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SAFETY OF A NOVEL INSECTICIDE, SUCROSE OCTANOATE, TO BENEFICIAL INSECTS IN FLORIDA CITRUS

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ABSTRACT

Laboratory trials were used to estimate the toxicity of sucrose octanoate to beneficial insects representing four insect orders of importance in biological control in Florida citrus. First instars of the ladybeetles *Cycloneda sanguinea* L., *Curinus coeruleus* Mulsant, *Harmonia axyridis* Pallas and *Olla v-nigrum* Mulsant (Coleoptera: Coccinellidae) and the lacewing *Chrysoperla rufilabris* Burmeister (Neuroptera: Chrysopidae) survived topical sprays of sucrose octanoate at 8,000 ppm without significant mortality, a concentration corresponding to twice the recommended field rate required to kill aphids and other soft bodied pests. Similarly, adults of the red scale parasitoid, *Aphytis melinus* De Bach (Hymenoptera: Aphelinidae) and second instars of the predatory bug *Orius insidiosus* (Say) (Hemiptera: Anthocoridae) survived 24 h exposures to residues of 8,000 ppm sucrose octanoate on leaf disks without significant mortality. The efficacy of sucrose octanoate as a contact insecticide against various homopteran pests of citrus, combined with its low toxicity to key beneficial insects in the citrus ecosystem, suggest that it may be a valuable material for incorporation into IPM programs for Florida citrus.

Key Words: *Aphytis melinus*, *Curinus coeruleus*, *Cycloneda sanguinea*, *Harmonia axyridis*, *Olla v-nigrum*, *Orius insidiosus*, sucrose octanoate

RESUMEN

Pruebas de laboratorio fueron usadas para estimar la toxicidad de octanoate de sucrosa para insectos benéficos representantes de cuatro ordenes. Larvas de primer estadió de los cocinelidos *Cycloneda sanguinea* L., *Curinus coeruleus* Mulsant, *Harmonia axyridis* Pallas y *Olla v-nigrum* Mulsant y el crisópido *Chrysoperla rufilabris* Burmeister sobrevivieron asperciones topicales de octanoate de sucrosa en dosis de 8,000 ppm sin mortalidad significativa, una concentración corespondiente al doble de la dosis necesaria para matar áfidos y otras plagas homópteras en cítricos. En forma parecida, adultos del parásitoide de la escama roja, *Aphytis melinus* De Bach (Hymenoptera: Aphelinidae) y ninfas de segundo estadió de *Orius insidiosus* (Hemiptera: Anthocoridae) sobrevivieron sin mortalidad significativa un periodo de 24 h expuestos a dosis residuales de octanoate de sucrosa de 8,000 ppm aplicadas en discos de hoja. La eficacia del octanoate de sucrosa como insecticida de contacto contra varias plagas homópteras de cítricos, en combinación con su toxicidad baja contra insectos benéficos en el ecosystema citrícola, sugiere que este material puede ser valioso para inclusión en programas de IPM en cítricos en la Florida.

Translation provided by author

One of the challenges of insect control with pesticides in agricultural IPM programs is achieving selection and kill of target pests while minimizing mortality to beneficial insects. However, phytophagous pest insects typically are more resistant to synthetic toxins than are predacious and parasitic insects due to the evolution of mechanisms for detoxification of plant secondary compounds (Croft 1990). This problem might be overcome by the development of more selective compounds with modes of action specific to pest insects, or by selective application techniques such as spot treatments that permit the survival of beneficial insects in untreated refuges. Effective IPM programs require, or are in need of, new materials with novel modes of action that can be applied in rotation with existing pesticides to avoid strong directional selection for resistance development in pest populations.

Sucrose octanoate is one of a series of synthetic sugar esters that are analogues of compounds naturally occurring in the glandular trichomes of wild tobacco, *Nicotiana gossei* Domin. Sugar esters, also known as acyl sugars or polyol esters, are a relatively novel class of insecticidal compounds produced by reacting sugars with ali-

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phatic or aromatic fatty acids (Puterka et al. 2003). Sucrose esters are benign to the environment, occur naturally in plants and are commercially synthesized for use in the food industry (Chortyk et al. 1996). The exudates of glandular trichomes of *N. gossei* have been known for many years to contain compounds with insecticidal activity (Thurston & Webster 1962). It was determined during the last decade that the primary insecticidal compounds within these glandular trichomes are sucrose esters (Buta et al. 1993, Pittarelli et al. 1993). Synthetic sucrose esters that are similar in structure to those that naturally occur in *N. gossei* have comparable insecticidal activity (Chortyk et al. 1996). Both natural and synthetic sucrose esters have been shown to have contact toxicity with very rapid knockdown of soft-bodied arthropods, including aphids (Neal et al. 1994), whiteflies (Liu et al. 1996) and psyllids (Puterka & Severson 1995). Feeding and ovipositional deterrence to mites (Neal et al. 1994), whiteflies (Liu & Stansly 1995) and leafminers (Hawthorne et al. 1992) also have been demonstrated with sucrose esters.

Although the mode of action is unknown, it has been suggested that sugar esters affect the insect cuticle causing death by rapid desiccation (Thurston & Webster 1962). Parr and Thurston (1968) observed that topical applications of *N. gossei* trichome exudates applied to larvae of *Manduca sexta* (L.) turned the cuticle transparent and caused rapid loss of body fluids followed by death. Similarly, Liu and Stansly (1995) observed that nymphs of the whitefly *Bemisia argentifolia* Perring and Bellows dried quickly and detached from the leaf surface when treated with *N. gossei* extracts.

McKenzie and Puterka (2000) demonstrated an LC_{90} (topical spray) for sucrose octanoate ranging from 4,000-7,360 ppm for nymphs of the Asian citrus psyllid, *Diaphorina citri* Kuwayama, an important disease vector in citrus. Other work has demonstrated good insecticidal activity against the brown citrus aphid, *Toxoptera citricida* (Kirkaldy) at even lower concentrations (McKenzie, unpublished data). Although the safety of sucrose esters for beneficial insects in citrus has not yet been examined, Stansly and Liu (1997) found that they had little or no effect on the whitefly parasitoid *Encarsia pergandiella* Howard. In order to ascertain the safety of sucrose octanoate for natural enemies in citrus, we selected candidate species for testing that represented four different orders of beneficial insects known to be important in biological control of homopteran pests, the primary targets of this material. *Aphytis melinus* De Bach (Hymenoptera: Aphelinidae) is a primary parasitoid of the California red scale. The green lacewing *Chrysoperla rufilabris* Burmeister (Neuroptera: Chrysopidae), and the insidious flower bug, *Orius insidiosus* (Say) (Hemiptera: Anthocoridae), are both generalist predators of many small arthropods in citrus, including mites, aphids, psyllids and thrips. We also tested four species of ladybeetles, *Curinus coeruleus* Mulsant, *Cycloneda sanguinea* L., *Harmonia axyridis* Pallas, and *Olla v-nigrum* Mulsant (Coleoptera: Coccinellidae) that are all important predators of homopteran citrus pests (Michaud 1999, 2002a; Michaud et al. 2002).

Materials and Methods

Adult beetles of each of the four coccinellid species were maintained in 1-L ventilated glass mason jars (~100-130/jar) filled with strips of shredded wax paper for their first 9-12 days of life following emergence. During this period, beetles were fed a diet of frozen eggs of *Ephestia* sp. and bee pollen with water provided on a cotton wick. Mated adult females were transferred to individual plastic Petri dishes (5.5 cm dia × 1.0 cm) and provisioned with *Ephestia* eggs and water encapsulated in polymer beads. Eggs were harvested daily in the Petri dishes and held in an incubator at 24°C, 60 ± 5% RH under fluorescent light (P:S-16:8) and hatched ca. 3.5 ± 0.5 days later under these conditions. Newly hatched larvae were placed in individual plastic Petri dishes (as above) and reared on *Ephestia* eggs and water beads on a laboratory bench at 24 ± 2°C, 60 ± 5% RH, with fluorescent lighting (P:S = 16:8). Larvae were used for experiments when they were 24 ± 6 h old.

Eggs of *C. rufilabris* were obtained from Beneficial Insectary (Redding, CA) and held in an incubator at 24 ± 1°C until hatching. Larvae used in experiments were 24 ± 6 h old.

Adult *A. melinus* were obtained from Rincon-Vitova Insectaries Inc. (Ventura, CA). Adults were fed a diluted honey solution and used in experiments when they were 36-60 h old.

Newly hatched nymphs of *O. insidiosus* were obtained from Entomos, LLC (Gainesville, FL). Nymphs were provided with frozen *Ephestia* eggs and water beads and used in experiments when they molted to the second instar.

Topical Sprays

The Potter Precision Spray Tower (Burkard Manufacturing Co. Ltd., Rickmansworth Herts, UK) permits delivery of a standardized dose of an insecticide at a specified concentration with a consistent droplet size under controlled conditions. The Potter tower has been used previously to determine the toxic concentrations of various conventional pesticides to beneficial insects in citrus (Michaud 2001, 2002b). First instars of each coccinellid species (n = 20) were treated directly with a 1.0-ml aqueous solution of sucrose octanoate at 8000 ppm. Control larvae (n = 20) were treated with 1 ml of distilled water. Larvae were reared to

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adulthood in individual Petri dishes (as above) on a diet of frozen *Ephestia* eggs. Estimates of mortality incorporated all mortality through to emergence of adults. Data were corrected for control mortality by Abbott's correction (Abbott 1925) and analyzed with a Chi-square, Goodness-of-fit Test ($\alpha = 0.05$).

Leaf Residues

Due to their high activity levels, adult parasitoids and *Orius* nymphs were exposed to leaf residues instead of topical sprays. Leaf disks were punched from clean grapefruit leaves that had been washed in a 0.5%-sodium hypochlorite solution. Adaxial sides of the leaf disks (n = 25) were then sprayed with a 1.0 ml-aqueous solution of sucrose octanoate at 8000 ppm in the Potter Spray Tower; control disks (n = 25) were sprayed with 1 ml distilled water. Treated leaf disks were placed in individual Petri dishes (5.0 cm dia × 1.0 cm) and insects were transferred individually to each dish.

Adult *A. melinus* were provided with a droplet of diluted honey on the lid of the Petri dish and mortality was assessed after 24 h. Nymphs of *O. insidiosus* were confined on the leaf disks for 24 h, removed to clean dishes, and reared to adulthood on a diet of frozen *Ephestia* eggs and water beads. The mortality estimate for *O. insidiosus* incorporates all mortality from nymph through adult stage. Data from all experiments were adjusted for control mortality by Abbott's correction (Abbott 1925) and analyzed by a Chi-Square, Goodness-of-Fit test ($\alpha = 0.05$).

Results and Discussion

Treatment mortality was never significantly different from control mortality for any species of beneficial insect in any trial (Table 1). The fact that sugar esters seem to have active toxicity only in liquid form (Puterka & Severson 1995) may have influenced the results obtained for *O. insidiosus* and *A. melinus* with leaf disk residues. Yet these authors showed residual activity to newly eclosed nymphs. Contact with residues is probably the primary form of exposure for foraging natural enemies, so the lack of activity is significant. Similarly, Stansly and Liu (1997) found low toxicity of natural and synthetic sugar esters to *E. pergandiella*, an important parasitoid of the silverleaf whitefly, and concluded that these materials would be compatible with biological control of *B. argentifolia* in vegetable fields.

Materials demonstrating toxicity to beneficial insects in laboratory trials warrant further testing under field conditions before it can be concluded they pose a risk to biological control under real-world conditions (Croft 1990). This does not appear to be the case for sucrose octanoate. These laboratory trials demonstrate the lack of toxicity of sucrose octanoate for insects representing four different orders of beneficial insects that include most natural enemy species important for biological control in citrus. We conclude that sucrose octanoate appears to have good potential for inclusion in IPM programs designed to manage homopteran pests in citrus, with a low probability of adverse side effects on important beneficial species.

Plant chemical defenses are rarely 100% effective against herbivores, so advantages accrue to plants that can spare natural enemies, or even encourage their recruitment. The fact that sucrose octanoate has contact toxicity against certain herbivorous insects and mites, but not against larval predators, raises interesting questions regarding its mode of action. Are beneficial insects resistant to sucrose octanoate because its binding sites on the cuticle are lacking or insensitive? If so, characterizing differences in cuticular chemistry between resistant and susceptible insects may provide insights into the mode of action of sugar esters.

Table 1. Percent mortality of beneficial insects treated with topical sprays or 24 h exposure to leaf residues of a 2% sucrose octanoate solution (=8000 ppm).

Insect Order: Family	Beneficial species	Life stage	n	Adjusted mortality (%)[1]	P
Topical sprays @ 2%					
Coleoptera: Coccinellidae	*Curinus coeruleus*	1st instar larvae	20	5.3	ns
	Cycloneda sanguinea		20	10.9	ns
	Harmonia axyridis		20	0.0	ns
	Olla v-nigrum		20	4.7	ns
Neuroptera: Chrysopidae	*Chrysoperla rufilabris*		20	0.0	ns
Leaf residue @ 2%					
Hemiptera: Anthocoridae	*Orius insidiosus*	2nd instar nymphs	25	0.0	ns
Hymenoptera: Aphelinidae	*Aphytis melinus*	adults	25	0.0	ns

[1]Values were adjusted for control mortality using Abbott's correction (Abbott 1925).

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