Odor from herbivore-damaged plant attracts the parasitoid fly *Exorista japonica* Townsend (Diptera: Tachinidae)

Yooichi Kainoh,* Chiharu Tanaka and Satoshi Nakamura1

Institute of Agriculture and Forestry, University of Tsukuba, Tsukuba, Ibaraki 305–8572, Japan
1Japan International Research Center for Agricultural Sciences, Tsukuba, Ibaraki 305–8686, Japan

(Received 20 May 1999; Accepted 26 July 1999)

Abstract

The behavior of female *Exorista japonica* Townsend (Diptera: Tachinidae) in response to an herbivore-damaged plant was examined in a wind tunnel bioassay. We used the common armyworm, *Mythimna (=Pseudoaltesia) separata* Walker, as a host for this fly and as an herbivore to damage corn plants. Experienced flies conditioned to oviposit on the host/corn plant complex were attracted mostly to the host/plant complex and required a relatively short time to arrive at the plant. Damaged corn plants without host larvae and their frass were also attractive. However, only a few experienced flies were attracted to the undamaged plants. These two responses indicate that the damaged corn plants without the herbivore present emit an attenuated signal odor for female flies. The host larvae *per se* did not attract the flies. Naive flies had lower responses to the host/plant complex than the oviposition-experienced flies, indicating the importance of oviposition to the host with or without a damaged plant.

Key words: *Exorista japonica*, Tachinidae, attraction, wind tunnel, damaged plant odor

INTRODUCTION

The orientation of parasitoids to a potential host community location may be due at least in part to long-range cues emitted by herbivore-damaged plants (Vinson, 1985). In tachinid flies, the attraction of several species to plant odors has been demonstrated (Monteith, 1955, 1958, 1960; Franklin and Holdaway, 1966; Herrebout and van der Veer, 1969; Nettles, 1979, 1980). It has also been shown that damaged plants attract flies from a distance (Roth et al., 1982; Roland et al., 1989, 1995; Mondor and Roland, 1997) and stimulate oviposition at close range (Hassel, 1968; Odell and Godwin, 1984; Roland et al., 1989).

The tachinid fly, *Exorista japonica* Townsend, is a parasitoid of many kinds of lepidopterous larvae, particularly noctuid larvae, i.e., the common armyworm, *Mythimna separata* Walker, the common cutworm, *Spodoptera litura* Fabricius, and the cabbage armyworm, *Mamestra brassicae* Linne (Oku and Kobayashi, 1974). *E. japonica* lays heavy-shelled macrotpe eggs on the host cuticle (Nakamura, 1994). In such tachinid flies as *E. japonica*, which lay eggs directly on the host larvae, attraction of flies to the damaged host plant has not been clearly demonstrated in olfactometer studies. We, therefore, undertook studies to determine the role of attractive odors emanating from corn plants damaged by *M. separata* larvae.

MATERIALS AND METHODS

Host and parasitoid. The common armyworm, *M. separata*, was obtained from our stock culture and reared on an artificial diet (Silk Mate, Nihon Nosen Kogyo) according to Kanda (1991). *E. japonica* was obtained from our stock culture and adult parasitoids were reared in plastic containers (16×28×17 cm) with sugar and water after the method of Nakamura (1996) and Tanaka et al. (1999). All rearing and experiments were performed at 25±2°C, 40–80% R.H. and 16L–8D photoperiod.

**Corn plants.** Potted corn plants (20–30 cm in h.t.) were grown indoors from seeds under
natural sunlight filtered through a window during the summer and in an incubator under fluorescent lights during the winter. Plants were either planted individually in a small pot (6 cm in dia., 8 cm in ht.) and used for conditioning the wasps or planted in groups of 5 or 6 in a large pot (15 × 30 × 12 cm) that was used for wind tunnel experiments.

**Conditioning.** Flies were conditioned either by allowing females to oviposit on the host with a damaged plant (DP + H) or to oviposit on the host (H) alone. In the former conditioning, a mated female fly (4–5 day old) was confined to a cage (16 × 17 × 28 cm) with sugar, water and a small potted corn on which 5 last stadium *M. separata* larvae were fed and kept under a 16L–8D photoperiod for 24 h. On the following day, the potted plant with host larvae was removed from the cage and kept for a further 24 h before the bioassay. In the latter conditioning, a last stadium *M. separata* larva was exposed to a female fly in a cage and the host larva was taken out after she laid more than one egg on the day before bioassay. Flies without any conditioning were regarded as naive.

**Bioassay.** A wind tunnel was used for evaluating the response of flies to the test items. The tunnel was 50 cm high × 50 cm wide, and 150 cm in length and was made of clear polyvinyl chloride, 5 mm in thickness. Air was drawn through the tunnel at 25 to 30 cm/s and the light intensity on the tunnel floor was 2,200 lx. All wind tunnel tests were performed between 1200–1700 h when the flies were active enough to fly (Tanaka and Kainoh, personal observation). As a release point for a fly, a metal platform (10 × 10 cm, 20 cm in ht.) was placed 25 cm upwind of the downwind end and a sugar cube in a glass Petri dish (3 cm in dia.) was put at the center. An individual female fly was released by transferring it with a plastic cup (3 cm in dia., 5 cm in ht.) to the sugar cube. We waited for the fly to stop feeding and begin to fly, after which, the time it took for the fly to arrive at the target, placed 1 m upwind from the platform, was measured with a stopwatch. If the fly did not take off within 5 min, we replaced that individual with a new fly. If the fly did not land on the target within 2 min after she had taken off from the platform, we discarded it. Fifteen to 17 flies were released in each treatment.

**Target items.** Four kinds of target items were prepared and tested one at a time at 25 cm downwind of the upwind end of the tunnel. The first target was large potted corn plants on which 5 last stadium host larvae had been feeding for 4–5 h (DP + H). The second was the same as the first except the host larvae and frass were removed from the pot or plant (DP). The third one was an undamaged corn plant (UP), and the fourth was 5 last stadium host larvae in a 9 cm Petri dish placed on a platform (20 cm in ht.) (H).

**RESULTS**

**Behavioral patterns of flies in the wind tunnel**

After a female fly finished feeding on the sugar, several types of behavior were observed. Some flies took off immediately from the platform, orientating straight upwind to the plant. In this case, the female landed on the plant within 2 or 3 s. Other flies took off and landed on the wall of the tunnel and then walked or flew to the plant. A third flight pattern was to take off and land on the wall and walk around for the rest of the assay. A fourth group did not fly at all but instead remained on the platform either walking or remaining still.

**Rate of flight**

With naive flies which were tested with damaged plants and hosts (DP + H), 73% took off from the release point. Flies with oviposition experiences (H), when subjected to host larvae (H), had a take off rate of 87%. In other experiments, all the flies released took to flight within 5 min.

**Rate of flies landing on plants**

When naive flies were tested with damaged plants and hosts (DP + H), 45% of them landed on the plant within 2 min and one fly did so within 10 s (Fig. 1A). When the females were conditioned with oviposition on hosts (H) and subjected to DP + H, 71% of them landed on plants within 2 min and half of them landed within 10 s (Fig. 1B). Some of them flew directly to the plant. If they had been conditioned with damaged plants and hosts (DP + H), 75% of them landed on the plant within 2 min, 56% of
them within 10 s (Fig. 1C). This response decreased slightly when they were subjected to damaged plants without host larvae and frass (Fig. 1D). However, their (DP + H) response greatly decreased (27%) with undamaged corn plants (UP). Only two out of 4 flies landed within 10 s (Fig. 1E). None of the flies with host (H) conditioning landed on the host larvae (Fig. 1F). The rate of flies landing on the plant within 2 min did not differ among treatments, but that of flies landing within 10 s differed significantly by a χ²-test.

**Time from takeoff to landing**

No significant difference was obtained among the treatments (Fig. 2). When the percentage of flies was high (Fig. 1, B, C, and D), the time from takeoff to landing on a target was relatively short (Fig. 2, B and C). None of the conditioned flies with host oviposition (H) landed on the host larvae (H) within 2 min (Fig. 1F); instead they flew around or walked on the wall of the wind tunnel.

**Fig. 1.** Percentage response of *E. japonica* with various conditionings (H: host oviposition; DP + H: host oviposition on damaged corn) to different targets (DP + H: 5 host larvae on damaged corn; DP: damaged corn without host and frass; UP: undamaged corn; H: 5 host larvae). Dark areas represent the percent of flies which reached the target within 10 s, and bars represent the percent of those that flew within 2 min. Numbers in parentheses indicate the number of flies tested. Dark areas with the same letters are not significantly different by a Tukey-type multiple comparison test following a χ²-test (5%).

**Fig. 2.** Response of flies in time from takeoff to landing on a target. Symbols are the same as in Fig. 1. Vertical bars show standard errors of the means. Values among treatments were not significantly different by a Kruskal-Wallis test (5%).

**DISCUSSION**

A large number of oviposition-experienced (H) or fully-experienced (DP + H) flies landed on damaged plant targets (Fig. 1, B, C, and D) as compared with undamaged plants (Fig. 1E). This indicates the importance of odor from damaged plants. However, undamaged plants are slightly attractive, which may show the presence of common attractive chemical(s) in both damaged and undamaged plants, or that undamaged plants were inadvertently damaged during our experimental procedures. The effect of odor from damaged plants on parasitoid fly attraction has been shown in several tachinid fly species. *Cyzenis albicans* is attracted to odors from oak trees damaged by the winter moth *Operophtera brumata* (Roland et al., 1989, 1995). *Drino bohemia* and *Bessa harveyi* are attracted to insect-damaged foliage especially on unhealthy plants (Monteith, 1964). *Lixophaga diatraeeae* (Townsend) are attracted to sections of a cage containing sugarcane infested with larvae of the host, sugarcane borer (Roth et al., 1982). In *Leschenaultia exul*, the flies are attracted to the host-aspen poplar complex, in a wind tunnel (Mondor and Roland, 1997). Attraction of flies to healthy plants was shown in several species. *Eucelatoria* spp. is attracted to healthy plants or their extracts (Nettles, 1980; Martin et al., 1990). *Lydella grisescens*, a
parasitoid of the European corn borer *Ostrinia nubilalis* is attracted to corn plants (Franklin and Holdaway, 1966).

Female *E. japonica* that had experienced oviposition on damaged plants showed the strongest flight response to damaged plants and hosts (Fig. 1C). Naive (A) or oviposition experienced (B) flies were less attracted to the same target, which suggests that the experience of oviposition with damaged plants is important. Experience of the host/plant complex has a large effect on further attraction in some hymenopteran parasitoids (e.g., Turlings et al., 1989; Powell et al., 1998). Damaged plants and hosts are attractive even to naive flies (Fig. 1A), however, oviposition experience (Fig. 1B) enhances this attraction. Sensitization through oviposition experience might have an effect on this response as can be seen in an ichneumonid parasitoid, *Campoletis sonorensis* (McAuslane et al., 1991).

Even if flies experienced oviposition on damaged plants (DP+H), the response to only the damaged plant was lower (Fig. 1D) than that to the damaged plant/host complex (DP+H), possibly due to the absence of frass odor. In *L. exul*, the flies spent more time on the side of the wind tunnel containing volatiles from host frass (Mondor and Roland, 1997). The host itself was not attractive, even though flies experienced oviposition (Fig. 1F). The effect of frass itself needs to be investigated in future studies.

In the present experiments, we demonstrated the apparent attraction of tachinid flies to odor from damaged corn plants, however, effects of visual stimuli cannot be ruled out, since experienced flies responded to the undamaged plants (Fig. 1E). To examine this possibility, we will test flies further with a fine mesh screen to prevent visual attraction and by using healthy or damaged plant extracts.

**ACKNOWLEDGEMENTS**

We thank Dr. DeMar Taylor for reviewing the manuscript and Dr. Ryo Osawa for statistical advice.

**REFERENCES**


