Feeding Responses of *Trichopoda pennipes* (F.) (Diptera: Tachinidae) to Selected Insecticides[1]

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Abstract Feeding responses of the parasitoid *Trichopoda pennipes* (F.) to acetamiprid, cyfluthrin, dicrotophos, indoxacarb, oxamyl, and thiamethoxam were determined in laboratory tests. *Trichopoda pennipes* adults exhibited repellency to a sugar water food source treated with oxamyl, cyfluthrin, indoxacarb, and acetamiprid and diminution of feeding when they actually fed on sugar water containing any of the insecticides. Although four of the insecticides in this study exhibited antifeedant activity, ingestion of food treated with any of these compounds always resulted in the death of the flies. Therefore, repellency to the insecticides was the only response by the flies that insured their survival.

Key Words feather-legged fly, repellent, antifeedant, oral toxicity

The southern green stink bug, *Nezara viridula* (L.), is a widely distributed pest in the tropical and subtropical regions of the world (Panizzi 1997). The organophosphate dicrotophos is the standard insecticide used for control of this pest in cotton. The carbamate oxamyl also has been used for control of *N. viridula* in cotton and soybean (Greene et al. 2003; Willrich et al. 2003; Willrich et al. 2004). The pyrethroid cyfluthrin can provide control for *N. viridula* stink bugs (Emfinger et al. 2001, Greene et al. 2001). Indoxacarb, acetamiprid, and thiamethoxam are three new compounds that target plant-feeding pests. Indoxacarb is an oxadiazine insecticide that is active on foliar-feeding lepidopteran larvae (Wing et al. 2000). Acetamiprid is a neonicotinoid insecticide with excellent systemic and translaminar properties and high residual activity (Takahashi et al.1992), and thus it is particularly effective in controlling small plant-sucking pests such as whiteflies, aphids, and plant bugs. Thiamethoxam is a second-generation neonicotinoid compound with contact and ingestion activity for many important sucking pests such as whiteflies, aphids, thrips, and plant bugs (Mason et al. 2000).

The tachinid *Trichopoda pennipes* (F.) is one of the most important natural enemies of *N. viridula* (Jones 1988). Thus, behavioral and feeding responses of this natural enemy to insecticides generally used in production of agricultural crops are important issues in integrated pest management of the southern green stink bug.

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Insecticides, especially botanical insecticides, can affect the feeding behavior of insects. Azadirachtin and other limonoids from the neem tree, *Azadirachta indica* A. Juss., are antifeedants for a wide range of insect species (Mordue and Blackwell 1993, Isman 1997). Toosendanin, a limonoid constituent of chinaberry, *Melia azedarach* L., is an effective repellent against *Pieris brassicae* (L.) (Luo et al. 1995, Jimenez et al. 1997). The goal of the research reported herein was to examine the behavioral and feeding responses of *T. pennipes* to six synthetic insecticides, acetamiprid, cyfluthrin, dicrotophos, indoxacarb, oxamyl, and thiamethoxam.

Materials and Methods

Insects. *Nezara viridula* adults parasitized by *T. pennipes* were collected from sorghum in Tift Co., GA, in 2004, transported to the laboratory, and placed in a cage (29.85 × 29.85 × 29.85 cm) with a hardware cloth screen (3.18 mm mesh) on the bottom and held at 24-27°C and 40-50% RH. Stink bugs were fed raw, shelled peanuts and pole beans. When last-instar *T. pennipes* larvae emerged from their hosts, they fell through the screen on the bottom of the cage onto a tray placed under the cage. These parasitoids were allowed to pupate underneath paper towels on the tray. Upon emergence, *T. pennipes* adults were fed sugar water (300 g granulated sugar and 5 g ascorbic acid in 3.8 L of distilled water) for 2-3 d before being used in experiments. Voucher specimens of these insects are held in the USDA-ARS Crop Protection & Management Research Laboratory in Tifton, GA.

Insecticides. Doses of each insecticide used in these experiments simulated the concentrations of field-use rates based on applications at a total volume of 93.5 L/ha. The test included the following six treatments and rates: (1) acetamiprid (Assail™ 70 [577 µg/ml], Cerexagri, Inc., King of Prussia, PA), (2) cyfluthrin (Baythroid™ 2 [346 µg/ml], Bayer Corp., Atlanta, GA), (3) dicrotophos (Bidrin™ 8 [3,806 µg/ml], Amvac, Los Angeles, CA), (4) indoxacarb (Steward™ 1.25 [1038 µg/ml], DuPont, Wilmington, DE), (5) oxamyl (Vydate™ 2 [2883 µg/ml], DuPont), and (6) thiamethoxam (Centric™ 25 [715 µg/ml], Syngenta, Greensboro, NC). All insecticides were mixed in the sugar water solution described above.

Feeding experiments. To examine the behavioral responses of *T. pennipes* adults to the insecticides, insects were given the opportunity to feed on insecticide-treated food for 1 h. Before the test, ~0.3 ml of treated sugar water was pipetted into a cap of a 1.5-mm centrifuge micro tube. Sugar water was used as a control. Parafilm™ (American National Can, Menasha, WI) was stretched over the top of the cap to eliminate exposure of insects to residues of the compound with a ~0.2 cm narrow opening left on one side of the cap to facilitate feeding by the fly. These centrifuge caps with insecticide-treated sugar water will be heretofore referred to as feeding wells. After individual feeding wells were placed in Petri dishes (60 × 15 mm), *T. pennipes* adults were placed singly into these feeding arenas. A randomized complete block design was used with two pairs (each pair with one male and one female) of insects per block (day) for 4 d (16 insects per treatment).

Insects were starved overnight (12 h) before the test was conducted. During the 1-h time period for the test, the feeding behavior of *T. pennipes* adults was continuously observed. The length of time in minutes before the insect began to feed and the total amount of time in seconds in which the insect fed were recorded. The flies that did not feed during the test were each given the opportunity to feed on insecticide-free sugar water after the test. The length of time in seconds for an insect to begin feeding on this food was recorded for each of these flies. Mortality data were recorded at 2 d after treatment of all insects.

Statistical analysis. Feeding data were analyzed using the PROC MIXED procedure of the Statistical Analysis System (SAS Institute 1999). The fixed effects were insecticide, sex, and insecticide by sex. Random effects were block, block by insecticide, pair number within block, pair number by sex within block, and residual error. Least squares means were separated by least significant difference (LSD) (SAS Institute 1999) where appropriate. Some individual flies did not feed during the tests, and they will be heretofore referred to as nonfeeders. For nonfeeders, the length of time in minutes before the insects began to feed was set at 60.1 min, or 0.1 min after the end of the observation period. Means and standard deviations for times for nonfeeders to begin feeding on insecticide-free sugar water after the initial feeding test were determined using PROC MEANS procedure (SAS Institute 1999).

Results and Discussion

Insecticide significantly affected the time for *T. pennipes* adults to initiate feeding ($F = 10.72$; df = 6, 18; $P = 0.0001$). Factorial analysis revealed no significant effect in response to sex ($F = 1.67$; df = 1, 77; $P = 0.2$) or treatment × sex interaction ($F = 0.54$; df = 6, 77; $P = 0.7751$). The length of time for adult *T. pennipes* to begin feeding was significantly higher for oxamyl, cyfluthrin, indoxacarb, and acetamiprid treated food compared with control food (Table 1). The flies were less likely to begin feeding on food containing oxamyl than on food mixed with any of the other chemicals. These results strongly indicate that these four insecticides acted as repellents to *T. pennipes* adults and that repellency was stronger for oxamyl than for all other insecticides.

Data on total feeding times were analyzed separately for each sex because of a significant treatment × sex interaction ($F = 2.54$; df = 6, 66; $P = 0.0282$). A significant insecticide effect was detected for the total amount of time males ($F = 9.1$; df = 6, 18; $P = 0.0001$) and females ($F = 15.77$; df = 6, 42; $P = 0.0001$) fed. Total feeding time was significantly lower for all insecticide-treated sugar water compared with control food for both male and female *T. pennipes* (Table 1). Diminution of feeding was greater for oxamyl and cyfluthrin for females and for these 2 insecticides along with acetamiprid, dicrotophos, and thiamethoxam for males compared with the other insecticides. All these compounds were highly toxic to this parasitoid when feeding on insecticide-treated sugar water, for all flies that fed on any of these insecticides were dead 2 d after treatment.

When nonfeeders were given insecticide-free sugar water after rejecting food contaminated with oxamyl, acetamiprid, cyfluthrin, or indoxacarb, all of them began to feed on the food within 2-7 min (Table 2). This feeding behavior showed that the previous nonfeeding behavior of these insects was not due to lack of hunger for food or inability to feed on food. All flies that did not feed on insecticide-treated were living 2 d after treatment.

Trichopoda pennipes adults exhibited repellency to food treated with four of the insecticides and diminution of feeding when they actually fed on food containing any of the insecticides. Antifeedants can work as feeding deterrents and/or toxins (Bentley et al. 1990, Schmutterer 1990, Mendel et al. 1991, Gonzalez-Coloma et al. 1995). Although the insecticides in this study exhibited antifeedant activity, feeding on insecticide-treated food for any length of time resulted in the death of all flies. Therefore,

Table 1. Least squares means for the time for adult *T. pennipes* to begin feeding and for the total amount of time male and female *T. pennipes* fed on sugar water treated with acetamiprid, dicrotophos, cyfluthrin, indoxacarb, oxamyl, and thiamethoxam

Insecticide	µg/m	Time to begin feeding (min)	Total feeding time (sec)	
			Males	Females
Oxamyl	2883	46.31 a	6.95 c	0.03 d
Cyfluthrin	346	24.61 b	10.12 c	2.94 d
Indoxacarb	1038	21.21 bc	59.08 b	30.09 b
Acetamiprid	577	17.28 bcd	10.25 c	7.99 cd
Thiamethoxam	715	11.42 cde	9.09 c	6.58 cd
Dicrotophos	3806	4.77 de	13.95 c	20.31 bc
Control		2.67 e	101.84 a	62.85 a

Least squares means within a column followed by the same lowercase letter are not significantly different between insecticides for the time for adults to begin feeding (PROC MIXED, LSD, $P > 0.05$, n = 16, SE = 6.38, df = 18). Least squares means within a column followed by the same lowercase letter are not significantly different between insecticides for the total amount of time males (PROC MIXED, LSD, $P > 0.05$, n = 16, SE = 17.14, df = 18) and females (PROC MIXED, LSD, $P > 0.05$, n = 16, SE = 7.89, df = 42) fed.

Table 2. Means (±SD) for the time for non-feeders to begin feeding on sugar water after rejecting food contaminated with acetamiprid, cyfluthrin, indoxacarb, and oxamyl

Insecticide	µg/ml	n*	% non-feeders	Time to begin feeding (sec)**
Oxamyl	2883	10	62.5	1.5 ± 0.8
Acetamiprid	677	3	18.8	2.8 ± 2.0
Cyfluthrin	346	2	12.5	2.9 ± 3.2
Indoxacarb	1038	2	12.5	7.2 ± 4.0

* n, sample number.
** For information only.

these compounds acted as toxicants upon ingestion, and repellency to the insecticides was the only response by the flies that insured their survival.

The antifeedant activity of insecticides originating from plants, especially the neem tree, *Azadirachta indica* A. Juss., is well documented for pests (Schmutterer 1990). Only a few studies have been conducted on the antifeedant activity of natural and synthetic insecticides on natural enemies of pests. It has been reported previously that feeding on food with residues of acetamiprid, dicrotophos, oxamyl, and thiamethoxam also reduces feeding by the spined soldier bug, *Podisus maculiventris* (Say) (Tillman and Mullinix 2004). Indoxacarb acted as a feeding deterrent, not killing *Geo-*

coris punctipes Say females, but reducing the females' ability to feed, when females were allowed to feed on insecticide-treated eggs (Tillman et al. 2001).

These results suggest that some benefit by way of reduced impact on *T. pennipes* may be derived from use of insecticides that are repellent to this parasitoid. Given that the standard stink bug control material (dicrotophos) is both nonrepellent and highly toxic to *T. pennipes,* the use of alternative insecticides for stink bug control that exhibit repellency to *T. pennipes* and provide satisfactory efficacy against stink bugs (oxamyl and cyfluthrin) might be a more acceptable method of limiting economic damage due to stink bugs whereas also conserving these parasitoids. The repellant characteristics of certain insecticides to *T. pennipes,* as demonstrated in this study invites additional work to evaluate these and other stink bug control materials to determine, in the field, whether repellency leads to conservation of *T. pennipes* and whether this would lead to measurable effects on producer economics.

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References Cited

Bentley, M. D., M. S. Rajab, M. J. Mendel and A. R. Alford. 1990. Limonoid model insect antifeedants. J. Agric. Food Chem. 38: 1400-1403.

Emfinger, K., B. R. Leonard, J. Gore and D. Cook. 2001. Insecticide toxicity to southern green, *Nezara viridula* (L.), and brown, *Euschistus servus* (Say), stinkbugs, Pp. 1159-1161. *In* D. D. Hardee and E. Burris [eds.], Proceedings, Beltwide Cotton Conferences, Anaheim, California, Jan. 7-12, 2001. National Cotton Council, Memphis, TN.

Gonzalez-Coloma, A., M. Reina, R. Cabrera, P. Castanera and C. Gutierrez. 1995. Antifeedant and toxic effects of sesquiterpenes from *Senecio palmensis* to Colorado potato beetle. J. Chem. Ecol. 21: 1255-1270.

Greene, J. K., G. A. Herzog and P. M. Roberts. 2001. Management decisions for stink bugs, Pp. 913-917. *In* D. D. Hardee and E. Burris [eds.], Proceedings, Beltwide Cotton Conferences, Anaheim, California, Jan. 7-12, 2001. National Cotton Council, Memphis, TN.

Greene, J. K., C. Capps, G. M. Lorenz, S. Y. Young and C. Norton. 2003. Evaluation of insecticides for control of insect pests on soybean, 2002. Arthropod Management Tests 28: F97.

Isman, M. B. 1997. Neem insecticides. Pestic. Outlook 8: 32-38.

Jimenez, A., R. Mata, R. Pereda-Miranda, J. Calderon, M. B. Isman, R. Nicol and J. T. Arnason. 1997. Insecticidal limonoids from *Swietenia humilis* and *Cedrela salvadorensis.* J. Chem. Ecol. 23: 1225-1234.

Jones, W. A. 1988. World view of the parasitoids of the southern green stink bug, *Nezara viridula* (L.) (Heteroptera: Pentatomidae). Ann. Entomol. Soc. Am. 81: 262-273.

Luo, L. E., J. J. A. van Loon and L. M. Schoonhoven. 1995. Behavioural and sensory responses to some neem compounds by *Pieris brassicae* larvae. Physiol. Entomol. 20: 134-140.

Mason, G., M. Rancati and D. Bosco. 2000. The effect of thiamethoxam, a second generation neonicotinoid insecticide, in preventing the transmission of tomato yellow leaf curl geminivirus by the whitefly, *Bemisia tabaci.* Crop Prot. Oxf. 19: 473-479.

Mendel, M. J., A. R. Alford, M. S. Rajab and M. D. Bentley. 1991. Antifeedant effects of citrus limonoids differing in A-ring structure on Colorado potato beetle (Coleoptera: Chrysomelidae) larvae. J. Econ. Entomol. 84: 1158-1162.

Mordue, A. J. and A. Blackwell. 1993. Azadirachtin: An update. J. Insect Physiol. 39: 903-924.

Panizzi, A. R. 1997. Wild hosts of pentatomids: ecological significance and role of their status on crops. Annu. Rev. Entomol. 42: 99-122.

SAS Institute. 1999. SAS/STAT user's guide, version 8. SAS Institute, Cary, NC.

Schmutterer, H. 1990. Properties and potential of natural pesticides from the neem tree, *Azadirachta indica*. Annu. Rev. Entomol. 35: 271-297.

Takahashi, H., J. Mitsui, N. Takakusa, M. Matsuda, H. Yoneda, J. Suzuki, K. Ishimitsu and T. Kishimoto. 1992. NI-25, a new type of systemic and broad spectrum insecticide, Pp. 89-96. *In* Proceedings, Brighton Crop Protection Conference-Pests and Diseases, Farnham, Surrey, United Kingdom.

Tillman, P. G., G. G. Hammes, M. Sacher, M. Connair, E. A. Brady and K. Wing. 2001. Toxicity of a formulation of the insecticide indoxacarb to the tarnished plant bug, *Lygus lineolaris* (Hemiptera: Miridae), and the big-eyed bug, *Geocoris punctipes* (Hemiptera: Lygaeidae). Pest Manag. Sci. 58: 92-100.

Tillman, P. G. and B. G. Mullinix Jr. 2004. Comparison of susceptibility of pest *Euschistus servus* and predator *Podisus maculiventris* (Heteroptera: Pentatomidae) to selected insecticides. J. Econ. Entomol. 97: 800-806.

Tillman, P. G. 2006. Susceptibility of pest *Nezara viridula* (Heteroptera: Pentatomidae) and parasitoid *Trichopoda pennipes* (Diptera: Tachinidae) to selected insecticides. J. Econ. Entomol. In Press.

Willrich, M. M., J. Temple, R. H. Gable and B. R. Leonard. 2003. Evaluation of insecticides for control of nymph and adult southern green stink bugs, 2002. Arthropod Management Tests 28: F77.

Willrich, M. M., B. R. Leonard, D. R. Cook and R. H. Gable. 2004. Evaluation of insecticides for control of stink bugs on cotton, 2003. Arthropod Management Tests 29: F61.

Wing, K. D., M. Sacher, Y. Kagaya, Y. Tsurubuchi, L. Mulderig, M. Connair and M. Schnee. 2000. Bioactivation and mode of action of the oxadiazine indoxacarb in insects. Crop Prot. 19: 537-545.