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Egg Load in Wild Females of the Small White *Pieris rapae crucivora* (Lepidoptera, Pieridae) in Relation to Mating Frequency

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Abstract Females of the small white *Pieris rapae crucivora* were caught in the wild and dissected to investigate whether the reproductive output is affected by the mating frequency. Mating frequency was determined by counting spermatophores in the bursa copulatrix. Monogamous old females loaded smaller mature eggs than young ones. Reproductive output was measured as the change in the number of mature eggs stored in the ovaries. Females oviposited in the morning and the vitellogenesis was active in the ovaries mainly at night. Polygamous females were estimated to lay 50 eggs daily but monogamous ones 40 eggs. Thus, mating frequency is seen to be important for reproductive output in females of the species.

Key words: Mature eggs; Monogamous; Polygamous; *Pieris rapae cruscivora*; Egg size.

Introduction

Extensive study has been done on oviposition behavior of the pierid butterflies (e.g. STERN & SMITH, 1960; TAKATA & ISHIDA, 1957). Data on lifetime reproductive schedule in females have been proposed on *Pieris rapae crucivora* BIOSDUVAL 1836 (SUZUKI, 1978), *P. melete* (KIMURA & TSUBAKI, 1986) and *P. napi* (YAMAMOTO, 1981). The effect of the mating frequency on oviposition, however, has not been involved in such studies, because all the females used in the laboratory were monogamous. A possible relationship between mating frequency and lifetime fecundity may exist in pierid butterflies (e.g. BOGGS & WATT, 1981; RUTOWSKI *et al.*, 1983). WATANABE & ANDO (1993) clarified the lifetime fecundity in relation to mating frequency in the wild females of *P. rapae*. In addition, diurnal oviposition activity of *P. rapae* has been described in the field (YAMAMOTO & OHTANI, 1979).

The present paper deals with the estimated number of eggs laid by *P. rapae crucivora* in the field. The sampling was carried out day and night to investigate on the diurnal rhythm of egg production in relation to mating frequency.

Materials and Methods

The data were obtained mainly from the summer generations of the small white *P. rapae* in Shirouma of Nagano Prefecture, which is located in a cool-temperate zone of Japan. The habitat consists of rice-fields and margins of deciduous forests where adults may feed on nectar plants, and larvae on food plants.

Females engaged in various activities, e.g., feeding, roosting, flying, copulating and ovipositing, were collected during the day and at night, from late July through mid-August of both 1989 and 1990. Sampling was made on windless sunny days (total of 19 days). Immediately after captured, their abdomens were amputated and immersed in a 50% ethanol solution, and their wing conditions and forewing length recorded. Although WATANABE & ANDO (1993) divided females into 5 age groups, we classified them into 2 age groups on the basis of the degree of wing wear (young and old females).

All females dissected were examined for number of spermatophores in their bursa copulatrix. Mature eggs in the ovaries were counted. They were found primarily in the oviducts and were large, yellow-colored and well-formed enough to be ready for oviposition.

Results and Discussion

The number of matings was 1.3 ± 0.51 ($\bar{x} \pm SD$, $n=176$) and 2.2 ± 1.05 ($n=101$) for young and old females dissected, respectively. Out of 176 young females, 7 were virgin. No virgin old females were found. Although monogamous females appeared in both age groups, the number of matings increased significantly with age ($Z=7.861$, $P<0.01$, by U-test).

One of the benefits from polyandry in butterflies may be to achieve an adequate sperm supply. LABINE (1966) pointed out that sperm may deteriorate with age and must be replaced with a fresh supply, because there may be too few spermatozoa in one insemination to fertilize all of the eggs that a female will lay. However, as a rule one mating provides a female with enough sperm to fertilize all of eggs in pierid butterflies (e.g. RUTOWSKI, 1984; SUZUKI, 1978). Thus polyandry might not be ascribed to sperm replenishment.

The size of a mature egg in the oviducts was calculated as a spherical cone formula. It remained constant irrespective of mating frequency in young females (Table 1). The mature egg of young monogamous females was larger than that of old ones ($F=9.663$, $P<0.01$). Thus, there seems to be a slight decrease in mean egg volume with the age, though there was no significant difference in polygamous females.

Weight of an egg laid by females mated only once decreased with female age in *P. rapae* (KIMURA & TSUBAKI, 1985). In this study, the effect of the age on egg size appeared in monogamous females. If every female has a similar quantity of nutrients derived from larval food plants, the egg size in old females may tend to decrease. However, the mature eggs of polygamous old females seemed to be somewhat larger than that of mongamous ones, though there was no significant difference between them ($F=1.623$, $P>0.05$). The variation in egg size in *P. rapae*

Table 1. Volume of a mature egg in the oviduct for monogamous and polygamous females in each age (mm^3 ±SE).

	Young	Old	
Monogamous	0.0893±0.0016 (141)	0.0780±0.0035 (34)	*P*<0.01
Polygamous	0.0879±0.0023 (58)	0.0837±0.0023 (93)	n.s.
	n.s.	n.s.	

( ): numb r of mature eggs examined.

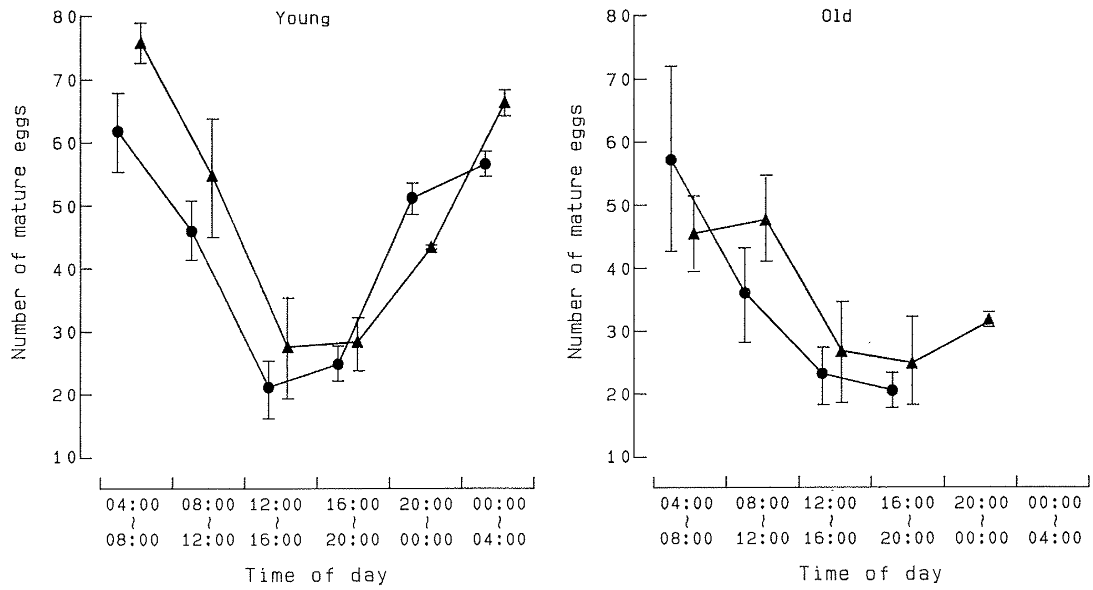

Fig. 1. Daily change in the number of mature eggs for monogamous (circle) and polygamous (triangle) females. Each bar represents SE.

might be associated with the number of spermatophores collected by females, as indicated by RIDLEY (1988).

The number of mature eggs found in the ovaries of virgin females was 16.4± 11.6 (n=7), irrespective of sampling time. Since non-mature eggs accounted for the majority of total eggs, however, WATANABE & ANDO (1993) made a rough estimate of *P. rapae* fecundity as about 550.

Variation in the numbers of mature eggs may occur due to different oviposition pattern and process of egg development in the ovaries, as in the swallowtail butterflies (WATANABE & NOZATO, 1986). In order to estimate the number of eggs deposited within a day, females were classified in four-hour intervals of the time of capture. Figure 1 shows daily changes in the number of mature eggs in relation to mating frequency. In the summer season in Shirouma, the times of sunrise and sunset are around 05: 00 and 19: 00, respectively. Thus, more than 14 hours were available for *P. rapae* activity, although most females roosted in early morning and late evening (OHTANI, 1985).

In young monogamous females, the number of mature eggs was about 60 in the morning, and decreased toward afternoon (ca. 20 eggs). This supports that butterfly females generally oviposit actively in the morning (WATANABE & NOZATO, 1986). During the night, this number increased up to 60. The number of mature eggs in the morning and at night were similar. If we assume that few eggs were matured during the oviposition period, the rate of egg maturation at night was 5.0 egg/hr, with 40 eggs added over the course of 8 hours.

In young polygamous females, the number of mature eggs observed in the morning (ca. 75 eggs) was higher than that in monogamous ones ($Z=1.821$, $P<0.05$, by U-test). The number also decreased toward the afternoon (ca. 25 eggs), in which there was no significant difference between polygamous and monogamous females ($Z=0.307$, $P>0.05$). The polygamous females also recovered the mature eggs at night. The number of mature eggs in mid-night for polygamous females attained to that in the morning, and also higher than that for monogamous females ($Z=1.769$, $P<0.05$). The rate of egg maturation at night was estimated 6.3 eggs/hr, as 50 eggs were added over the course of 8 hours. Therefore, the rate of egg maturation at night in polygamous females was higher than that in monogamous ones. This suggests that one of the benefit from polyandry may be to enhance female reproductive output through male nutrient delivery (e.g. BOGGS, 1990; WATANABE, 1988).

Although we have no data on the number of mature eggs in old females at midnight, the number of mature eggs might probably recover in the morning. Old females tended to load fewer mature eggs than young females.

Since females generally feed on a more protein-rich food in the larval stage than in the adult stage (BOGGS, 1981), female reproductive output may be primarily dependent upon resources accumulated in the larval stage (BOGGS & WATT, 1981). Accordingly, adequate nutrients for egg production seemed to be limited. However, estimated number of eggs actually laid increased with mating frequency in *P. rapae* (WATANABE & ANDO, 1993). This may suggest that the benefit of polyandry enhances her daily oviposition activity through male-derived nutrients.

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