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Number, Larval Durations and Body Weights of Queen-Reared Workers of a Japanese Paper Wasp, *Polistes chinensis antennalis* (Hymenoptera, Vespidae)

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Abstract Queens of *Polistes chinensis antennalis* raised about ten workers by themselves in the pre-emergence stage. Larval duration gradually increased among them. They were small as compared with those of subsequent emerging workers but not different from each other. From these facts queens of *P. chinensis antennalis* were inferred to make first workers small (probably by enhancing larval metamorphosis) in order to obtain workers as early as possible.

Key words: social wasp, *Polistes chinensis antennalis*, body weight, larval duration, queen-reared workers.

Haplometrotic-nest-foundation (foundation of nests by single overwintered females) widely prevailes in temperate social wasps and bees. All of eight *Polistes* species and two *Parapolybia* species in Japan principally found their nests by single females (Matsuura, 1977). In these species queens perform all of their nesting activities alone before worker emergence. When first worker(s) emerges and undertakes nesting duties except oviposition, their social life starts. The period from nest foundation to first worker emergence is called pre-emergence stage and it is known that most of colony failures (by deaths of queens, by attacks of ants on nests, etc.) take place in this period (Yoshikawa, 1954; Miyano, 1980). Pleometrotic and swarm nest foundings are considered to have evolved to secure colony survival during this period (West-Eberhard, 1975; Itô, 1987). Developmental period of the first worker determines the length of pre-emergence stage. It is known that queens hasten embryonic development by nesting in the microclimatically warmer place (Miyano, 1981).

The purpose of the present paper is to describe the number, larval durations and body weights of queen-reared workers of *Polistes chinensis antennalis* and to discuss the adaptive significance of such a larval rearing method of queens. In the present paper queen-reared workers mean the first several workers which have spun cocoons before the first worker emergence and which, therefore, are raised by queen's labour only.

Materials and Methods

1. Number and durations of queen-reared workers

Data collected at Itako (35°57′N and 140°35′E), Ibaraki Pref., Japan, in 1977 were used for analysis (for the precise descriptions of the field, see Miyano, 1980). Development of 64 nests which were started by solitary queens from mid April to early May was traced by recording cell maps, as a rule, every day. Among them 30 nests produced at least the first worker and these were used for analysis.

2. Body weights of queen-reared workers

Nine nests which had about 10 or more cocoons and no emerging worker were collected with their queens on the bank of Tsubo River, Seki (35°29′N and 136°25′E), Gifu Pref., Japan, in early June of 1981. The criterion of 10 or more cocoons with no emerging worker was determined by the result of earlier observation (see Results 1).

Queens were individually put in small vials, killed by freezing and stocked in a refrigerator. Each nest was kept in a small paper box in the laboratory and emergences of wasps were checked at least once a day. Emerging wasps were recorded for their nest codes and dates of emergence and stocked in a refrigerator by the same procedure as for queens. Stocked queens and wasps were later dried in a desiccator to no weight decrease and weighed by microbalance with a sensitivity of 0.1 mg.

Results

1. Number of queen-reared workers

Solitary queens of *P. chinensis antennalis* raised 5 to 14 ($\bar{x}=10.2$, SD=2.3, n=30) larvae up to cocoon stage before the emergence of the first worker(s) (Fig. 1). The number of queen-reared workers was small in the nests in which queens tore cocoon caps and destroyed the pre-pupae or pupae in the cells. But the reason for this behavior is unclear.

2. Change of larval durations of queen-reared workers

The larval duration was shortest in the first worker and it gradually increased with the order of hatching except in three nests out of thirty (Fig. 2). Average larval durations of the first, the middle and the last workers were 14.8±2.40, 18.5±2.53, 22.2±3.67 days respectively in 30 nests (Table 1) and they were significantly different from each other ($P<0.001$, Wilcoxon's test). The average difference in larval duration between the first and the last workers (7.4 days) was equal to half of larval duration of the first one.

Durations of first to 4th instar larval stages fluctuated less and exhibited no marked tendency regarding the order of hatching, while duration of 5th instar clearly showed a fluctuation pattern similar to that of duration of total larval stages (Fig. 3). Coefficient of correlation between the 5th instar larval and the total larval durations was very high (r=0.98, Fig. 4).

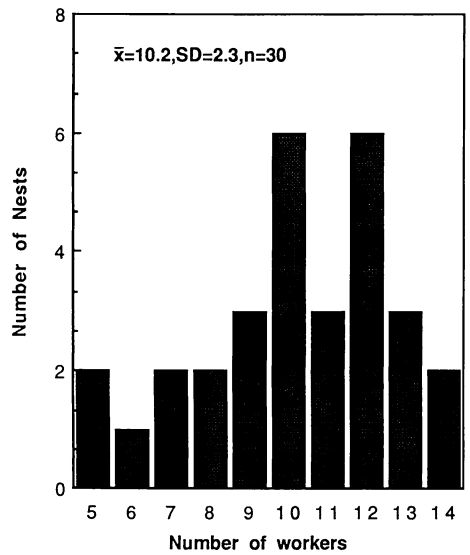

Fig. 1. Frequency distribution of the number of queen-reared workers in *P. chinensis antennalis*. Average ($\bar{x}$), standard deviation (SD) and sample size (n) are shown.

3. Body weights of queen-reared workers

Dry weights of queen-reared workers were nearly the same within a colony, regardless of the order of emergence (Fig. 5). Average dry weight was 19.0-27.4 mg for each colony (Table 2) and it was less than half of dry weight of the queen (Fig. 5). There was no tendency that large queen reared large workers (r=0.06, Fig. 6). Some 5th instar larvae (2-6 individuals per colony) cocooned without being fed after the nest collection and later emerged as adults, although most of such larvae starved to death. The lightest was 10 mg in dry weight and it may be the lower physiological limit of adult size in this species.

Discussion

The number of queen-reared workers in *P.*

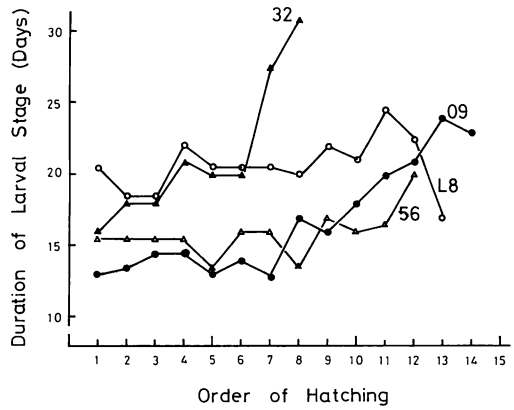

Fig. 2. Changes of larval durations among queen-reared workers in some selected nests of *P. chinensis antennalis*. 32, 09 and so on are nest codes.

Table 1. Larval durations of first, middle and last individuals in queen-reared workers.

	First	Middle	last
n	30	30	30
Range	10.5-19.5	14.5-24.0	12.5-34.0
Average	14.8	18.5	22.2
S.D.	2.40	2.53	3.67

chinensis antennalis was hitherto reported to be 5 -10 (Morimoto, 1954) and 8.9-13.8 (Suzuki, 1980). The present result supports these reports. It is interesting that the number is also about ten in a several species of *Polistes* and *Vespa* inhabited Japan (Yoshikawa, 1962; Yamane, 1969; Matsuura, 1984; Makino, 1989). It is probably a common

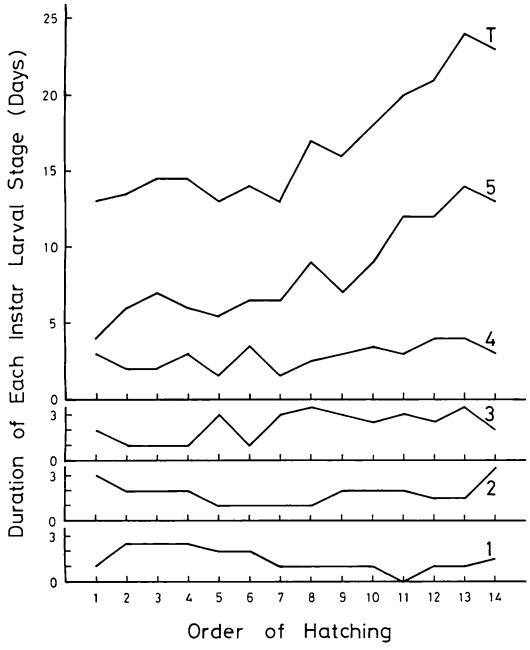

Fig. 3. Changes of durations of 1st to 5th instar (1 to 5) and total (T) larval stages among queen-reared workers in a representative nest (Nest Code 09).

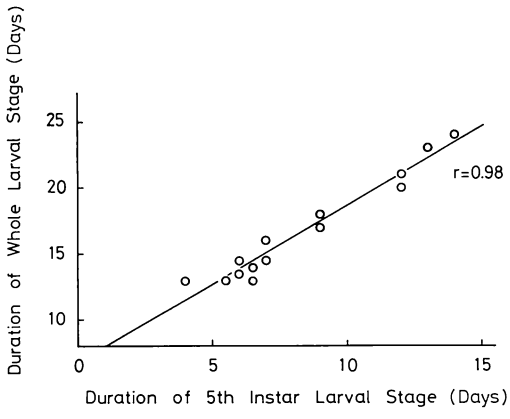

Fig. 4. Relationship between durations of 5th instar larval stage and whole larval stage in a representative nest (Nest Code 09). Coefficient of correlation (r) is shown.

Table 2. Dry weights of queen-reared workers (mg).

Colony Code	n	Range	$\bar{x}$	S.D.
A	9	16.4-22.8	19.8	2.4
B	12	21.0-30.1	25.1	2.5
C	11	20.3-26.2	22.7	2.0
D	10	24.4-28.2	26.1	1.4
E	12	22.2-27.5	24.5	1.4
F	6	19.3-28.4	25.6	3.2
G	14	22.0-28.8	25.4	1.9
H	18	15.5-24.3	19.0	2.4
I	16	20.5-31.4	27.4	3.0
Average	12		24.0	

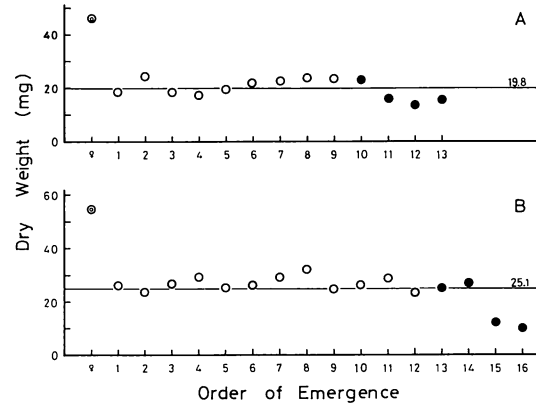

Fig. 5. Dry weights of the queen (double circle), queen-reared workers (open circle) and wasps which were 5th instar larvae at the time of the nest collection (solid circle). Average dry weight of queen-reared workers is shown.

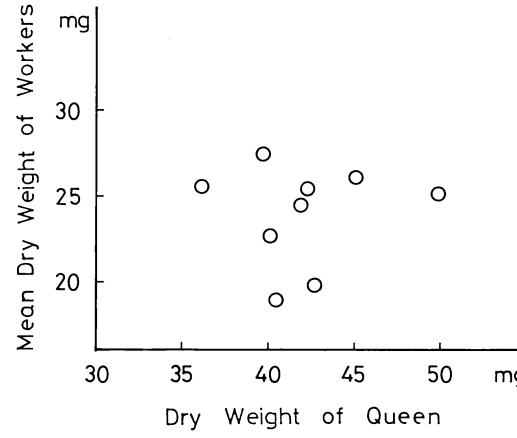

Fig. 6. Relationship between dry weight of the queen and mean dry weight of queen-reared workers in *P. chinensis antennalis*.

feature of haplometrotic-nest-founding social wasps, at least, in temperate region.

In *P. chinensis antennalis* it is known that larval durations of first several workers are very short as compared with those of subsequently emerging worker-reared workers (Miyano, 1981) and that the weights of emerging wasps gradually increase through the nesting period (Miyano, 1983). From these facts, Miyano (1983) suggested the possibility of queen control over the larval development of workers. Shorter larval duration of first workers are also known in some social wasps (Jeanne, 1972; Kojima, 1989). However, Miyano's data are insufficient for precise comparison of these two variables among queen-reared workers, because he dealt with all wasps emerging in all nesting period and his data for body weights were obtained by measuring weights of living wasps, which are inevitably influenced by the amount of water content. The present study revealed that larval durations gradually increased among first about ten workers which were solely reared by queens but that their body weights were not different from each other.

Colony failure rate is in general highest in the pre-emergence stage (Yoshikawa, 1954; Miyano, 1980) and so it is inferred that natural selection favored the shortening of the incubation period of first workers. In fact queens hasten embryonic development by nesting in the microclimatically warmer places (Miyano, 1981). For the purpose of obtaining first workers early, it must be a promising method for queens to make body sizes of first workers small; small individuals need a small amount of food to complete their larval growth and resultant small pupae may require short duration for metamorphosis. However, the method must not be cutting down of food supply but some means of enhancing larval metamorphosis, because food shortage usually results in a prolonged growing period (Huffaker and Rabb, 1984). Judging from the present result that first several workers are small and, especially the first one, have short larval durations, queens of *P. chinensis antennalis* are inferred to raise first workers by just such a manner, although the precise method of it is so far unclear. It is noteworthy that queens equally make all the queen-reared workers small, but that their sizes are still larger than the physiological limit. Too small workers are probably not suitable for effective performer of nesting activities.

It is an interesting question whether or not the shortest larval duration of the first worker and subsequent increment of it in queen-reared workers are results of queen's another tactics to obtain the first worker earlier by concentrating her feeding effort to the most advanced larva. The length of the 5th instar larval stage determines the whole larval duration, therefore, uneven preferential feeding of the most advanced larva by the queen, if it exists, should be observed at 5th instar larval stage among queen-reared workers. It needs more studies to clarify this question.

In conclusion the small body sizes of queen-reared workers in *P. chinensis antennalis* cannot be considered the result of food shortage, but are inferred to be caused by queen's some influence. It should be pursued the precise mechanisms of queen control over larval growth in the future.

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フタモンアシナガバチの女王が単独で育てる働き蜂の数，幼虫期間および体の大きさ

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フタモンアシナガバチの女王は，単独でおよそ10匹の働き蜂を育てた．これら最初の働き蜂の幼虫期間は，順次長くなっていった．一方，その体の大きさは，羽化の順序に関わりなくほぼ同じであり，その後に引き続いて羽化してくる働き蜂に比べ，小さいものであった．このような事実から，フタモンアシナガバチの女王は，できるだけ早く働き蜂を得るために，最初の働き蜂を（おそらく幼虫の変態を促進することによって）小さく育てているものと推定された．