratings (Table 1). Of the 117 orchids (all genera) used in the phytotoxicity study, 114 received the same rating or better after treatment with Silwet L-77, while 3 of the orchids received a reduced rating. Of these 3, two were water controls (ratings reduced from 9 to 8.5 and 6 to 5) and 1 was treated with Silwet L-77 (7 to 6.5).

Silwet + Oil Efficacy Trial (Boisduval Scale)

When applied at a rate of 0.05% (v:v), Silwet L-77 significantly increased the efficacy of the 435 light horticultural oil (experiment 1a: $P < 0.0001$, experiment 1b: $P < 0.0001$) and the Prescription Treatment Ultra-Fine oil (experiment 2a: $P < 0.0001$, experiment 2b: $P < 0.0001$) in reducing Boisduval scale populations on the *Cattleya* orchids in each experiment under the described conditions (Table 2). No phytotoxicity on leaves, flowers, flower buds, or roots (data not shown) was observed in these experiments.

Mortality of female Boisduval scale was increased with the addition of 0.05% Silwet L-77 to each oil in each experiment and ranged from 86 to 93%, which is significantly better than the oil alone (39 to 47%) or the water control (2% to 8%) ($P < 0.0001$) (Table 2).

Silwet + Oil Efficacy Trial (Flat Mite)

Silwet L-77 significantly improved the efficacy of the Prescription Treatment Ultra-Pure oil in reducing the number of flat mites on *Dendrobium* orchids in both experiments (experiment 4a: $P = 0.0017$, experiment 4b: $P < 0.0001$) (Table 3). However, there was no significant difference between the oil or oil + Silwet L-77 treatments when used to treat *Grammatophyllum* orchids for flat mite infestations, although the oil alone and the oil + Silwet L-77 treatments were both significantly better than the water control (experiment 3: $P < 0.0001$).

Discussion

The results show that the addition of 0.05% Silwet L-77 to petroleum oil 435, Prescription Treatment Ultra-fine oil, or Prescription Treatment Ultra-pure oil significantly increased the efficacy of these oils against the Boisduval scale and the flat mite. Previous research has demonstrated that Silwet L-77 alone is toxic to several other important arthropod pests (Tipping et al. 2003; Cowles et al. 2000; Hollingsworth 2005; Wood et al. 1997; Liu and Stansly 2000; Imai et al. 1995; Purcell and Schroeder 1996; Srinivasan et al. 2008; Cocco and Hoy 2008). This study demonstrates, for the first time, that Silwet L-77 could be an important management tool to increase the efficacy of oil against Boisduval scale and the flat mite on orchids. The reason for the increased efficacy is not clear. Silwet L-77 greatly reduces the surface tension of water, allowing it to infiltrate plant leaf stomata (Neumann & Prinz 1974) and hydathodes (Zidack et al. 1992). It is plausible that this reduction in surface tension of water around the body of an arthropod may allow an infiltration of water into the spiracles, drowning the arthropod (Cowles et al. 2000; Shapiro et al. 2009).

In the present study, three petroleum oils were used. After the initial work with the 435 light horticultural oil, the study was repeated with oil labeled for use on orchids, the Prescription Treatment Ultra-Fine oil. Upon completion of the experiments with the Ultra-Fine oil, we were informed by the manufacturer that it would no longer be available, but a replacement, Prescription Treatment Ultra-Pure oil, was available. The addition of 0.05% (v:v) Silwet L-77 significantly increased the efficacy of all 3 oils tested against the Boisduval scale on *Cattleya* orchids or the Ultra-Pure oil against the flat mite on *Dendrobium* orchids when compared to the water control.

There was no significant difference between the oil alone and the oil + Silwet L-77 treatment when treating *Grammatophyllum* orchids for flat mite infestations, perhaps due to the fact that *Grammatophyllum* orchids have large, thin leaves that show very little pitting as a result of feeding by the flat mite. In contrast, *Dendrobium* orchids have smaller, thicker leaves that produce deep pitting from flat mite feeding, and flat mites are often located in these pits. Because pitting of the *Grammatophyllum* orchid foliage was very superficial, the mites were easily removed by both

TABLE 2. EVALUATION OF SILWET L-77 (0.05%) IN COMBINATION WITH 2 OILS FOR CONTROL OF BOISDUVAL SCALE INFESTATIONS IN CATTLEYA MERICLONE ORCHIDS.

		Mean pre-spray rating of scale density[a]	Mean post-spray rating of scale density ±SE[ac] Scale mortality (%) ±SE[bc]			
Date, environmental conditions at time of treatment, and type of oil used	*n*	Scale mortality (%)	Water	Oil	Silwet + Oil	*P*
Exp. 1a, Sep 22, 2007. 25.5°C, 64% RH. Petroleum Oil 435 (2%)	30	10.0	10.0 ± 0 a	8.4 ± 1.1 a	3.7 ± 0.7 b	<0.0001
		0	2.0 ± 2.0 a	44.0 ± 10.8 b	93.0 ± 5.0 c	<0.0001
Exp. 1b, Oct 27, 2007. 24.4°C, 62% RH. Petroleum Oil 435 (2%)	30	10.0	10.0 ± 0 a	6.2 ± 0.6 b	1.8 ± 0.4 c	<0.0001
		0	8.0 ± 2.9 a	47.0 ± 3.7 b	86.0 ± 5.0 c	<0.0001
Exp. 2a, Nov 10, 2007. 25.5°C, 70% RH. Prescription Treatment Ultra Fine Oil (1%)	30	10.0	9.8 ± 0.1 a	8.7 ± 0.3 b	2.2 ± 0.4 c	<0.0001
		0	3.0 ± 2.1 a	39.0 ± 4.8 b	89.0 ± 6.6 c	<0.0001
Exp. 2b, Nov 26, 2007. 25.0°C, 62% RH. Prescription Treatment Ultra Fine Oil (1%)	30	10.0	9.7 ± 0.2 a	7.3 ± 0.2 b	1.4 ± 0.2 c	<0.0001
		0	2.0 ± 1.3 a	46.0 ± 3.1 b	91.0 ± 2.3 c	<0.0001

[a]Assessment rating of scale density based on number of female scales present. 0: 0 scales; 1: 1-20 scales; 2: 21-40 scales; 3: 41-60 scales; 4: 61-80 scales; 5: 81-100 scales; 6: 101-120 scales; 7: 121-140 scales; 8: 141-160 scales; 9: 161-180 scales, 10: 181-200+ scales.

[b]Mortality was calculated by randomly selecting 10 remaining scales on each plant and determining if they were alive or dead with a metal probe and a hand lens.

[c]Treatment means were analyzed with the PROC GLM procedure and means separated by Fishers' LSD with P = 0.05. Levene's test for homogeneity of variance was performed. Treatments with the same letter within a row are not significantly different from each other.

TABLE 3. EVALUATION OF SILWET L-77 (0.05%) IN COMBINATION WITH PRESCRIPTION TREATMENT ULTRA PURE OIL FOR CONTROL OF FLAT MITE (*TENUIPALPUS PACIFICUS*) INFESTATIONS IN *DENDROBIUM* OR *GRAMMATOPHYLLUM* ORCHIDS.

Type of orchid used and environmental conditions at time of treatment	*N*	Mean % mites removed ±SE after 24 h[a]			
		Water	Oil	Silwet + Oil	*P*
Experiment 3. *Grammatophyllum* orchids. Jan 11, 2009. 30.5°C, 49% RH	9	27.7 ± 5.8 a	94.8 ± 2.7 b	98.7 ± 1.3 b	<0.0001
Experiment 4a, *Dendrobium* orchids. Jan 14, 2009. 20.8°C, 53% RH	9	25.5 ± 2.2 a	65.4 ± 0.6 b	98.8 ± 1.2 c	0.0017
Experiment 4b, *Dendrobium* orchids. Jan 22, 2009. 24.5°C, 60% RH	9	19.6 ± 1.6 a	38.1 ± 1.9 b	98.4 ± 1.6 c	<0.0001

[a]Treatment means were analyzed with the PROC GLM procedure and means separated by Fishers' LSD with P=0.05. Levene's test for homogeneity of variance was performed. Treatments with the same letter within a row are not significantly different from each other.

oil or oil + Silwet, whereas the addition of the Silwet L-77 to oil appeared to better penetrate into pits containing flat mites on the *Dendrobium* leaves, removing them. Due to the lack of available *Grammatophyllum* orchids infested with mites, the experiment was only performed once and should be repeated.

It was discovered after experiment 1a that the addition of oil to Silwet L-77 not only increased mortality of Boisduval scale, but also removed them from the plant. This property could be beneficial where tolerance for arthropod infestations is essentially zero and plants are sold and appreciated based on aesthetic value (Bethke & Cloyd 2009). However, as suggested by Tipping et al. (2003) and Liu & Stansly (2000) it is essential that 100% coverage is achieved to obtain adequate control.

Tipping et al. (2003) demonstrated that Silwet L-77 alone increased mortality of Western flower thrips, Pacific spider mite, and cotton aphid, (≥93.8%), but 100% mortality was not achieved, possibly due to lack of complete coverage. Liu & Stansley (2003) suggest that complete coverage is necessary for good control due to contact activity. For orchids, this includes the abaxial and adaxial leaf surfaces, stems, pseudobulbs, inflorescences, under sheaths (*Cattleya* orchids), and possibly the roots. This requirement may preclude the use of oil + Silwet L-77 by large commercial orchid growers where pesticides are generally delivered to large groups of plants by irrigation or by large overhead booms, which may make it difficult obtain complete coverage. In addition, because there is no residual activity, re-applications may be necessary to obtain acceptable control.

Several caveats must be considered before using Silwet L-77 + petroleum oil to treat arthropod infestations in orchids. Although no evidence of phytotoxicity was observed in any of the orchids used in these tests, it is possible that other genera, intergeneric hybrids, or certain cultivars may be susceptible to phytotoxicity. It is recommended that growers check a representative of the plants to be treated for signs of phytotoxicity before extending treatment to large groups of plants. In addition, environmental conditions may play a role in phytotoxicity, so label recommendations for the oil should be followed. Humidity also may be important for increased efficacy and should be taken into consideration. Liu & Stansly (2003) suggest that environmental conditions (drying) may affect efficacy, and Imai et al. (1995) demonstrated that the toxicity of Silwet L-77 to the green peach aphid *Myzus persicae* (Sulzer) increased from 23.8% ± 7.2 at 30% RH to 99.3% ± 0.46 at 90% RH.

Gottwald et al. (1997) suggested that an adjuvant, such as Silwet L-77, may increase the incidence of bacterial diseases. The decrease in water tension could allow entry sites for plant pathogenic bacteria into leaf stomata (Melotto et al. 2008), which may allow bacteria to gain entry and cause infection (Gottwald et al. 1997; Zidack et al. 1992). However, no bacterial diseases were observed on any of the orchids tested throughout this study. This could be due to the absence of bacteria or lack of a conducive environment, so caution should be exercised if it is known that pathogens are present or there is a history of bacterial infections.

There are several advantages to using oil + Silwet L-77 to control orchid arthropod pests. No arthropod is known to have developed resistance to petroleum oil (M. A. Hoy, Dept. Entomology, University of Florida, personal communication). Therefore, Silwet L-77 could be used as an adjuvant with petroleum oils to increase their effectiveness with the development of resistance a minimal concern (Butler et al. 1993). Also, the use of a petroleum oil with the addition of Silwet L-77 is safer and may be less expensive than some pesticides (Liu and Stansly 2000) and may assist in the conservation of natural enemies, one of the goals of an integrated pest management program. Wood & Tedders (1997) noted that Silwet L-77 had little or no effect on adults or larvae of lady beetles and green lacewings, suggesting that Silwet L-77 could be an important tool for an integrated pest management program.

We conclude that Silwet L-77 increases the efficacy of oil against Boisduval scale and the flat mite on orchids. Because complete coverage is required, its use may be most relevant to hobbyists or small commercial growers who want to use a chemical control with reduced toxic effects on non-target organisms, the environment, and human health.

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