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Studies on foraging activity, pollen quantification and natural enemies of Indian honey bee, *Apis cerana* on mixed vegetation

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Abstract
A study on the foraging activity of bees (*Apis cerana*) indicates that, in summer, the peak foraging activity of bees were 28.00, 24.30 and 24.63 bees / 5 min (with pollen) and 24.35, 26.68 and 26.98 bees / 5 min found during 0800, 0900 and 1000, respectively. The highest pollen quantity recorded during 1200 to 1800 hours ranges from 90 to 98 mg/ 10 bees. In *kharif*, the peak foraging activity of bees were 21.63, 24.68 and 21.33 bees / 5 min (with pollen) and 26.68, 30.08 and 36.10 bees / 5 min found during 0900, 1000 and 1100, respectively. Pollen quantity has increased in the later months of August and September it ranges from 10 to 68 mg/10 bees. In *rabi*, the peak foraging activity of bees were 21.80, 24.88 and 23.60 bees (with pollen) and 31.68, 31.98 and 30.10 bees / 5 min found during 0900, 1000 and 1100 h, respectively. The highest pollen quantity of 118.16±0.5 mg followed by 110.48±0.5 mg in January. The least pollen quantity from 10 bees recorded in the early hours of the day of October month (56.00 ±1.0 mg). among the natural enemies greater wax moth, *Galleria mellonella* were dominated and causing damage to bee colony to the tune of 15-30%. Next in the order of importance yellow banded wasp, *Vespa cincta* which caused mortality of 5-6% of bee colonies in the region.

Keywords: Bee forage, beekeeping, *Apis cerana*, vegetation, wax moth, wasp

Introduction
Honeybees are most familiar and productive insects known to mankind from prehistoric times. Man has maintained intimate association with honeybees from times immemorial and developed. There is a Social liking for honeybees for their fascinating and spectacular ways of life. Beekeeping has a greater scope in India to develop as a prime agro-horticulture and forest based rural industry ideally suitable to the rural, tribal and weaker sections of the population.
Beekeeping is a multifaceted activity, (Singh, 1997) [18] the value of many aspects like bee pollination, wax production, medicinal properties of honey and others have enabled it to become the most viable industry. Beekeeping is practiced under wide agro climatic conditions in the plains and hills up to 2700 m. Honeybee like any other animal performs wide varieties of functions in order to avail the basic necessities of life and also to procure food and shelter.
Honeybees are social insects and are distributed throughout the world with which man has established a harmonious co-existence (Mishra *et. al.* 1998) [10]. These insects are of great importance because they not only produce honey, but also are also important pollinating agents for many plants (Jadhav, 1981; Abrol and Bhat, 1985) [9, 1]. Foraging is a social enterprise in which bees collect pollen, nectar, water and propolis from plants. The act of collecting all these is called foraging and the bee is a forager. The foraging behaviour of the honeybee is dependent on its innate capacity and responses to the various environmental stimuli. The foraging behaviour is an important aspect of their biology that enables them to adapt themselves to the available vegetational and climatic conditions. When the bee begins to forage, it will usually make several trips per day when the weather conditions are favorable. A single foraging trip may last up to an hour or more, with the pollen-gathering trip often making more time than a nectar-gathering trip. Bees utilize pollen and nectar as food source and nectar is converted into honey and pollen is used to build combs. With this background an investigation on study of foraging activity of Indian Honey bee, *Apis cerana* on mixed vegetation in Haveri was undertaken.

Material and Methods

The investigations were carried in Krishi Vigyana Kendra (KVK), Hanumanamatti (14^0 17', 15^0 01", 75^0 35" to 75^0 50', 750 m amsl), Haveri District, Karnataka during 2009-11

Foraging activity

Diurnal and seasonal activity (foraging behavior) of *A. cerana* of uniform strength of five colonies was maintained in the bee hive box. Observations on number of bees returning with pollen load and without pollen load for every five minutes per hive were recorded at hourly intervals starting from 0600 to 1800 hours at the hive entrance. The incoming bees with pollen load in their legs (corbicula) considered as pollen foragers and those without pollen loads as nectar foragers. Such observations were made at every fortnight interval. Data of each hour was averaged to a week and later to a month. During study period weather parameters *viz.*, temperature, relative humidity and rainfall were recorded to correlate with peak activity of the bees and foraging behavior as the methodology followed by Banakar (2010) [2].

Pollen Quantification

Along with the foraging activity of *A. cerena*, the pollen quantity of the bees were also recorded during 2009 to 2010. The foragers were evaluated for pollen load. The returning foragers were captured at the hive entrance to collect the pollen loads following methods suggested by Suryanarayana, 1992. The incoming pollen foragers of 10 bees were caught at an each interval by hand by holding the wings. The pollen load in their legs were gently removed into a clean paper and pollen samples were collected at every two hours interval and weighed (Santec 7093VO97-TM) at every month for twelve months.

Seasonal activity of natural enemies

At every 15 days interval, the bee hives were inspected to study the natural enemies particularly a wax moth and mites followed by parasitoids on wax moth larva. Further observations are also taken at hive entrance for different predators against worker bees of *A. cerana* and weather parameters were recorded for the study.

Result and Discussion

Foraging activities of Indian bee, *A. cerana* was documented during summer (Feb-May) 2009 -2010 at KVK, Hanumanamatti, Haveri. As a measure of foraging activity of *A. cerana* the average number of bees entering the bee hive with or without pollen for five minutes periods were recorded. A perusal of data indicated that maximum mean number of bees with pollen fluctuated around 5.8 bees and stretched up to 11.50 bees during March and bees without pollen fluctuated around 6.70 bees and stretched up to 18.00 bees during February (Table and fig1). The mean number of bees were entering the beehive without pollen always exceeded the bees with pollen. The peak foraging activity of bees were 28.00, 24.30 and 24.63 bees / 5 min (with pollen) and 24.35, 26.68 and 26.98 bees / 5 min found during 0800, 0900 and 1000, respectively. This was followed by 21.75, 25.40 bees with pollen and 24.80, 26.60 bees without pollen during 1600 and 1700. The number of bees entering the hive with pollen were generally less between 1200, 1300 and 1400 with average of 9.60, 9.90 and 8.83 bees and without pollen were 12.10, 12.18 and 14.35 bees per five minutes, respectively. This is the time when the temperature will be quite high the activity of the bees is quite less. This trend was observed and found consistent in all the four months of summer season (fig.1). Bisht and Pant (1968) [4] reported that *A. cerana* gathered pollen pellets throughout the year under Delhi conditions. The highest pollen gathering activity was recorded during January to March, where as May to June were the periods of lesser activity. Present study is in line with the Rangarajan *et al*. (1974) [15] they studied the foraging behavior of *A. cerana* and *A. florea* on Sunflower, *H. annuus* bloom and noticed maximum activity from 0600 h to 1000 h, where as 1200 h to 1430h was the period of limited activity. Naim and Phadke (1976) [14] divided the annual foraging cycle of *A. cerana* season-wise and found that January to March was peak period of pollen collection, while honey storing activity was at its peak during March to April. Naim and Bisht (1978) [13] reported that January to March was peak period of pollen collection and honey-storing activities were at peak during March to April.

The quantification of pollen of ten bees in different seasons with time was presented in table 1. The results revealed that the mean pollen collection by *A. cerana* during February to May month. The highest pollen quantity recorded during 1200 to 1800 hours ranges from 90 to 98 mg/ 10 bees. The least pollen weight recorded during early timing of the day from 0600 to 0800 ranges from 10 to 30 mg / 10 bees in all the four months. Tanda and Goyal 1979a [20] observed the peak period of pollen collection by *A. cerana* and *A. mellifera* in the morning hours on Cotton, *Gossypium* spp. They concluded that no bees from either species collected mixed pollen on all foraging trips on the same day. Pollen availability was maximum in the morning and decreased in the afternoon, consequently some pollen foragers of both the species shifted to nectar collection and they assumed pollen collection next day morning. Maximum foraging activity of the Indian honey bee, *A. cerana* was noticed in July and minimum activity during January. More number of pollen plus nectar collectors were recorded than pollen or nectar collectors alone. It was also observed that there was greater variation among pollen collectors over nectar or water collectors (Reddy, 1980).

In *kharif*, the maximum mean number of bees with pollen fluctuated around 1.4 bees and stretched upto 8.80 bees and without pollen bees fluctuated around 3.20 bees and stretched upto 3.80 bees during September (Table and fig 2). The mean number of bees entering the beehive without pollen always exceeded the bees with pollen. The peak foraging activity of bees were 21.63, 24.68 and 21.33 bees / 5 min (with pollen) and 26.68, 30.08 and 36.10 bees / 5 min found during 0900, 1000 and 1100, respectively. The numbers of bees entering the hive with pollen were generally less between 0600 and 0700 with average of 3.08 and 6.93 bees and without pollen was 7.90 and 11.03 bees per five minutes, respectively. This is the time when the temperature will be quite high the activity of the bees is quite less. This trend was observed and found consistent in all the four months of *kharif* season (fig.2). Foraging activity was directly proportional to the increasing ambient temperature and also with increasing radiation up to a certain level. However, it did not appear to be correlated with changes in atmospheric humidity and pressure (Burrill and Dietz, 1981) [5]. Thakur *et al*. (1982) [21] reported that at noon, the foraging activity was maximum (300 bees returning in 5 minutes) and there were more pollen foragers in the morning than afternoon. Further June to September being the *kharif* recorded and similar trend was followed in timing and quantity of pollen collection. The

quantity pollen recorded least in the month of June and July ranges from 9 to 20 mg/ 10 bees. Pollen quantity was increased in the later months of August and September it ranges from 10 to 68 mg/10 bees (Table 2).

In *Rabi*, the maximum mean number of bees with pollen fluctuated around 2.4 bees and stretched up to 30.0 bees and bees without pollen fluctuated around 8.30 bees and stretched upto 37.7 bees during January (Table and fig 3). The mean number of bees entering the beehive without pollen always exceeded the bees with pollen. The peak foraging activity of bees were 21.80, 24.88 and 23.60 bees (with pollen) and 31.68, 31.98 and 30.10 bees / 5 min found during 0900, 1000 and 1100, respectively. The number of bees entering the hive with pollen were generally less between 0600 and 0700 with average of 3.75 and 6.08 bees and without pollen were 13.33 and 15.90 bees per five minutes, respectively. This is the time when the temperature will be quite high the activity of the bees is quite less. This trend were observed and found consistent in all the four months of *rabi* season (fig.3). Singh (1980) [17] found that pollen was collected throughout the year by *A. cerana* at Saharanpur (U.P.) with maximum activity during October. The second peak was recorded during February to April. From June to October pollen foragers started their activity at 0600 or 0700 h, but in November and December pollen foraging did not commence till 1000 h. The foraging activity began at 1400 h and 1800 h in December and July, respectively.

Foraging activity was greater during 0800-1200 h followed by 1700 h – 1800 h. The number of nectar gatherers was high in the early morning (0600 - 0800 h) or from 1200 - 1600 h. Whereas, the number of pollen gatherers were the highest in the late morning (0900 - 1200 h), decreased in the afternoon and there was a sharp increase between 1700 – 1800 h (Reddy, 1983) [16]. Bhalla *et al.* (1983) [3] reported that honey bees started foraging after 0900 h and were most active from 1100 h to 1600 h.

Honey bees gathered pollen and nectar throughout the year irrespective of climatic conditions. The number of pollen foragers were highest between 0900 and 1200 h, while the number of nectar foragers were highest between 1000 h and 1500 h. There were little foraging before 0600 h and after 1800 h. Pollen foraging was the highest during February to March and July to October (Verma, 1983). Gupta *et al.* (1984) [8] studied the foraging activity of *A. cerana* and *A. mellifera* on *Plectranthus* flowers at Rampur, Himachal Pradesh and noticed the variations in the rate of foraging activity during different day hours. Maximum number of pollen gatherers of *A. cerana* were seen during 0700-0900 h, while nectar collection activity reached the peak at 1200 h. Whereas *A. mellifera* showed peak pollen collection activity between 0900 and 1000 h.

The peak period of foraging activity of *A. cerana* was in May and June. Foraging data showed the varying peak activity during different seasons. In summer, peak activity of pollinators predominantly honey bees occurred at 0800 and 1000 to 1600 h, during rainy season at 0900 and 1000 h, in autumn between 0900 and 1000 to 1200 h, in early winter between 0900 and 1400 h, in late winter at 1100 h and in spring season between 0800 and 1100 h. The percentage of nectar collectors were greater than pollen or pollen plus nectar collectors in all the seasons of the year and greater seasonal variations were observed in the percentage of nectar collectors compared to other categories of foraging bees (Muttu and Verma, 1985) [11]. Verma and Chauhan (1985) [22] observed the maximum foraging activity of *A. cerana* between 1100 and 1200 h and again between 1400 and 1500 h. Verma and Dulta (1986) [23] compared the foraging behavior of *A. mellifera* and *A. cerana* on apple flowers. *A. cerana* workers started activity significantly earlier in the morning than *A. mellifera* and their activity ceased late in the evening hours. Similar results observed in case of Abrol and Bhat (1987), Reddy (2014) [12] and Viraktamath (1990) [24], Chowde Gowda *et al*. (2005) [6].

The results pertaining to pollen quantification by *A. cerana* presented in table 3. Highest pollen collection by *A. cerana* during October to January months (*Rabi*) in 2009-10 recorded highest pollen quantity ranges from 56 to 118 mg /10 bees from morning to evening hours in all the four months (Table 3). The highest pollen quantity 118.16±0.5 mg followed by 110.48±0.5 mg in the month of January. The least pollen quantity from 10 bees recorded in the early hours of the day of October month (56.00 ±1.0 mg). Investigations conducted by Nagarathna and Reddy (2014) [12] showed quantified the pollen and nectar load carrying behavior of *A.mellifera*. This study primarily helped to investigate the size of the foraging population with reference to the bees foraging for pollen or nectar at different hours of the day and then throughout the year in different agroclimatic ecozones of Karnataka. The pollen and nectar collected by the honeybees showed variations not only in the same area but also in different geographic ecotypes. A wide seasonal variation was observed in the foraging activity. The efficient management of these bees in an area solely depends on the detailed knowledge of their behavioral pattern.

The individual bee quickly changed from nectar collection to pollen collection and vice -versa, in accordance with their colony needs. The proportion of pollen foragers and the amount of pollen collected increased with the amount of brood present. When colonies were deprived of brood, they foraged less and many former pollen gatherers shifted to nectar collection. Irrespective of the presence or absence of brood, absence of queen increased nectar collection and decreased pollen collection (Free, 1967) [7].

Of the natural enemies greater wax moth, *Gelloria mellonella* was dominated, causing damage to bee colony to the tune of 15-30%. Next in the order of importance yellow banded wasp, *Vespa cincta* which cause mortality of 5-6% of bee colonies in the region. The other natural enemies documented were of lesser importance however it may be inferred from the observations that in study area there should be regular monitoring of honey bee colonies and protect them from parasites and predators. Similar studies were conducted by Swamy (2008) [19], 25 species of insect enemies were recorded on four species of honey bees. Among insect enemies greater waxmoth *Galleria mellonella*, ants, *Camponotus compressus* and *Oecophylla smaragdina*, yellow banded wasp, *Vespa tropica* were predominant, observed in large scale and caused higher infestation to all the four species of honey bees.

This study primarily helped to investigate the size of the foraging population with reference to the bees foraging for pollen or nectar at different hours of the day and then throughout the year in different agroclimatic ecozones of Karnataka. The pollen and nectar collected by the honey bees showed variations not only in the same area but also in different geographic ecotypes. A wide seasonal variation was observed in the foraging activity. The efficient management of these bees in an area solely depends on the detailed knowledge of their behavioral pattern.

Table 1: Pollen quantity (mg/ 10 bees) of Indian Honey bee, *A. cerana* during *summer* (Feb-May) 2009-10

Time	Month			
	February	March	April	May
0600	14.86±0.4	16.44±0.8	12.31±0.2	10.18±0.2
0800	25.18±1.0	24.13±0.3	27.72±0.7	19.48±0.4
1000	38.63±0.2	29.38±0.7	33.13±1.2	22.16±1.7
1200	90.63±0.5	87.14±1.0	94.12±1.5	81.32±0.7
1400	97.86±0.5	96.44±0.4	98.31±0.8	93.18±0.5
1600	90.18±0.1	94.13±1.0	94.72±0.5	88.48±0.2
1800	91.60±0.2	85.38±1.1	97.13±0.6	98.16±1.5
Mean	64.13±0.4	61.86±0.8	65.35±1.5	58.99±1.3

Mean ±SD; n= 10 bees

Table 2: Pollen quantity (mg/ 10 bees) of Indian Honey bee, *A. cerena* during *kharif* (June-Sept) 2010-11

Time	Month			
	June	July	August	September
0600	09.08±1.1	10.11±0.8	12.08±0.4	10.22±0.1
0800	9.98±0.5	10.02±0.6	14.91±0.5	29.40±1.1
1000	12.10±0.5	12.60±1.0	15.06±1.4	32.16±1.0
1200	13.32±0.4	11.32±1.5	25.32±1.0	41.32±0.5
1400	14.05±0.1	13.18±1.0	23.18±1.1	53.18±0.1
1600	18.40±1.0	17. 86±0.6	28.48±0.9	68.48±0.3
1800	18.16±1.0	18.48±0.7	32.16±0.3	58.16±0.9
Mean	13.58±1.2	12.62±1.1	21.60±1.6	41.85±0.4

Mean ±SD; n= 10 bees

Table 3: Average pollen quantity (mg/ 10 bees) of Indian Honey bee, *A. cerena* during *Rabi* (Oct- Jan) 2010-11

Time	Month			
	October	November	December	January
6.00	56.00±1.0	59.06±0.4	68.31±0.7	72.18±0.7
8.00	64.56±1.1	65.18±0.7	87.72±0.5	79.48±1.8
10.00	86.38±0.1	88.03±0.5	97.13±0.5	95.16±1.0
12.00	88.00±1.4	100.63±0.4	104.12±0.3	101.32±1.3
14.00	100.88±1.2	92.86±0.8	98.31±1.0	103.18±0.3
16.00	105.53±1.0	109.18±1.1	94.72±1.2	110.48±0.5
18.00	107.08±0.6	102.60±0.9	97.13±1.3	118.16±0.5
Mean	86.92±1.3	88.22±1.5	92.49±1.0	97.14±1.6

Mean ±SD; n= 10 bees

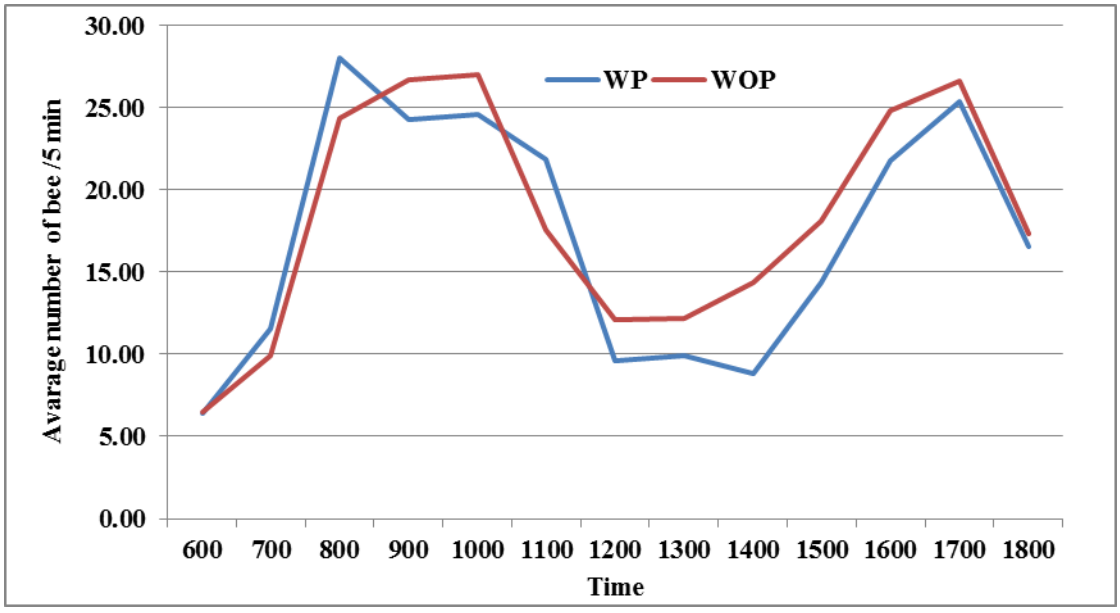

Fig 1: Foraging activities of Indian Honey bee, *A. cerena* during *summer* (Feb-May) 2009-10

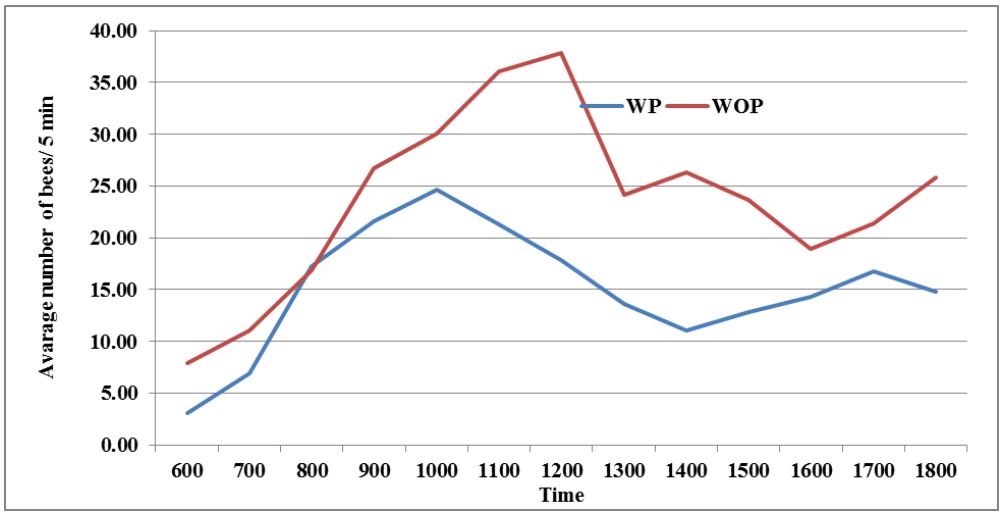

Fig 2: Foraging activities of Indian Honey bee, *A. cerena* during *kharif* (June-Sept) 2010-11

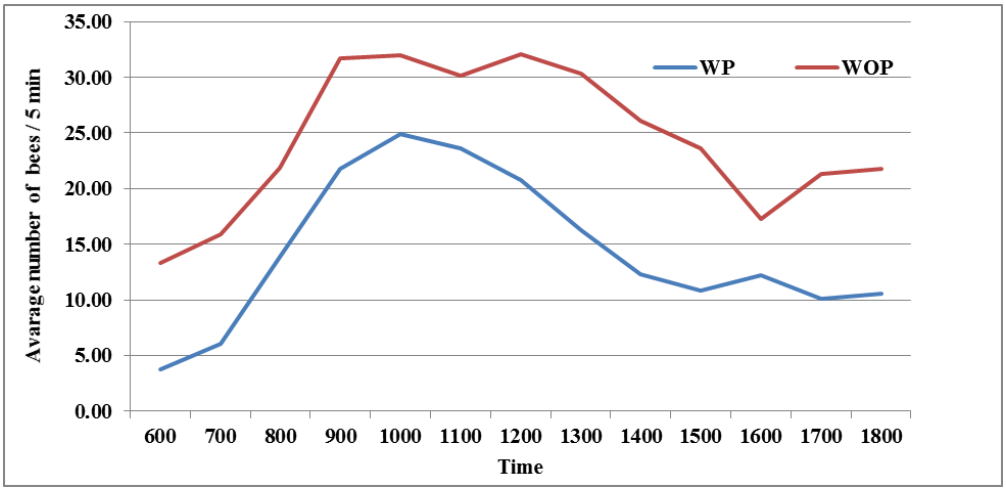

Fig 3: Foraging activities of Indian Honey bee, *A. cerana* during *Rabi* (Oct- Jan) 2010-11

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