Nontarget Hymenoptera Collected in Pheromone- and Synthetic Floral Volatile-Baited Traps

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ABSTRACT Monitoring traps baited with lepidopteran sex pheromones and synthetic floral volatiles were used to collect adult Hymenoptera in fields of cotton and corn. Species from Apoidea, Pompiloidea, Scolioidea, Sphecoidea, and Vespoidea were collected, including the genera *Ammophila, Apis, Bombus, Cerceris, Larra, Melissodes, Myzinum,* and *Tachytes.* More *Bombus* spp. were collected from traps baited with *Spodoptera frugiperda* (J. E. Smith) sex pheromone than those baited with phenylacetaldehyde, whereas more Sphecoidea were collected in phenylacetaldehyde-baited traps. Trap design was also an important factor in capture of various species. More Sphecoidea and Tiphioidea were collected in fabric cone-shaped traps than plastic funnel traps. Efforts should be made to develop traps and lures that consistently capture the target pest but do not attract or easily capture aculeate Hymenoptera to preserve beneficial populations.

KEY WORDS *Bombus, Apis, Larra, Cerceris,* nontarget insects

Various trap designs, colors, and lures are used in agricultural systems to monitor for adult lepidopteran pests. Many of the traps also capture nontarget insects, such as Coleoptera, Diptera, and Hymenoptera, which include numerous beneficial insects (Gauthier et al. 1991). Some studies found trap design to be more important than lure in capture of nontarget Hymenoptera (Adams et al. 1989, Mitchell et al. 1989), whereas other research has shown trap color, trap height above crop canopy, and lure influence Hymenoptera movement and subsequent capture (Gross and Carpenter 1991).

Currently, populations of adult male *Spodoptera* spp. are monitored using plastic funnel traps (Universal Moth Traps or "bucket" traps) with a synthetic blend of sex pheromone components as a lure (Mitchell et al. 1985, Tumlinson et al. 1986, Mitchell and Tumlinson 1994). However, chemicals other than sex pheromones are being assayed as moth attractants. For instance, floral compounds that attract noctuid moths have been isolated and identified (Cantelo and Jacobson 1979, Haynes et al. 1991, Heath et al. 1992). Male and female *Trichoplusia ni* (Hübner) were attracted to synthetic phenylacetaldehyde in flight tunnel, greenhouse, or screen cage bioassays (Haynes et al. 1991, Landolt et al. 1991, Heath et al. 1992). Synthetic phenylacetaldehyde was tested in flight tunnel bioassays with male fall armyworm, *S. frugiperda* (J. E. Smith), and was found to increase upwind flight and contact in combination with a sex pheromone lure (Meagher and Mitchell 1999). This material and other compounds are being tested in the field as additional attractants. Because few studies have documented the species and number of nontarget Hymenoptera that are captured in traps intended for agricultural lepidopteran pests, our objectives for this research were to identify Hymenoptera that were collected in traps and compare these captures among trap designs and lures that may be used for fall armyworm.

Materials and Methods

1997. All white bucket traps (white canopy, funnel, and bucket) (International Pheromone Systems, Wirral, Merseyside, England) were placed in northwestern Alachua County, FL, from 23 July to 10 October, to capture male fall armyworm. This part of the county was planted to over 470 ha of cotton, *Gossypium hirsutum* L., and offered fields separated by paved and unpaved roads and forested strips. Traps baited with Trécé (Trécé, Salinas, CA) red septa lures were placed along pivot roads and edges in an 80-ha field from 18 June to 10 October.

Three treatments were used in the experiment: the pheromone blend alone, phenylacetaldehyde (Aldrich, Milwaukee, WI) in plastic caps (0.5 ml per cap) alone, or a combination of both lures. Pheromone lures were attached to the bottom of a cork that was placed in a hole in the canopy of the bucket trap. The cap with phenylacetaldehyde was hot-gun glued (Arrow Fastener, Saddle Brook, NJ) to the bottom of the cork, which was placed in the trap canopy. The combination lure was composed of a cork with attached cap and the pheromone lure attached to the outside of the cork. All traps contained insecticide strips to kill insects that were captured (Hercon Vaportape II [Emigsville, PA] containing 10% 2, 2-dichlorovinyl dimethyl phosphate). Trap contents were removed 3 times per week and pheromone and phenylacetaldehyde lures were replaced every 2 wk. The experiment was designed as a randomized complete block with 4 replications of the 3 treatments. The location of each trap within each replication was changed weekly.

1998. In late March, the same area in northwestern Alachua County was planted to silage corn, *Zea mays* L. An experiment was designed to compare the effect of trap design on the collection of Hymenoptera. The experiment contained 4 treatments: bucket traps with either Trécé or Scentry (Ecogen, Langhorne, PA) *S. frugiperda* sex pheromone lures, and *Heliothis* "cone" traps (Ecogen) with either lure. Cone traps are made of fabric mesh and are designed in the style of hardware cloth traps (Hartstack et al. 1979). *Heliothis* cone traps are composed of 2 cones: the base cone measures 80 cm long, with a bottom opening of 34 cm that narrows to 15 cm at the top; the apex cone measures 27 cm long, with a bottom opening of 15 cm that narrows to 6 cm at the top. The bottom portion of the apex cone is secured to the top portion of the base cone with Velcro material. The lure is placed in the middle of the base cone; insects fly into this opening and up through the 15-cm opening toward the apex cone, eventually going through the 6 cm opening and being trapped in a fabric container around the apex cone. No insecticide strips were used with the cone traps. Traps were placed in similar locations as in 1997, and the experiment was designed as a randomized complete block with 4 replications of the 4 treatments. Trap location within a replication was randomized weekly, and trapping began 8 April and ended 12 June.

Individuals were identified by using keys (Stange 1992) and by comparing with identified specimens. Voucher specimens (FLDA, V01–V30) were placed in the Florida State Collection of Arthropods, Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Gainesville. Species were placed within superfamilies [using the classification of Borror et al. (1989)] for analysis. Numbers per day for each superfamily in each field were compared across treatments using analysis of variance (ANOVA). To satisfy ANOVA assumptions, counts were $log\ (x + 1)$ transformed before analysis. Seasonal means and treatment combinations were separated using a least significant difference (LSD) mean separation test or orthogonal comparisons (PROC GLM, CONTRAST statement, SAS Institute 1996). Untransformed means (±SE) are given in text and figures, whereas statistical results refer to transformed data.

Results

1997. Various aculeate Hymenoptera including species from Apoidea, Pompiloidea, Scolioidea, Sphecoidea, and Vespoidea were collected (Table 1). More than 50 individuals of the bumblebee *Bombus pennsylvanicus* (De Geer) and the sphecid *Larra bicolor* F. were collected.

As a group, numbers of Apoidea were not different among treatments ($F = 4.9$; df = 2, 6; $P = 0.0557$), although there was a trend for more Apoidea to be collected in pheromone-baited traps than in phenylacetaldehyde-baited traps (Fig. 1). When *Bombus* spp. were analyzed separately, more were found in pheromone-baited traps than the combination or phenylacetaldehyde-baited traps (Trécé 0.15 ± 0.06 per day, Trécé + phenylacetaldehyde 0.03 ± 0.02, phenylacetaldehyde 0.03 ± 0.02) ($F = 7.4$; df = 2, 6; $P = 0.0241$). The reverse was true for Sphecoidea (mostly *L. bicolor*), where more wasps were collected in traps

Table 1. Species and number of Hymenoptera collected in the 1997 and 1998 experiments, Alachua County, FL

Superfamily/Family/Tribe/Genus/Species	No. collected	
	1997	1998
Apoidea		
Anthophoridae		
Anthophorinae		
Melissodes bimaculata (Lepeletier)	1	2
Melissodes spp.	1	3
Svastra o. obliqua (Say)	1	0
Xylocopinae		
Xylocopa virginica (L.)	2	1
Unidentified anthophorids	6	12
Apidae		
Bombinae		
Bombus bimaculatus Cresson	1	0
B. fraternus (Smith)	2	1
B. impatiens Cresson	0	4
B. pennsylvanicus (De Geer)	57	59
Apinae		
Apis mellifera L.	17	6
Colletidae		
Colletes sp.	0	1
Halictidae		
Halictinae		
Agapostemon splendens (Lepeletier)	9	84
Pompiloidea		
Pompilidae		
Pompilinae		
Anoplius sp.	3	1
Scolioidea		
Scoliidae		
Campsomerinae		
Campsomeris (Dielis) plumipes fossulana (F.)	1	2
C. (Pygodasis) quadrimaculata (F.)	3	0
Scoliinae		
Scolia (Discolia) n. nobilitata (F.)	0	5
Sphecoidea		
Sphecidae		
Larrinae		
Larra bicolor F.	55	45
L. analis F.	1	0
Tachytes sp.	0	41
Tachysphex sp.	0	2
Philanthinae		
Cerceris bicornuta Guérin	2	73
Sphecinae		
Ammophila procera Dahlbom	1	0
Ammophila sp.	1	42
Chalybion californicum (Saussure)	0	1
Prionyx parkeri Bohart & Menke	1	2
Sphex (S.) ichneumoneus (L.)	1	0
Tiphioidea		
Tiphiidae		
Myzininae		
Myzinum sp.	1	36
Vespoidea		
Vespidae		
Eumeninae		
Euodynerus megaera (Lepeletier)	0	3
Polistinae		
Polistes fuscatus (F.)	0	10
Polistes sp.	2	14

Fig. 1. Number of aculeate Hymenoptera captured per day in Trécé *S. frugiperda* pheromone lure, phenylacetaldehyde lure (PA), or combination pheromone + PA lure (+ PA) bucket traps in cotton, Alachua County, FL, 1997. Means within Sphecoidea followed by the same letter are not significantly different.

baited with phenylacetaldehyde alone than with pheromone alone ($F = 6.0$; df = 2, 6; $P = 0.0375$) (Fig. 1). Few numbers of Scolioidea or Vespoidea were collected, and there were no differences in capture among treatments ($P > 0.22$; Fig. 1).

1998. This experiment was designed to compare capture of Hymenoptera between different trap types within pheromone sources. Similar species were collected in 1998, although fewer Apoidea and more Sphecoidea were collected (Table 1). Several species were collected in relatively large numbers, including *Tachytes* sp., *Cerceris bicornuta* Guérin, *Ammophila* sp., and *Myzinum* sp.

No differences were found comparing numbers of Hymenoptera captured in traps baited with *S. frugiperda* supplied by Trécé versus Scentry; therefore, capture numbers were combined and reanalyzed. More Sphecoidea and Tiphioidea were collected in cone traps than bucket traps (Fig. 2) (Sphecoidea, $F = 15.5$; df = 1, 9; $P = 0.0034$; Tiphioidea, $F = 9.6$; df = 1, 9; $P = 0.0129$). Two species, *C. bicornuta* (Sphecidae) and *Myzinum* sp. (Tiphiidae), were collected only from cone traps. There was a trend for more Apoidea to be found in bucket compared with cone traps ($F = 4.0$; df = 1, 9; $P = 0.0758$). No other superfamily showed differences between trap treatments.

Fig. 2. Number of aculeate Hymenoptera captured per day in *S. frugiperda* pheromone lure in bucket and cone traps in corn, Alachua County, FL, 1998. Means within Sphecoidea followed by the same uppercase letter and Tiphioidea followed by the same lowercase letter are not significantly different.

Discussion

Several studies have documented the presence of aculeate Hymenoptera in monitoring traps (Adams et al. 1989, Mitchell et al. 1989, Gauthier et al. 1991), with the emphasis generally on capture of *Bombus* spp. Certain trap designs and colors have been implicated in the capture of bumblebees. Research in sweet corn showed that more "stinging" Hymenoptera (bumblebees, honey bees, and yellowjackets) were collected in cone than bucket traps (Adams et al. 1989). Our results suggested a trend for more Apoidea to be collected in bucket traps. Several studies have demonstrated that white or yellow traps attracted large numbers of *Bombus* spp. (Hamilton et al. 1971, Mitchell et al. 1989), but that green-colored traps reduced bumblebee capture (Hamilton et al. 1971).

Research in western North Carolina showed that trap color alone did not influence bumblebee movement into the trap (Gross and Carpenter 1991). Fall armyworm pheromone lure alone or in combination with insecticide strips (dichlorovos) increased capture of several *Bombus* spp. Our results suggested that *Bombus* spp. were collected in higher numbers in *S. frugiperda* pheromone-baited traps than phenylacetaldehyde-baited traps. We have seen a trend for traps baited with beet armyworm, *S. exigua* (Hübner), pheromone to collect fewer bees than those with phenylacetaldehyde as the lure (unpublished data). Perhaps one of the components in the fall armyworm pheromone and not in the beet armyworm pheromone is attractive to bumblebees; however, more testing of the components involved with each pheromone blend would be needed to verify these conclusions.

Bumblebees appear to have separate behaviors for gathering nectar and pollen (Liu et al. 1975), and apparently do not communicate information about these sources to other nestmates (Michener 1974). Therefore, individual bees must make decisions on what plants to sample for nectar and pollen (Plowright and Laverty 1984). Bumblebees travel relatively long distances from their nest and forage over large areas (Dramstad 1996). It is probable that separate sensory modalities are needed to search for plants that provide food. Bucket and cone traps placed within agricultural crops apparently provide both visual cues (trap color and placement) and olfactory cues (pheromone components and floral volatiles) that can attract and capture large numbers of bumblebees.

The food foraging activities and nesting behavior of other Hymenoptera most likely influence their ability to be attracted or captured by different traps. *Larra bicolor* females sting, paralyze, and oviposit on *Scapteriscus* mole crickets, and neonate larvae develop as external parasitoids on active hosts. This natural enemy was imported to Florida from Bolivia (Frank et al.

1995), and was previously collected in pheromone traps (Meagher and Frank 1999). *Cerceris bicornuta*, *Ammophila* spp., and *Tachytes* spp. are generally solitary ground-nesting sphecids that provision their cells with different insect prey. *Cerceris* spp. prey primarily on Coleoptera (Scullen and Wold 1969) and *C. bicornuta* prefer *Sphenophorus* (corn billbugs, Curculionidae, Rhynchophorinae) (Evans 1971). *Ammophila* provision nests with "naked" lepidopterous larvae (Powell 1964), either with 1 large prey item or several smaller items (Field 1992). *Ammophila procera* Dahlbom prefer notodontid and noctuid prey (Powell 1964). *Tachytes* consists of 35 species in the United States and Canada (Bohart 1994), and females provision their nests with adults and nymphs in the orthopteran families Acrididae, Tettigoniidae, and Tridactylidae (Kurczewski and Kurczewski 1984, Kurczewski and Spofford 1986). Adults of all these sphecids were collected in higher numbers in cone traps compared with bucket traps, or in traps baited with synthetic floral extracts. These insects are active and feed throughout the day on plant nectar (Scullen and Wold 1969, Rosenheim 1987).

Efforts should be made to develop traps and lures that are not attractive or that do not easily capture aculeate Hymenoptera, but consistently capture the target pest. Related species of Hymenoptera within the genera collected in this study are potentially important crop pollinators (Berger et al. 1988, Plowright and Laverty 1984) or natural enemies against economic pests (Frank et al. 1995, Gillaspy 1979, Gould and Jeanne 1984). The ecological significance of removal of these beneficials is not known, but it may be of value to study their interactions within field crop agroecosystems.

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