RESPONSES TO CLIMATIC FACTORS BY FORAGERS OF *Plebeia pugnax* MOURE (*IN LITT.*) (APIDAE, MELIPONINAE)

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ABSTRACT

Flight activity of *Plebeia pugnax* Moure (*in litt.*) was studied in six colonies coming from Cunha, SP, from July to October 1994. Twice a week, from 8:00 a.m. to 6:00 p.m., for 5 minutes every half-hour, all the bees entering and leaving the hives were counted. Six hundred counts were made and the materials that foragers carried were recorded. Data were analysed in relation to temperature, relative humidity, light intensity and day time. Foragers' flight activity was relatively constant in a wide range of temperature, from 22ºC to 34ºC. The minimum temperature for the beginning of flight activity was 14ºC. Effective flight activity (when foragers of all colonies were leaving the hives) occurred at 15ºC. These bees also flew within a wide range of relative humidity, from 30% to 100%, decreasing slowly after 50%. Flight activity increased as light intensity rose and it has also increased as the hours passed by, reaching a peak around midday and decreasing gradually afterwards. Pollen was collected all day long, while resin collection was relatively constant and debris transportation was slightly higher after 10:00 h. From all known *Plebeia* species, this one flew on the lowest temperature ever registered for this genus.

Key words: flight activity, stingless bees, climatic factors.

RESUMO

Respostas de forrageiras de *Plebeia pugnax* Moure (*in litt.*) aos fatores climáticos (Apidae, Meliponinae)

A atividade de vôo de *Plebeia pugnax* Moure (*in litt.*) foi estudada em seis colônias provenientes de Cunha, SP, de julho a outubro de 1994. Todas as abelhas que entraram e saíram da colméia foram contadas e o material que elas carregaram foram identificados. Foram realizadas 600 observações de 5 minutos cada, das 8 às 18 h, duas vezes por semana. Os dados foram analisados em relação à temperatura, umidade relativa, intensidade luminosa e hora do dia. A atividade de vôo das forrageiras foi relativamente constante em uma ampla variação de temperatura, entre 22ºC e 34ºC. A temperatura mínima para início da atividade de vôo foi de 14ºC. A atividade de vôo efetiva (em que forrageiras de todas as colônias saíram das colônias) ocorreu à temperatura de 15ºC. Estas abelhas também voaram em uma ampla faixa de umidade relativa, de 30% a 100%, diminuindo paulatinamente acima de 50%. A atividade de vôo aumentou ao mesmo tempo em que a intensidade luminosa elevou-se e esta também aumentou com o passar das horas, alcançando um pico ao redor do meio-dia e decrescendo gradualmente depois. Foi coletado pólen ao longo de todo o dia, enquanto a coleta de resina foi relativamente constante e o transporte de detritos foi ligeiramente superior depois das 10 h. De todas as espécies de *Plebeia* conhecidas, esta voou na temperatura mais baixa já registrada para esse gênero.

Palavras-chave: atividade de vôo, meliponíneos, fatores climáticos.

INTRODUCTION

Foragers fly to attend colony needs as food (pollen, nectar), water and construction materials (as resin and mud), as well as to clean up the hives, leaving with debris. In stingless bees, workers defecate inside the colony, in places called debris depots; these can also contain brood cells' remains, which are not reused after emergence of the adult. Besides inner colony conditions, environmental limits acting on flight activity determine different foraging patterns for several simpatric species. Several authors studied flight activity of stingless bees, mainly of species of the Trigonini tribe (Oliveira, 1973; Iwama, 1977; Fowler, 1979; Kleinert-Giovannini, 1982; Imperatriz-Fonseca & Aguilar, 1984; Mouga, 1984; Imperatriz-Fonseca *et al.*, 1985; Heard & Hendrikz, 1993; Azevedo, 1997).

The aim of this work is to establish a relationship between flight activity of *Plebeia pugnax* Moure (*in litt.*) and abiotic factors.

MATERIAL AND METHODS

Bees from the genus *Plebeia* are commonly known as "mirins" (minims). They nidify in hollow trees, stonewalls, ravines etc. Food pots are ovoid and brood combs are generally disposed horizontally, with the exception of *Plebeia minima* (Nogueira-Neto, 1970, 1997; Zucchi *et al.*, 1999). According to Ducke (1916), the species of this genus are found in subtropical and tropical regions, from Northern Argentina to Mexico. *Plebeia pugnax* Moure (*in litt.*) has approximately the same size as *Plebeia emerina*, but it is much more active than other species of its genus, presenting a greater entrance, always with guards, which follow visitors up to 30 meters away. It is found on the border of the Atlantic Rainforest and its nests are located on tree branches. This is why it is regionally known as tip tree minim.

Six colonies of *Plebeia pugnax* (named P_1 to P_6) were used in this study. They came from Cunha (SP) (23°05'S, 44°55'W) and were kept at the Bee Laboratory of the Departamento de Ecologia Geral, Instituto de Biociências, Universidade de São Paulo (23°33'S, 46°43'W). P_1, P_2, P_3 and P_6 were in rational hives (Nogueira-Neto, 1970); P_4 and P_5 were in natural nests, inside hollow trunks. All colonies had plenty of workers, with the exception of P_2.

A total of 600 counts were made from July to October 1994. Twice a week, from 8:00 a.m. to 6:00 p.m., for 5 minutes every half-hour, all the bees entering and leaving the hives were counted and the material they carried (pollen, resin or debris) were registered. These data were associated to some environmental conditions (temperature, relative humidity and light intensity) as well as to day time.

Ten workers from each of the following species of *Plebeia*: *pugnax*, *droryana* Friese, *emerina* Friese, *remota* Holmberg and *saiqui* Friese were weighted (dry weight) for further comparisons of influence of size on flight activity.

RESULTS

Despite intercolonial differences, flight activity increased with the rising of temperature and was relatively constant in a wide range of temperature, from 22°C to 34°C (Fig. 1). The lowest temperature where the bees flew was 14°C. Effective flight activity (the lowest temperature when foragers from all colonies flew) was observed at 15°C.

These bees flew within all values of relative humidity registered in this study, from 30% to 100%, decreasing slowly beyond 50% (Fig. 2).

Flight activity rose as the hours passed by, reaching a peak between 11:00-13:00 h, decreasing gradually afterwards (Fig. 3).

Light intensity seems not to affect flight activity of this species. Bees flew at low light intensities, although a higher number of bees left the hive beyond 20,000 lux (Fig. 4).

Maximum pollen collections occurred around 8:00 h and 17:00 h. These peaks were statistically significant (X^2-test in a binomial comparative trial; $X^2 = 4.50$, $v = 1$, $p = 0.034$).

Resin transportation was relatively constant. Debris were carried out mainly after 10:00 h (Fig. 5).

Table 1 shows a comparison of data obtained for species of *Plebeia* studied until now.

Although wind speed and rainfall were not measured, strong winds and beginning of rain made foragers come back quickly to the nests and diminished the number of bees leaving the hives.

Table 2 shows that workers of *Plebeia pugnax* are almost of the same size as those of *Plebeia emerina*, being bigger than those of *Plebeia droryana* and smaller than *Plebeia remota* and *P.*

saiqui. Differences between dry weight of these species were statistically significant (single-factor, model I ANOVA; $F = 82.99$, d.f. = 4, 45, $p = 3.543 \times 10^{-20}$).

DISCUSSION

Corbet *et al.* (1993) mentioned that the knowledge of the optimum range for flight activity of social bees' species is very important to pollination projects in different areas. An additional hypothesis is that this optimum range should directly influence the relative abundance of these species in a given area.

Nogueira-Neto *et al*. (1959), studying insect pollinators activity on coffee plantations, observed that three species of *Plebeia* did leave their hives in temperatures around 17-18ºC. Käpylä (1974) assigned that flight activity depends on insects' body size. Bigger species fly on temperatures and light intensities lower than smaller ones, thus demonstrating a better capacity to absorb heat. Imperatriz-Fonseca *et al.* (1985) noted that the observed range of temperatures for effective flight activity (Table 1) would be related to workers' size of the different species of *Plebeia*. In this study, the temperature for the beginning of flight activity (14ºC) and the temperature in which foragers of all colonies were flying (15ºC) were much lower than could be expected for bees of this size (as *Plebeia emerina*, and even *Plebeia remota* and *Plebeia saiqui*, which are the biggest bees yet studied of this genus). Furthermore, these bees flew within a wider range of temperature than others species of similar size did.

In this way, not only bee size is important for the beginning of flight activity, but also unknown physiological parameters should act decisively to the beginning of external movement in colonies of *Plebeia pugnax*.

From the species already studied only *Plebeia saiqui* and *Plebeia droryana* (Oliveira, 1973) were active in a wide range of relative humidity as *Plebeia pugnax*, although these bees also diminished somehow their flight activity above 50%. In other species relative humidity restricted flight activity of the bees in some way, as observed by Iwama (1977) for *Tetragonisca angustula* and by Kleinert-Giovannini (1982) for *Plebeia emerina*. Even bigger bees from the genus *Melipona* were affected by changes in relative humidity, as shown by Guibu & Imperatriz-Fonseca (1984) and Hilário *et al*. (2000) for *Melipona quadrifasciata quadrifasciata* and *Melipona bicolor bicolor*, respectively.

Colony conditions also influence the beginning of flight activity as observed by Hilário *et al.* (2000) for *Melipona bicolor bicolor.* Not only colony conditions influence outside movement, but also it affects internally the behaviour of bees, as shown by Lacerda *et al.* (1991) for *Geotrigona inusitata.*

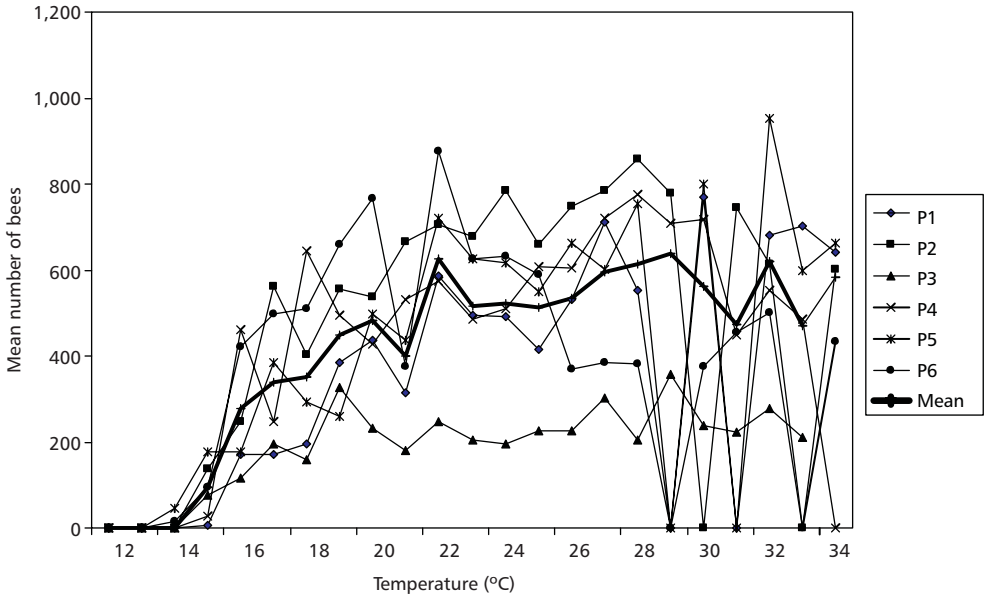

Fig. 1 — Flight activity of *Plebeia pugnax* related to temperature.

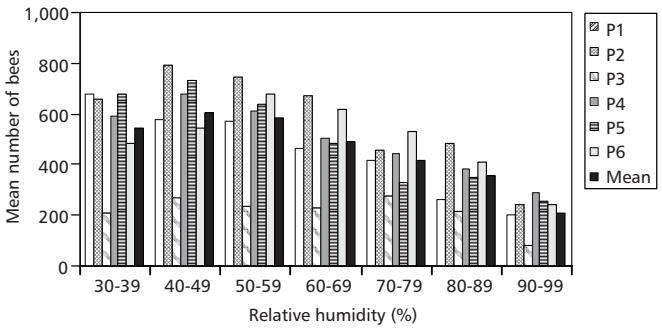

Fig. 2 — Flight activity of *Plebeia pugnax* related to relative humidity.

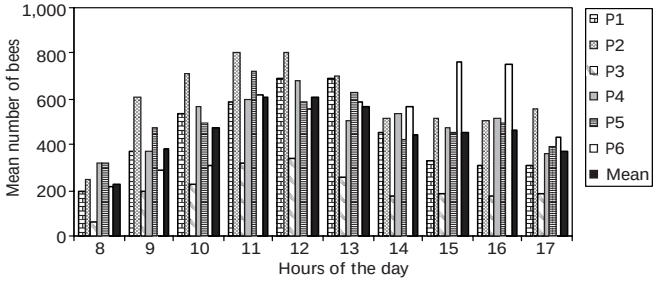

Fig. 3 — Flight activity of *Plebeia pugnax* related to hours of the day.

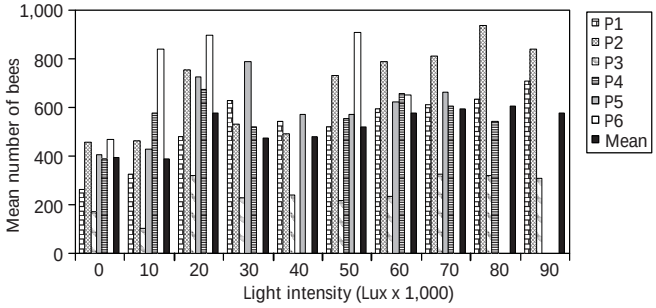

Fig. 4 — Flight activity of *Plebeia pugnax* related to light intensity.

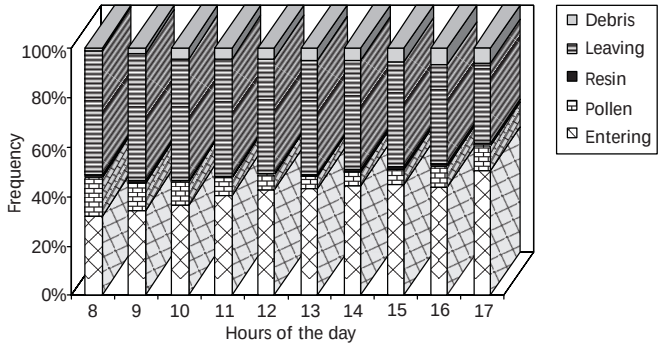

Fig. 5 — Flight activity of *Plebeia pugnax* in the different hours of the day showing the frequency of bees entering the hive with pollen; resin or without any material; and leaving the hive with debris and without any material.

TABLE 1

Flight activity related to temperature, relative humidity and day time for five species of *Plebeia.*

Species	Temperature for the beginning of flight activity (°C)	Effective flight activity	Ideal temperature (°C)	Ideal relative humidity (%)	Ideal time for flight activity	Authors
Plebeia remota	16-18	18	22-29	60-84	11-15 h	Imperatriz-Fonseca *et al.* (1985)
Plebeia saiqui	16-18	18	26-32	35-90	10-14 h	Oliveira (1973)
Plebeia emerina	16-22	19	21-27	40-70	13-14:30 h	Kleinert-Giovannini (1982)
Plebeia droryana	17-19	19	22-32	25-90	13:30-16 h	Oliveira (1973)
Plebeia pugnax	14-15	15	20-34	30-60	11-13 h	This work

TABLE 2

Dry weight of workers (ten individuals) from five species of *Plebeia* (in mg).

Species / Individuals	*Plebeia droryana*	*Plebeia emerina*	*Plebeia pugnax*	*Plebeia remota*	*Plebeia saiqui*
1	0.9	1.3	1.3	2.3	2.4
2	0.9	1.3	1.3	2.3	2.4
3	1.0	1.3	1.3	2.4	2.5
4	1.0	1.4	1.4	2.4	2.5
5	1.0	1.4	1.4	2.5	2.5
6	1.0	1.4	1.4	2.5	2.6
7	1.0	1.5	1.4	2.6	2.6
8	1.0	1.5	1.5	2.9	2.7
9	1.0	1.5	1.6	3.1	2.9
10	1.1	1.6	1.9	4.0	2.9
Mean	1.0	1.4	1.5	2.7	2.6

The several species of stingless bees living in a same place have different peaks of activity along the day, perhaps as a result of competition between species and colonies for more quantitative and qualitative floral resources. Heinrich & Raven (1972) mentioned that the energetic cost is greater for bee species (generally the biggests) that leave the nests earlier or in lower temperatures, but the caloric reward they gain is greater than for those who arrive later. *Plebeia pugnax* leaves the nest early in the morning, as had never be seen for other species of its size, and it is active all day long, with a peak around midday.

Light intensity seems to determine the end of outside activities of bees, as shown by Heard & Hendrikz (1993) for *Trigona carbonaria* in Australia. They noted that temperature and light intensity were the most important factors determining flight activity, as did Azevedo (1997) for *Partamona helleri.* It is clear that temperature and light intensity are related in some way, but bees from colonies of *Plebeia pugnax* did not seem much affected by changes in light intensity.

Bruijn & Sommeijer (1997) noted a temporal division for nectar, pollen and resin collection by *Melipona beecheii* and *M. fasciata*, being the peaks

of foraging for each of these materials apart in time. Hilário *et al.* (2000) verified something similar for *Melipona bicolor bicolor*. This was not observed for *Plebeia pugnax*. There were two peaks in the pollen collection: at early morning and at noon. Resin collection was relatively constant. In the tropics, pollen availability is not a limiting factor. Nevertheless intraspecific competition within species can occur, as noted by Hilário *et al.* (*op. cit*.) for *Melipona bicolor bicolor* and also confirmed by Roubik (1996).

Plebeia pugnax also exhibits another behaviour never found in species of this genus already studied: the workers fly quickly around the nest entrance in an assemblage. This behaviour can last up to an hour and could be an alarm display. Moreover, this intensive activity does not impede the continuous movement of bees entering and leaving the hive and it is alike male flights typical for some Trigonini. However, samples of bees collected within this crowded flight showed that it can be constituted only by workers or it can have males and workers. After this flight the bees enter the hive. This aspect of flight activity is being studied in detail, and it will be presented opportunely.

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