EFFECTS OF WEIGHT OF QUEENS AFTER DIAPAUSE ON COLONY DEVELOPMENT IN THE BUMBLEBEE, *Bombus terrestris* L.*

Ayhan GOSTERIT[a] Fehmi GUREL
Akdeniz University, Faculty of Agriculture, Deparment of Animal Science, 07059, Antalya-Turkey

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Abstract

The effects of weight of queens after diapause on colony development in *Bombus terrestris* were investigated in this study. The weight of 57 queens was determined to be an average of 0.79 ± 0.01 g after diapause. Approximately 82% of the queens laid eggs and 64% of egg laying queens produced worker. No significant statistical correlation was found between the weight of the gueen after diapause and colony development patterns in *B. terrestris*. Only the correlation between the weight of the queen after diapause and the number of workers produced in the first brood was found to be significant ($p<0.05$, $r = 0.42$, $n = 30$). There is a significant variation between the colonies respect of development patterns in year round rearing of *B. terrestris*. Many factors affect on the variation between the development patterns of colonies and the colony foundation of queens. However, according to the results of this study, the weight of the queen after diapause has no effect on this variation.

Keywords: Bumblebee, *Bombus terrestris*, queen weight, diapause, colony development

***Bombus terrestris* (L.) Arılarında Diyapoz Sonrası Ana Arı Ağırlığının Koloni Gelişimi Üzerine Etkileri**

Özet

Bu çalışmada, *Bombus terrestris* arılarında diyapoz sonrası ana arı ağırlığının koloni gelişimi üzerine etkileri araştırılmıştır. Araştırmada kullanılan toplam 57 adet ana arının diyapoz sonrası ağırlıklarının ortalaması 0,79± 0,01 g olarak belirlenmiştir. Kullanılan ana arıların yaklaşık % 82'si yumurtlamış ve yumurtlayan bu ana arıların % 64'ü işçi arı üretmiştir. Fakat, diyapoz sonrası ana arı ağırlığı ile koloni gelişim özellikleri arasında istatistiki olarak önemli bir ilişki bulunmamıştır. Sadece diyapoz sonrası ana arı ağırlığı ile birinci kuluçka döneminde üretilen işçi arı sayısı arasındaki ilişki önemli bulunmuştur ($p<0,05$, $r = 0,42$, $n = 30$). *B. terrestris* arılarının kontrollü koşullarda yetiştiriciliği yapılırken, koloniler arasında gelişim özellikleri bakımından büyük varyasyon görülmektedir.Bir çok faktör koloni gelişim özellikleri arasındaki bu varyasyonda ve ana arıların koloni oluşturmasında etkili olmaktadır. Ancak, elde edilen sonuçlara göre, diyapoz sonrası ana arı ağırlığı bu varyasyonda etkili değildir.

Anahtar kelimeler: Bombus, *Bombus terrestris*, Ana Arı Ağırlığı, Diyapoz, Koloni Gelişimi

1. Introduction

In recent years, the commercial use of insects for pollination has become prevalent (Free, 1993). There is a steadily growing interest in bumblebees due to their pollination efficiency and the increasing quality and quantity of crops, especially in greenhouses (Heemort et al., 1990; Corbet, 1995). Bumblebees, of which 239 species have been determined, are used for the pollination of 25 different cultivated plants in more than 30 countries (Goodwin and Steiner, 1997; Benton, 2000). In comparison with other bumblebee species, *Bombus terrestris* has the most year round rearing, because their rearing is easier and their colony population is larger than the others.

A *B. terrestris* colony containing approximately 60 workers can be used in greenhouse pollination for only two months due to the commencement of progeny queen and male production. For this reason, it is recommended that in commercial rearing the colonies should have a long life span and the population of workers should be large. Early male and progeny queen producing in the colonies, mating, managing diapause and the

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[a] Corresponding author: A. Gosterit, e-mail address: gosterit@akdeniz.edu.tr

founding of new colonies are major problems during the year round rearing of bumblebees. Major losses occur during these stages and it was estimated that the suitable colony foundation ratio of queens is 40-50% even in commercial companies, which produce bumblebees for use in greenhouses. Significant differences are observed among *B. terrestris* colonies in the numbers of males, workers and queens produced. Furthermore, there is significant variation in the time of the switch point, when the queen lays haploid rather than diploid eggs and in the time of the competition point, during which the mutual aggression among the workers or between the workers and the founder queen begins and the workers lay eggs (Michener, 1974; Röseler, 1985; Duchateau and Velthuis, 1988; Beekman et al., 1999; Gürel et al., 1999; Cnaani et al., 2000). It was estimated that many factors such as worker density in the nest, worker/larva ratio, hormones, environmental conditions inside and outside the nest, illness and parasites, the quality of the founder queen and food available cause these differences (Beekman and Stratum, 2000; Cnaani et al., 2000).

The quality of the queens is an important factor, which affect colony development patterns in *B. terrestris.* The weight of the honeybee queen affects her egg laying capacity (Szabo, 1973; Harbo, 1986). Studies relating to the weight of bumblebee queens have been focused mainly on the effect of the weight on survival during diapause. The weight of the queens before diapause affects their survival rate during diapause. Queens weighing less than 0.6 g before diapause die during diapause. Success of colony foundation is not affected by the weight of the queen before diapause (Beekman et al., 1998), but the correlation between the weight of the queen after diapause and colony characteristics has not been fully explained. Therefore, the main objective of this study is to investigate the effects of the weight of the queen after diapause in colony development patterns and the colony foundation ratio of the queens, which are major problems in the year round rearing of *B. terrestris*.

2. Materials and Methods

A total of 57 *B. terrestris* queens, which had emerged from diapause and had not estabilished a nest, was used in this study. Each of the queens was weighed and noted. After they had been weighed, they were numbered and placed separately in the starting boxes. CO_2 was given to all the queens before weighing in order to stimulate their egg laying. One newly emerged *B. terrestris* worker and its pupae were placed in the starting box together with the queen (Gretenkord and Drescher, 1997). These workers were changed every five days until the first workers emerge; in order to prevent competition with the queen. This study was carried out in a dark rearing room maintained 28-30 ^{o}C and 60-65% R.H. (Duchateau and Velthuis, 1988).

During the experiment, the queens and colonies were fed ad libitum with a sugar syrup (1:1 sugar / water) and fresh frozen pollen collected from *Sinapis arvensis, Cistus* spp. and *Papaver rhoeas* by honeybees (*Apis mellifera* L.). The pollen used for feeding contained approximately 20-22% crude protein (Baydar and Gürel, 1998). The nests were checked every day and the syrup and pollen were replaced when necessary.

A daily note was made of the queens that laid eggs, or did not lay eggs or died. After first workers emerged, the colonies were put into the larger rearing boxes. Due to the intermittent egg laying patterns of *B. terrestris* queens, the first, second and third broods occur in colonies. The weight of the queens, the time of first egg laying of the queens, the time of emergence of first worker, male and progeny queen, the switch and competition points in the social phase, the total number of workers, males and progeny queens produced and the time of reaching 50 workers were determined in colonies by periodical observation. Colonies were observed from colony initiation to all bees die. During this observation, the dead bees were counted and removed from the colonies in order to determine the number of workers, males and queens.

Switch and competition points were calculated from the emergence of the first

workers (social phase initiation) and other characteristics were calculated after the queens had been put into the starting boxes. The time of switch point was calculated for all colonies as follows:

- Switch point time = (time of first male emerging – time of first worker emerging) - development time of the male. Males needed about 26 days to complete their development (Duchateau and Velthuis, 1988).

The competition point between queens and workers was recognized by workers' behavior such as egg robbing, egg laying and attacking the founder queen and by founder queen's behavior such as oophagy.

The results were evaluated using the MINITAB statistical program. Descriptive statistics relating to the traits were given. Furthermore, correlation coefficients were calculated to determine the relationship between characteristics.

3. Results

The weight of the queens weighed before being placed in the starting boxes was an avarage of 0.79 ± 0.012 g (min: 0.59 g, max: 0.98 g). Other colony development characteristics in the colonies were given in Table 1. No significant statistical correlation was found between the weight of the gueen after diapause and colony development patterns in *B. terrestris*. Only the correlation between the weight of the queen after diapause and the number of workers produced in the first brood was found to be significant ($p<0.05$, $r = 0.42$, $n = 30$). Characteristics related with the first, second and third broods in the colonies were given in Table 2.

Table 2. Characteristics Related with the First, Second and Third Broods in the Colonies

	n	$\bar{x} \pm S_{\bar{x}}$
Nr .of egg cells in 1st br.	47	4.7 ± 0.2
Nr .of workers in 1st br.	30	9.1 ± 0.9
Initiation time of 2nd br.	25	25.7 ± 1.1
Nr .of egg cells in 2nd br	25	8.0 ± 0.6
Nr .of workers in 2nd br.	20	37.0 ± 4.9
Initiation time of 3rd br.	24	44.3 ± 1.7
Nr .of egg cells in 3rd br	25	40.28 ± 3.2
Nr .of workers in 3rd br	20	145.4 ± 21.8

The number of male and queens is crucial in year round rearing of bumblebee. Because progeny queens are required to produce new colonies and male are required to mate these young queens. The producing of males and young queens in colonies is affected by many factors, however no significant correlation was found between the weight of the gueen after diapause and number of males ($p<0.05$, $r = 0.11$, $n = 17$) and young queens ($p<0.05$, $r = 0.001$, $n = 9$) produced in *B. terrestris* colonies.

4. Discussion and Conclusion

There are problems in the year round rearing of *B. terrestris* during the colony foundation period. A proportion of the

Table 1. The Weight of Queens and Some Colony Development Characteristics in the Colonies

	n	$\bar{x} \pm S_{\bar{x}}$	min	max
The weight of the queens (g)	57	0.79 ± 0.01	0.59	0.98
Colony initiation (day)	47	7.64 ± 0.83	1	23
First worker emerging (day)	30	36.47 ± 1.30	27	52
First male emerging (day)	20	68.55 ± 4.39	35	97
First queen emerging (day)	11	89.55 ± 5.72	49	125
Switch point (day)	14	21.93 ± 2.27	4	34
Competition point (day)	19	45.11 ± 3.21	31	76
Total number of workers	21	197.60 ± 23.50	27	392
Total number of males	17	132.40 ± 26.90	13	442
Total number of queens	9	60.80 ± 12.70	9	120
Time to reach 50 workers	13	67.08 ± 2.74	53	80

queens die in the egg laying stage, some of the remaining queens lay eggs but some do not lay eggs. Some of the egg laying queens do not find healthy colonies. The weight of the queen does not affect the egg laying ratio, colony development and other colony development characteristics. This result is in agreement with the findings relating to the weight of the queen before diapause, which were reported by Beekman et al. (1998). The weight of the queen has more effect on its survival during diapause.

The colony foundation ratio, the time of colony initiation, the number of workers and egg cells produced in the first and second broods in the colonies are in agreement with the parameters determined for *B. terrestris* (Dutchateau and Velthuis, 1988; Greetenkord and Drescher, 1997; Beekman et al., 1999; Yeninar et al., 2000). The time of the first worker emerging (beginning of the social phase) and the worker development period were determined to be an avarage of 36.47 ± 1.30 and 27.86 ± 0.75 days, respectively. Duchateau and Velthuis (1988) reported that the development period of the *B. terrestris* worker varied among the colonies from 19 to 35 days. It was estimated that many factors affect on the variation in colony development patterns and the colony foundation ratio of queens during the year round rearing of *B. terrestris*. However, according to the results of this study, the weight of the queen after diapause has no effect on this variation

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