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Foraging pattern and harvesting of resources of subterranean stingless bee *Geotrigona subterranea* (Friese, 1901) (Hymenoptera: Apidae: Meliponini)

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ABSTRACT

Flight activity of bees is influenced both by environmental factors and by internal condition of the colonies. Information about external activity of bees is very important, because it provides data of the species biology, supplying subsidies for the use of these insects in the pollination of crops. The present work aim to evaluate the flight activity of Geotrigona subterranea *(Friese, 1901) (Hymenoptera: Apidae) in natural environment. This study was performed on the Instituto Federal do Norte de Minas Gerais, in the municipality Januária, Minas Gerais State. Two natural nests were observed. The activities of bees of the colonies were recorded three days each month, during the period of December 2011 to November 2012, totaling 924 observations. It was recorded the number of bees leaving and entering the nest, and the type of material transported by them for ten minutes each hour from 5 a.m. to 7 p.m. The bees entered the colony carrying pollen, resin, detritus and also without apparent material. The bees began external activities by 6 a.m. at 20°C and finished at 6 p.m. at 28.8°C. The peak of activity of* G. subterranea *occurs on schedule from 1 to 2 p.m. Even though* G. subterranea *makes their nests in underground, their foraging activities are very similar to others stingless bee species that usually nest on tree cavities or aerial places. This indicate that despite their particular nesting way the external factors as climatic ones will significantly modulate their foraging pattern in a daily and seasonal way.*

Key-Words: Foraging behavior; Meliponini; Pollen; Resin; Detritus.

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INTRODUCTION

Flight and foraging of social insects, such as stingless bees, are influenced both by the internal conditions of the colony and the variation of external conditions, including climatic conditions and availability of resources for foraging (Kleinert-Giovannini & Imperatriz-Fonseca, 1986; Kerr *et al.,* 1996; Biesmeijer *et al.,* 1999; Nascimento & Nascimento, 2012).

The internal conditions of the colony are strongly influenced by the nest population that determines the amount of bees foraging (Kerr *et al.,* 1996). The body size determines the distance of flight and the response of workers to weather factors (Pereboom & Biesmeijer, 2003; Araújo *et al.,* 2004).

Environmental factors such as temperature, precipitation, light intensity, wind speed, and relative humidity influence the flight activity of stingless bees, its variation throughout the year and therefore the pollination (Kleinert-Giovannini & Imperatriz-Fonseca, 1986; Bruijn & Sommeijer, 1997; Hilário *et al.,* 2003). The flowering characteristics such as availability, time of occurrence, duration, quality and sugar concentration in nectar are also important to external activity of bees (Marques-Souza, 1996; Biesmeijer *et al.,* 1999).

Information about external activity of bees is very important because it provides data of the species biology and aspects of their behavior that impact on their potential for crop pollination (Iwama, 1977; Hilário *et al.,* 2000). These features include the amount of bees that enter and leave the hive and the resources collected by them.

Flight and foraging activity of stingless bee are better known for those species nesting in tree cavities. However, to date, few studies have addressing these issues in subterranean stingless bees. *Geotrigona subterranea* occurs in the Brazilian states of Bahia, Minas Gerais, Paraná and São Paulo (Camargo & Moure, 1996). Its nest is built in subterranean cavities of various types, usually abandoned nests of ants and termites. The genus *Geotrigona* has the particularity of collecting detritus that are deposited around the entrance hole, helping the foragers in the nest location (Nogueira-Neto & Sakagami, 1966; Barbosa *et al.,* 2013). This paper aimed to evaluate the foraging pattern and harvesting of floral and non-floral resources by *G. subterranea* in a natural environment.

MATERIAL AND METHODS

The study was carried in the municipality of Januária, (15°29'16"S, 44°21'43"W; 554 meters of altitude), Minas Gerais, Brazil. The vegetation in the region is characterized by areas of transition between the Cerrado and Caatinga biomes. The climate type in the region, according to Köppen classification, is Aw, with a dry winter and a wet summer.

We recorded the number of bees in flight activity in two feral colonies (distanced 170 m) through the observation of the amount of bees leaving and entering the nest and the type of transported material, in order to assess the foraging strategy adopted by these bees and their adaptation to the environment. The evaluations were performed on three days per month, from 5 a.m. to 7 p.m., between December 2011 and November 2012. The amount of bees in flight activity was determined by direct counting of individuals entering and leaving the nest during the period of 10 minutes every hour for the colony, 924 observations. We calculated an average of the data for the two colonies investigated.

The type of material transported by bees was identified based on visible characteristics by each material: resin (shiny appearance); pollen (clearest colorations); and detritus (loaded in the mandibles). We also observed bees entering the colony without apparent material (WAM), presumably nectar and water (Roubik, 1989).

Temperature and humidity data were taken locally using a station TFA® installed on the nests observation site. The monthly precipitation during the study period was obtained in the database of conventional meteorological stations INMET (government institution that provides information about the weather and the climate throughout Brazil).

We performed a Spearman test in order to evaluate whether there would be correlation between foraging activity of bees and climatic variables. This analysis was carried out using the Statistical Analysis System (SAS, 2002).

RESULTS

Regarding external activity during the day, the bees leave the colonies after 6 a.m., seldom occurring activity prior to this time. The flight activity lasted until the interval 6-7 p.m. and after that rarely flight activities were observed (Fig. 1). Monthly flight activity and collected resources by *G. subterranea* varied throughout the year, occurring greater activity in May 2012, after the rainy period. In November there was the slightest movement of bees leaving and entering the colony. This was also the wettest month during the study period (Fig. 2).

TABLE 1: Correlation coefficient (non-parametric Spearman test) between environmental conditions and external activity of *Geotrigona subterranea.* (TEM = temperature, RH = relative humidity, WAM = without apparent material, POL = pollen load, RES = resin load, DET = detritus load, ENT = entering bees, EXT = leaving bees).

	RH	WAM	POL	RES	DET	ENT	EXT
TEM	0.98 ***	0.79 ***	0.36 ns	0.82 ***	0.94 ***	0.70 **	0.54 *
RH	—	-0.72 **	-0.24 ns	-0.74 **	-0.89 ***	-0.59 *	-0.42 ns
WAM	—	—	0.71 **	0.96 ***	0.85 ***	0.95 ***	0.86 ***
POL	—	—	—	0.76 **	0.44 ns	0.86 ***	0.94 ***
RES	—	—	—	—	0.86 ***	0.96 ***	0.89 ***
DET	—	—	—	—	—	0.77 **	0.64 *
EXT	—	—	—	—	—	—	0.97 ***

Significance level: (*) < 0.05; (**) < 0.01; (***) < 0.001.

The beginning of flight activity occurred at an average temperature of 19.6°C and relative humidity of 77.4% (at 6-7 a.m.), with the peak activity occurring in the range of 1-2 p.m., at an average temperature 32.5°C and humidity of 42.4%. The temperature and humidity at the end of the activity were 28.8°C and 49.7%, respectively (Fig. 3). There was a positive correlation between temperature and entering ($p < 0.01$) and leaving ($p < 0.05$) of bees. Humidity and 'entrance in the colony' were negatively correlated ($p < 0.05$), however there was no significant correlation between relative humidity and 'leave the colony' (Table 1).

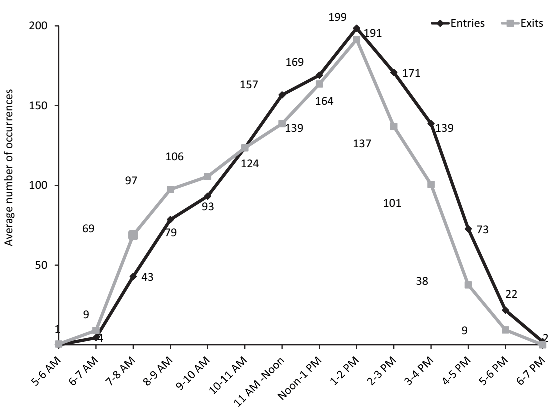

FIGURE 1: Daily pattern of flight activity (means of 12 months and 2 nests) of workers of *Geotrigona subterranea* at Januária, MG, southeastern Brazil.

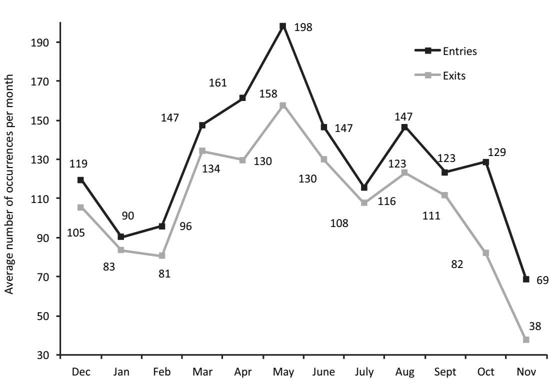

FIGURE 2: Monthly flow of entries and exits of *Geotrigona subterranea* in the nests.

Bee's entries in the colony WAM, presumably nectar and water, occurred throughout the day and was greater in the afternoon, reaching peak activity in the interval of 1-2 p.m. (Fig. 4). The movement of bees WAM occurred throughout the year.

There was pollen collection during the entire period of activity, occurring greater foraging in the interval of 11 a.m. – noon. This activity was higher in May and September (Fig. 5), during which the precipitation was 25.7 mm.

The gathering of resin started a little later and focused on the afternoon shift, reaching a peak between 1-2 p.m. The resin collection activity occurred in all months, although it was higher in the dry season, between the months of March and October. This activity was positively correlated with temperature ($p < 0.001$).

Detritus was collected from the ground, in places where there is the availability of small kin-

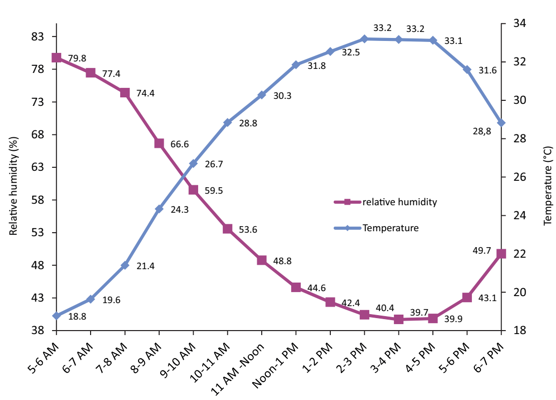

FIGURE 3: Temperature and humidity range in Januária, MG, throughout the day.

dling and little pieces of leaves, petals of little flowers and small clay pellets. The collection began around 11 a.m., achieved greatest activity in the period of 2-3 p.m. and continued until 6 p.m. The bees collected detritus throughout almost the entire year, except for the months of February, June and July, with a higher activity in March (Fig. 5). The transport of detritus showed positive correlation with temperature ($p < 0.001$) and negative correlation with humidity ($p < 0.001$).

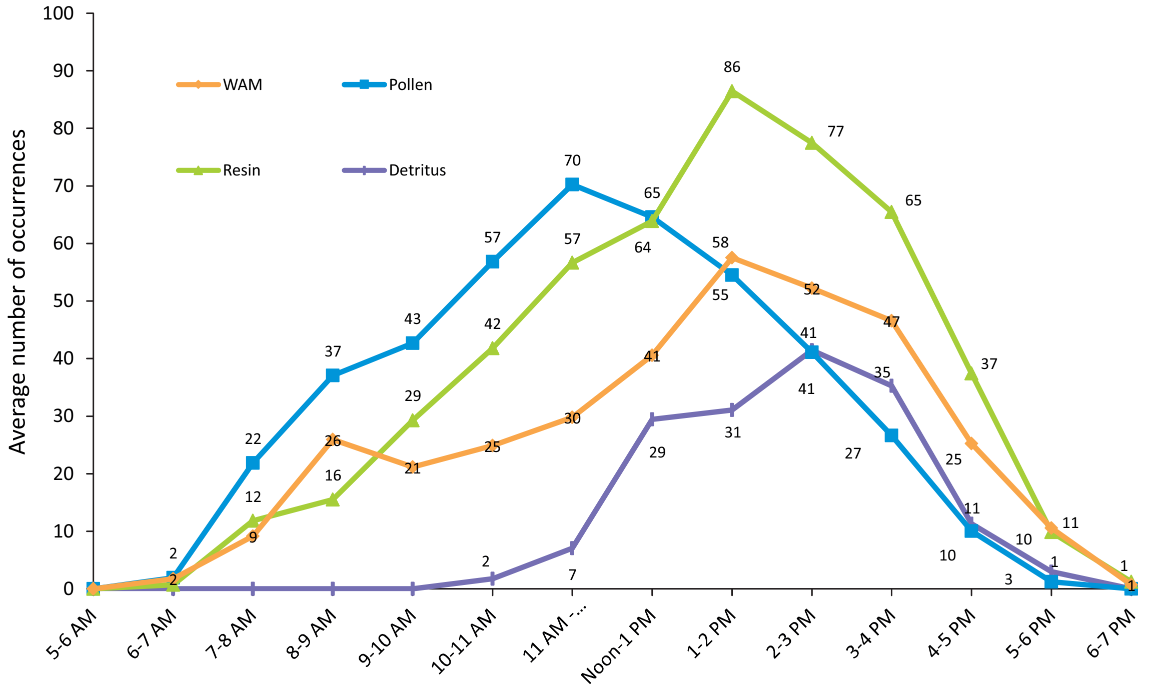

FIGURE 4: *Geotrigona subterranea* flow throughout the day according to the type of transported material.

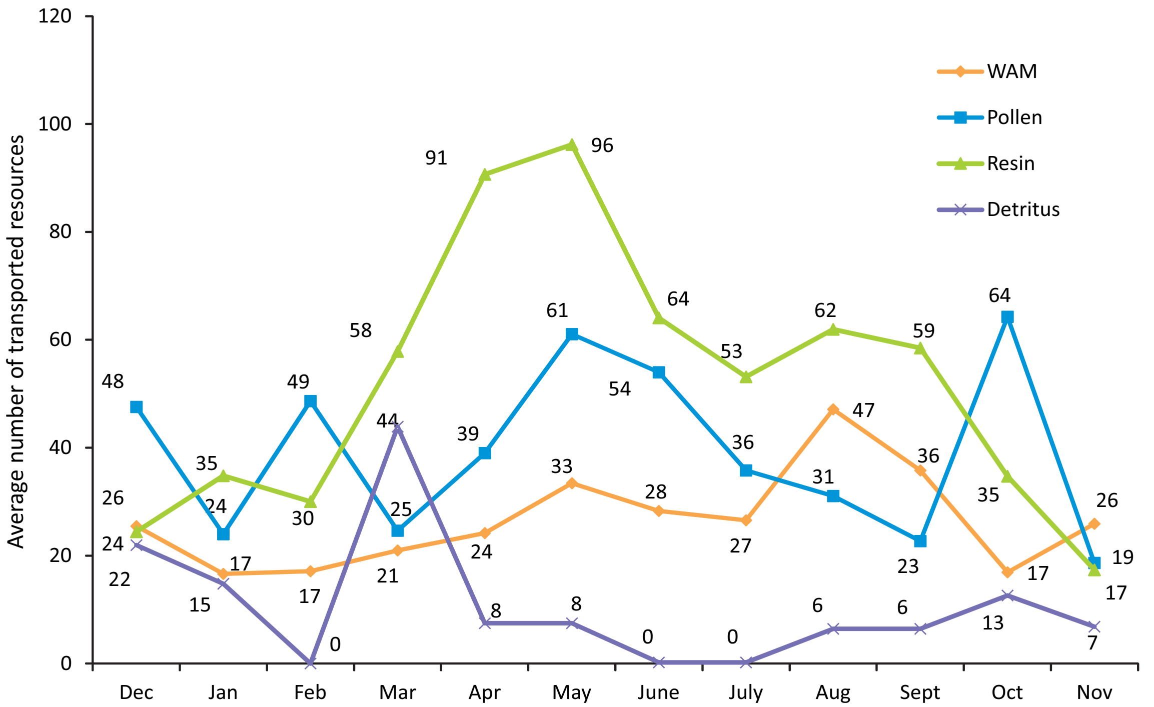

FIGURE 5: Monthly flow of *Geotrigona subterranea* according to the type of transported material.

DISCUSSION

The foraging activity of subterranean stingless bees seem indeed to be affected by climatic factors. For example, the sister species *G. mombuca* also has been observed to be affected by temperature and relative humidity (Gobatto & Knoll, 2013). Most likely both subterranean stingless bee species (*G. mombuca* and *G. subterranea*) possess similar foraging pattern not only because they are taxonomically closely related each other, but because their populations inhabit similar natural environments.

Flight activity at high temperatures can be influenced by the color and body size. Black bees, such as the species of this study, can present problems related to dehydration and individual thermal regulation (Pereboom & Biesmeijer, 2003). In *G. subterranea* the period of maximum activity coincides with the high temperature time during the day. Despite having black color, this species is small (5.80 mm long (Camargo & Moure, 1996)), an important feature, since smaller Meliponini species suffer less restrictions at warmer periods, compared to larger species (Roubik, 1993).

The activity of bees without apparent material (WAM) was higher during the early afternoon and this behavior can be explained by the possibility of nectar quality increment in the hottest time, since throughout the day the concentration of sugar may increase in some blossoms (Roubik, 1989).

The pollen collection activity by *G. subterranea* was highest in the late morning, suggesting that there may be temporal partition with other bee species since most of the pollen is available in the morning (Roubik, 1989) and the larger species of stingless bees tend to concentrate the pollen gathering in the first hours of the day (Silva *et al.,* 2011). This aspect can be seen in flight activity studies of relatively large species of *Melipona,* as *M. quadrifasciata* (Guibu & Imperatriz Fonseca, 1984), *M. bicolor bicolor* (Hilário *et al.,* 2000), *M. scutellaris* (Pierrot & Schindwein, 2003; Silva *et al.,* 2011), *M. rufiventris* (Fidalgo & Kleinert, 2007), *M. eburnea* (Nates-Parra & Rodriguez, 2011). However other small species of stingless bees, including smaller *Melipona* presented other pattern of foraging, it is the case of *M. marginata* (Kleinert-Giovannini & Imperatriz-Fonseca, 1986; Von B Borges & Blochtein, 2005), *M. asilvai* (Souza *et al.,* 2006), *Geotrigona mombuca* (Gobatto & Knoll, 2013), *Paratrigona subnuda* (Mouga, 1984). It is possible that smaller species of Meliponini use floral resources after they have been exploited by larger bees (Silva *et al.,* 2011).

Regarding collection of resin, the highest activity during the dry period can be explained by increased demand of this material in this period for the construction of structures in the nest, since the flow of foragers with pollen and WAM was also higher, indicating growth of the nest. The collection in the hottest hours of the day can be explained by the ease handling of the resin by bees under high temperature conditions.

The collection of detritus is intensified during periods of rain and a possible explanation for this behavior is that bees make use of this material as mulch to prevent seed germination around the entrance hole (Barbosa *et al.,* 2013). Another hypothesis is that there is a greater availability of detritus in the dry season when there is leaf fall. The occurrence of this activity only during the afternoon can be explained by the low moisture of the material in the hottest time, allowing that detritus to be more easily transported. Costa-Pereira (2014) found that two species of *Melipona* collect clay with less moisture to reduce the energy cost during transport.

A higher flight activity in the dry season can be explained by variations in the quantity and quality of food between different seasons (Roubik, 1989). The variation in the activity influenced by climatic factors may be different depending on the season, as reported by Nascimento & Nascimento (2012) for *Melipona asilvae.* This difference was observed in *Trigona carbonaria* by Heard & Hendrikz 1993, which presented different pattern of activity between warm and cold months. Vossler *et al.* (2010) found that the *Geotrigona argentina* accumulates large amounts of nectar and pollen during the dry season and decreases the collection activity during the rainy season. Studying the flight activity of a subterranean bee species, Nagamitsu & Inoue (2002) suggested that in the collection of pollen and nectar, the response of foragers is more closely linked to variations of resources in time scale than the general availability of sources for foraging.

CONCLUSION

Even though *G. subterranea* makes their nests in underground, their foraging activities are very similar to others stingless bee species that usually nest on tree cavities or aerial places. This indicate that despite their particular nesting way the external factors as climatic ones (temperature, humidity, precipitation) will significantly modulate their foraging pattern in a daily and seasonal way.

RESUMO

A atividade de vôo das abelhas é influenciada por fatores ambientais, como temperatura, umidade e intensidade luminosa; e pelas condições internas da colônia. Informações sobre a atividade externa das abelhas é de grande importância, pois proporciona dados importantes para o conhecimento da biologia das espécies, fornecendo subsídios para o uso destes insetos na polinização de cultivos. O presente trabalho teve como objetivo avaliar a atividade de voo de Geotrigona subterranea *(Friese, 1901) (Hymenoptera: Apidae) em ambiente natural. Este estudo foi realizado no Instituto Federal do Norte de Minas Gerais, no município de Januária, Estado de Minas Gerais. Foram observados dois ninhos naturais. A atividade das abelhas foi registrada por três dias a cada mês, durante o período de dezembro de 2011 a novembro de 2012, totalizando 924 observações. Foi registrado o número de abelhas que sai e entra no ninho, e o tipo de material transportado por estas, durante dez minutos a cada hora (das 5 às 19 horas). As abelhas entraram na colónia transportando pólen, resina, detritos e também entraram sem aparente material (néctar ou água). As abelhas iniciaram a atividade externa por volta das 6 horas da manhã, a 20°C e encerraram às 18 horas, a 28,8°C. O pico da atividade de* G. subterranea *foi observado em torno das 13-14 horas. Apesar de* G. subterranea *construir seus ninhos em cavidades subterrâneas, suas atividades de forrageamento são semelhantes a de outras espécies de abelhas sem ferrão que constroem ninhos externos ou em cavidades de árvores. Isto indica que, apesar de seu hábito de nidificação, os fatores climáticos afetam seu padrão de forrageamento diária e sazonalmente.*

Palavras-Chave: Comportamento de forrageamento; Meliponini; Pólen; Resinas; Detritos.

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