J Indian Inst. Sci., Sept -Oct. 1992, 72, 395–401.

Foraging in honeybees *Apis cerana indica* F. and *A. dorsata* F. (Hymenoptera: Apidae)—Activity and weather conditions

D. P. ABROL*
Section of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology, Regional Agriculture Research Station, R. S. Pura 181 102, Jammu, Jammu and Kashmir, India.

Received on February 22, 1991; Revised on March 9, 1992, and September 14, 1992.

Abstract

Flight activity of honeybees, *Apis cerana indica* F. and *A. dorsata* F. was studied on peach flowers (*Prunus persica* Batsch) in relation to some weather factors. Initiation of flight was a function of dual threshold of temperature and light intensity and cessation was controlled by reduction in light intensity for both bee species. Foraging populations correlated significantly and positively with ambient temperature, light, solar energy, nectar–sugar concentration and negatively with relative humidity. Only one factor, namely, light intensity directly influenced the flight activity of *A. c. indica* while the flight activity of *A. dorsata* was influenced by both temperature and light intensity.

Key words: *Apis cerana indica, A. dorsata*, peach flowers, environmental factors, path analysis, pollination.

1. Introduction

Varieties of commercial peach are generally self-incompatible and depend upon insects for pollination[1]. Honeybees have been reported as important pollinators of peach flowers[2]. A good yield of fruit is therefore dependent on efficient pollination by honeybees. However, a limiting factor in commercial fruit production is the abundance of foraging bees to pollinate the flowers[3]. The foraging activity of bees itself is under the influence of several environmental factors such as temperature, wind, light intensity, nectar–sugar concentration and time of the day[4–8]. Several studies have examined the role of these factors on the foraging activity of the European honeybee *A. mellifera*[6–8]. An attempt is made in the present study to improve our understanding of the role of environmental factors in modulating the foraging activity of Indian honeybee species *A. c. indica* and *A. dorsata*.

* Present address: 327, Rehari Colony, Jammu 180 005, Jammu and Kashmir, India.

2. Materials and methods

The data for this study were recorded for eight days at weekly intervals during January–February 1988 on two honeybee species *A. c. indica* and *A. dorsata* frequenting flowers of peach (*Prunus persica*). The appearance of the first bee on the peach flowers marked the commencement of pollination activity, whereas their complete disappearance from the field indicated the cessation of the activity. The initiation and cessation of foraging was always between 0900 and 1700 h; therefore, bees were counted during this period at hourly intervals following Abrol[3]. Counting was done by marking branches, one from each tree, at a height of 1·5 to 2·0 m from the ground. The bees visiting each branch were counted for 5 min at the beginning of each hour. The mean of these five counts constituted the reading for each hour. Simultaneously, environmental variables were also recorded. Air temperature and relative humidity were recorded with a 'dry and wet' bulb thermometer. Light intensity was recorded with a luxmeter (Luxomet–300) manufactured by M/s Research Instrumentation, New Delhi, India. Solar radiation was recorded with a solarimeter (SM–201) manufactured by M/s Central Electronics Pvt Ltd, New Delhi. Total dissolved solids (TDS) in nectar were estimated with a pocket refractometer (Model 1093) manufactured by M/s Toshniwal Brothers Pvt Ltd, New Delhi. An estimate of TDS was obtained by sampling nectar from 20 flowers with the help of microcapillary pipettes at hourly intervals and immediately transfering on to the prismatic surface of the refractometer to obtain the percentage of dissolved solids in it.

The recorded data were analysed for simple correlations by the method of least squares[9]. If the bee activity was found to be linearly related to a factor (a condition specified by Li[10], for path-coefficient analysis), the data were further analysed by a path-coefficient analysis[11]. The method is simply a standardized partial regression coefficient and as such measures the direct influence of one variable upon another and permits the separation of correlation coefficient into components of direct and indirect effects. Thus, it provides more precise determination than correlation analysis of the relative importance of each factor. Bee activity was considered as the resultant (dependent) variable and temperature, relative humidity, light, solar radiation and nectar–sugar concentration as causal variables.

3. Results and discussion

Foraging in *A. c. indica* commenced when the temperature ranged between 12 and 15°C, relative humidity between 58·0 and 67·0% and light intensity between 1200 and 1700 lx, while in the case of *A. dorsata* it started when the temperature was 15–19°C, relative humidity 54·0–64·0% and light intensity 1300–1900 lx. The initiation of foraging activity in both the bee species was a function of temperature and light intensity (Table I). Cessation of flight activity in both the bee species was influenced by reductions in light intensity values, which were considerably lower than those required at initiation. The present findings are similar to the studies made by Szabo and Smith[12] for *Megachile rotundata* F. and Dhaliwal and Bhalla[13] for *A. c. indica*.

Table I

Relationship between temperature, relative humidity and light intensity at commencement and cessastion of flight activity in honeybees *A. c. indica* and *A. dorsata* frequenting peach flowers during January–February, 1988

Bee species	*Factor combination*	*Correlation coefficient (r)*	*Coefficient of determination (R^2)*
	Commencement		
A. c. indica	Temperature with relative humidity	− 0·410 ns	0·168
	Temperature with light intensity	− 0·919**	0·844
	Relative humidity with light intensity	0·361 ns	0·130
A. dorsata	Temperature with relative humidity	− 0·437 ns	0·190
	Temperature with light intensity	− 0·896**	0·802
	Relative humidity with light intensity	− 0·332 ns	0·110
	Cessation		
A. c. indica	Temperature with relative humidity	0·221 ns	0·048
	Temperature with light intensity	− 0·381 ns	0·145
	Relative humidity with light intensity	− 0·172 ns	0·029
A. dorsata	Temperature with relative humidity	0·126 ns	0·015
	Temperature with light intensity	− 0·386 ns	0·148
	Relative humidity with light intensity	− 0·236 ns	0·055

** P ≤ 0·01, ns = not significant

Bee activity increased with temperature, light intensity, solar radiation and nectar–sugar concentration and decreased with relative humidity (Fig. 1). Foraging population of both the bee species peaked between 1200 and 1400 h on all observation days when temperature ranged between 18 and 24°C, relative humidity between 48·0 and 57·0%, light intensity between 5500 and 8000 lx, solar radiation between 50·0 and 80·0 mW/cm^2 and nectar–sugar concentration between 35·00 and 43·00%. Bee activity correlated significantly and positively with temperature, light intensity, solar radiation, nectar–sugar concentration and negatively with relative humidity in both the species (Table II). Further, the environmental factors are interrelated. Therefore, path-coefficient analysis was used to obtain direct and indirect effects of various environmental factors on the flight activity of bees.

Light intensity directly influenced the flight activity of *A. c. indica* (Table III). Light intensity exerted the greatest positive influence on bee activity (0·4410) followed by temperature (0·1120) and solar radiation (0·1080). The overall significant association of these factors with *A. c. indica* activity was largely through their positive or negative interactions with other factors. The direct effect of relative humidity was low and negative (− 0·1415). It strongly influenced the bee activity indirectly *via*

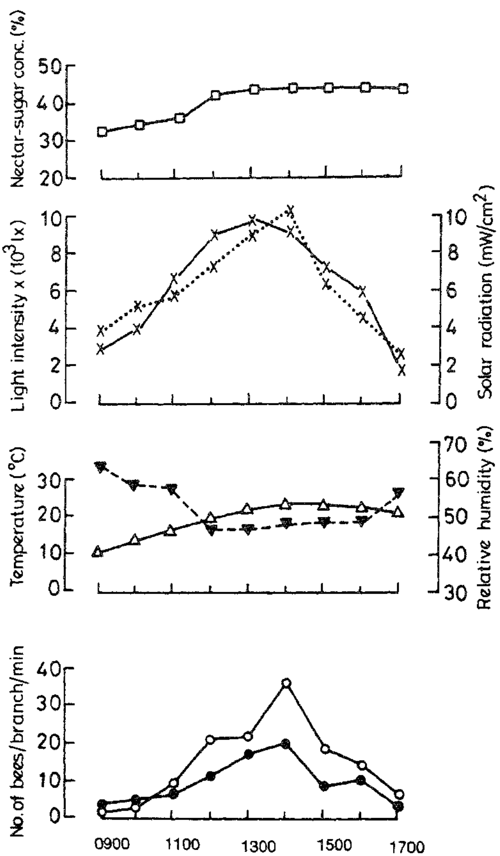

FIG. 1. Diurnal variation in foraging population of *A. c. indica* (–o–) and *A. dorsata* (–●–) on *P. persic* flowers in relation to temperature (–Δ–), relative humidity (–▼–), light intensity (–X–) solar radiatio (· · X · ·) and nectar-sugar concentration (–□–).

Table II

Correlation coefficient matrix exhibiting interrelationships of various environmental factors influencing flight activity of honeybees *A. c. indica* and *A. dorsata* frequenting peach flowers during January–February, 1988

Factors	*Correlation coefficient (r)*					
	A. c. indica	*A. dorsata*	*Nectar–sugar concentration*	*Solar radiation*	*Light intensity*	*Relative humidity*
Temperature	0·445**	0·715**	0·660**	0·590**	0·480**	− 0·930
Relative humidity	− 0·564**	− 0·652**	− 0·650**	− 0·162 ns	− 0·680**	
Light intensity	0·552**	0·506**	0·435 ns	0·570**		
Solar radiation	0·452**	0·594**	0·720**			
Nectar–sugar concentration	0·472**	0·550**				

** P≤ 0·01, ns = Not significant.

Table III

Direct and indirect effects of various abiotic and biotic factors on the flight activity of *A. c. indica* and *A. dorsata*

Bee species	*Pathways of association*	*Effect via*					*Correlation coefficient with bee activity (r)*
		Temperature	*Relative humidity*	*Light intensity*	*Solar radiation*	*Nectar–sugar concentration*	
A. c indica	Temperature	0·1120	− 0·2101	0·3100	0·1760	0·0580	0·445
	Relative humidity	− 0·2100	− 0·1415	− 0·0100	− 0·2187	0·0158	− 0·564
	Light intensity	0·0087	− 0·2130	0·4410	0·3080	0·1080	0·552
	Solar radiation	0·1147	− 0·0087	0·1600	− 0·1080	0·0780	0·452
	Nectar–sugar concentration	0·1182	− 0·0200	0·2482	0·1083	0·0180	0·472
	Residual						0·210
A. dorsata	Temperature	0·3148	− 0·2452	0·3210	0·2245	0·1008	0·715
	Relative humidity	− 0·2518	− 0·2312	− 0·1061	− 0·0210	− 0·0420	− 0·652
	Light intensity	0·2432	0·0152	0·4212	0·1951	0·0220	0·506
	Solar radiation	0·2108	0·0052	0·1046	− 0·0800	0·1942	0·594
	Nectar–sugar concentration	0·2444	− 0·2503	0·3004	0·2112	− 0·0510	0·556
	Residual						0·130

Figures underlined denote direct effects.

temperature and solar radiation. The strong negative interactions with the latter two factors, *viz.*, temperature and solar radiation were largely responsible for its significant, negative association with bee activity ($r = -0{\cdot}564$). The direct effect of nectar–sugar concentration on the bee activity was negligible (0·0180). Significant positive association of nectar–sugar concentration with bee activity was largely a reflection of its positive interactions with temperature, light intensity and solar radiation.

For *A. dorsata*, the direct effect of light intensity was positive and pronounced (0·4212) followed by temperature (0·3148). The overall significant positive correlation of temperature and light intensity with bee activity was developed through their positive interactions with other factors. The direct effects of relative humidity (− 0·2312), solar radiation (− 0·080) and nectar–sugar concentration (0·0510) on bee activity were negligible.

The results suggest that flight activity in *A. cerana indica* is influenced by light intensity alone while in *A. dorsata* two factors, namely, light intensity and temperature appear to modulate flight activity. This demonstrates that different, yet closely related, bee species differ in their responses to environmental conditions. The differences in response of the bees are species specific and indicative of their different adaptations. For instance, Sihag and Abrol[4] found that for *A. florea* relative humidity and solar radiation were the important factors influencing flight activity. Burill and Dietz[7] found solar radiation important for *A. mellifera*. Nunez[6] reported that the morning activity of *A. mellifera* was related to nectar flow, whereas the afternoon activity was correlated with photoperiod. Bailey *et al*[14] reported on the role of humidity, whereas Lerer *et al*[5] emphasized solar energy in the pollination activity of *Megachile rotundata* F.

Path-coefficient analysis was found to be more useful to specify the cause–effect relationship of various environmental factors. This is because simple correlation measures the mutual association without considering causation, whereas path-coefficient analysis measures the relative importance of each factor. As simple correlation analysis rarely provides real links between different factors the use of path-coefficient analysis provides a more precise picture of cause–effect relationship between bee activity and different environmental factors. The present study shows that the foraging activity is influenced by several environmental factors. This is evident from the small residual value (21% for *A. c. indica* and 13% for *A. dorsata*). Parameters which may account for this residual value may be atmospheric pressure, wind velocity, flower density, caloric rewards and perhaps other unknown factors.

Acknowledgements

The author wishes to thank Shri S. D. Batra for computer analysis of the data. Thanks are also due to the Editor and anonymous reviewers for valuable suggestions and constructive criticism on an earlier draft of this paper.

References

1. FREE, J. B. — The behaviour of honeybees visiting the flowers of fruit trees, *J. Anim. Ecol.*, 1960, **29**, 385–395.

2. FREE, J. B. — *Insect pollination of crops*, 1970, Academic Press.

3. ABROL, D. P. — Studies on abundance, diversity, behaviour and importance of native pollinators for crop production, *Korean J. Apic.*, 1989, **4**, 25–40.

4. SIHAG, R. C. AND ABROL, D. P. — Correlation and path coefficient analysis of environmental factors influencing flight activity of *Apis florea*. F., *J. Apic. Res.*, 1986, **25**, 202–208.

5. LERER, H., BAILEY, W. G., MILLS, P. F. AND PANKIW, W. — Pollination activity of *Megachile rotundata* F., *Environ. Entomol.*, 1982, **11**, 997–1000.

6. NUNEZ, J. A. — Nectar flow by melliferous flora and gathering flow by *Apis mellifera Liguistica*, *J. Insect Physiol.*, 1977, **23**, 265–276.

7. BURILL, R. M. AND DIETZ, A. — The responses of honeybees to variations in solar radiation and temperature, *Apidologie*, 1981, **12**, 319–328.

8. KEFUSS, J. A. AND NYE, N. P. — The influence of photoperiod on the flight activity of honeybees, *J. Apic. Res.*, 1970, **9**, 133–139.

9. SNEDECOR, G. W. AND COCHRAN, W. G. — *Statistical methods*, p. 593, 1967, Oxford & IBH Publishing Co., New Delhi, India.

0. LI, C. C. — The concept of path coefficient and its impact on population genetics, *Biometrics*, 1956, **12**, 190–192.

1. DEWEY, D. R. AND LU, K. U. — A correlation and path coefficient analysis of components of crested wheat grass seed production, *Agron. J.*, 1959, **51**, 515–518.

2. SZABO, T. I. AND SMITH, M. V. — The influence of temperature and light intensity on the activity of alfalfa leafcutter bee, *Megachile rotundata* F. under field conditions, *J. Apic. Res.*, 1972, **11**, 157–165.

3. DHALIWAL, H. S. AND BHALLA, O. P. — On foraging ecology of *Apis cerana indica* F. In *Proc. 2nd Int. Conf. Apic. Trop. Climates*, K. N. Mehrotra (ed.), 1983, pp 513–527, Indian Agric. Res. Inst., New Delhi, India.

4. BAILEY, W. G., LERER, H. AND MILLS, P. F. — Humidity and pollination activity of *Megachile rotundata* F., *Environ. Entomol.*, 1982, **11**, 1063–1066.