The biology of the parasitoid fly *Drino inconspicuoides* (Diptera: Tachinidae) in the host *Mythimna separata* (Lepidoptera: Noctuidae)

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Abstract

The biology of the tachinid fly, *Drino inconspicuoides*, a gregarious ovolarviparous parasitoid of some lepidopteran pests, was studied in the laboratory at 25°C, 60–70% RH and a 16L : 8D photoperiod in the host *Mythimna separata*. The duration of mating averaged 79.4 ± 9.2 min (mean $\pm$ SE). After mating, the parasitoid had a pre-oviposition (gestation) period of 6.3 ± 0.3 d. Females of *D. inconspicuoides* had a daily oviposition rate of 11.6 eggs and a mean fecundity of 163.6 ± 13.4 eggs during a mean oviposition period of 14.8 ± 1.3 d. Total lifetime fecundity per female varied from 57 to 271 eggs. The mean longevity of mated females provided with hosts, including the pre-oviposition period was 21.1 ± 1.5 d. Mated female parasitoids deprived of hosts lived an average of 29.3 ± 2.9 d, which was significantly longer than that of their un-deprived counterparts. Unmated males lived an average of 15.5 ± 1.9 d. When one egg was laid per host, the larval period averaged 7.9 ± 0.4 d for males and 8.3 ± 0.3 d for females, and the puparial period averaged 10.5 ± 0.2 d for males and 11.4 ± 0.2 d for females. The mean total developmental period for males and females was 18.5 ± 0.4 and 19.7 ± 0.4 d, respectively.

Key words: Parasitoid; Tachinidae; *Drino inconspicuoides*; biology

INTRODUCTION

Members of the genus *Drino* (Diptera: Tachinidae) are parasitic on either sawfly or lepidopteran larvae (Shima, 1999). Among the host insects, the common armyworm, *Mythimna separata* (Walker) (Lepidoptera: Noctuidae), is known as an international pest attacking many agricultural plant species, particularly maize (*Zea mays*), sorghum (*Sorghum bicolor*), and rice (*Oryza sativa*) (Hill, 1975; Sharma and Sullivan, 2000).

D. inconspicuoides (Baranov) is a gregarious and ovolarviparous parasitoid, which lays incubated eggs directly on its host (Shima, 1999). This fly is polyphagous and parasitizes lepidopteran larvae such as the chestnut tiger, *Parantica sita niponica* Moore (Lepidoptera: Danaidae), and the Chinese comma, *Polygonia c-aureum* (Linnaeus) (Lepidoptera: Nymphalidae), in Japan (Shima, 1999), and the cabbage cluster caterpillar, *Crocidolomia pavonana* (Fabricius) (Lepidoptera: Crambidae), in the Pacific (Baranov, 1934). In central

Japan, it is the dominant species of tachinids attacking the fall webworm, *Hyphantria cunea* (Drury) (Lepidoptera: Arctiidae), along with *Exorista japonica* (Townsend) and *Compsilura concinnata* (Meigen) (Watanabe, 2005).

Although *D. inconspicuoides* would be an important natural enemy of a number of pest species, no information exists on the biology of this parasitoid. In the present study, we examined the following biological attributes of this parasitoid: parasitization capacity (fecundity), developmental time, oviposition periods, mating duration and adult longevity.

MATERIALS AND METHODS

Host and parasitoid. Parasitoid flies used in this study were drawn from a culture initiated from parasitized larvae of *H. cunea*, which were collected at the campus of the Japan International Research Center for Agricultural Sciences (JIRCAS) (36°3'N; 140°5'E), Tsukuba, Japan, in October

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2004. They were reared in ventilated cages ($35 \times 21 \times 28$ cm, width $\times$ diameter $\times$ height), in which sugar cubes and water were provided as a diet until the experiments. The parasitoids were maintained in the way described in Nakamura (1996). Male and female parasitoids emerging from puparia weighing between 35 and 50 mg were used in the experiments to minimize variation in fecundity associated with body size (Mani and Nagarkatti, 1983; Nakamura, 1995; Reitz and Adler, 1995; Allen and Hunt, 2001; Kolluru and Zuk, 2001).

Larvae of *M. separata* were obtained from a stock culture and were reared on an artificial diet after the methods of Hattori and Atsushima (1980). One-day-old (day 1) last instar larvae were used as hosts in all experiments.

Mating duration, fecundity and longevity. The optimum time of mating among tachinids, is when the male is 2–5 d and the females are just emerging (Nakamura, 1994; Zhang et al., 2003), and preliminary studies on *D. inconspicuoides* indicated similar results (Nakamura, S., unpublished). Therefore, to determine the duration of mating, a naïve female parasitoid within 24 h of emergence was put together with a naïve male (day 2–3) from the same cohort in a plastic cup (12×10 cm, diameter $\times$ height). Their mating behaviour was observed and mating duration was measured.

Adult longevity of both sexes was examined. Male longevity was determined as newly emerged males were individually kept in a plastic cup and provided with water and a sugar cube as food. Female longevity was measured in the presence and absence of hosts, to examine the effects of host provision and/or deprivation on parasitoid longevity. Soon after copulation, to measure longevity for mated females deprived of hosts, female flies were kept individually in a plastic cup and provided with food in the same method as described previously. They were monitored daily until death. There were 20–23 replications made using these set-ups.

Fecundity and longevity of females in the presence of a host were simultaneously measured. Five hosts were provided to the parasitoid fly for parasitization 1 d after mating and were replaced every 24 h with unparasitized hosts, consecutively, until the parasitoid died. The eggs of the flies hatch within 2–3 s after oviposition and the larvae penetrate the host cuticle directly through the bottom of

the egg chorion that remains on the host cuticle for a while (Nakamura, S., unpublished). The hosts were examined daily to count the number of eggs (eggshells or holes made by maggots) on the host. Following parasitization, the location (distribution) of the eggs on different regions of the host body was also recorded.

Developmental time. One host was exposed to a mated female parasitoid in a fly rearing cage for 5–10 min ($n=30$). Behaviours of the fly and host were observed to ensure that only one egg was laid per host. Preliminary observation had suggested that the developmental time is influenced by the number of eggs per host (Kalyebi, A., unpublished). Immediately after female oviposition on a host, the host was withdrawn from the cage. Parasitized host larvae were individually placed in a Petri dish (9×2 cm, diameter $\times$ height) and supplied with the diet. The durations from oviposition to pupariation and from pupariation to adult emergence were recorded.

All the experiments were conducted at 25°C, 60–70% RH and a 16L : 8D photoperiod.

RESULTS

Mating duration and pre-oviposition period

The duration of mating was 79.38 ± 9.2 min (mean $\pm$ SE) (Table 1). The pre-oviposition (gestation) period for female *D. inconspicuoides* averaged 6.3 ± 0.3 d and ranged from 3–9 d.

Lifetime fecundity and oviposition period

The mean total number of eggs laid by an individual female in a lifetime was 163.6 ± 13.4 (Table 1). The most fecund female laid 271 eggs in its lifetime. The mean daily egg production during the oviposition period was 11.6 eggs. One-third of the females laid 161–200 eggs, while each of the 81–120, 121–160 and 241–280 oviposition range were recorded by 17.4% of the females (Fig. 1). Although all the females laid eggs, the oviposition pattern varied with 61.9% females laying eggs daily, while 38.1% had some 1, 2 or 3 d intervals for oviposition. Most of the females (76.2%) laid eggs until the day of their death, while the rest (23.8%) stopped laying eggs 1–2 d prior to death. Dissection of females soon after death found that 75% of the females still had a number of viable eggs in the ovary, while 25% had exhausted their

Table 1. Life history parameters of *D. inconspicuoides* adults

Life history parameter	<i>n</i>	Mean $\pm$ SE	Range
Mating duration (min)	23	79.38 $\pm$ 9.2	25–205
Oviposition period (d)	23	14.8 $\pm$ 1.3	3–30
Gestation period (d)	20	6.3 $\pm$ 0.3	3–9
Longevity of males (d)	20	15.5 $\pm$ 1.9	3–36
Longevity of females with hosts (d)	23	21.3 $\pm$ 1.6	7–41
Longevity of females without hosts (d)	23	29.3 $\pm$ 2.9	3–60
Fecundity	23	163.6 $\pm$ 13.4	57–271

Fig. 1. Distribution of *D. inconspicuoides* females according to total number of eggs laid on the host *M. separata*. Fig. 2. Mean daily fecundity of female *D. inconspicuoides* ($n=23$) on the host *M. separata*.

viable egg load.

The oviposition period among parasitoid females varied from 3–30 d with a mean duration of 14.8 ± 1.3 d (Table 1). Similarly, the fecundity per female varied greatly from one day to another (Fig. 2) and an analysis of variance showed a significant difference between days ($F=3.08$; $df=46$, 2,423; $p<0.0001$). The oviposition peak occurred between day 7 and 11 of oviposition. Using a 5 d-interval classification (Fig. 3), 56.52% of the females had a relatively longer oviposition period, 11–20 d. Percentage parasitism of the host larvae in the tested sample was 61.6% ($n=445$). The highest number of eggs laid by an individual female per day was 52.

Regardless of the number of eggs laid per host, the females had an ovipositional preference on host body parts ($F=16.93$; $df=2$, 2,423; $p<0.0001$). A total of 2,486 eggs were laid (on 274 host larvae), 42.8% were deposited on the head and thorax region (Fig. 4), while 32.18 and 25.02% were on the anterior (1–5) and posterior (6–10) abdominal segments, respectively.

Fig. 3. Distribution of *D. inconspicuoides* females according to the duration of oviposition period (d), while parasitizing the host *M. separata*.

Adult longevity

Adult longevity of mated females provided with hosts varied between 7 and 41 d (Table 1). Their average lifetime was 21.3 ± 1.6 d. Female survivorship during oviposition followed a type I survivorship curve (Pearl, 1928) (Fig. 5). Mated females

Fig. 4. Egg distribution on the host *M. separata* by *D. inconspicuoidea* on head (H), thorax (T1–3) and abdominal segments (A1–10).

Fig. 5. Survival rate (%) of unmated males, mated females (with hosts) and mated females (without hosts) of *D. inconspicuoidea*.

deprived of hosts lived an average of 29.3 ± 2.9 d, significantly longer than those un-deprived of hosts (Student's *t*-test, $F=3.12$; $df=22, 22$; $p=0.01$). Males had an average lifespan of 15.5 ± 1.9 d (Table 1) and also had a type I survivorship (Fig. 5). However, their longevity was considerably shorter than that of females in both deprived and un-deprived states ($F=9.9$; $df=2, 41$; $p=0.0003$).

Developmental time

Larval developmental period and developmental periods from puparium formation to adult emergence for both sexes are shown in Table 2. The total developmental period (length of larval and puparial periods) for the parasitoids averaged 18.5 ± 0.44 d for males and 19.7 ± 0.36 d for females. The difference in developmental periods (d)

Table 2. Developmental period (d) of *D. inconspicuoidea* in the host *M. separata*

	Mean $\pm$ SE	Range
Male ($n=17$)		
Larval period	7.9 ± 0.36	5–11
Pupal period	10.5 ± 0.17	9–12
Total period	18.5 ± 0.44	15–21
Female ($n=13$)		
Larval period	8.3 ± 0.26	6–10
Pupal period	11.4 ± 0.18	10–12
Total period	19.7 ± 0.36	16–21

between sexes was not significant (Student's *t*-test; $F=1.96$; $df=16, 12$; $p=0.24$). Adults successfully emerged from all the puparia tested.

DISCUSSION

The mean fecundity of 163.6 ± 13.4 for *D. inconspicuoidea* in the present study is comparable to those of other tachinids of similar oviposition behaviour (i.e., those that lay incubated eggs directly on the host cuticle). The fecundity of *D. solennis* (Walker) was 196.4 eggs (Peter et al., 1983), while *D. inconspicua* (Meigen) laid 100 eggs (Herting, 1960). Similarly, Bryan et al. (1969) found that *Lespesia archippivora* (Riley), an indigenous parasitoid of many lepidopterous pests of crops in North America, has a mean fecundity of 145 eggs at 25°C.

D. inconspicuoidea oviposited most often on the thoracic segments and occasionally on the anterior and posterior abdominal segments including the prolegs. The same characteristic behaviour of females ovipositing on certain parts of a host body has been also found in other tachinid flies (Chauthani and Hamm, 1967; Danks, 1975; Turnock, 1978; Valovage and Kulman, 1983; Martin et al., 1989; Nakamura, 1997; Ichiki et al., 2004). Nakamura (1997) observed *E. japonica* to oviposit more often on the head and thoracic segments of its larval host, while Yamawaki et al. (2002) found *E. japonica*'s orientation to be frequently towards the head of its host. This ovipositional site preference is widely regarded to be an adaptation by the fly to avoid host attempts to remove or destroy eggs (Chauthani and Hamm, 1967; Danks, 1975; Turnock, 1978; Valovage and Kulman, 1983; Martin et al., 1989; Nakamura, 1997; Ichiki et al.,

2004).

The longevity of *D. inconspicuoides* observed in the present study was similar to that recorded for other tachinids held in the laboratory. In most of the cases, the mean longevity of females was longer than that of males (e.g., Jackson et al., 1976; Turnock, 1978; Grant and Shepard, 1983; Nakamura, 1994; Cardoza et al., 1997). The fact that parasitoids deprived of hosts lived longer has also been well documented among tachinids. Lauzière et al. (2001) found that *Lydella jalisco* Woodley, a tachinid solitary parasitoid of the Mexican rice borer *Eoreuma loftini* (Dyar), lived longer when deprived of hosts. Some other tachinids showed a similar tendency. Females that were provided with hosts less frequently lived longer than those provided with hosts more often (Bryan et al., 1969; Nakamura, 1994). Trade offs between reproduction and survival could explain the fact that individuals deprived of oviposition opportunities live substantially longer than those allowed oviposition continuously (Roitberg, 1989; Ellers et al., 2000; Papaj, 2000).

D. inconspicuoides males usually emerged from puparium earlier than females on average, although the difference in total developmental period was not significant between sexes in the present study. Similarly, the pupal period for *E. japonica* was found to be 11.42 ± 0.89 d for males and 11.89 ± 0.83 d for females at 25°C (Nakamura, 1994). Grant and Shepard (1983) found that males of *Voria ruralis* (Fallén) emerge 0.7 d earlier than females at 27°C. Males of adult *L. aletiae* also emerge about 1 d before females at 25°C (Cardoza et al., 1997).

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