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KAIROMONES AND THEIR USE FOR MANAGEMENT OF ENTOMOPHAGOUS INSECTS XIV. Response of *Telenomus remus*[1] to Abdominal Tips of *Spodoptera frugiperda*,[2] (*Z*)-9-Tetradecene-1-ol Acetate and (*Z*)-9-Dodecene-1-ol Acetate[3,4]

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Abstract—*Telenomus remus* Nixon is a parasitoid that attacks egg masses of *Spodoptera frugiperda* (J.E. Smith). Increased host-seeking behavior was elicited from *T. remus* females in Y-tubes, Petri dish, and greenhouse bioassays by *S. frugiperda* female abdominal tips as well as (*Z*)-9-tetradecene-1-ol acetate and (*Z*)-9-dodecene-1-ol acetate.

Key Words—Kairomone, pheromone, parasitoid, *Telenomus remus*, Hymenoptera, Scelionidae, *Spodoptera frugiperda*, Lepidoptera, Noctuidae, fall armyworm, (*Z*)-9-tetradecene-1-ol acetate, (*Z*)-9-dodecene-1-ol.

INTRODUCTION

Telenomus remus Nixon, a scelionid egg parasitoid indigenous to Sarawak and New Guinea, was introduced into Israel for control of *Spodoptera littoralis* Boisduval (Gerling, 1972) and has been successfully established in Barbados and Montserrat on *Spodoptera frugiperda* (J.E. Smith), *Spo-*

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doptera eridania (Cramer), and *Spodoptera sunia* (Guénee) (Wojcik et al., 1976). *T. remus* was introduced into Florida (near Homestead) from May 1975 to May 1977 but apparently was not established (Waddill and Whitcomb, 1982).

Sekul and Sparks (1967) identified (*Z*)-9-tetradecen-1-ol acetate (*Z*-9-TDA) as the sex pheromone of *S. frugiperda*. However, *Z*-9-TDA proved to be ineffective as a sex attractant in the field, although it does elicit wing fanning and copulatory behavior in the laboratory (Mitchell and Doolittle, 1976; Sparks, 1980) and was referred to as a secondary sex pheromone by Jones and Sparks (1979). Sekul and Sparks (1976) identified a second compound, (*Z*)-9-dodecen-1-ol acetate (*Z*-9-DDA), from *S. frugiperda* female abdominal tips, and this compound is highly attractive in the field to *S. frugiperda* males (Mitchell, 1979; Sparks, 1980).

The involvement of kairomones in the host-location behavior of parasitoids has been demonstrated on numerous occasions (Weseloh, 1981; Arthur, 1981; Jones, 1981). There have also been several demonstrations of compounds that function as pheromones in intraspecific interactions and as kairomones in interspecific interactions (Rice, 1969; Vité and Williamson, 1970; Sternlicht, 1973; Kennedy, 1979; Corbet, 1971; Lewis et al., 1982). As an example, Lewis et al. (1982) demonstrated that the compounds comprising the sex pheromone of *Heliothis zea* (Boddie) (Klun et al., 1980) increased rates of parasitization by *Trichogramma* spp. in the laboratory and field.

The study reported here was designed to determine if chemicals emanating from the abdominal tips of *S. frugiperda*, and particularly *Z*-9-TDA and *Z*-9-DDA, have any effect on the host-finding behavior of *T. remus*.

METHODS AND MATERIALS

The *T. remus* used in this study were reared on *H. zea* eggs that had been processed with a sodium hypochlorite wash as described by Burton (1969) and irradiated with ca. 25 krad (^{60}CO source) when 8–36 hr old, at ca. 70% relative humidity and 26°C using the method described by Lewis and Redlinger (1969) for *Trichogramma*. Female parasitoids were used in the experiments when 1–2 days old.

The *S. frugiperda* moths and egg masses used in this study were obtained from a laboratory culture maintained according to the procedure of Perkins (1979). The *H. zea* eggs used were also obtained from a laboratory culture, processed as stated above, and stored at ca. 10°C.

The abdominal tip extract used in this study was obtained from the tips excised from 2-day-old virgin *S. frugiperda* moths. The moths were anesthetized with CO_2, their abdomens squeezed, and the tips cut with scissors. The excised tips were washed twice in hexane and twice in anhydrous ether; the solvent extracts were combined and filtered through a fine-fritted Buchner funnel over sodium sulfate and then concentrated to 10 female equivalents (FE)/ml.

The *Z*-9-TDA used in these studies was supplied by Dr. U.E. Brady (Department of Entomology, University of Georgia, Athens, Georgia 30602; ENT33474a) and the *Z*-9-DDA used was obtained from Midwest Research Institute (425 Volker Blvd., Kansas City, Missouri, 64110; MRI No. 71-68-9).

Statistical analysis was done by analysis of variance. Arcsin transformations were conducted on all percentages prior to analysis.

RESULTS

Y-Tube Olfactometer Experiments. The Y-tube olfactometer used in these studies consisted of a basic Y tube, each arm of which was 20 cm long and a leg 33 cm long made of 2-cm-ID glass tubing. Air that had been passed through an activated charcoal filter was introduced at ca. 20 ml/min through each arm with the flow controlled by separate flow meters. These experiments were run at room temperature in a laboratory lighted with fluorescent lights and with an incandescent bulb (150 watt) at ca. 50 cm directly over the Y tube.

During the experiment, the treated side of the olfactometer was alternated so that effects of irregularities in the Y tube itself or room lighting would be eliminated. The treatment was applied to Whatman No. 1 filter paper (ca. 6 cm^2), and a piece of untreated paper was placed in the control arm of the olfactometer. *T. remus* females were released from 2-dr shell vials into the end of the leg of the olfactometer (10/rep), and at the end of 10 min the number of parasitoids in each arm of the Y tube was counted. At the end of each replication, the olfactometer was thoroughly washed with soap and water, rinsed with acetone, and dried in an oven.

The results are given in Table 1 and indicate that *T. remus* females are attracted to extracts of *S. frugiperda* female abdominal tips as well as to *Z*-9-TDA and *Z*-9-DDA.

Petri Dish Bioassays. Comparative evaluations of parasitism rates by *T. remus* on *H. zea* eggs were made in 150 × 15-mm Petri dishes on a laboratory table. A pipet was used to apply the treatment solution to the bottom of the treated dishes at the rate of 1 ml/dish. Control dishes received no such treatment. *H. zea* eggs were applied to the bottom surface with three groups of five eggs. The groups were evenly distributed around the dish, ca. 30 mm from the outside edge. The eggs in each group were within 1 mm of

TABLE 1. RESPONSE OF *Telenomus remus* FEMALES TO EXTRACT OF *Spodoptera frugiperda* FEMALE ABDOMINAL TIPS AND TO SPECIFIC CHEMICALS OCCURRING IN TIPS[a]

Replications	Treated	Control
	Abdominal tip extract (0.05 FE/run)	
24	3.4 (±0.4)	0.6 (±0.1)
	(*Z*)-9-DDA (0.1 μg/run)	
24	3.5 (±0.3)	1.8 (±0.3)
	(*Z*)-9-TDA (0.1 μg/run)	
24	4.6 (±0.3)	1.9 (±0.2)

[a]Means significantly different ($P < 0.05$) as determined by ANOVA.

each other. Two female *T. remus* were introduced and allowed to search and oviposit for 1 hr. Percent parasitization was determined by the method described by Lewis and Redlinger (1969) for determining parasitization by *Trichogramma*.

The results of these experiments, given in Table 2, demonstrate that the abdominal tip extract as well as the *Z*-9-TDA and *Z*-9-DDA elicit increased rates of parasitization in Petri dishes.

Greenhouse Experiments. In these experiments, pans of pink-eyed purple hull cowpeas were arranged on greenhouse tables in groups of three (close enough together that the foliage touched) with ca. 0.75 m between groups. *S. frugiperda* egg masses, on paper, were pinned to the leaves in the pans, 3 egg masses/pan. The treatment was applied to two cotton rolls (No. 2 medium, Uni-Disco, Inc., P.O. Box 4450, Detroit, Michigan 48228). The two rolls were placed on the greenhouse table in the center of each group of treated pans. The control groups received no such treatment. Two

TABLE 2. PERCENT PARASITIZATION OF *Heliothis zea* EGGS BY FEMALE *Telenomus remus* IN A LABORATORY PETRI DISH BIOASSAY OF FEMALE *Spodoptera frugiperda* ABDOMINAL TIP EXTRACT AND SPECIFIC CHEMICALS OCCURRING IN TIPS[a]

Replications	Treated	Control
	Abdominal tip extract (1 FE/ml)	
60	27.3 (±5.1)	7.0 (±2.0)
	(*Z*)-9-TDA (1 μg/ml)	
80	14.0 (±2.0)	6.6 (±1.2)
	(*Z*)-9-DDA (1 μg/ml)	
80	21.2 (±2.3)	12.5 (±2.0)

[a]Means significantly different ($P < 0.05$) as determined by ANOVA.

TABLE 3. MEAN PERCENTAGE PARASITIZATION OF *Spodoptera frugiperda* EGG MASSES ON PANS OF PINK-EYED PURPLE HULL COWPEAS IN A GREENHOUSE, BY FEMALE *Telenomus remus* IN RESPONSE TO TREATMENTS OF *S. frugiperda* FEMALE ABDOMINAL TIP EXTRACT OR SPECIFIC CHEMICALS FOUND IN TIPS[a]

Replications	Treated	Control
	Abdominal tip extract (1 FE/ml)	
30	75.5 (±2.1)	62.2 (±2.5)
	(*Z*)-9-TDA (0.5 μg/cotton roll)	
20	43.3 (±2.3)	28.9 (±1.9)
	(*Z*)-9-DDA (0.5 μg/cotton roll)	
15	49.6 (±2.8)	35.6 (±2.7)

[a]Means significantly different ($P < 0.05$) as determined by ANOVA.

vials of 6 female *T. remus* each were released under the foliage, on opposite sides of each group. The parasitoids were allowed to search for ca. 5 hr. The egg masses were then collected and stored at ca. 70% relative humidity and 26°C until the parasitized eggs turned black. Each egg mass that had parasitized eggs was counted as a parasitized egg mass, even though not all the eggs in the mass were parasitized. A pair of one treated and one control group of pans constituted a replication.

The results of this series of experiments, given in Table 3, again demonstrated that the abdominal tip extract, *Z*-9-TDA, and *Z*-9-DDA elicit increased rates of parasitization in the greenhouse. It should be noted that although it is possible that the parasitoids made direct contact with the cotton rolls containing the test materials, the response of increased host search and the resulting increased rates of parasitization occurred some distance from the rolls.

DISCUSSION

The data presented in this study clearly demonstrate that *T. remus* females respond to chemicals emanating from the abdominal tips of *S. frugiperda* and to *Z*-9-TDA and *Z*-9-DDA, in particular, two compounds that have been identified as sex pheromones of *S. frugiperda* (Sekul and Sparks, 1967, 1976). The presence of these compounds stimulates increased rates of parasitization by *T. remus* females and can apparently function without direct contact.

Thus, we have an additional example of pheromones also functioning as a kairomone. The possibility of integrating augmentation of entomophagous insects and mating disruption techniques into a control strategy for *S. frugiperda*, should *T. remus* be established in the United States or used in augmentative releases, is evident. It may also be possible that these materials could be used in traps to monitor establishment and dispersion of the parasitoid in any future release efforts.

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