Sweetpotato Whitefly Nymph Mortality and Adult and Nymph Honeydew Production Following Treatment with Applaud or Knack

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Abstract

Cotton lint contamination from honeydew excreted by sweetpotato whiteflies, Bemisia tabaci (Gennadius), is a serious problem in the textile industry resulting in reduced lint processing efficiency. The insect growth regulators, Applaud® and Knack®, provide effective control of sweetpotato whiteflies on cotton by interfering with their reproduction and development. Protection from honeydew lint contamination is attributed to reduced sweetpotato whitefly populations. We investigated the potential direct effect of Applaud and Knack on sweetpotato whitefly honeydew production. In the field, amounts of the major sugar components of honeydew produced by adults and nymphs collected on day six following Applaud or Knack applications to cotton field plots were not significantly different compared to amounts produced by those collected from untreated plots. In the laboratory, adult mortality and amounts of honeydew sugars produced by adults were not affected by confinement for 48 h on Applaud or Knack residues from cotton leaf dips or following nebulizer contact spray applications. In contrast, mortality of first and second instar nymphs on leaves was higher on day six following leaf dips in Applaud solutions compared with leaf dips in Knack or water solutions. Nymph mortality on day six following leaf dips in Knack solutions was higher than mortality of nymphs following leaf dips in water. Honeydew collected during the period between two to 50 h after leaf dip treatment had reduced amounts of glucose, fructose and trehalulose, but not sucrose and melezitose per nymph compared with honeydew from nymphs on leaves dipped in water. Results were more variable for sugars in honeydew collected 96 to 144 h after leaf dip treatment. Nebulizer sprays of Applaud and Knack to nymphs on cotton leaves also resulted in reduced amounts of sugars in honeydew and nymph mortality following treatments.

Introduction

Sweetpotato whitefly, *Bemisia tabaci* (Gennadius), infestations in cotton often result in the development of lint stickiness (Hector and Hodkinson 1989). Nymphs and adults feed in cotton plant phloem tissue and obtain sap containing mostly sucrose (See Hendrix et al. 1992 for review). Their excretions, called honeydew, contain sucrose and other metabolized sugars. The honeydew sugar components may vary depending on plant species (Hendrix et al. 1992). Honeydew contaminated cotton lint is sticky and the honeydew also serves as a substrate for sooty molds

This is a part of the 2002 Arizona Cotton Report, The University of Arizona College of Agriculture and Life Sciences, index at http://ag.arizona.edu/pubs/crops/az1283

that discolor the lint. Sticky cotton adheres to machinery in textile mills and interferes with processing. Sticky cotton reduces harvesting and ginning efficiency and may cause health related problems for textile mill workers (Johnson et al. 1982, Hector and Hodkinson 1989, Ayars et al. 1986). Losses of 10% of the lint value may occur (Hector and Hodkinson 1989). Under grower conditions, the degree of lint stickiness is influenced by the magnitude of infestations as determined by the efficacy of sweetpotato whitefly population management. Control efforts, for the most part, are insecticide based, but the most successful management is facilitated by an understanding of the biology and ecology of the species and melding of chemical with cultural and other controls.

We previously reported results suggesting that under field conditions several commonly used insecticides for control of sweetpotato whitefly on cotton reduced numbers of adult and nymphs in small plots. In some cases, for as long as 18 days following applications there were no measurable effects on honeydew production of adults or nymph collected from the plots treated compared with untreated plots (Henneberry et al. 1999). Materials evaluated were buprofezin [Applaud®, 405C, AgrEvo Corp., NC], pyriproxyfen [Knack®, Valent, CA], endosulfan [Thiodan®, FMC Corporation, PA], and a mixture of fenpropathrin and acephate [Danitol®, Orthene®, Valent Corp., CA]. Applications were made with a four row, rear-mounted spray boom on a Hi-Boy tractor. The results suggested that effectiveness of insecticides for reducing cotton lint stickiness (Henneberry et al. 1995, 1996) was a result of reduced sweetpotato whitefly populations as opposed to any direct effect on honeydew production by the insects. Additional studies were warranted since only one application of each chemical or chemical mixture was applied. Rainfall occurred on days three and six following the applications that may have resulted in reduced residual insecticide activity and adult sweetpotato whiteflies disperse readily from plant to plant and between small plots. Thus, some of our collected sweetpotato whiteflies may have entered the plots from untreated cotton or other sources. Applaud and Knack have proven to be highly effective for sweetpotato whitefly management in cotton (Ellsworth et al. 1996) and were of particular interest for additional study in relation to honeydew production because of their effect on whitefly nymph development. Less honeydew was produced by nymphs collected from plants treated with Applaud or Knack compared to those from untreated control plants. The results were variable and differences were not statistically significant (Henneberry et al. 1999). Applaud is a chitin synthesis inhibitor that is mainly effective by preventing normal nymph development. Knack is a juvenile hormone that sterilizes sweetpotato whitefly adults and eggs and interferes with adult emergence from nymphal cases (Ellsworth et al. 1996).

Materials and Methods

Field studies. Cotton plots were located at the University of Arizona's, Maricopa Agricultural Center, Maricopa, AZ. A four-acre field was treated with Applaud (0.39 kg AI/ha) on 13 July, 2001. On the same date, four 0.4 ha cotton plots were treated with Knack (0.06 kg AI/ha). The controls were a 0.4 ha and four 0.04 ha untreated cotton plots. Treatments were made with a spray boom mounted on a high clearance tractor similar to that previously described. On 19 July, 6 days after treatments, 100 to 200 adults were collected from the center of each plot with hand held aspirators. Nymph infested leaves were also collected from each plot.

For adult honeydew collection, two leaf-clip cages with removable plastic bottoms as described by Henneberry et al. (1999) were installed, one per leaf, on each of five untreated, uninfested cotton plants. Five adults were confined in each cage for 48 h. Removable plastic cage bottoms coated with honeydew drops were removed and held in a freezer until lyophilization and high performance liquid chromatographic (HPLC) analysis.

For nymph honeydew collections, ten fifth mainstem node leaves with petioles intact were harvested from each plot. Individual leaves were examined under a microscope to determine the presence of living nymphs and record their numbers. All adults were removed. Leaves with nymphs were placed in 10 cm diameter ventilated petri dishes. Leaf petiole ends were cut-off at an angle and placed in cylindrical vials containing 50 ml of water. A vertical groove was cut into the side of each petri dish to accommodate the cotton-wrapped seedling stems. After 48 h, petri dish bottoms with honeydew were collected and held in a freezer. Adult honeydew in leaf clip cage bottoms described above and nymph honeydew in petri dish bottoms, in each case, was washed from the containers in deionized water and frozen.

Laboratory leaf dip treatments. Clear plastic boxes (23-cm long x 13-cm wide x 10-cm deep) were modified to enclose four-to six- leaf growth stage cotton seedlings growing in soil-filled pots. Two, 5-cm diameter, muslin covered holes in the sides of each box provided ventilation. Openings of 0.63-cm wide x 2.54-cm long were cut in the middle and on opposite sides of each other in each of the bottom hinged halves of the boxes. The openings accommodated cotton-wrapped seedling stems when the box halves were closed.

Forty cotton seedlings with four to six leaves were used in the study. Ten sets of four plants each were enclosed in the cages described. Approximately 100 sweetpotato whitefly adults were introduced into each of 20 of the cages (five sets of four plants each). The remaining 20 cages were uninfested. All adults were removed from the plants in infested cages after 24 h. Infested and uninfested plants enclosed in the plastic boxes were held in the greenhouse for 10 days while eggs deposited on the infested plants hatched and developed to first and second instar nymphs. Four infested and four uninfested plants, in each case, were dipped in water solutions containing one-half, or one-quarter the recommended rates of Applaud or Knack. These rates were approximately 2,000 and 1,000 parts per million (ppm) for Applaud and 600 and 300 ppm for Knack, in each case, based on application of the chemical in 94 liters of water per hectare. Four infested and four uninfested plants dipped in water alone served as controls.

For adults, after air-drying, two clip cages (Henneberry et al. 1995) with removable plastic bottoms were installed on uninfested plants, four, in each case, dipped in treatments of Knack, Applaud or water. Five sweetpotato whitefly adults were placed in each clip cage. Honeydew was collected for 48 hs on the clip cage bottoms. Cages were removed and adults counted. Cage bottoms with honeydew were frozen until analyzed. After an additional 48 h (residues 96 hs old) clip cages were replaced on different leaves of the same plants. Five new adult females were placed in each clip cage. Honeydew was collected for an additional 48 h. After this period, cages were removed, adults counted and cage bottoms with honeydew frozen as described.

For plants with nymphs dipped in Applaud, Knack or water solutions, a leaf-clip cage was installed on one leaf of each of four plants in each treatment category. Cages were positioned to enclose living nymphs. Honeydew was collected for 48 h, the cages were removed, nymphs were counted, and removable cage bottoms with honeydew were held in a freezer. After 48 additional hs, 96 hs after nymphs were treated, clip cages, one per leaf, were reinstalled on leaves of nymph infested applaud, knack or water-dip treated plants. Honeydew was collected for 48 hs, cages removed, living and dead nymphs counted, and honeydew collection clip-cage bottoms frozen.

Laboratory nebulizer spray applications. Sweetpotato whitefly adults and nymphs were treated using a Devilbiss nebulizer (Sunset Medical HHG Inc. Longmont, CO) spray technique described by Hagler (1997). Adults were confined in 1.4 liter, covered plastic containers. Lids of the containers had 7.6 cm diameter nylon mesh covered openings for ventilation. During nebulizer spray treatment, net covered openings were covered with a solid piece of plastic sheeting. A 2.5 cm opening accommodated the nebulizer mouthpiece. One ml of aqueous solution containing 2000 ppm of Applaud or 600 ppm of Knack, was placed in the nebulizer well. An air source attached to the nebulizer atomized the 1 ml solutions to completion into the described containers containing 2 to 3 hundred adults. Following treatment and air-drying, five adults were confined in leaf clip cages and honeydew collected after 48 h as described for adult confinement on leaves following leaf dip treatment. Also, plants with eggs laid by sweetpotato whiteflies during the 48 h honeydew collection were held in a 26.7° C controlled temperature cabinet for 10 days. Eclosed nymphs were counted and leaf cages were attached to leaves encompassing nymph infested areas. Honeydew was collected from the insects for 48 h.

First and second instar nymphs on plants were also treated with nebulizer sprays of Applaud and Knack. The plants with nymphs were enclosed in hinged, rectangular, plastic boxes described by Henneberry et al. (2000). Nebulizer water sprays were controls. Rates of applications were 2000 or 600 ppm for Applaud and Knack, respectively. First- and early-second instar nymphs were obtained as described for the leaf dip treatments. Honeydew was collected for 48 h in leaf clip cages. Removable cage bottoms with honeydew were frozen.

High Performance Liquid Chromatography. All honeydew samples collected were washed from the leaf cages or petri dish bottoms with 3 ml of warm deionized water which was then frozen. Frozen honeydew samples were lyophilized and reconstituted in 125 µl of deionized water. The identity and amounts of trehalulose, melezitose, glucose, fructose, and sucrose in the samples were determined using the high performance liquid chromatography (HPLC) methods of Hendrix and Wei (1994) and sampled sugars were quantified by comparison with peak areas of known sugar standards.

Statistical Analysis. All data were analyzed using analysis of variance (ANOVA) (MSTAT-C 1988), and means separated contingent on a significant F test using the method of least significant differences at $P \leq 0.05$.

Results

Field studies. Amounts of honeydew sugars produced by sweetpotato whitefly adults and nymphs collected from Applaud or Knack-treated cotton plots were not significantly different compared with sugars produced by adults and nymphs collected from untreated cotton plots (Table 1). Adult data were consistent, but nymph data were variable. The amounts of honeydew sugars and their totals were lower in Applaud and Knack treated compared with untreated plots, but the differences were not statistically significant.

Laboratory leaf dip treatments - adults. Exposure for 2 to 50 hs or 96 to 144 hs old residues from leaf dip applications of Applaud and Knack had no significant effect on adult mortality (average < 10% across all treatments). These data are not tabulated. Amounts of major honeydew sugars produced by sweetpotato whitefly adults confined on residues of Applaud or Knack on cotton plants were also not affected as compared to adults confined on untreated cotton plants (Table 2).

Nymphs. Leaf dip treatment of first and early second instar sweetpotato whitefly nymphs resulted in averages of 86 to 87% mortality for Applaud, 34 to 39% for Knack and 11% for water controls determined, in each case, on day six following treatment (Table 3). Sweetpotato whitefly nymphs during hours two to 50 following leaf dip treatment with Applaud and Knack excreted significantly less glucose, fructose, and trehalulose, but not sucrose and melezitose as compared to nymphs dipped in water. Results were similar for Applaud during hours 96 to 144 following treatment, but were more variable for Knack applications. In most cases honeydew sugars produced by nymphs dipped in the lower rates of Knack were not significantly different compared with those dipped in water.

Laboratory nebulizer spray application – adults. Treatment of adults with nebulizer sprays containing Applaud or Knack had no significant effect on amount of any of the HPLC measured honeydew sugars (Table 4). Numbers of nymphs produced per adult treated with Applaud or Knack were significantly reduced compared with nebulized water treatment alone. However, honeydew sugars produced by surviving nymph progeny of adults treated with nebulizer sprays of Applaud or Knack were not significantly affected (Table 4).

Laboratory nebulizer spray vs. leaf dip applications nymphs. Significantly lower amounts of glucose, fructose, trehalulose and sucrose, but not melezitose were found in honeydew of Applaud-treated nymphs compared with Knack or water-treated sweetpotato whitefly nymphs (Table 5). Lower amounts of glucose and fructose occurred in honeydew from Knack-treated nymphs compared with water-treated nymphs, but the differences were not statistically significant. Average amounts of all honeydew sugars excreted per nymph were higher from nebulizer-treated nymphs compared with leaf dip-treated nymphs.

Discussion

Our field results in this study agree with our previous report that some commonly used insecticides for sweetpotato whitefly control, including Applaud and Knack did not significantly affect honeydew production of adults and nymphs collected from insecticide-treated compared with untreated fields (Henneberry et al. 1999). Lower amounts of some honeydew sugars were produced by nymphs collected from Knack or Applaud-treated fields but the differences were not statistically significant. In the laboratory, honeydew production of adults confined to residues on leaves following leaf dips in Applaud or Knack also was not affected compared to confinement on leaves dipped in water.

Under field conditions adults may disperse from treated plots and this could confuse efforts to sample field treated insects. Also, adults may not be exposed long enough or to high enough levels of the chemicals by residual contact from field applications to affect honeydew production. Additionally, neither chemical has much effect on adult sweetpotato whitefly mortality (Ellsworth 1999) and they may simply be non-toxic to adults. Nymphs are not mobile after the first instar, but the preferred underleaf habitat has been repeatedly suggested as a problem to conventional field applied insecticides because of the difficulty in obtaining good coverage which may also explain field results for nymphs exposed to sprays. However, coverage in the field was adequate for sweetpotato whitefly control and populations in the treated plots showed 36.1 to 47% fewer small nymphs and no large nymphs in Applaud and Knack treated plots, respectively (Akey, personal communications[1]) compared with untreated plots, indicating significant reductions following applications with standard ground spray equipment. Adults per leaf turn were not significantly different and averaged 6.2, 6.7, and 5.0 for Applaud, Knack and untreated control plots, respectively. In the laboratory, adults were confined on residues within one h following leaf dip treatment. There were no measurable effects on honeydew production, supporting the hypothesis of lack of residual treatment activity. For nymphs on leaves dipped in Applaud or Knack solutions in the laboratory, significantly reduced amounts of some but not all honeydew sugars per nymph occurred. The significance of the different effects on various honeydew sugars is unknown. High nymph mortality occurred from Applaud compared with Knack and water treatment, but mortality for Knack-treated nymphs was higher compared to water leaf dip treatment.

The mechanism(s) resulting in reduction in honeydew sugar production following nebulizer spray applications or leaf dip treatment of first and second instar nymphs with Applaud or Knack are not known, although the reported adverse effect of Applaud and Knack on normal nymph development (Ellsworth 1999) and possible interrelationships with feeding may provide a partial explanation. In view of the highly important sticky cotton problem to the cotton industry, additional studies are recommended since there may be alternative and/or improved methods of achieving the same type of reduced honeydew production using other methods to interfere with the fundamental physiological, biochemical or other mechanisms essential to sweetpotato whitefly life processes.

Acknowledgements

The authors appreciate the help of Ron Redlin in the High Performance Liquid Chromatography analyses of sweetpotato whitefly honeydew samples.

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Table 1. Mean (± SE) µg of Honeydew Sugars per Sweetpotato Whitefly Adult or Nymph per day Collected from Control and Applaud or Knack-treated Cotton Field Plots.

Treatment[2/]	Honeydew Sugars[1/]					
	Glucose	Fructose	Trehalulose	Sucrose	Melezitose	Total
			Adults			
Applaud	0.11 ± 0.03 a	0.10 ± 0.03 a	0.75 ± 0.26 a	0.01 ± 0.01 a	0.00 ± 0.00 a	0.96 ± 0.31 a
Knack	0.13 ± 0.03 a	0.12 ± 0.03 a	0.91 ± 0.22 a	0.01 ± 0.01 a	0.01 ± 0.01 a	1.12 ± 0.28 a
Control	0.15 ± 0.03 a	0.15 ± 0.03 a	0.99 ± 0.25a	0.02 ± 0.01 a	0.00 ± 0.00 a	1.31 ± 0.31 a
F (P)[3/]	1.25 (>0.05)	1.61 (>0.05)	0.60 (>0.05)	1.89 (>0.05)	2.14 (>0.05)	0.78 (>0.05)
			Nymphs			
Applaud	0.29 ± 0.22 a	0.22 ± 0.18 a	0.01 ± 0.01 a	0.06 ± 0.04 a	0.01 ± 0.01 b	0.58 ± 0.44 a
Knack	0.22 ± 0.11 a	0.24 ± 0.10 a	0.12 ± 0.02 a	0.10 ± 0.05 a	0.22 ± 0.04 a	0.89 ± 0.26 a
Control	1.03 ± 0.43 a	1.10 ± 0.51 a	0.09 ± 0.05 a	0.22 ± 0.12 a	0.08 ± 0.04 b	2.57 ± 1.01 a
F (P)	2.31 (≤0.05)	2.49 (≤0.05)	4.06 (≥0.05)	2.07 (≥0.05)	14.74 (≤0.05)	2.67 (≤0.05)

[1/] Mean of 10 replication. Adult mortality negligible, averaging less than 5% for all treatments. Means in a column and the same sweetpotato whitefly lifestage followed by the same letter are not significantly different.

[2/] Applaud, 0.39 kg AI/ha, Knack, 0.06 kg AI/ha, in each case in 281 liters/ha.

[3/] df = 2,10 for all F values, $P \leq 0.05$.

Table 2. Mean (± SE) Sweetpotato Whitefly µg of Honeydew Sugars per Adult per day Confined for 48 h in Leaf Cages on Residues of Applaud or Knack (ppm) Dipped Cotton Leaves.

Treatment/ppm[1/]	Hours After Leaf Dip Treatment[2/] 2 to 50	96 to 144
Applaud		
2,000	7.80 ± 1.28 a	10.78 ± 5.92 a
1,000	8.19 ± 1.51 a	7.36 ± 2.83 a
Knack		
600	12.02 ± 1.19 a	8.08 ± 3.93 a
300	9.93 ± 0.59 a	7.40 ± 4.33 a
Control	10.28 ± 2.10 a	8.09 ± 1.80 a
F, 4,12 df	1.43 (*P*≥0.05)	0.16 (*P*≥0.05)

[1/] Adult mortality negligible for all treatment means of < 10% missing or dead for all treatments. Means of 4 replications in a column followed by the same letter were not significantly different.

[2/] Includes glucose, fructose, trehalulose, sucrose, melezitose and T = total F values, df 4,12 over 2 to 46 h = 0.90, 0.36, 1.54, 0.18, 0.97 and 1.43, respectively and for 96 to 144 h, 1.18, 0.75, 0.04, 1.19, 1.29 and 0.16, respectively. P≥0.05 in all cages. 4 replications.

Table 3. Mean (± SE) Sweetpotato Whitefly Nymph Mortality and µg of Honeydew Sugars per Nymph per day Following Leaf Dip (ppm) Applications of Applaud or Knack in the Laboratory.

Treatment (PPM)	% Mortality	Sugar[1/] Glucose	Fructose	Trehalulose	Sucrose	Melezitose
		Honeydew collected during hours two to 50 following treatment				
Applaud						
2,000	--	0.05 ± 0.02 b	0.08 ± 0.03 b	0.42 ± 0.14 b	0.08 ± 0.05 a	0.15 ± 0.05 a
1,000	--	0.04 ± 0.01 b	0.07 ± 0.02 b	0.34 ± 0.07 b	0.18 ± 0.03 a	0.19 ± 0.05 a
Knack						
600	--	0.05 ± 0.02 b	0.10 ± 0.05 b	0.45 ± 0.15 b	0.20 ± 0.19 a	0.21 ± 0.14 a
300	--	0.06 ± 0.01 b	0.13 ± 0.03 b	0.60 ± 0.30 b	0.20 ± 0.08 a	0.20 ± 0.06 a
Control	--	0.14 ± 0.02 a	0.26 ± 0.03 a	1.04 ± 0.21 a	0.45 ± 0.03 a	0.29 ± 0.06 a
F (P)[1/]	--	6.69 (≤0.01)	4.42 (P≤0.02)	3.21 (≤0.05)	2.05 (>0.05)	0.44 (>0.05)
		Honeydew collected during hours 96 to 144 following treatment				
Applaud						
2,000	86.5 ± 2.4 a	0.07 ± 0.07 c	0.07 ± 0.06 b	0.90 ± 0.76 b	0.08 ± 0.06 a	0.04 ± 0.03 c
1,000	86.1 ± 1.1 a	0.03 ± 0.02 c	0.05 ± 0.02 b	0.24 ± 0.05 b	0.00 ± 0.00 a	0.04 ± 0.02 c
Knack						
600	38.7 ± 14.5 b	0.13 ± 0.04 bc	0.19 ± 0.06 b	0.43 ± 0.03 b	3.04 ± 1.92 a	0.27 ± 0.09 bc
300	33.8 ± 5.3 b	0.31 ± 0.09 ab	0.46 ± 0.13 a	2.60 ± 1.32 ab	0.61 ± 0.19 a	0.59 ± 0.16 a
Control	10.7 ± 3.9 c	0.37 ± 0.10 a	0.58 ± 0.15 a	3.79 ± 1.32 a	0.57 ± 0.36 a	0.37 ± 0.17 ab
F (P)	20.3 (≤0.01)	5.94 (<0.01)	8.33 (≤0.01)	3.56 (≤0.05)	1.85 (>0.05)	5.91 (≤0.01)

[1/] Means of 4 replications in a column within the same residue exposure not followed by the same letter are not significantly different. Method of least significant differences, *P*≤0.05, df 4,12. Means of 4 replications.

Table 4. Mean (± SE) Sweetpotato Whitefly Nymph, Adults and their Progeny µg of Honeydew Sugars per Insect per day Following Nebulizer (ppm) Applications of Applaud or Knack in the Laboratory.

Treatment (PPM)	Nymph/ Adult	Sugar[1]					Total
		Glucose	Fructose	Trehalulose	Sucrose	Melezitose	
		Adult honeydew collected during a 48 h period two to 50 following treatment					
Applaud 2,000	3.94 ± 0.82 b	0.40 ± 0.04 a	0.32 ± 0.03 a	4.03 ± 0.65 a	0.05 ± 0.02 a	0.13 ± 0.04 a	4.93 ± 0.69 a
Knack 600	1.71 ± 0.45 b	0.46 ± 0.05 a	0.38 ± 0.03 a	3.27 ± 0.19 a	0.04 ± 0.01 a	0.05 ± 0.05 a	4.20 ± 0.25 a
Control	15.45 ± 1.71 a	0.48 ± 0.11 a	0.39 ± 0.10 a	4.53 ± 1.05 a	0.65 ± 0.03 a	0.00 ± 0.00 a	5.47 ± 1.25 a
F (P)[1]	44.4 (≤ 0.05)	0.37 (> 0.05)	0.51 (> 0.05)	0.99 (> 0.05)	0.57 (> 0.05)	31.2 (> 0.0)	0.73 (> 0.05)
		Nymph progeny honeydew collected during 48 h period, 11 days following treatment of the parents					
Applaud 2,000	--	0.01 ± 0.00 a	0.01 ± 0.00 a	0.06 ± 0.01 a	0.06 ± 0.03 a	0.00 ± 0.00 b	0.13 ± 0.04 a
Knack 600	--	0.01 ± 0.00 a	0.01 ± 0.01 a	0.10 ± 0.02 a	0.11 ± 0.02 a	0.04 ± 0.01 a	0.26 ± 0.05 a
Control	--						
F (P)	--	1.07 (> 0.05)	3.55 (> 0.05)	1.82 (> 0.05)	1.28 (> 0.05)	7.13 (≤ 0.05)	2.92 (> 0.05)

[1] Means of 4 replications in a column within the same residue exposure followed by the same letter are not significantly different. Method of least significant differences, df 2,8. Means of 5 replications.

Table 5. Mean (± SE) Numbers of Sweetpotato Whitefly Nymphs and µg of Honeydew Sugars per Nymph Following Nebulizer Spray or Leaf Dip Applications of Applaud or Knack in the Laboratory.

Treatment (PPM)	Nymphs (No.)	Glucose	Fructose	Trehalulose	Sucrose	Melezitose	Total
			Pretreatment				
Nebulizer spray							
-	108.7 ± 14.1 b	0.01 ± 0.01 a	0.03 ± 0.01 a	0.21 ± 0.02 a	0.14 ± 0.01 a	0.16 ± 0.03 a	0.55 ± 0.05 a
Leaf dip							
-	172.7 ± 28.8 a	0.01 ± 0.01 a	0.03 ± 0.01 a	0.18 ± 0.03 a	0.13 ± 0.01 a	0.18 ± 0.04 a	0.53 ± 0.08 a
F (P)[1/]	5.19 (≤ 0.05)	0.11 (> 0.05)	0.29 (> 0.05)	0.74 (> 0.05)	0.66 (> 0.05)	0.26 (> 0.05)	0.04 (> 0.05)
			Post treatment				
Nebulizer spray							
Applaud 2000	84.0 ± 17.1 a	0.01 ± 0.01 a	0.02 ± 0.01 a	0.17 ± 0.03 a	0.08 ± 0.01 a	0.02 ± 0.01 b	0.30 ± 0.05 a
Knack 600	76.0 ± 16.6 a	0.03 ± 0.01 a	0.08 ± 0.01 a	0.46 ± 0.03 a	0.23 ± 0.02 a	0.25 ± 0.09 a	1.06 ± 0.13 a
Control	70.0 ± 16.0 a	0.04 ± 0.01 a	0.07 ± 0.01 a	0.33 ± 0.04 a	0.23 ± 0.06 a	0.08 ± 0.03 b	0.75 ± 0.13 a
Leaf dip							
Applaud 2000	126.6 ± 5.6 a	0.01 ± 0.01 a	0.02 ± 0.01 c	0.11 ± 0.01 a	0.10 ± 0.03 a	0.06 ± 0.04 b	0.28 ± 0.07 a
Knack 600	83.4 ± 25.3 a	0.01 ± 0.01 a	0.04 ± 0.01 a	0.23 ± 0.02 a	0.15 ± 0.05 a	0.05 ± 0.02 b	0.48 ± 0.07 a
Control	161.2 ± 41.1 a	0.06 ± 0.01 a	0.06 ± 0.01 a	0.26 ± 0.10 a	0.15 ± 0.04 a	0.10 ± 0.03 b	0.60 ± 0.17 a
F (P)[2/]	0.94 (> 0.05)	1.30 (> 0.05)	2.21 (> 0.05)	1.68 (> 0.05)	1.35 (> 0.05)	4.35 (≤ 0.05)	3.27 (> 0.05)
Main effects							
Applaud 2000	105.3 ± 8.6 a	0.01 ± 0.01 c	0.02 ± 0.01 b	0.14 ± 0.02 b	0.09 ± 0.01 b	0.04 ± 0.02 a	0.29 ± 0.04 b
Knack 600	79.7 ± 14.4 a	0.02 ± 0.01 b	0.06 ± 0.01 a	0.35 ± 0.04 a	0.19 ± 0.03 a	0.15 ± 0.05 a	0.77 ± 0.12 a
Control	115.6 ± 25.8 a	0.03 ± 0.01 a	0.07 ± 0.01 a	0.29 ± 0.05 a	0.19 ± 0.04 a	0.09 ± 0.02 a	0.67 ± 0.11 a
F (P)[3/]	0.72 (> 0.05)	19.26 (≤ 0.05)	14.58 (≤ 0.05)	8.71 (≤ 0.05)	6.28 (≤ 0.05)	3.39 (> 0.05)	9.96 (≤ 0.05)
Nebulizer spray	76.7 ± 9.0 a	0.02 ± 0.01 a	0.06 ± 0.01 a	0.32 ± 0.04 a	0.18 ± 0.03 a	0.12 ± 0.04 a	0.70 ± 0.10 a
Leaf dip	123.7 ± 24.4 a	0.01 ± 0.01 b	0.04 ± 0.01 b	0.20 ± 0.04 b	0.13 ± 0.02 a	0.07 ± 0.02 a	0.45 ± 0.07 b
F (P)[4/]	3.51 (> 0.05)	11.31 (≤ 0.05)	8.51 (≤ 0.05)	8.62 (≤ 0.05)	3.16 (> 0.05)	1.49 (> 0.05)	7.35 (≤ 0.05)

[1/] Means of 15 replications, df = 1,20. These and all other means in a column in a group not followed by the same letter are significantly different.
[2/] Means of 10 replications, df = 2,20.
[3/] Means of 10 replications, df = 2,20.
[4/] Means of 15 replications, df = 1,20.