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Diversity and relative abundance of insect visitors to litchi inflorescence with special reference to the foraging behaviour of honeybee (*Apis mellifera* L.)

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ABSTRACT: The study on insect pollinators of litchi, revealed 227 specimens of insect fauna belonging to 24 species of six different orders and 15 families. Hymenoptera, (belonging to Apidae, Andrenidae, Megachilidae, Vespidae and Sphecidae) was the most dominant (72.68%), followed by Diptera (19.38%), Coleoptera (3.08%), Lepidoptera (2.2%), Hemipter (1.76%) and the lowest, Odonata (0.88%). Among Hymenopterans, honeybees were the pre-dominant insect pollinators (72.68%), *viz.,* A*pis florea* (37%), *A. cerana* (15.41%), *A. mellifera* (7.04%) and *A. dorsata* (3.08%) on litchi bloom. Foraging activity of *A. mellifera* began early in the morning (mean 5 53h) and cessation of flight took place at evening (mean 18 01h). While the mean foraging speed of *A. mellifera* was maximum at 9 00h, the minimum foraging speed was at 17 00h. Maximum foraging rate was observed at 17 00 and minimum at 1100h.

KEY WORDS: Pollinators, abundance, diversity, dominance index, foraging activity

Litchi chinenesis Sonn., a self- infertile, cross-pollinated and entomophilic plant, requires different group of insects for pollination and production of fruit. Male flowers which open initially, have only stamens and produce pollen; hermaphrodite flower which function as female flower open lately, having functional pistil and fertilizable ovules but non-functional stamens; and the last to open was male hermaphrodite flowers, having functional stamen which release pollen but non-functional pistil without fertilizable ovule (Stern and Gazit, 1996). The opening time of male flowers in daylight was about 8 to 16 hour (Malhotra *et al.,* 2018). Different insect pollinators show diverse foraging behaviour depending on the availability of floral diversity (Bashir *et al.,* 2018; Ahmad *et al.,* 2021; Khan *et al.,* 2021; Saleh *et al.,* 2021). Researchers have zeroed upon honeybees as pollinators of litchi, following observation that they are frequent and effective flower visitors (Davenport and Stern, 2005; Abou-Shaara *et al.,* 2013). Domestic hives of Asian honeybee *A. cerana* and European honeybee *A. mellifera* have been employed to increase pollination and enhance production in some industrial litchi plantation in India and China (Davenport and Stern, 2005; Kumar and Kumar, 2014). The present study was carried out the following three objectives - to collect and identify different insects visiting litchi flower, to determine relative abundance and diversity of sampled insects

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and to study foraging behaviour of *A. mellifera* on litchi crops.

Observation was conducted in individually managed litchi orchards at two locations [26°09'09"N; 85°14'06"E, 79m msl and 26°05'46"N; 85°26'17"E, 78m msl (above mean sea level), Muzaffarpur, Bihar, India. At location one, orchard holder made independent decision about managements. During flowering period pesticide application was minimised to avoid adverse impacts on pollinators at the same time domesticated beehives were not release there. Whereas domesticated beehives put in action at location two. Samples of insect visiting litchi flowers were taken up from the start of blooming until fading of approximately 95 per cent of the flowers. Insect pollinators were monitored using sweep net, pan trap and visual observations. Collected insects were preserved in 70 per cent ethanol. All insects were subsequently identified up to their species level by using available literature and matching it with museum specimen. The number of flower visitors (insect that vosited any part of flower) was studied by direct visual observations on five randomly selected trees. Within each tree 4 inflorescence with flowers in four different direction were observed for 5 min period in morning (7 00 to 9 00h) and evening (15 00 to 17 00h) between 4-25 March 2023 at 3 days interval.

Relative abundance of pollinators visiting flowers was calculated using following formula.

$$\text{Abundance (\%)} = \frac{\text{Population of particular flower visitor species}}{\text{Total population of flower visitor species}} \text{ X } 100$$

Microsoft office 2016 was used for statistical analysis of collected data at 5% level of significance. Diversity, evenness and dominance of insect visitors; Species diversity, evenness and dominance were calculated using Shannon diversity H' (Shannon, 1948), Pielou's j and Berger-Parker Dominance Index respectively.

$$\text{Shannon diversity index } H' = \sum_{i=1}^{R} p_i \log p_i$$

Where P_i = Proportion of i^{th} species, log P_i = Natural log of P_i and R = Total number of species

$$\text{Pielou's J} = \frac{H'}{\ln (S)}$$

Where H' = Shannon-Wiener index and ln(S) = Natural log of species evenness i.e. total number of species

$$\text{Berger-Parker Dominance Index d} = \frac{n_{max}}{N}$$

Where n_{max} = Number of individual in most abundant species and N= Total number of individual in the sample.

Foraging time of *A. mellifera* was estimated in terms of timing of initiation and cessation of flight activity. It was done by recording the time when first honeybee started its flight in the morning and the last honeybee enter into hive in the evening. Foraging behaviour was studied in terms of foraging speed and foraging rate. Time spent by *A. mellifera* on each flower within an inflorescence has been referred to foraging speed. Number of flowers visited by *A. mellifera* per minute per panicle has been referred to as foraging rate.

Litchi flowers started blooming from 1st week of March. Half of the flowering occurred in the mid-March and it continued until the last week of March. During the observation, total 227 insects were collected, belonging to 6 different orders, 15 families and 24 species (Table1). Among them, Hymenoptera was principal order comprising of 11 species from 5 different families, namely Apidae, Andrenidae, Megachilidae, Vaspidae, and Sphecidae. Hymenopterans were most dominant (72.68%) litchi flower visiting insects, followed by Diptera (19.38% with 6 species from 3 families), Coleoptera (3.08%), Lepidoptera (2.2%), Hemiptera (1.76%) and the lowest being Odonata (0.88%). Honeybees *A. dorsata, A. cerana, A. florea* and *A. mellifera* were dominant pollinators (62.55%) of total insect species visiting litchi bloom.

Honeybee abundance was in following order. *A.florea* (37%) > *A. cerana* (15.41%) >*A. mellifera* (7.04%) > *A.dorsata* (3.08%). Among various insect pollinators *A. florea* was the most

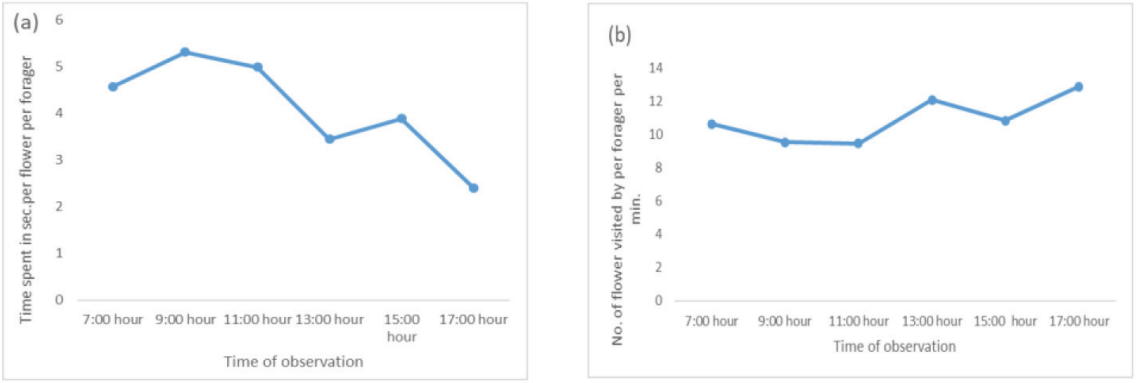

Fig. 1(a) Foraging speed (time spent in second per flower per forager) of *A. mellifera* on litchi flower
(b) Foraging rate (No. of flowers visited per forager per minute) of *A. mellifera* on litchi flower

dominant species found visiting flower during the entire litchi blooming period. The Shannon diversity index of insect pollinator of litchi during the flowering period was H' = 2.33, Evenness E = 0.73 and Dominance D = 0.37 showing significant results. In the present study insect diversity was moderate. According to Shannon-Wiener diversity index (low diversity (<1.5), medium diversity (>1.5) and high diversity (>2.5)). Evenness value closer to 1 shows species are evenly distributed i.e. population is dominated by less number of species. Dubey *et al.* (2020) found 1.07 Shannon diversity index of insect pollinator of litchi during the flowering period in Chitwan, Nepal. Kumari *et al.* (2023) found 1.15 Shannon diversity index of insect pollinator of litchi during the flowering period in Kangra, Himachal Pradesh.

A. mellifera started foraging as early as 5 46h (mean 5 53h) in the morning hours, while in the evening *A. mellifera* ceased their flight at 18 08h (mean 18 01h). Maximum foraging time was at 12 22h (mean duration 12 05h). Foraging speed of *A. mellifera* was observed with start of foraging activity by abundance of foragers at 7 00 – 7 30h with 4.57 seconds on a flower (Fig. 1a). Highest foraging speed was recorded at 9 00h with 5.13 seconds on a flower. Time spent on flowers gradually decreases with increase in daytime and temperature. Lowest foraging speed recorded on 17 00h with 2.40 seconds on a flower. Like foraging speed, observations on foraging rate (Fig. 1b) was also carried out from early morning, 7 00h. Foraging rate at 7 00h were 10.63 flowers per minute per forager, which gradually declined till 11 00h (9.47 flowers per minute). Maximum foraging rate was observed at 17 00h with 12.89 flowers per minute per forager. Minimum foraging rate observed at 11 00h (with 9.47 flower per minute per forager). Bhatnagar and Karnatak (2010) observed the impact of day hours on the foraging behaviour of *A. mellifera* visiting litchi,

In present study, 24 insect species were found visiting litchi inflorescence. Srivastava *et al.* (2017) in Muzaffarpur Bihar, Thapa (2006) at Rampur Chitwan Nepal, Dubey *el al.* (2020) at Rampur Chitwan Nepal, reported 23, 21 and 23 species respectively, on litchi inflorescence. In West Bengal, Das (2019) found 13 insect visitors in Nadia district. Kumari *et al.* (2023) reported 75 insect species in Kangara, Himanchal Pradesh. Wide variations in insect pollinators may result due to different agro climatic regions. In the present study it has been found that hymenopterans as the most effective pollinators and among them honey bees occupy the top positon. Among the honey bees, the authors have found *A.florea* to be the most effective pollinators of litchi flowers, as has been found by Kumar *et al.* (2013), Rai *et al.* (2017), Srivastava *et al.* (2017), Dubey *et al.* (2020) who all found hymenopterans as the most effective pollinators and among them honey bee holding the top position. However, the findings varied as far as the particular

Table 1. Diversity and relative abundance of visitor insect of litchi

No	Common Name	Scientific Name	Family	Order	No.	Abundance (%)
1	Rock bee	*Apis dorsata*	Apidae	Hymenoptera	7	3.08
2	Asiatic honey bee	*A. cerana*	Apidae	Hymenoptera	35	15.41
3	Red dwarf bee	*A. florea*	Apidae	Hymenoptera	84	37
4	European honey bee	*A. mellifera*	Apidae	Hymenoptera	16	7.04
5	Bumble bee	*Bumbus* spp.	Apidae	Hymenoptera	1	0.44
6	Carpenter bee	*Xylocopa fenestrata*	Apidae	Hymenoptera	3	1.32
7	Leaf cutter bee	*Megchile* spp.	Megchilidae	Hymenoptera	5	2.2
8	Mining bee	*Andrena* spp.	Andrenidae	Hymenoptera	3	1.32
9	oriental wasp	*Vespa orientalis*	Vespidae	Hymenoptera	3	0.88
10	Paper wasp	*Polistis* spp.	Vespidae	Hymenoptera	2	0.88
11	Thread waisted wasp	*Sphecid* spp.	Sphecidae	Hymenoptera	6	2.64
12	Damselfly	*Agriochemis* spp.	Coenagrionidae	Odonata	2	0.88
13	Rice bug	*Leptoeorisa* spp.	Alydidae	Hemiptera	1	0.44
14	Jewel bug	*Scutelleridae*	Scutelleridae	Hemiptera	3	1.32
15	Sandal wood defoilator	*Amata parsalis*	Eribidae	Lepidoptera	2	0.88
16	Cabbage butterfly	*Pieris brassicae*	Pieridae	Lepidoptera	1	0.44
17	Grey pansy	*Jumonia atlites*	Nymphalidae	Lepidoptera	2	1.32
18	House fly	*Musca domistica*	Muscidae	Deptera	4	1.76
19	Blue Bottle fly	*Calliphora vomitoria*	Calliphoridae	Deptera	7	3.08
20	Long Hoverfly	*Spherophoria* spp.	Syrphidae	Deptera	18	7.92
21	Hoverfly	*Crystoxum festerum*	Syrphidae	Deptera	3	1.32
22	Marmalade hoverfly	*Episyrphus* spp.	Syrphidae	Deptera	7	3.08
23	Syrphid fly	*Eristalinus* spp.	Syrphidae	Deptera	5	2.2
24	Lady bird beetle	*Coccinella septumpunctata*	Coccinellidae	Coleoptera	7	2.64
	Total collection				227	

species of a honey bee as the most effective pollinator is concerned. Srivastava *et al.* (2017) reported *A. mellifera* as the most effective pollinator whereas Rai *et al.* (2017), Das *et al.* (2019) and Dubey *et al.* (2020) ranked *A. dorsata*. The effectiveness of different honeybees, appear to be influenced by local factors.

Foraging activity of *A. mellifera* began early in the morning (mean 5 53h) and cessation of flight took place at evening (mean 18 01h). Joshi and Joshi (2010) at Uttarakhand who reported that *A. mellifera* started their foraging 6 17h and ceased their activity 18 38h (mean duration 12 hour 47 minute). It appears that Sunrise and Sun set times have influence on the onset and cessation of activities of *A. mellifera*. Since the Sunrise is delayed in Uttarakhand, the beginning of activities is also delayed. The result also highlighted that the foraging speed of *A. mellifera* is significantly higher at 9 00h and less at 17 00h. Mishra and Kumar (2018) reported similar result that foraging speed of *A. mellifera* was highest at 9 00h and minimum at 15h. The present result show that maximum foraging rate at 17 00 and minimum at 11h. Das (2019) found similar results that foraging rate of *A.mellifera* was maximum between 15 00 -17 00h (12.98 flower visited by a forager per minute) and minimum between 9 00 -11 00h (9.51 flower visited by a forager per minute) on litchi flower.

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