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Investigation of Fecundity and Sex Ratio in the Parasitoid *Bracon hebetor* Say (Hymenoptera: Braconidae) in Relation to Parasitoid Age

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Abstract: The effect of parasitoid age on fecundity and sex ratio in *Bracon hebetor* Say (Hymenoptera: Braconidae) was examined at 26 ± 2 °C and 60 ± 5% relative humidity. *Galleria mellonella* (L.) and *Ephestia kuehniella* (Zell.) were used as host species. It was found that the fecundity of the female parasitoid did not change significantly during the first 5 days of the female's lifespan but afterwards it decreased significantly. Under laboratory conditions, the offspring sex ratio was male biased on both host species. The fecundity of the female parasitoids reared on late stage larvae of *G. mellonella* was higher than that of those reared on *E. kuehniella*.

Key Words: Host, parasitoid, fecundity, sex ratio, *Galleria mellonella*, *Ephestia kuehniella*

Parazitoit *Bracon hebetor* Say (Hymenoptera: Braconidae)'da Parazitoit Yaşına Bağlı Olarak Verim ve Eşey Oranının İncelenmesi

Özet: Parazitoit yaşının *Bracon hebetor*' da verim ve eşey oranına etkisi 26 ± 2 °C sıcaklık ve %60 ± 5 nisbi nem koşullarında incelendi. Konak olarak *Galleria mellonella* (L.) and *Ephestia kuehniella* (Zell.) kullanıldı. Dişi parazitoitin veriminin ergin hayatın ilk beş günü süresince önemli ölçüde değişmediği, ancak daha sonra önemli ölçüde azaldığı belirlenmiştir. Laboratuvar koşullarında, oğul döldeki eşey oranı her iki konakta da erkek eğilimliydi. *G. mellonella* olgun larvalarında yetiştirilen dişi parazitoitlerin verimi *E. kuehniella* larvalarında yetiştirilenlerden daha fazla oldu.

Anahtar Sözcükler: Konak, parazitoit, verim, eşey oranı, *Galleria mellonella*, *Ephestia kuehniella*

Introduction

The braconid *Bracon hebetor* Say is a gregarious, idiobiont, arrhenotokous, ectoparasitoid wasp, attacking lepidopteran larvae (Tunçyürek, 1972; Cline et al., 1984; Gül and Gülel, 1995; Heimpel et al., 1997; Darwish et al., 2003). It has been widely used in studies of host-parasitoid interactions because of its high reproductive rate, short generation time and considerable range of host species (Tunçyürek, 1972; Gül and Gülel, 1995).

Biological control researchers have recognized the importance of the behavioral and physiological interactions between parasitoid and host to ensure the success of biological control programs (Collier, 1995; Uçkan and Gülel, 2002).

As an ideal biological control agent, parasitoids would be able to regulate a pest species population at a level that is economically acceptable (Hentz et al., 1998). Therefore, sufficient numbers of the parasitoid must be present in the management area. Knowledge of the fecundity and sex ratio in the parasitoid is important for the implementation of an efficient mass-rearing system (Orr and Boethel, 1990; Ramadan et al., 1995; Hentz et al., 1998).

In haplodiploid hymenopteran parasitoids, the offspring sex ratio is determined by females controlling the fertilization of eggs (Godfray, 1994; Harvey and Gols, 1998; Jarosik et al., 2003). Females develop from fertilized eggs and males develop from unfertilized eggs (Harvey and Gols, 1998; Damiens et al., 2003; Fuester et al., 2003; Jarosik et al., 2003). It has been shown that various abiotic and biotic factors such as temperature, humidity, parasitoid age, host type, host size and host diet also influence the fecundity and the offspring sex ratio of parasitoid species (Smith and Pimentel, 1969; Tillman and Cate, 1993; Harvey and Gols, 1998; Honda and Kainoh, 1998; Ueno, 1998; Ueno, 1999; Harbison et al., 2001; King, 2002; Uçkan and Gülel, 2002; Jarosik et al., 2003).

The main aim of this study was to evaluate the effect of parasitoid age on progeny production and sex ratio in the parasitoid *B. hebetor.*

Materials and Methods

B. hebetor was used as the parasitoid and late stage larvae of *Galleria mellonella* (L.) (Lepidoptera: Pyralidae) and *Ephestia kuehniella* (Zell.) (Lepidoptera: Pyralidae) were used as the hosts. A newly emerged female parasitoid was introduced into a vial containing a male and a honey (50%) saturated cotton pad. The female was provided with a healthy host and allowed to attack it. Parasitized hosts were held at 26 ± 2 °C, 60 ± 5% RH and continuously illuminated laboratory conditions until the wasps emerged. This treatment was maintained until the female parasitoid died. Newly emerged wasps were used for the fecundity and sex ratio experiments.

To investigate the age dependent fecundity and sex ratio of adult females of *B. hebetor*, 18 newly emerged females were divided into age classes at 4 day intervals, ranging from 1 to 10 days old, inclusive. A female parasitoid was placed in a vial provided with a male and a honey saturated cotton pad. In the first age group (1-day-old), a female was exposed to one host on the first day of emergence. In the others (5-day-old and 10- day-old), a female was provided with a honey saturated cotton pad and a male for 4 and 9 days, respectively. One host was placed into each vial on the fifth and tenth day of emergence, respectively. Every other day, the female was removed and transferred into a new vial containing a healthy host and a honey saturated cotton pad. Treated vials were then maintained under the same conditions until the progeny of the parasitoid emerged. Every day, vials were examined and the number of wasps emerging and sex were recorded. The experiment was replicated 3 times for each host type.

The effect of parasitoid age on offspring production and sex ratio were compared using one-way analysis of variance (ANOVA) and means were separated using the Student-Newman-Keul (SNK) multiple range test when the ANOVA was significant ($P < 0.05$). The percentage data were transformed to arcsine square root (Sokal and Rohlf, 1981) before analysis.

Results

Results involving the effect of parasitoid age on the fecundity and sex ratio of *B. hebetor* reared on *G. mellonella* are presented in Table 1.

The mean numbers of total progeny per female changed in relation to the female's age (Table 1). These changes between 1-day-old and 5-day-old females were not statistically significant ($P > 0.05$). However, in the 10-day-old females, offspring production decreased significantly ($P < 0.05$). The mean sex ratios (female %) were 45.99, 40.72 and 37.38 in the first, second and third age groups, respectively.

The results of the experiment with relation to the effects of parasitoid age on the fecundity and the sex ratio of *B. hebetor* raised on *E. kuehniella* are shown in Table 2.

Offspring production per female was high in the first 2 age groups; these groups were not statistically different

Table 1. Effect of the parasitoid age on the fecundity and sex ratio of *Bracon hebetor*, reared on *Galleria mellonella*. Means within the same column followed by the same letter are not statistically different (one-way ANOVA, P > 0.05).

Age (Days)	Number of Progeny			Female % of Total Progeny
	Female (Mean ± SE)	Male (Mean ± SE)	Total Progeny	
1	29.28 ± 2.8a	34.39 ± 3.1a	63.67a	45.99a
5	25.11 ± 2.7a	36.56 ± 2.5a	61.67a	40.72ab
10	17.44 ± 1.4b	29.22 ± 2.4a	46.66b	37.38b

Table 2. Effect of the parasitoid age on the fecundity and sex ratio of *Bracon hebetor*, reared on *Ephestia kuehniella*. Means within the same column followed by the same letter are not statistically different (one-way ANOVA, P > 0.05).

Age (Days)	Number of Progeny: Female (Mean ± SE)	Number of Progeny: Male (Mean ± SE)	Total Progeny	Female % of Total Progeny
1	21.17 ± 1.4a	25.78 ± 2.3a	46.95a	45.09a
5	18.17 ± 1.3a	26.50 ± 2.4a	44.67a	40.68ab
10	11.11 ± 1.0b	19.67 ± 1.9a	30.78b	36.09b

from each other (P > 0.05), whereas in the last age group it was significantly decreased (P < 0.05). The mean sex ratios (female %) of 1, 5 and 10 days old females were 45.09, 40.68 and 36.09, respectively.

Discussion

Offspring production per female decreased with the female's age. The decrease in offspring production during the first 5 days of the female's lifespan was not significant (P > 0.05), whereas in the last age group it was significantly different (P < 0.05) (Tables 1 and 2). Similar results have been reported for *Dibrachys boarmiae* (Walker), *Catolaccus grandis* (Burks) and *Apantales galleriae* (Wilkinson) (Gülel, 1982; Morales-Ramos and Cate, 1992; Uçkan and Gülel, 2002).

As older females laid fewer eggs than younger ones (Gül and Gülel, 1995), the decrease in fecundity during the female's lifespan was physiologically age-dependent.

Age-dependent fecundity in insects is generally divided into 3 general periods: the pre-ovipositional period, the fecundity plateau and the period of declining fecundity. The pre-ovipositional period starts at emergence and ends with the first oviposition. During the fecundity plateau, fecundity is at a maximum level and it starts when ≥ 50% of the females reach maximum fecundity and ends when the females have oviposited ≥ 60% of their total oviposition potential. The period of declining fecundity starts when the females have oviposited approximately 60% of their total oviposition potential and ends with their death (Morales-Ramos and Cate, 1992; Medeiros et al., 2000). We determined that the declining fecundity period started at the tenth day of age and ended with the death of females. This result was similar to those of Gül and Gülel (1995).

The progeny sex ratio of *B. hebetor* was male biased on both host species. Fuester et al. (2003) reported similar results for the braconid *Glypapantales flavicoxis*. The male biased sex ratio may be the result of a variety of factors, including sperm depletion, sperm death, physiological aging, active sperm digestion by the female, sperm disintegration while stored in the spermathecae, the number of copulations and the differential mortality of the sexes during larval development (Uçkan and Gülel, 2002; Damiens et al., 2003; Fuester et al., 2003).

In conclusion, our results indicate that age is a critical factor affecting the progeny production and sex ratio of *B. hebetor*. Moreover, we determined that the sex ratio of *B. hebetor* was male biased under laboratory conditions. Because only female wasps kill hosts for feeding and/or oviposition, overproduction of males in parasitic wasps is undesirable. Further experimental studies are needed to determine which of these factors are responsible for the sex allocation of *B. hebetor*.

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