Journal of Environmental Biology

ISSN : 0254-8704 (Print) ISSN : 2394-0379 (Online) CODEN : JEBIDP

REPRINT

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Volume 36

Number 3

May 2015

Pages 577-581

JEB
Journal of Environmental Biology

Journal Home page : www.jeb.co.in
E-mail : editor@jeb.co.in
ISSN: 0254-8704 (Print)
ISSN: 2394-0379 (Online)
CODEN: JEBIDP

Foraging activity of Indian honey bee, *Apis cerana* in relation to ambient climate variables under tropical conditions

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Abstract

Climate plays a significant role in influencing the foraging activity and behavior of social insects especially honey bees. Studies were conducted at Indian Institute of Horticultural Research, Bengaluru, India during 2011-13, to assess the effect of four abiotic factors *viz*., temperature, relative humidity, rainfall and wind speed on the foraging activity of Indian honey bee, *Apiscerana* F. Foraging activity was determined in terms of the number of worker bees going out of hive to forage and those coming in with pollen or nectar, per five minutes. Daily observations were recorded three times at 8.00 a.m., 12.00 noon and 4.00 p.m. Significant diurnal and seasonal variations were recorded in the foraging activity. Among all climatic factors, maximum temperature (>30°C)was the most crucial one which had negatively affected bee activity with correlation coefficients of -0.72, -0.59 and -0.61 for outgoing bees, pollen and nectar collectors respectively. Regression equation explained up to 68% variation in the number of bees moving out due to maximum temperature. The number of worker bees going out to forage came down significantly at temperature beyond 30ºC. Contrary to this, the minimum temperature showed a positive impact on outgoing bees (r = 0.66) and nectar collectors (r = 0.67) while pollen collectors showed no significant correlation. The relative humidity also showed positive impact on the frequency of worker bees moving out of hive (r = 0.69) and those coming in with nectar (r = 0.68) but negatively affected the number of pollen collectors. Diurnal variations showed peak activity of bee foragers between 6.00 and 10.00 a.m. Rainfall hampered foraging activity while wind speed was found to have no significant effect on bee activity.

Key words

Apis cerana, Climate, Foraging, Honey bee, Temperature

Publication Info

Paper received:
23 November 2013

Revised received:
15 March 2014

Accepted:
05 May 2014

Introduction

Indian honey bee, *Apis cerana* F., also known as Asian honey bee or Eastern honey bee, is native to the subcontinent and occurs both in wild and domesticated forms. Bee keeping with *A. cerana* is common across Asia, though it has declined significantly in northern states of India, following introduction of the European bee, *A. mellifera* (Oldroyd and Nanork, 2009). However, in southern states, where *A. mellifera* is not as popular as in the northern parts of the country, *A. cerana* still holds the primary position in commercial beekeeping. The species is valued not only for honey production but also as an effective pollinator of a wide range of wild flora as well as crops including fruits, vegetables, oil seeds etc. (Partap, 2011).Being an indigenous species, *A. cerana* is preferred to *A. mellifera* from pollination point of view, as it has coevolved with native flora. The successful survival of honey bee colony depends on the foraging efficiency of worker bees and hence, the number of bees going out for foraging per unit time is an indicator of colony activity. Besides, the availability of sufficient flora within the foraging range and the prevailing environmental factors could affect foraging activity through energy needs of bees for flight activity (Abrol, 2005). Variability in foraging activity of honey bees during different seasons and weather conditions was reported by several workers, with particular reference to *A. mellifera* (Al Ghamdi, 2002; Corbet *et al*., 1993).

Honey bees being ectothermic, are unable to control internally their body temperature with changes in the ambient temperature and hence environmental factors such as ambient air temperature, solar radiation etc. significantly influence their body temperature (Reddy *et al*., 2012). Although, individual bee cannot control its body temperature, a populous honey bee colony can regulate the interior temperature, of the hive. In normal colonies, the brood-nest temperature is maintained constant around 32°C. During nectar and pollen foraging, honey bees are exposed to a broad range of ambient temperature which affect their thermoregulatory ability (Kovac and Stabentheiner, 2011). The cavity nesting honey bee species *viz*., *A.mellifera* and *A. cerana* display the most advanced regulation of nest climate (Heinrich, 1996). Of these two species, *A. mellifera* has been intensely investigated concerning thermal regulation of body, as well as colony (Stabentheiner *et al*., 2010). The efforts that go into the thermal homeostasis of a honey bee colony are bound to affect the foraging activity of worker bees. The available reports on climate induced changes in foraging activity pertain mainly to *A. mellifera* in temperate regions and similar studies on *A. cerana* are required. Understanding the effect of temperature gains further importance keeping in view the potential impact which the ensuing climate change would have on plant-pollinator interactions. With this objective, studies were conducted on the foraging activity of *A. cerana* worker bees in relation to temperature and other abiotic factors.

Materials and Methods

Studies were conducted at the Indian Institute of Horticultural Research, Bengaluru, India during 2011-13 to understand the influence of climatic variables on foraging activity of the Indian honey bee. Three colonies of *A. cerana,* with a nearly uniform strength of eight brood frames, were selected for recording observations. Each colony was considered a replication. They were maintained in a field block surrounded by several horticultural species and natural vegetation, thus assuring continuous availability of floral resources. Foraging activity was determined in terms of the number of worker bees going out and coming in per five minutes, at specified time intervals. The number of foragers coming in with pollen loads was separately recorded. Those bees returning without pollen loads were considered nectar gatherers, as it is known that on a single foraging trip, *A. cerana* foragers tend to collect either pollen or nectar and not both from a single species of plant (Corlette, 2011). The time was recorded using a stop watch while the bees were counted using a hand tally counter. In order to study the seasonal variations, daily observations were recorded for 5 min at three times *viz.,* 8.00 a.m., 12.00 noon and 4.00 p.m. To understand the diurnal patterns, weekly observations were recorded for five minutes at hourly interval starting from 6.00 a.m. till 6.00 p.m. from each colony. The mean of the values obtained at three intervals was taken as the foraging activity value of that particular day. The meteorological data pertaining to maximum and minimum temperature (ºC), relative humidity (% RH), rainfall (mm) and wind speed (kmph) were recorded from the weather station located within 500m distance from the experiment colonies. The daily and the weekly data on the mean number of worker bees going out and coming in (pollen and nectar collectors) were correlated with the weather data of the corresponding days. Analysis of variance (ANOVA) at 5 % significance was used to test the significance of mean differences of hourly and monthly observations. The contribution of independent climatic factor to variability was determined through Co-efficient of determination (R^2).

Results and Discussion

Among several abiotic factors, temperature is the most important factor that affects honey bee activity (Corbet *et al.*,1993).Honey bee larvae and pupae are extremely stenothermic, *i.e.,* they strongly depend on accurate regulation of brood nest temperature for proper development (Stabentheiner *et al*., 2010). Under extreme conditions they have to put extra efforts to regulate body and colony temperature which in turn, impacts their foraging efficiency. In the present study, significant variations were recorded in the foraging activity of *A. cerana* as a function of maximum temperature (Fig.1). The worker bees have to maintain and regulate their body as well as colony temperatures according to the external conditions which, in turn, would affect their foraging efficiency. It is clearly evident from the results that maximum temperature had negatively affected (r =-0.72) the number of bees moving out to forage (Table 1). Maximum temperature during the study period ranged between 27 ºC and 34 ºC and the mean number of bees exited per minute at these temperatures was 75.49 and 14.36, respectively (Fig. 1a). There was a decreasing trend in the number of bees going out with increase in temperature which became more pronounced (< 20/5 min) at temperature

Table 1: Correlation of foraging activity of *A. cerana* with climate variables

Factor	Correlation Coefficient (r)		
	No. of bees going out/5min	No. of bees coming in with pollen	No. of bees coming in with nectar
Maximum temperature(°C)	- 0.72**	- 0.59**	- 0.61**
Minimum temperature (°C)	0.66**	0.41	0.67**
Relative humidity (%)	0.69**	- 0.43	0.68**
Wind speed (kmph)	- 0.40	- 0.35	- 0. 26
Rainfall (mm)	- 0.83**	- 0.74**	- 0.67**

**significant at p = 0.01

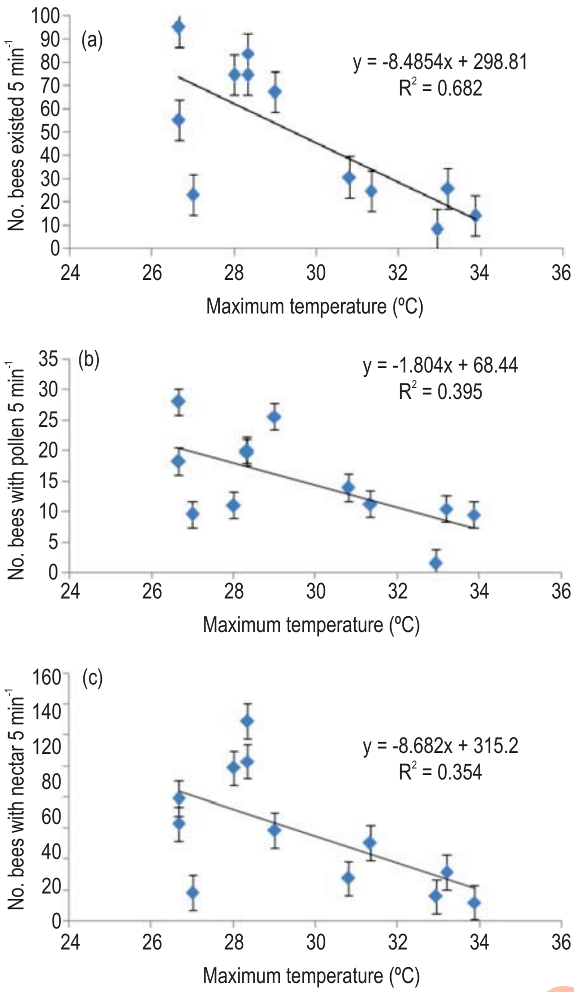

Fig. 1 : Effect of maximum temperature on bee foraging activity: a) worker bees going out to forage; b) bees coming in with pollen loads and c) those with nectar

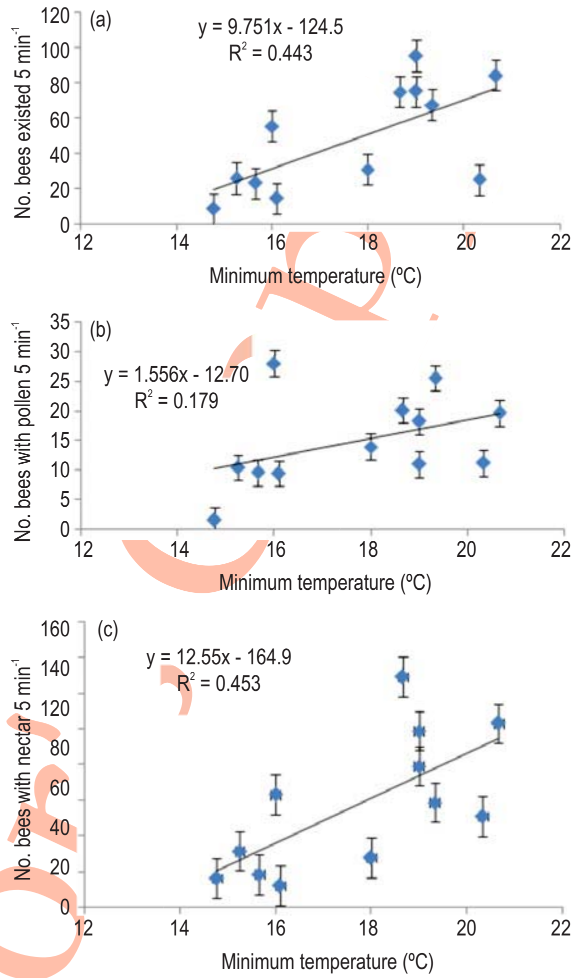

Fig. 2 : Effect of minimum temperature on bee foraging activity: a) worker bees going out of hive to forage; b) bees coming in with pollen loads and c) withnectar

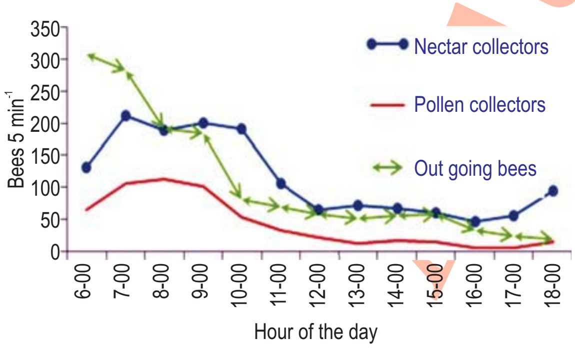

Fig 3 : Diurnal variations in foraging activity of *Apis cerana*

beyond 30°C. Regression equation (Fig.1) explains that up to 68% variation in the number of worker bees venturing out was due to maximum temperature. Maximum temperature also showed significant negative effect on incoming bees, comprising pollen and nectar collectors with r values of - 0.59 and -0.61 respectively. Several workers reported marked effect of temperature on flight activity of honey bee, *A. mellifera* (Puškadija *et al.,* 2007). Though bees are known to withstand temperatures as high as 45 ºC-50 ºC, their foraging activity was found to go down drastically at temperature beyond 35°C (Cooper *et al.*, 1985). The ability of some bees to forage above 30°C range of air temperature was attributed to their behavioural and physiological mechanisms of regulating the temperature of their flight muscles, which differ with foraging rewards and the age of worker bee (Heinrich, 1996).

The mean monthly minimum temperature ranged from 13.5ºC in November to 20.6ºC in April. Significant effect of the minimum temperature was observed on bee movement. Contrary to the negative influence of the maximum temperature, the minimum temperature showed positive effect on the number of bees exiting the hive (r = 0.66) and those entering with nectar (r = 0.67). However, the number of pollen collectors was not significantly affected by variation in the minimum temperature. The positive impact can be interpreted as it serves as a precursor to the ensuing day temperature and influencing the bees' response (Fig. 2). Higher temperature and low humidity were reported to adversely affect the flight activity of honey bees**.** At higher temperatures, the number of pollen collectors decreases as compared with nectar and water collectors. Pollen foragers carry relatively little fluid during hotter periods, and pollen foraging decreases at high ambient temperatures, which was reported to reflect in higher thoracic temperatures of pollen collectors and that of water and nectar gatherers (Al Qarni, 2006).

The pattern of bee activity varied, not only, over seasons but also at different hours of the day, with maximum during early hours between 6.00 and 11.00 am (Fig.3).The number of bees going out of the hive ranged from 309.10 at 6.00 am to 17.76 at 6.00 pm. In case of pollen collectors, peak was recorded between 7.00 and 9.00am with 100-110 foragers/5 min entering the hive with pollen loads. Trend was almost similar with nectar collectors. Across the day, it was observed that nectar gatherers outnumbered pollen collectors. The foraging activity declined considerably after 12.00 O'clock and the lean period continued till evening except for a minor peak in the number of nectar collectors at 6.00 pm.The decreased activity during late afternoon hours, coinciding with higher day temperatures, could be attributed to two factors. The first being the requirement of more number of bees to maintain the colony temperature, thus the number available for foraging is less. Secondly, the anthesis of a large number of flowers takes place in early morning and hence, pollen availability was sumptuous as compared to hot hours. In addition, nectar solidified with increased temperature, requiring more time and energy to harvest, prompting bees to make maximum use in morning hours. The preferential foraging in morning hours may be an evolutionary adaptation to maximize their resource collection efficiency. From an applied angle, the relatively lesser activity in late hours of the day could as well, be made use by farmers to spray pesticides (if at all unavoidable during blossom period) during the lean period to reduce the harmful effect to bees. The findings of the study are also very important from climate change point of view. Increased global temperatures mean, reduced number of bees venturing out to collect pollen and nectar, which in turn, will affect the pollination efficiency. Variations may as well lead to disrupt the synchrony between flowers and their pollinators (Potts *et al*., 2001; Wang *et al*., 2009; Reddy *et al*., 2012). An interesting implication of diurnal variations of bee foraging is the probable effect on the interpretation of honey bee surveys. Surveys of two sites at different times of day could record different number of bees and hence, comparison of survey results may therefore require adjustments for time of day (Pyke *et al*., 2011).

Relative humidity plays an important role in brood development and egg hatching (Human *et al*., 2006). A significant positive relation was recorded between relative humidity and foraging activity, especially the bees going out for foraging (r = 0.69) and nectar collectors (r = 0.68). However, the correlation of pollen collectors with relative humedity, though negative, was non-significant. (r = -0.43). Joshi and Joshi (2010) reported that relative humidity showed less effect on the flight activities of *Apis* species. Nevertheless, combination of temperature and humidity was considered to affect the availability of pollen thus, low temperature and high humidity might slow down the release of pollen. This could be attributed to potential negative relation observed in our studies. Wind, particularly strong current, tends to reduce the ground speed of bees and hence reduces the number of flights per day. The results indicated a negative correlation between wind speed and bee foraging activity, though it was statistically not significant (Table 1). A wind stronger than 12 mph was reported to affect honey bee foraging as they could not carry load upwind at a speed > 15 mph. Strong winds may also affect bee foraging indirectly by causing injury to flowers resulting in loss of pollen. However, in the present study, average wind speed during the experimental period varied from 4.28 to 9.5 kmph. It indicates that the given range of wind speed did not affect the foraging activity of *A. cerana* significantly.

Significant negative correlation was established between the foraging activity of *A. cerana* and rainfall. The r values for outgoing bees, pollen and nectar collectors were - 0.83, - 0.74 and - 0.67 respectively. Reduction in number of bees coming could be attributed not only to the lower number of bees moved out but also to the death of foragers caught in heavy rain. Abou-Shaara *et al*. (2012)also noted that the flight activity came down drastically during rain and both *A. cerana* and *A. mellifera* were reported to prefer to be in their hives during rain.Though there was a significant reduction in bee movement during the rainy period, considerable level of activity was observed during light drizzling. The breakeven point of rain intensity, where exactly bee activity comes to complete stand still needs to be estimated. Another implication of heavy rainfall will be the washout of pollen and nectar, which adversely affects the foraging as well as pollination efficiency of bees.

The present study indicated that among all climatic factors, day temperature had significant impact on foraging activity of *A. cerana* by adversely affecting the number of worker bees moving out of hive. With increase in minimum temperature and relative humidity, there was an increase in bee activity but the latter adversely affected pollen collection efficiency of bees. Rainfall had hampered the foraging activity while wind speed was found to have no significant effect. These results give an indication that climate change, characterized by the elevated temperature may force honey bees to remain in hive for longer hours, thus bringing down their pollination efficiency.

Acknowledgments

The financial support extended by the National Initiative on Climate Resilient Agriculture (NICRA), Indian Council of Agricultural Research, New Delhi, India is gratefully acknowledged. Authors also thank the Director, Indian Institute of Horticultural Research, Bengaluru, India for providing necessary facilities.

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1/206, Vikas Nagar, Lucknow - 226 022 (India)
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Website: www.jeb.co.in; **e-mail:** editor@jeb.co.in