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Effects of abiotic factors on the foraging activity of *Apis mellifera* Linnaeus, 1758 in inflorescences of *Vernonia polyanthes* Less (Asteraceae)

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ABSTRACT. Knowledge on the foraging activity of *Apis mellifera* under the influence of abiotic factors has not been fully elucidated. Knowing the interactions between bees and plants with beekeeping relevance is fundamental to develop management strategies aimed at improving the beekeeping productivity. In this way, this study aimed to determine the foraging schedule of *A. mellifera* and to assess the influence of environmental factors on the foraging on inflorescences of *Vernonia polyanthes*. The study was conducted in the rural area of Valença, Rio de Janeiro State. Visits of *A. mellifera* workers to *V. polyanthes* inflorescences occurred from 9 am to 4 pm, especially between 11 am and 3 pm. Among the abiotic variables, relative humidity ($rs = -0.691$; $p < 0.0001$) and temperature ($rs = 0.531$; $p < 0.0001$) were correlated with foraging activity. Increase in temperature and decrease in humidity resulted in increased frequency in bee foraging activity, accounting for 46.9% of the activity in *A. mellifera*. This study provides subsidies to the development of apiculture, emphasizing the importance of *V. polyanthes* as a food resource during winter, representing a good alternative to increase the productivity, especially in areas of grasslands or abandoned crops, where 'Assa-peixe' is abundant.

Keywords: beekeeping, abiotic factors, Africanized honeybees, Assa-peixe.

Efeito dos fatores abióticos sobre a atividade forrageadora de *Apis mellifera* Linnaeus, 1758 em inflorescências de *Vernonia polyanthes* Less (Asteraceae)

RESUMO. O conhecimento das atividades de forrageio de *Apis mellifera* sob a influência dos fatores abióticos ainda não está completamente elucidado. Conhecer as interações entre abelhas e plantas de importância apícola é fundamental para o desenvolvimento de metodologias de manejo, que visem à produtividade e desenvolvimento da apicultura. Sendo assim, este trabalho tem como objetivo conhecer o horário de forrageio de *A. mellifera* e avaliar a influência dos fatores ambientais sobre o forrageio nas inflorescências de *Vernonia polyanthes.* O estudo foi conduzido em uma área rural da cidade de Valença, Estado do Rio de Janeiro. As visitas das operárias de *A. mellifera* as inflorescências de *V. polyanthes* ocorreram das 9 às 16 h, com maior atividade entre 11 e 15 h. Dos fatores abióticos estudados, umidade relativa do ar ($rs = -0,691$; $p < 0,0001$) e temperatura ($rs = 0,531$; $p < 0,0001$) se correlacionaram com a atividade forrageadora. O aumento da temperatura e diminuição da umidade aumentou a frequência no forrageio das abelhas, sendo responsáveis por 46,9% da atividade de *A. mellifera*. Este trabalho fornece subsídios para o desenvolvimento da apicultura, uma vez que destaca a importância de *V. polyanthes* como fonte de recurso para *A. mellifera* durante o inverno, sendo uma boa alternativa para os apicultores melhorarem a produtividade dessa atividade econômica, principalmente em áreas de pastagem ou cultivos abandonados, com abundância de Assa-peixe.

Palavras-chave: apicultura, fatores abióticos, abelhas africanizadas, Assa-peixe.

Introduction

Eusocial bees are dominant pollinators of plant communities. The success of this dominance is mainly related to the ability to recruit other bees in the hive to forage (Amdam et al., 2005; Potts, Vulliam, Dafni, Ne'eman, Willmer & 2003) and to the efficiency in communicating the food source (Dyer, 2002). Workers of *Apis mellifera* Linnaeus, 1758, compare the volume and the concentration of sugars in the nectar from different plant species, and select the resource with better energy rewards (Goulson, 1994). This species is preferred by Brazilian beekeepers because of the characteristics that distinguish it from other species, such as high

yield, disease resistance, ease of handling and efficient foraging ability (Goulson, 1994; Marchini et al., 2001).

The characteristics of *A. mellifera* combined with the high demand for bee products put beekeeping as a key activity for ecosystem conservation and economic development (Camazine, 1993; Potts et al., 2010), thus attracting great interest in different sectors of society and generating income for the farmer; this activity is widely used in the pollination of many crops (Meffe, 1998). In this sense, knowledge of plant species with beekeeping relevance, the foraging strategies of *A. mellifera* and its relationships with the different environmental variables, are important for the development of beekeeping and management strategies, for the best use of resources by bees.

As the Africanized honeybees are sensitive to environmental changes (Amdam et al., 2005), climate variables are directly related to the productivity of the colony (Costa et al., 2007), since they are related to the energy expenditure to control foraging activity (Biesmeijer & de Vries, 2001; Grüter & Farina, 2007). In addition to direct effects on the foraging behavior of bees, abiotic factors influence the production of floral resources (Hilário, Imperatriz-Fonseca and Kleinert, 2001), so the dynamics of production of these resources varies between seasons. During the winter, bees tend to collect less nectar (Malerbo-Souza & Silva, 2011), given the lower supply of resources related to the senescence of most plant species in this season (Baylão Junior et al., 2008). Plants flowering this time of year are important in maintaining bee communities (Ramalho, Batista & Silva, 2004).

Vernonia polyanthes Less (Asteraceae), popularly known as Assa-peixe, is a shrubby species that flowers during winter and is widely distributed in the states of Minas Gerais, São Paulo and Rio de Janeiro (Baylão Junior et al., 2008; Yamamoto, Kinoshita & Martins, 2005). Its inflorescences are distributed in the form of heads, where the reproductive organs and its corolla remain highly exposed, thus facilitating the collection of nectar and pollen by bees (Baylão Junior et al., 2008). Because of the considerable supply of food resources during winter, time of scarce resources, *V. polyanthes* is a species with beekeeping relevance and therefore its flowerings are widely used by beekeepers for honey production, much appreciated and with high commercial value (Barth, Maiorino, Benatti & Bastos, 2005; Baylão Junior et al., 2008).

Knowledge about the influence of abiotic factors during the foraging activity of Africanized honeybees still needs further investigations. Besides that, there are few studies that contribute to improve the management of this species during the flowering of plants with beekeeping relevance importance of foraging activity of *A. mellifera* on *V. polyanthes* and aims to know the foraging schedule of *A. mellifera* during the day and to evaluate the influence of environmental factors on the foraging of this species, during the flowering of *V. polyanthes*.

Material and methods

This study was conducted in a rural area of the municipality of Valença, Rio de Janeiro State. The phytophysiognomy of the area consists of pastures, abandoned crops, with predominance of native vegetation at pioneering stage and some fragmented patches of the Atlantic Rain Forest (22º 15' 54" S e 43º 49' 41" W). The climate is tropical altitude Cwa (Köppen & Geiger, 1928), with two distinct seasons: hot and rainy summer (October to April), dry and cold winter (May to September), with shorter days.

Workers of *A. mellifera*, popularly known as Africanized honeybees, were collected weekly with entomological net, during *V. polyanthes* flowering (July to August), winter 2012 and 2013, according to the methodology proposed by Sakagami et al. (1967). Sessions of 10 min. were performed every hour in the morning (9 to 12h) and afternoon (12 to 16h), totaling 800 minutes of sampling effort during two years. Every hour, we recorded abiotic factors (temperature, relative humidity and wind speed), with a digital thermo-hygrometer-anemometer, LUTRON® LM-8000.

Data were tested for normality (Shapiro-Wilk test) and homoscedasticity (Levene), with a significance level of p = 5%. Values of absolute abundance of each hour were subjected to Mann-Whitney test to check for differences between the periods of the day (morning x afternoon) using the software SAS (2004). The correlation between foraging activity and abiotic factors was tested by Spearman correlation coefficient (rs). To evaluate the influence of environmental variables on the foraging behavior, a multiple linear regression was run using the software Biostat 5.0 at 5% significance level. The linear model of the foraging activity *A. mellifera* was represented by the following equation:

$Y' = 43.909 + (-0.407) . X1 + (-1.636) . X2 + (-0.468) . X3$ [relative humidity (X1), wind speed (X2), temperature (X3)].

Results and discussion

During the study period, we collected 620 *A. mellifera* workers, 269 in the morning (43.4%) and 351 in the afternoon (56.6%). Visits of *A. mellifera* workers

to *V. polyanthes* started at 9h and continued until late afternoon around 16h. The time of higher activity of bees was between 11 and 15h. Before and after that period, the foraging activity was less intense and mostly absent (Figure 1).

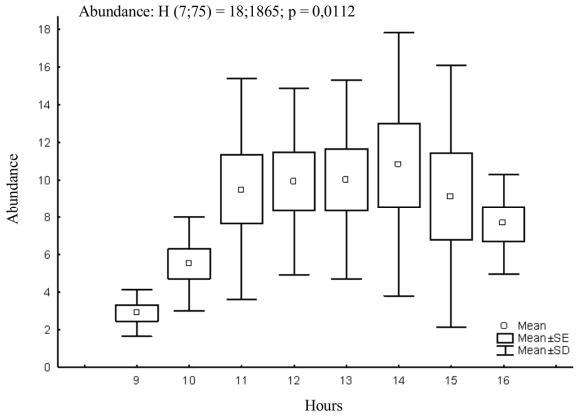

Figure 1. Foraging schedule of *A. mellifera* over the day on inflorescences of *V. polyanthes*. SE (standard error); SD (standard deviation).

According to Malerbo-Souza and Silva (2011), bee foraging during the winter is more concentrated in the morning, when there is greater availability of food resources, mainly nectar. In the afternoon (after 13h), the frequency of the activity is drastically reduced by the lack of resources (Schuster, Noy-Meir, Heyn & Dafni, 1993). Despite the foraging activity of *A. mellifera* workers, during the winter of 2012 and 2013, there was no significant difference (U = 521, df = 75, p = 0.054) in the abundance of bees between the periods of morning and afternoon (Figure 2), not corroborating the results of Malerbo-Souza and Silva (2011). This may be because this botanical species provides resources throughout the day, standing out as an indispensable source of resource for maintaining communities of bees during the winter. Therefore, bees enhance the foraging activity in the late morning, extending throughout the day.

The relative humidity (RH%) was negatively correlated (rs = -0.691; p < 0.0001) with *A. mellifera* abundance (Figure 3A). When the humidity was above 81%, there was no activity of this bee species, probably because the flight becomes more difficult, as the wings and the body of bees become heavier, which results in greater energy expenditure (Borges & Blochtein, 2005; Kleinert-Giovannini & Imperatriz-Fonseca, 1986). Similarly, Pegoraro, Neto, Lazzari and Silva (2011) observed that the onset of foraging of Africanized honeybees is related to the decrease in relative humidity. Besides directly affecting bees, this variable also acts in the concentration of sugars in the nectar. Therefore, when the humidity is high, there is a decrease in this concentration, thus reducing the attractiveness of resources for the bees and the foraging activity (Silva, Dutra, Nucci & Polatto, 2013).

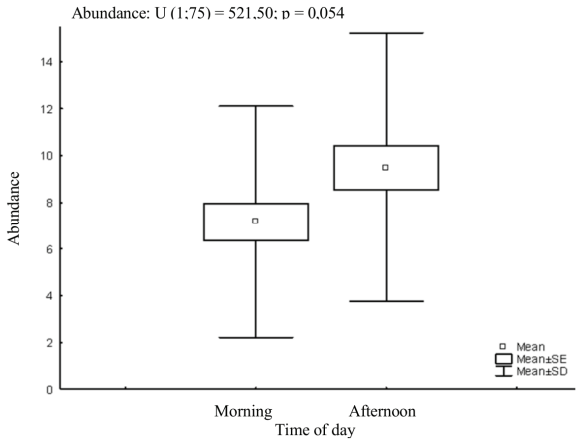

Figure 2. Absolute abundance of *A. mellifera* workers in the morning (9 to 12 h) and afternoon (12 to 16 h) on *V. polyanthes* inflorescences. The absolute abundance between the periods of morning and afternoon was compared by Mann-Whitney test (U).

Humid places, such as inside forests, can be limiting for the development of beekeeping and should not be used for the installation of apiaries, because Africanized bees are constantly weakened by fungi and microbial diseases when installed in those environments (Roubik & Wolda, 2001). A study conducted in the Amazon forest recorded no activity of *A. mellifera* inside the forest, only in open areas where the humidity was lower (Oliveira, Dias, Costa, Filgueira & Sobrinho, 2012), showing that this species is not well adapted to these sites. Thus, open areas with grasslands or abandoned crops with abundance of Assa-peixe, as the area of the present study, are ideal for the development of beekeeping, since the chances of survival of Africanized honeybees in these areas are higher, given the lower influence of humidity and lower chances to be weakened by fungi and bacterial diseases (Oliveira et al., 2012; Roubik & Wolda, 2001) and the high availability of resources provided by *V. polyanthes* (Baylão Junior et al., 2008).

The temperature was positively correlated (rs = 0.531, p < 0.0001) with *A. mellifera* abundance (Figure 3B). The first workers started their activities when the temperature reached 16°C. Malerbo-Souza and Silva (2011) recorded a positive correlation between temperature and the *A. mellifera* abundance during the winter. According to these authors, the foraging activity of *A. mellifera* started when the ambient temperature was around 15°C.

Temperatures below this range may be a limiting factor for the foraging of this species during the winter. Thus, the workers begin their activities when the outside temperature is favorable, around 14ºC (Hilário et al., 2001), which corroborate those obtained by Malerbo-Souza and Silva (2011).

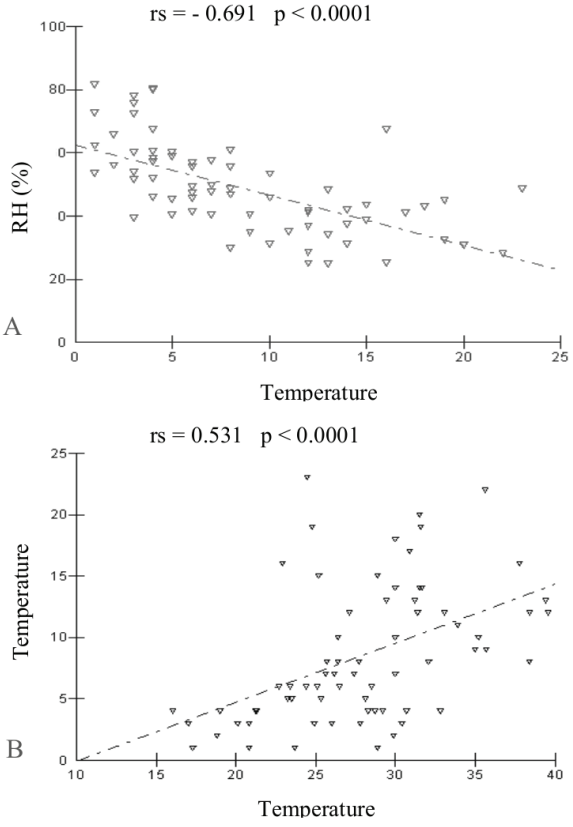

Figure 3. Spearman correlation coefficient (rs) between the abundance of *A. mellifera* and environmental variables in inflorescences of *V. polyanthes*. (A) correlation between relative humidity and *A. mellifera* abundance, (B) correlation between temperature and *A. mellifera* abundance.

The multiple regression revealed that among abiotic variables, only temperature and relative humidity, influenced the foraging activity of *A. mellifera* ($R^2 = 0.469$; $p < 0.0001$), accounting for 46.9% of this activity. Oliveira et al. (2012) observed that the abiotic variables (temperature and humidity) also influenced directly the foraging activity of *Melipona subnitida* Ducke, following the pattern found in this study.

In general, the foraging activity registered herein followed a pattern already described in other studies (Kovac & Stabentheiner, 2011; Malerbo-Souza & Silva, 2011; Polatto, Chaud-Netto & Alves-Junior, 2014), in which the temperature increase and relative humidity reduction influenced the frequency of foraging of *A. mellifera*. The activity of Africanized honeybees in this study was more intense when the temperature was high, around 29.4°C ± 4.9, and the relative humidity was low, around 43.6% ± 11.2. Thus, the choice of sites for the development of beekeeping, aiming at high productivity, should take into account the variation in temperature and relative humidity between seasons.

Conclusion

A. mellifera workers foraged almost throughout the day, with the peak activity in the afternoon, influenced by the increase in temperature and decrease in relative humidity.

This study provides subsidies to the development of beekeeping, pointing out the importance of *V. polyanthes* as a source of resources for *A. mellifera* during winter, representing a good alternative to increase the productivity of this economic activity, especially in areas of grasslands or abandoned crops, where Assa-peixe is abundant. Furthermore, information about the *A. mellifera* foraging behavior assist management activities performed by beekeepers, contributing to better use of resources provided by *V. polyanthes* and to develop beekeeping activity.

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