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REPRODUCTIVE DECISION AND WORKER PRODUCTION IN BUMBLEBEE COLONIES

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ABSTRACT

Reproductive decision in bumblebee, *Bombus terrestris* colony indicates the onset of males and queens production i.e. the colony may be protandous or protogynous. In this study reproductive decision and worker production were observed by development of colonies with 2, 3, 4 and 5 months diapaused queens. The colonies were also regulated with worker population 50, 100, 150 and 200 for each foundress queen. Worker population and diapause duration had influenced the reproductive decision of colonies. The foundress queens diapaused for 3 months and colonies populated with 200 workers produced the highest and lowest percentage of protandous and protogynous colonies, respectively and also had the highest number of worker production.

Key words: *Bombus terrestris, colony, diapause, worker*

INTRODUCTION

Bumblebees, *Bombus terrestris* (Hymenoptera: Apidae) are annual social insects and have been deliberately introduced to new countries to enhance pollination of field and garden crops (Goulson, 2003a). Only young mated queens go into hibernation in late summer to survive winter in small cavities (Alford, 1969). The queens leave their hibernation in spring and initiate to build up colonies by producing haploid eggs those develop into workers. These workers assist the queen to take care of the subsequent broods. The colonies produce more workers while sexuals (drones and gynes) emerge later in the cycle. Although workers do not mate and cannot lay fertilized eggs (diploid eggs) but they can produce haploid eggs which develop into male offsprings (Trivers and Hare, 1976). The workers start foraging after 2 to 3 days of their emergence. All of the workers do not leave the nest and forage, some of the smallest workers remain inside the nest and performing 'household duties' (Heinrich, 1979). Pollination efficiency of a colony depends on the number of the workers in the colony and on the colony growth rate (production of workers, males and queens) which is related to the foraging and nursing efforts of workers (Oster and Wilson, 1978). The colony growth rate is affected by the availability of food, relative number of foraging and nursing workers, diapause duration of the foundress queen and the lifetime of colony (Duchateau and Velthuis, 1988; Beekman and van Stratum, 2000). Roseler and Roseler (1974) suggested that the production of males and queens would depend on the number of workers or their density in the brood area. In mature colony, ovary developed workers destroyed queen laid eggs and replaced them with their own eggs. This kind of physical conflict between workers and queen may be resulted in workers killing the queen (Bourke, 1994). Duchateau and Velthuis (1988) reported that in early switching colonies, queens start to lay haploid eggs relatively early and colonies produced mainly males (Protandrous). On the other hand, in late switching colonies, queens start to lay haploid eggs relatively late and the colonies produced mainly queens (protogynous). Worker egg-laying and aggression occur in both types of colonies (Duchateau

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and Velthuis, 1988). Beekman and van Stratum (2000) observed that queen's lifetime decreases with increasing diapause period. They stated that total number of worker production in the colony and colony lifetime increases when the length of diapause increases from 0 to 4 months. Therefore, the aim of this study was to figure out how many worker populations in the colony and diapause duration of foundress queen is feasible to produce optimum number of sexuals and worker population.

MATERIALS AND METHODS

Bumblebee, *B. terrestris* L., queens which were artificially hibernated for 2, 3, 4 and 5 months in a refrigerator at 4°C were obtained from the mass rearing system of the Department of Agricultural Biology, Kyungpook National University, Daegu, Korea. The queens were transferred into (40×30×30 cm) flying cages having mesh screen and illumination facility. The bee diet consisted with *ad libitum* frozen pollen and sugar solution (1.75:1 w/v), and the cages with bees were kept in a room at 25 ± 1°C and 50 ± 5% RH for activation of the queens. After one week, the queens were kept separately in small transparent plastic boxes (16× 11× 7 cm) for oviposition in a room at 28 ± 1°C, 50 ± 5% RH and red light of 10 Lux during observation time. Frozen pollen and sugar solution (1.5:1 w/v) was provided inside the boxes. To stimulate oviposition, one frozen queen pupa attached with paraffin on a hard drawing paper was supplied to the box. Pollen was provided daily and sugar solutions were changed weekly. After emergence of the workers of the first brood, the colonies were transferred to big colony boxes measuring 27× 18× 13 cm which were provided with ample pollen bar and sugar solutions. To examine the reproductive characteristics, colonies were maintained with 50, 100, 150 and 200 worker population. For each diapause treatment and worker population category, five colonies were raised. The colonies were observed daily and newly emerged workers were marked on their thorax with white glue. When the colonies produced the worker population 50, 100, 150 or 200, the marking was stopped and excessive workers were collected daily and they were removed from the colonies. Colonies were monitored daily and emergence of sexuals (males and queens) and total number of workers produced in the colonies were recorded. Data were analyzed by analysis of variance (ANOVA) and post hoc Duncan's Multiple Range Test (DMRT) using SPSS (PASW statistics 18).

RESULTS AND DISCUSSION

Figure 1 shows the effect of diapause duration and worker population on the production of protandous and protogynous colonies. Colonies populated with 50 workers and queens diapaused for 2, 3, 4 and 5 months, respectively produced 40, 60, 60 and 80% protandrous colonies, and the protogynous colonies were found 60, 40, 40 and 20%, respectively. On the other hand, colonies populated with 100 workers and queens diapaused for 2, 3, 4 and 5 months, respectively produced 60, 60, 40 and 60% protandrous colonies, and 40, 40, 60 and 40% protogynous colonies. The colonies were raised with 150 workers and queens diapaused for 2, 3, 4 and 5 months showed 40, 80, 60 and 40% protandrous colonies, whereas the protogynous colonies were found 60, 20, 40 and 60 %. The queens those diapaused for 3 months and colonies populated with 200 workers had 100% protandrous colonies and the results showed that with increasing diapause duration production of protandrous colonies decreased and percentage of protogynous colonies increased.

Figure 2 shows that in 50 workers populated colonies, diapause duration of the foundress queens had significant effect ($F_{3, 16} = 2.21$, $P < 0.05$) on the production of workers, and 3 months diapaused queens produced the highest number (326.8 ± 77.19) of workers. In case of 100 workers populated colonies, 2 months diapaused queens produced significantly the highest number (375 ± 34.74) of workers ($F_{3, 16} = 4.67$, $P < 0.01$). On the contrary, queens diapaused for 2 months and colonies raised with 150 workers did no show significant difference ($F_{4, 20} = 1.49$, $P = 0.25$). Colonies populated with 200 workers showed that 3 months diapaused queens produced the highest number (453.00 ± 123.29) of workers and the diapause durations of the queens had significant effect ($F_{3, 16} = 6.38$, $P < 0.01$).

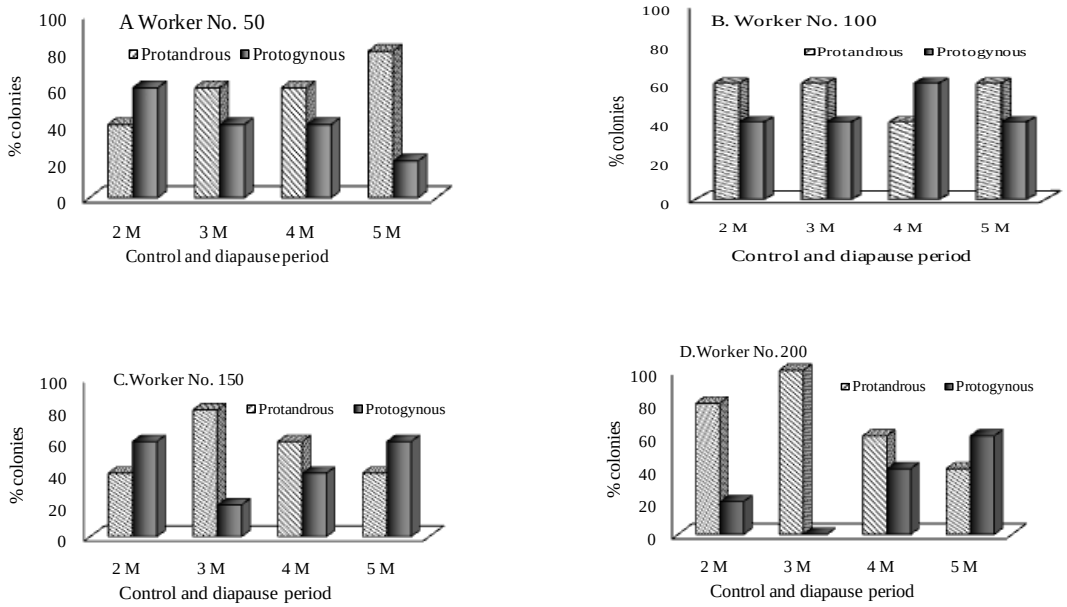

Figure 1. Rate (%) of protandrous and protogynous colonies produced in relation to worker population and diapause duration.

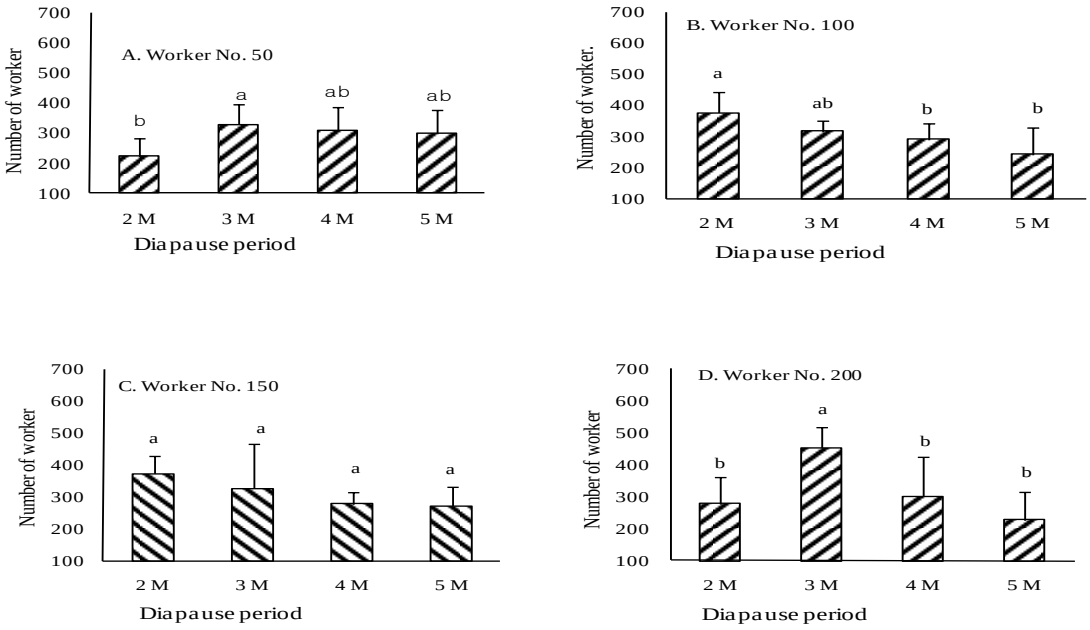

Figure 2. Number of workers (mean ± SD) produced in relation to worker population and diapause duration. Asterisk on the bar indicates significant differences ($LSD_{0.05}$).

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Beekman and van Stratum (1998) experienced that small colonies produce mainly males because of a smaller number of workers responsible to collect sufficient resources. Larger colonies lead to the lower rates of colony growth (Oster and Wilson, 1978). In this study, the highest percentage of protandrous colonies appeared by the queens diapaused for 3 months and the colonies were populated with 200 workers. It may be supported by the kin selection theory and the findings of Lopez-Vaamonde *et al.* (2003), showed that there was no evidence that worker aggression had a negative effect on the production of new queens. However, the present investigation showed that the production of worker was related to the size of the colony. But the colonies were developed with different diapaused queens which may have role on the production of offspring. Michener (1964) showed in hymenopterous species that the reproductivity per female is a function of reproductivity per colony. In semisocial groups, and early season colonies of social insects, reproductivity per female increases with decreasing colony size. Tsuchida *et al.* (2003) showed that the frequency of workers' sons within queen right colonies did not increase with colony size. Nevertheless, the worker density did not play significant role on the timing of queen production. But, the timing of new queen production was dependent on the number of worker density and diapause duration of the foundress queen. It was suggested by Pomeroy and Plowright (1982) that the initiation of queen production seems to be associated both with the presence of male brood and with the size of worker population. The timing of the production of sexual is determined by the amount of food brought into the colony by the workers (Beekman *et al.*, 1998). So, a range of worker population in the colony is important to flow the food, nourishment of broods and queen's reproductive decision.

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