plants had reached a salable size, they could be shipped *in vitro* direct to the consumer. We have observed that direct transfer of *in vitro* generated aquatic plants into the aquarium environment is possible (Kane, unpublished).

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AZADIRACHTIN FROM NEEM TREE (*AZADIRACHTA INDICA* A. JUSS.) SEEDS FOR MANAGEMENT OF SWEETPOTATO WHITEFLY [*BEMISIA TABACI* (GENNADIUS)] ON ORNAMENTALS

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Abstract. **Egg, second to early third stage nymph, late third to early fourth stage nymph, late fourth stage nymph ("pupa") and adult sweetpotato whiteflies (*Bemisia tabaci* (Gennadius)) developing on poinsettia (*Euphorbia pulcherrima* Wild.) leaves were treated with Margosan-O® preparations of azadirachtin extracted from neem (*Azadirachta indica* A. Juss.) tree seeds. Single foliar spray applications of 20 ppm azadirachtin to these life stages resulted in 4.0%, 96.0%, 74.0%, 40.7% and 8.0% mortality respectively. Nymphs hatching from eggs treated with the spray were not killed. In another experiment, 20 or 40 ppm preparations were applied to second and third stage nymphs 1 to 3 times at 3-day intervals. Mortality of immature sweetpotato whiteflies was higher at 40 ppm than at 20 ppm. At 20 ppm, mortality was increased by a second application but mortality was not increased by a second application at 40 ppm. Azadirachtin (237 ml of a 20 ppm preparation) applied as a soil drench to 15 cm diameter pots of poinsettias infested with second stage nymphs did not increase mortality significantly among the insects. Four weekly applications of 28 ppm azadirachtin did not damage gerbera daisy (*Gerbera jamesonii* H. Bolus ex Hook.f.), Persian violet (*Exacum affine* Balfour), gloxinia (*Sinningia speciosa* Lodd. Hiern.) or African violet (*Saintpaulia ionantha* Wendl.). Four weekly applications of 38 ppm azadirachtin did not damage any of 5 poinsettia cultivars. Commercial azadirachtin can be a useful tool to manage sweetpotato whitefly on ornamental crops.**

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The azadirachtin extracted from seeds of the neem tree (*Azadirachta indica* A. Juss.) has been available for development as an insecticide for several years and properties of neem seed extracts to affect the behavior and development of insects recently have been summarized by Schmutterer (5). Effects of these extracts upon arthropods injurious to ornamentals have been reported by Knodel et al. (3), Larew et al. (4) Webb et al. (6), and others. Coudriet et al. (1) found that applications of 2% aqueous solutions of neem seed extract to sweetpotato whitefly (*Bemisia tabaci* (Gennadius)) resulted in reduced egg viability and oviposition, prolonged larval periods and larval mortality. They believed that the extracts acted as an antiecdysteroid or may have affected the neuroendocrine control of ecdysteroids. Flint and Parks (2) found that 160 ppm azadirachtin applied in aqueous sprays to sweetpotato whitefly on cotton resulted in 60% reductions in numbers of immatures, but at 20 ppm sprays were ineffective.

A commercial preparation of azadirachtin, Margosan-O (Grace-Sierra, Fogelsville, PA.), is registered for use on ornamental crops. This paper reports research conducted in 1988 and 1989 to determine the usefulness of the commercial preparation of azadirachtin for management of sweetpotato whitefly on poinsettia (*Euphorbia pulcherrima* Wild.) and other ornamental crops.

Materials and Methods

General. Insects used in these experiments were sweetpotato whiteflies from a laboratory colony held for ca. 2 yr on poinsettia. The original stock was from poinsettia naturally infested in Bradenton, FL. Plants used in product efficacy experiments were ca. 6-weeks old 'V-14 Glory' poinsettias grown from rooted cuttings supplied by Paul Ecke Poinsettia Ranch, Encinitas, California. Single stem poinsettias were grown in each 15 cm pot.

Expt. 1. A randomized complete block experiment with 4 replications was designed to detect effects of 20 ppm azadirachtin to various lifestages of the sweetpotato whitefly. Poinsettias were reduced to 2 middle leaves and were placed into an insectary where approximately 5,000 adult sweetpotato whiteflies were released. Adult females were allowed to lay eggs on undersides of leaves for 1 day after which all adults were collected with a vacuum pump aspirator. As the insects developed to the second and early third nymphal stage ("small nymphal"), late third and early fourth nymphal stage ("large nymphal"), or late fourth nymphal ("pupal") stage, 25 insects per leaf (1 experimental unit) were encircled with a 5-mm diameter circle made from a laboratory marking pen and experimental treatments were applied. Experimental treatments were an untreated check, bifenthrin (Talstar® 10WP) at 120 ppm a.i. (a standard for use in the Florida poinsettia industry), or 20 ppm azadirachtin applied with a hand-held aerosol applicator to upper and lower surfaces of leaves. Treated plants were returned to the greenhouse and the insects were allowed to develop to the adult stage or die. After insects had died or emerged as adults, numbers of dead immatures or exuviae remaining after emergence of adults were counted to provide percentage mortality.

Pesticides' effects on adults were evaluated by treating the upper and lower surfaces of leaves of poinsettia plants, allowing the leaves to dry in the greenhouse for 1 hr, then removing 4 middle leaves. Petioles were placed in a water vial and leaves and vials were placed into a 1.43 liter, clear plastic container outfitted with a ventilating screen top and side. Twenty-five adult sweetpotato whiteflies were introduced onto the leaves. Numbers of live and dead adults were counted 48 hr later.

Data were transformed by the arcsin transformation and analyzed by an analysis of variance. Means were calculated and means separations were provided by Duncan's multiple range test.

Expt. 2. A 2x3 factorial experiment was designed with 4 replicates to detect effects of 20 ppm and 40 ppm azadirachtin applied 1, 2, or 3 times to sweetpotato whitefly nymphs. A group of plants was prepared to have whitefly eggs as in Expt. 1. As the insects reached the early second nymphal stage, first applications of experimental treatments were applied as in Expt. 1. Three days later, plants to receive 2 or 3 applications were treated a second time and after an additional 3 days, plants to receive 3 applications were treated. Post treatment evaluations and data analysis were performed as in Expt. 1.

Expt. 3. A randomized complete block experiment was designed with 4 replications to detect systemic effects of soil applied azadirachtin and other systemic insecticides on nymphal sweetpotato whiteflies. A group of plants was prepared to have whitefly eggs as in Expt. 1 except that no leaves were removed from the plants. When the insects reached the early second stage, insecticidal treatments were applied to the soil. Insecticidal treatments were 237 ml of 20 ppm azadirachtin, 237 ml of a 304 ppm preparation of oxamyl (Vydate® L), 0.16 g of formulated oxamyl (Oxamyl® 10G), 0.15 g of formulated aldicarb (Temik® 10G), and 0.11 g of formulated disulfoton (Disyston® 15G) applied to the soil of each pot and watered. Post treatment evaluations of the experiment and data analysis were performed as was done in Expt. 1 except that mortality response was determined from 25 encircled immatures on each of an upper, middle, and lower leaf.

Expt. 4. A randomized complete block experiment with 4 replications was designed to evaluate the phytotoxic reaction of selected greenhouse ornamental plants to azadirachtin sprays. Preparations of 28 ppm azadirachtin were applied as sprays to groups of 24 'Small Inc. Mix' gerbera daisies (*Gerbera jamesonii* H. Bolus ex Hook.f.), 24 'Blue Champion' and 6 'White Champion' Persian violets (*Exacum affine* Hiern.), and 24 'Small Inc. Mix' African violets (*Saintpaulia ionantha* Wendl.). Similar untreated checks were provided. Treatments were applied weekly for 4 weeks beginning 6 June 1989 and an additional treatment was applied to open flowers as they appeared. Applications were made with a hand-held spray gun delivering ca. 14 kg/cm^2 pressure and 1870 liters/ha. After each spray application, the conditions of treated plants were compared to those of the untreated check.

Expt. 5. A randomized complete block experiment in 4 replications was designed to evaluate the phytotoxic reaction of selected cultivars of shadehouse grown poinsettias. Preparations of 38 ppm azadirachtin were applied to groups poinsettias that included 3 of each of 38-cm tall, multistem 'Annette Hegg Lady', Gutbier 'V-14 Glory', Gutbier 'V-10 Amy', Gutbier 'V-17 Angelika', and Gross 'Sup-Jibi' poinsettias. Untreated checks were provided. Treatments were applied weekly for 4 weeks beginning 12 June 1989, before plants were showing color. Applications were made using a hand-pumped knapsack sprayer that delivered ca. 2800 liters/ha. After each spray, the conditions of treated plants were compared to those of the untreated checks.

Results and Discussion

Expt. 1. Results of Expt. 1 are presented in Table 1. High levels of mortality occurred among small nymphs and among large nymphs treated with azadirachtin, with the highest level, 96%, occurring when small nymphs were treated. A moderate level of 41% mortality occurred when pupae were treated with azadirachtin. Compared to the untreated check, there was no significant increase in mor-

Table 1. Mortality (%) of sweetpotato whitefly lifestages on poinsettia treated with a naturally occurring or synthetic insecticide.

Treatment	Egg	First instars[z]	Small nymphs	Large nymphs	Pupae	Adults
Untreated	0 a[y]	0 b	6 b	8 b	0 b	4 b
Bifenthrin (120 ppm)	0 a	87 a	98 a	12 b	1 b	95 a
Azadirachtin (20 ppm)	0 a	4 b	96 a	74 a	41 a	8 b

[z]First instars were not treated but emerged from eggs that had been treated.
[y]Mean separation in columns by Duncan's multiple range test, 5% level.

Table 2. Interactive effects of aqueous sprays of 20 ppm or 40 ppm azadirachtin applied to nymphal sweetpotato whiteflies on poinsettia.

Treatment	No. times applied	% dead immatures
Untreated	—	7 d[z]
Azadirachtin 20 ppm	1	27 c
Azadirachtin 20 ppm	2	55 b
Azadirachtin 20 ppm	3	55 b
Azadirachtin 40 ppm	1	83 a
Azadirachtin 40 ppm	2	91 a
Azadirachtin 40 ppm	3	88 a

[z]Mean separation by Duncan's multiple range test, 5% level.

Table 3. Mortality (%) of immature sweetpotato whiteflies on poinsettia after soil treatments with systemic insecticides.

Treatment	% dead immatures
Untreated	37 b[z]
Azadirachtin, 237 ml of a 20 ppm a.i. preparation	41 b
Aldicarb (Temik) 10G, 0.15 g formulation	72 a
Oxamyl (Vydate L), 237 ml of 304 ppm a.i. preparation	72 a
Oxamyl (Oxamyl 10G), 0.16 g formulation	42 b
Disulfoton (Disyston) 15G, 0.11 g formulation	40 b

[z]Mean separation by Duncan's multiple range test, 5% level.

tality to sweetpotato whitefly eggs, or adults treated with 20 ppm azadirachtin, or to first instars hatching from eggs previously treated with 20 ppm azadirachtin. Efficacy of 20 ppm azadirachtin in this study is inconsistent with the results found by Flint and Parks (2). Perhaps the greenhouse experiment reported herein provided superior nymphal contact with the toxicant. Bifenthrin treatments resulted in increased mortality, compared to the untreated checks, when applied to small nymphs and adults. Bifenthrin also resulted in increased mortality to nymphs that emerged from eggs that had been treated.

Expt. 2. Results of Expt. 2 are presented in Table 2. There was a significant interaction between concentration of azadirachtin in the spray preparation and the number of times the preparations were applied. Mortality of the immature whiteflies was higher at 40 ppm azadirachtin than at 20 ppm and there was no additional mortality at 40 ppm when the preparation was applied more than once. At the 20 ppm concentration, mortality of immature whiteflies increased when a second application was performed; a third application did not increase mortality further. All treatment combinations resulted in increased mortality compared to the untreated check.

Expt. 3. Results of Expt. 3 are presented in Table 3. There was an unusually high mortality in the untreated check (37%), the reasons for which cannot be explained satisfactorily. Only 2 treatments resulted in higher mortality than was found in the untreated checks, aldicarb and oxamyl L. There was no significant increase in mortality, compared to the untreated checks, when azadirachtin, disulfoton or oxamyl 10G were applied.

Expt. 4 and 5. No apparent phytotoxic damage was observed on any of the foliage or flowers of plants to which azadirachtin was applied.

The results of these experiments indicate that azadirachtin applied as a spray at 20 to 40 ppm can be useful to control the nymphal stage sweetpotato whitefly. Since most greenhouse populations of the insect contain a complex of all lifestages, additional applications of azadirachtin or concomitant applications of an effective adulticide would be required to achieve control. The plant safety on a number of poinsettia cultivars and other flower crops indicates that large segments of the ornamentals industry likely could use the commercial azadirachtin. Azadirachtin can become an important tool for the management of sweetpotato whitefly, certainly on poinsettia and perhaps on other ornamentals as well.

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