Longevity and Fecundity of *Brachymeria lasus* (WALKER) (Hymenoptera: Chalcididae), a Pupal Parasitoid of the Oriental Tea Tortrix, *Homona magnanima* DIAKONOFF (Lepidoptera: Tortricidae)
under Laboratory Conditions

Hongxin MAO and Yasuhisa KUNIMI¹

*Department of Applied Biological Science, Faculty of Agriculture,
Tokyo University of Agriculture and Technology,
Fuchu, Tokyo 183, Japan*

(Received 16 September, 1993; Accepted 3 February, 1994)

The life span of *Brachymeria lasus* (WALKER) adults fed on 10% sugar solution was longer than those fed on 1% sugar solution and distilled water. Although no mature eggs were found in the ovaries of newly-emerged females, the mean number of mature eggs per female increased with age until 7 days after emergence with a maximum of 8 mature eggs. The mean preoviposition period was 4.7 days. The mean number of progeny per day produced by a single female fed on 10% sugar solution was about 6 for 5 weeks after emergence and decreased subsequently. The sex ratio of progeny was male biased and changed with age. No female progeny were observed at 13 weeks after emergence. The net reproductive rate and intrinsic rate of natural increase were 118.1 and 0.102, respectively, when females were fed on 10% sugar solution.

Key words: *Brachymeria lasus*, *Homona magnanima*, intrinsic rate of increase, parasitoid, biological control

INTRODUCTION

Brachymeria lasus (WALKER), a polyphagous pupal parasitoid of lepidopteran insects, is widely distributed throughout the Pacific area, including Japan, China, Philippines, Vietnam, India, Fiji, and Hawaii (HABU, 1960; HUSAIN and AGARWAL, 1982). *B. lasus* was introduced from Japan to North America for control of the gypsy moth, *Lymantria dispar* L. (WESELOH and ANDERSON, 1982). The oriental tea tortrix, *Homona magnanima* DIAKONOFF has been reported as one of its hosts (HABU, 1960; TAKAGI, 1974; MAO and KUNIMI, 1991). The percentage parasitism by *B. lasus* is high where the density of *H. magnanima* is low (MAO and KUNIMI, 1991). Therefore, it is a potential biocontrol agent.

HUFFAKER et al. (1971) listed the pertinent characteristics for a parasitoid to become an efficient biocontrol agent. These include fitness and adaptability to various physical conditions of the environment, searching capacity, rate of increase relative to that of the host, synchronization with host, host specificity, ability to survive host-free

¹ To whom correspondence should be addressed.

periods, and special behavioral traits. A series of studies have been conducted to evaluate the biological control potential of *Brachymeria intermedia* (NEES) which is a major pupal parasitoid of *L. dispar* (MINOT and LEONARD, 1976; BARBOSA and FRONGILLO, 1977, 1979 a, b; WESELOH, 1979; LASHOMB et al., 1983; BARBOSA et al., 1986; STOWELL and COPPEL, 1990), but little work on *B. lasus* has been reported. This study investigates the survival and reproductive ability of *B. lasus* adults under laboratory conditions.

MATERIALS AND METHODS

Insects. *B. lasus* adults and their host, *H. magnanima* were originally collected from tea gardens in Mizuho and Fuchu, Tokyo, Japan in 1989 and reared continuously in our laboratory. *H. magnanima* larvae were reared on the artificial diet proposed by TAMAKI (1966); *B. lasus* was reared on pupae of *H. magnanima*. *B. lasus* adults were paired and placed in a glass tube (3 × 18 cm), and fed on 10% sugar solution in a cotton swab. All insects were reared at 25°C, and 16L–8D photoperiod.

Development of eggs in ovaries. Ten female and 2 or 3 male newly-emerged parasitoids were introduced into the glass tube. The glass tubes were kept at 25°C and 16L–8D photoperiod. Parasitoids were provided with 10% or 1% sugar solution, or distilled water once each day. Ten to 15 female parasitoids aged 1, 3, 5, 7, 9, 11, 13, and 15 days, fed on the different diets were dissected to record the number of mature eggs in ovarioles.

Preoviposition period. Newly-emerged parasitoids were paired in glass tubes and fed on 10% sugar solution. One *H. magnanima* pupa was exposed to each mated female parasitoid for 30 min each day to observe the oviposition behavior. Females exhibiting oviposition were discarded and those not parasitized were used for the next experiment. To confirm deposition of the first egg, host pupae attacked by the parasitoids were transferred into smaller glass tubes (1 × 6 cm) and maintained at 25°C, and 16L–8D photoperiod until parasitoid emergence or host eclosion. Twenty-five females were used in the test.

Longevity. The newly-emerged parasitoids were divided into four groups and were introduced individually into the glass tubes. Each group was provided with 10% or 1% sugar solution, or distilled water, or no food. Parasitoids were reared at 25°C, and 16L–8D photoperiod, and were observed once daily to determine longevity under each food treatment. Forty-five to 55 parasitoids per group were used for this experiment.

Fecundity. To estimate the reproductive ability of female parasitoids, a newly-emerged female was paired with a male in a glass tube. Parasitoids were fed on 10% sugar solution and reared at 25°C, and 16L–8D photoperiod. When the females were 7 days old, the test was started. Ten *H. magnanima* pupae aged 1–3 days were exposed to each of the 7 mated female wasps, and the host pupae were replaced by new ones after 24 h. The test continued until the female parasitoids died. The pupae exposed to the female parasitoids were put into plastic dishes (60-mm diameter) and maintained at 25°C, and 16L–8D photoperiod to observe parasitoid emergence or host eclosion. The numbers and sex of emerged parasitoids were recorded daily. The dead pupae were dissected and the remnants of parasitoids found were recorded. The total number of emerged parasitoids and pupae with remnants of parasitoids was used to calculate

the fecundity. Mortality during the parasitoid immature stages was calculated as the total number of parasitized pupae divided by the number of pupae with remnants of parasitoids.

Since the developmental period of immature stages of the parasitoid has been calculated at 14.4 days under 25°C and 16L–8D photoperiod (MAO and KUNIMI, 1994), this value was used to estimate the intrinsic rate of natural increase. The net reproductive rate and intrinsic rate of natural increase were calculated according to the method of KREBS (1978). Sex ratio was expressed as the number of males/number of total progeny.

Statistical analyses. Chi-square analysis was used to compare the sex ratio of progeny. For all other analyses, the data were log-transformed and compared within each experimental plot using a one-way ANOVA and KRAMER's range test.

RESULTS

Development of eggs in ovaries

Newly-emerged females were reproductively immature and no eggs were found in their ovaries. Mature eggs began to appear in the ovaries 3 days after adult emergence, but the number was relatively small. The mean number of mature eggs per female increased with age until 7 days, then stabilized, with the maximum being 8 for females fed on 10% sugar solution (Fig. 1). A similar trend was seen in the females fed on 1% sugar solution, although the number of mature eggs in these females was significantly less than in females fed on 10% sugar solution at each age group (KRAMER's test, $p < 0.05$). Females fed on distilled water died within 7 days and few mature eggs were found in ovaries. Although most observed females had one mature egg in an ovariole, some females had two.

Fig. 1. Temporal fluctuations of numbers of mature eggs in ovarioles of *Brachymeria lasus* female under different food conditions. Females were dissected and mature eggs found in ovarioles were counted. ■, Females fed on 10% sugar solution; ●, females fed on 1% sugar solution; ▲, females fed on distilled water. Vertical lines represent 95% confidence limits.

Table 1. Longevity of *Brachymeria lasus* adults under different food conditions

Food condition	Life span (days) ^a			
	Male		Female	
	No.	Mean±SE	No.	Mean±SE
No food	24	3.0±0.1 a ^b	27	3.8±0.2 a
Distilled water	40	4.5±0.2 b	15	5.6±0.2 b
1% sugar solution	23	5.0±0.2 b	22	11.0±0.9 c
10% sugar solution	22	117.3±6.2 c	33	129.8±4.9 d

^a Adults were maintained at 25°C, and 16L–8D photoperiod.

^b Means followed by the same letters in the same column are not significantly different by ANOVA and KRAMER's test ($p>0.05$).

Fig. 2. Temporal fluctuations of number of progeny produced by single female per day (●) and survival rate of female adults of *Brachymeria lasus* (■). Females parasitized *Homona magnanima* pupae and were fed on 10% sugar solution. Vertical lines represent 95% confidence limits.

Preoviposition period and longevity

Female wasps parasitized *H. magnanima* pupae from day 3 to day 10, with the peak parasitism on day 4. The mean preoviposition period was estimated to be 4.7 days. The longevity of *B. lasus* adults was affected by the food composition (Table 1). The life span of females fed on 10% sugar solution was significantly longer than that of females fed on 1% sugar solution, distilled water or no food (KRAMER's test, $p<0.05$).

Fecundity

The oviposition rate (numbers of eggs laid by a single female per day) of females fed on 10% sugar solution ranged from 1 to 10 (Fig. 2). The rate during the first week was low and increased during the second week. The higher oviposition rate ranging from 5.4 to 6.3 continued until the week 5 and began to decrease at week 6.

Table 2. Temporal fluctuations of sex ratio of progeny produced by *Brachymeria lasus* female

Weeks ^a	No. of progeny	Sex ratio ^b
1	186	0.70 de
2	251	0.53 b
3	286	0.43 a
4	238	0.42 a
5	252	0.49 ab
6	243	0.58 bc
7	196	0.64 cd
8	150	0.77 e
9	113	0.72 de
10	72	0.90 f
11	52	0.98 f
12	19	1.00 f
Total	2,058	0.59

^a After beginning of experiment.^b Values followed by the same letters are not significantly different by χ^2 -test ($p > 0.05$).Table 3. Reproductive parameters of *Brachymeria lasus* female adults

Parameter	Value
Fecundity	270.2 ± 37.1
Oviposition period (days)	55.4 ± 8.3
Generation time (days)	49.3
Net reproductive rate (R_0)	118.1
Intrinsic rate of natural increase (r_m)	0.102

Females were fed on 10% sugar solution and maintained at 25°C, and 16L–8D photoperiod.

The progeny sex ratio during the first week was high and then gradually decreased until week 4 (Table 2). After week 5, the progeny sex ratio increased and no female wasps emerged at week 12. The mean sex ratio was 0.59 for all progeny. Most progeny developed successfully into adults. Mortality during the immature stages was 3.6%.

Table 3 shows reproductive parameters of *B. lasus* females fed on 10% sugar solution. The longest and average oviposition periods were 81 and 55.4 days, respectively. The net reproductive rate (R_0) and the intrinsic rate of natural increase (r_m) were 118.1 and 0.102, respectively.

DISCUSSION

The reproductive system of *B. lasus* is typically hymenopteran, containing two ovaries, each of which is comprised of three ovarioles just like *B. intermedia* (DOWDEN, 1935). Females of *B. intermedia* have only one well-developed egg in the ovariole at any one time and never lay more than 7 eggs per day (DOWDEN, 1935; BARBOSA and FRONGILLO, 1979 a, b). WESELOH and ANDERSON (1982) reported that *B. lasus* females

reared on *L. dispar* have 9.4 opaque eggs on average in their ovaries. In this study, some *B. lasus* females fed on 10% sugar solution laid more than 7 eggs in a day and most females had 8 mature eggs in their ovaries at one time.

The sex ratio of the progeny of parasitoids is affected by many factors, such as host size (CHARNOV et al., 1981), sex ratio (MOHAMED and COPPEL, 1986) and age (AVILLA and ALBAJES, 1984) of the parent parasitoids. In this study, when older females were exposed to hosts, the progeny had a high percentage of males. This may be due to exhaustion of the sperm supply in the spermatheca of older females, because *B. lasus* females mate only once (SIMSER and COPPEL, 1980). Also, a high percentage of males was produced at the beginning of the experiment. This phenomenon supports the hypothesis that production of more males at the beginning of the oviposition ensures fertilization of female progeny (MACKAUER, 1976; AVILLA and ALBAJES, 1984).

Under good feeding conditions, females live longer (Table 1). This suggests that if good food conditions exist in the field, adult *B. lasus* can parasitize 2–3 generations of *H. magnanima*, which needs about 1 month to complete development of one generation at 25°C (MAO and KUNIMI, 1990).

The R_0 and r_m values were estimated under optimal laboratory conditions and may represent the maximum value for the conditions. The r_m value of *B. lasus* (0.102) was lower than that of the host, *H. magnanima* (0.164) at 25°C under 16L–8D photoperiod. This suggests that the population growth potential of *B. lasus* is less than its host. Consequently, inundative release of *B. lasus* may be needed to suppress *H. magnanima* populations.

ACKNOWLEDGEMENTS

We wish to express our sincere thanks to Dr. K. KAMIJO of the Hokkaido Forest Experiment Station for identification of *Brachymeria lasus*.

REFERENCES

- AVILLA, J. and R. ALBAJES (1984) The influence of female age and host size on the sex ratio of the parasitoid *Opius concolor*. *Entomol. exp. appl.* **35**: 43–47.
- BARBOSA, P. and E. A. FRONGILLO, Jr. (1977) Influence of light intensity and temperature on the locomotory and flight activity of *Brachymeria intermedia* (Hymenoptera: Chalcididae), a pupal parasitoid of the gypsy moth. *Entomophaga* **22**: 405–411.
- BARBOSA, P. and E. A. FRONGILLO, Jr. (1979 a) Host parasitoid interactions affecting reproduction and oviposition by *Brachymeria intermedia* (Hym.: Chalcididae). *Entomophaga* **24**: 139–143.
- BARBOSA, P. and E. A. FRONGILLO, Jr. (1979 b) Photoperiod and temperature influences on egg number in *Brachymeria intermedia* (Hymenoptera: Chalcididae), a pupal parasitoid of *Lymantria dispar* (Lepidoptera: Lymantriidae). *New York Entomol. Soc.* **87**: 175–180.
- BARBOSA, P., P. MARTINAT and R. BENNETT (1986) Consequences of maternal age and development of *Brachymeria intermedia* (NEES) and the mortality of its gypsy moth (*Lymantria dispar*) host. *J. Appl. Entomol.* **101**: 215–223.
- CHARNOV, E. L., E. L. LOS-den HARTOGH, W. T. JONES and J. van den ASSEM (1981) Sex ratio evolution in a variable environment. *Nature* **289**: 27–33.
- DOWDEN, P. B. (1935) *Brachymeria intermedia* (NEES), a primary parasite, and *B. compsiluræ* (CWF.), a secondary parasite, of the gypsy moth. *J. Agr. Res.* **50**: 495–523.
- HABU, A. (1960) A revision of the Chalcididae (Hymenoptera) of Japan, with description of sixteen new species. *Bull. Natl. Agric. Inst. Sci., Ser. C*, No. 11: 131–363.
- HUFFAKER, C. B., P. S. MESSENGER and P. DEBACH (1971) The natural enemy component in natural control and the theory of biological control. In *Biological Control* (C. B. HUFFAKER, ed.). Plenum Press, New York, pp. 16–67.

- HUSAIN, T. and M. M. AGARWAL (1982) Indian species of *Brachymeria* WESTWOOD (Hymenoptera: Chalcididae). *Oriental Insects* **16**: 491–509.
- KREBS, C. J. (1978) *Ecology. The Experimental Analysis of Distribution and Abundance*. 2nd ed. Harper & Row, Publishers, Inc., New York, 678 pp.
- LASHOMB, J. H., Y. NG and W. METTERHOUSE (1983) Gypsy moth (Lepidoptera: Lymantriidae) pupal age as a determinant of suitability by *Brachymeria intermedia* (Hymenoptera: Chalcididae). *Environ. Entomol.* **12**: 855–857.
- MACKAUER, M. (1976) An upper boundary for the sex ratio in a haplodiploid insect. *Can. Entomol.* **108**: 1339–1402.
- MAO, H. and Y. KUNIMI (1990) Effects of temperature and photoperiod on development of the oriental tea tortrix, *Homona magnanima* DIAKONOFF (Lepidoptera: Tortricidae). *Jpn. J. Appl. Entomol. Zool.* **34**: 127–130.
- MAO, H. and Y. KUNIMI (1991) Pupal mortality of the oriental tea tortrix, *Homona magnanima* DIAKONOFF (Lepidoptera: Tortricidae), caused by parasitoids and pathogens. *Jpn. J. Appl. Entomol. Zool.* **35**: 241–245.
- MAO, H. and Y. KUNIMI (1994) Effects of temperature on the development and parasitism of *Brachymeria lasus*, a pupal parasitoid of *Homona magnanima*. *Entomol. exp. appl.* (in press).
- MINOT, M. C. and D. E. LEONARD (1976) Host preference and development of the parasitoid *Brachymeria intermedia* in *Lymantria dispar*, *Galleria mellonella* and *Choristoneura fumiferana*. *Environ. Entomol.* **5**: 527–532.
- MOHAMED, M. A. and H. C. COPPEL (1986) Sex ratio regulation in *Brachymeria intermedia*, a pupal gypsy moth parasitoid. *Can. J. Zool.* **64**: 1412–1415.
- SIMSER, D. H. and H. C. COPPEL (1980) Courtship and mating behavior of *Brachymeria lasus* (Hym.: Chalcididae), an imported gypsy moth parasitoid. *Entomophaga* **25**: 349–356.
- STOWELL, S. D. and H. C. COPPEL (1990) Mass rearing the gypsy moth pupal parasitoids *Brachymeria lasus* and *Brachymeria intermedia* (Hymenoptera: Chalcididae) for small-scale laboratory studies. *Great Lakes Entomologist* **23**: 5–8.
- TAKAGI, K. (1974) Monitoring of hymenopterous parasite in tea field. *Bull. Natl. Res. Inst. Tea* **10**: 91–131.
- TAMAKI, Y. (1966) Mass rearing of the smaller tea tortrix, *Adoxophyes orana* FISCHER von ROSLERSTAMM, on a simplified artificial diet for successive generations (Lepidoptera: Tortricidae). *Appl. Entomol. Zool.* **1**: 120–124.
- WESELOH, R. M. (1979) Comparative behavioral responses of three *Brachymeria* species and other gypsy moth parasitoids to humidity and temperature. *Environ. Entomol.* **8**: 670–675.
- WESELOH, R. M. and J. F. ANDERSON (1982) Releases of *Brachymeria lasus* and *Coccygominus disparis*, two exotic gypsy moth parasitoids, in Connecticut: Habitat preference and overwintering potential. *Ann. Entomol. Soc. Am.* **75**: 46–50.