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# Biodiversity and Foraging Behaviour of Major Insect Pollinators on Some Fruit Crops

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

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## ABSTRACT

Beekeeping entirely depends on the types of flowering plants available in any given area. The honey bees (*Apis* species) have a major role and are considered widely as pollinating agents. The present study was conducted at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar to find out the biodiversity and foraging behaviour of major insect pollinators on some fruit crops. The honey bees (*Apis* species) have major role and considered widely as pollinating agents. In most of the crops we largely seek for honey bees and depend on them for pollination services.

*Keywords: Bee-Flora; pollination; foraging; behaviour.*

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## 1. INTRODUCTION

Honeybees and flowering plants have been considered as an example for co evolution and mutualism. Significant increases in yields are recorded in cross pollinated fruit crops like litchi, apple, mango, peach, pear, plum etc., due to bee pollination. The honey bees (*Apis* species) have major role and considered widely as pollinating agents. In most of the crops we largely seek for honey bees and depend on them for pollination services. However there are many other insects especially Non *Apis* bees also called as native bees or pollen bees, which play significant role in pollination. These efficient pollinators often have a large share in pollinating the crops.

A pollinator is the biotic agent (vector) that moves pollen from the male gamete (anthers) of a flower to the female gamete (stigma) of a flower to accomplish fertilization or syngamy of the female gamete in the ovule of the flower by the male gamete from the pollen grain. There are roughly 200,000 varieties of animal pollinators in the wild, most of which are insects Entomophily, pollination by insects, often occur on plants that have developed colored petals and a strong scent to attract insects such as, bees, wasps and occasionally ants (Hymenoptera), beetles (Coleoptera), moths and butterflies (Lepidoptera), and flies (Diptera). Entomophily is a form of pollination whereby pollen is distributed by insects, particularly bees, Lepidoptera (*e.g.*, butterflies and moths), flies and beetles. Entomophilous species frequently evolve mechanisms to make themselves more appealing to insects, e.g., brightly-colored or scented flowers, nectar, or appealing shapes and patterns. Pollination of flowers requires insect like syrphid flies, honey bees, ants and wasps [1]. Honeybee species *Apis dorsata* F; *A. mellifera* L; *A. cerana* F. and *A. florea* F. were the most important and efficient pollinators of litchi flowers (*Litchi chinensis* Sonn.). They constituted more than 65% of the total pollinating insects. Between commencement and cessation, the foraging activity of all honeybee species followed the same general pattern as temperature, light intensity, solar radiation, and nectar sugar concentration and inversely with relative humidity. Path analysis revealed that all honeybee species differed in their responses to temperature, light intensity and solar radiation, the three most important factors in foraging behaviour [2]. The indiscriminate use of pesticides causing the major problems to our environment and also reducing the natural enemies from the ecosystems. Environmental stresses, population explosion and food shortage have caused serious problems to mankind on the globe. A shift towards biologically based agriculture becomes necessary to increase food productivity. Honeybees (Apidae: Apinae) are classified into the genus *Apis* which includes four main species: the common honeybee or Italian honeybee (*Apis mellifera* L.), the giant honeybee (*Apis dorsata* F.), the Asian honeybee (*Apis cerana* F.) and the little honeybee (*Apis florea* F.). There are more than 20,000 species of wild bees. Many species are solitary (e.g. mason bees, leafcutter bees (Megachilidae), carpenter bees and other ground-nesting bees). While others rear their young in burrows and small colonies (e.g., bumblebees and stingless bees).

Honeybees pollinate 16% of flowering plant species in the world and nearly 400 species of agricultural plants [3]. Fruits, vegetables or seed production from 87 of the 115 leading global food crops depends upon animal pollination Klein AM, Vaissière BE, Cane JH. (2007). The value of insect pollination for worldwide agricultural production is estimated to be 153 billion, which represents 9.5% of the value of the world agricultural production used for human food in 2005 Gallai N, Salles JM, Settele J, Vaissière BE. [4]. The sustainable development of agriculture has necessitated the reorientation of the present crop production technologies (Free, [5], Abrol, [6], Tikoo and Abrol, [7]. Honeybee species *Apis dorsata* F; *A. mellifera* L; *A. cerana* F. and *A. florea* F. were the most important and efficient pollinators of litchi flowers (*Litchi chinensis* Sonn.). They constituted more than 65% of the total pollinating insects. Between commencement and cessation, the foraging activity of all honeybee species followed the same general pattern as temperature, light intensity, solar radiation, and nectar sugar concentration and inversely with relative humidity. Path analysis revealed that all honeybee species differed in their responses to temperature, light intensity and solar radiation, the three most important factors in foraging behaviour (Abrol, 2006). Several horticulture crops cultivated in India derive benefit or are dependent on pollinating insects for effective qualitative and quantitative improvement in crops yield. Many temperate fruit trees have been investigated for their dependence on bees. A number of varieties of apples, pears, plums, peaches and cherries are known to be self–

sterile and re-benefited by bee pollination. Orchard growers in Himachal Pradesh initiated the practice of renting bee colonies for keeping in their orchards during the flowering of these crops for enhancing the fruit production [8].

### 1.1 Study Sites

Geographically Pantnagar is located in the sub-tropical zone at 29$^0$N latitude and 79.3$^0$E longitude and at an altitude of 243.8 m above the mean sea level in the "tarai" region of Uttarakhand in Northern India. The location has sub-humid tropical climate and is situated in the foot hills of "Shivalik" range of the Himalayas. The meteorological data indicate that the humid climate here is characterized by hot dry summer and cold winter. The temperature rises up to 40$^0$C in summer, while it falls to 2-10$^0$C in winter. Approximately, 1400 mm mean rainfall has been recorded and relative humidity fluctuates around 90 ± 5 per cent during rainy season.


**Fig. 1. Study area**

## 2. METHODOLOGY

### 2.1 Biodiversity of Insect Pollinators on some Cross-Pollinated Fruit Crops

Sweepings were made throughout the blooming period of these fruit crops at weekly intervals during from morning to evening. The collected insects were preserved as dry specimen.

### 2.2 Foraging Behaviour of the Insect Pollinators: Foraging Speed

Foraging speed of pollinators recorded in terms of time (second) spent by them on each flower and the number of flowers visited per minute following the method given by Free [5]. To know the foraging speed (time spent/ flower in seconds) at different day hours, the daily observation was taken on insect pollinators on each crop at different time intervals such as 0600-0800h, 0800-1000h, 1000-1200h and1600-1800h for 7 days. The time spent to insert the proboscis and suck up the nectar or brushing/collecting pollens was considered as the time spent per flower.

## 3. RESULTS AND DISCUSSION

### 3.1 Average Time Spent by Different Insect Species on *Pyrus amygdaliformis* Flowers at Different Hours of Day during February- March at Pantnagar

The data on foraging speed *i.e.* time spent by different insect species on *Pyrus amygdaliformis* flowers at different hours of day during March-July 2013 at Pantnagar have been presented in Table 2 revealed that in *Apis dorsata* mean foraging speed (time spent/ flower in seconds) 9.57 to 12.21, while in case of *Apis mellifera* and *Apis cerana* it was 9.28 to 12.52 and 7.97 to 9.37 seconds respectively. For *Musca domestica*, *Eristalis tenax, Episyrphus balteatus* and *Syrphus corollae* mean foraging speed (time spent/ flower in seconds) was 12.78 to 15.21, 11.92 to 15.28, 10.92 to 14.42 and 10.35 to 13.07 seconds respectively. *Musca domestica* was observed to spend maximum time (average 14..03 second per flower) was significantly higher than the *Eristalis tenax* (13.53 second), *Episyrphus balteatus* (12.94 second), *Syrphus corollae* (12.39 second), *Apis mellifera* (10.97 second), *Apis dorsata* (10.96 second), and lowest time spent by *Apis cerana* (8.67 second). The mean time spent by these insect species during 0800-1000 h of the day (13.15 seconds/flower) was significantly higher than the mean time spent by these insect species during 1000-1200 (11.54 seconds/flower) and at 1600-1800 h (10.40 seconds/ flower).

### 3.2 Average Time Spent by Different Insect Species on *Prunus persica* Flowers at Different Hours of Day during February-March at Pantnagar

The data on foraging speed *i.e.* time spent by different insect species on *Prunus persica* flowers at different hours of day during February to March 2014 at Pantnagar have been presented in Table. 4 revealed that in *Apis dorsata* mean foraging speed (time spent/ flower in seconds) 9.28 to 12.57 and in case of *Apis mellifera* and *Apis cerana* it was 8.75 to 13.01, 8.21 to 9.42 seconds respectively. In *Musca domestica* (11.85 to 15.07)*, Eristalis tenax* (10.64 to 14.35), *Episyrphus balteatus* (11.50 to 13.64)*, Syrphus corollae* (9.71 to 12.14) and *Melanostoma orientale* had 9.20 to 11.21 second respectively. *Musca domestica* was observed to spend maximum time (average 13..91 second per flower) was significantly higher than *Episyrphus balteatus* (12.62 second), *Eristalis tenax* (12.55 second), *Syrphus corollae* (11.33 second), *Apis mellifera* (11.13 second), *Apis dorsata* (11.08 second), *Melanostoma orientale* (10.34 second) and lowest time spent by *Apis cerana* (8.68 second). The mean time spent by these insect species during 0800-1000 h of the day (12.68 seconds/flower) was significantly higher than the mean time spent by these insect species during 1000-1200 (11.08 seconds/flower) and at 1600-1800 h (9.89 seconds/ flower).

### 3.3 Average Time Spent by Different Insect Species on *Prunus armeniaca* Flowers at Different Hours of Day during February- March at Pantnagar

The data on foraging speed *i.e.* time spent by different insect species on *Prunus armeniaca* flowers at different hours of day during February to March 2013 at Pantnagar have been presented in Table 6 revealed that in *Apis dorsata, Apis mellifera* and in *Apis cerana* mean foraging speed (time spent/ flower in seconds) was 9.64 to 12.24, 8.87 to 13.51, and 7.77 to 8.64 seconds respectively, while in case of *Musca domestica* (12.28 to 14.85) *Eristalis tenax* (10.35 to 14.35)*, Episyrphus balteatus* (12.00 to 13.71) and *Syrphus corollae* had 10.07 to 13.85 second respectively. *Musca domestica* was

observed to spend maximum time (average 13..46 second per flower) was significantly higher than *Episyrphus balteatus* (12.73 second), *Eristalis tenax* (12.28 second), *Syrphus corollae* (12.23 second), *Apis mellifera* (11.16 second), *Apis dorsata* (11.15 second) and lowest time spent by *Apis cerana* (8.23 second). The mean time spent by these insect species during 0800-1000 h of the day (12.97 seconds/flower) was significantly higher than the mean time spent by these insect species during 1000-1200 (10.90 seconds/flower) and at 1600-1800 h (10.14 seconds/ flower). The mean time spent these insect species during 1000-1200 (10.90 seconds/flower) was also significantly higher than during 1000-1200 h.

**Table 1. Diversity of insect pollinators on pear (*Pyrus amygdaliformis*) at Horticulture Research Centre (Pantnagar)**

| Sr. No. | Scientific Name | Order | Family | Foraging Activity | Status |
|---|---|---|---|---|---|
| 1. | *Apis dorsata* | Hymenoptera | Apidae | P,N | VF |
| 2. | *Apis mellifera* | Hymenoptera | Apidae | P,N | VF |
| 3. | *Apis cerana* | Hymenoptera | Apidae | P,N | VF |
| 4. | *Musca domestica* | Diptera | Muscidae | P | F |
| 5.. | *Eristalis tenax* | Diptera | Syrphidae | N | F |
| 6.. | *Episyrphus balteatus* | Diptera | Syrphidae | N | F |
| 7. | *Syrphus corollae* | Diptera | Syrphidae | N | F |
| 8. | *Vespa orientalis* | Hymenoptera | Vespidae | - | F |

*P=Pollen Gatherers, N= Nectar Gatherers, VF = Very Frequent, F = Frequent, R = Rare*

**Table 2. Average time spent by different insect species on *Pyrus amygdaliformis* flowers at different hours of day during February- March at Pantnagar**

| Bee species | Time spent/flower (sec) | | | | |
|---|---|---|---|---|---|
| | 0600-0800 | 0800-1000 | 1000-1200 | 1600-1800 | Mean |
| *Apis dorsata* | 12.11 | 12.21 | 9.95 | 9.57 | 10.96 |
| *Apis mellifera* | 12.21 | 12.52 | 9.85 | 9.28 | 10.97 |
| *Apis cerana* | 9.14 | 9.37 | 8.21 | 7.97 | 8.67 |
| *Musca domestica* | 14.28 | 15.21 | 13.85 | 12.78 | 14.03 |
| *Eristalis tenax* | 14.35 | 15.28 | 12.57 | 11.92 | 13.53 |
| *Episyrphus balteatus* | 13.35 | 14.42 | 13.07 | 10.92 | 12.94 |
| *Syrphus corollae* | 12.85 | 13.07 | 13.28 | 10.35 | 12.39 |
| **Mean** | 12.61 | 13.15 | 11.54 | 10.40 | 11.93 |
| | | | | **SE(m)** | **C.D. (p=0.05)** |
| Bee species | | | | 0.26 | 0.74 |
| Day hours | | | | 0.20 | 0.56 |
| Bee species x day hours | | | | 0.53 | 1.48 |
| **CV** | | | | 11.82 | |

**Table 3. Diversity of insect pollinators on peach (*Prunus persica*) at Horticulture Research Centre (Pantnagar) during February**

| Sr. No. | Scientific Name | Order | Family | Foraging Activity | Status |
|---|---|---|---|---|---|
| 1. | *Apis dorsata* | Hymenoptera | Apidae | P,N | VF |
| 2. | *Apis mellifera* | Hymenoptera | Apidae | P,N | VF |
| 3. | *Apis cerana* | Hymenoptera | Apidae | P,N | VF |
| 4. | *Musca domestica* | Diptera | Muscidae | P | F |
| 5.. | *Eristalis tenax* | Diptera | Syrphidae | N | F |
| 6.. | *Episyrphus balteatus* | Diptera | Syrphidae | N | F |
| 7. | *Syrphus corolla* | Diptera | Syrphidae | N | F |
| 8. | *Melanostoma orientale* | Diptera | Syrphidae | N | F |

*P=Pollen Gatherers, N= Nectar Gatherers, VF = Very Frequent, F = Frequent, R = Rare*

**Table 4. Average time spent by different insect species on *Prunus persica* flowers at different hours of day during February-March at Pantnagar**

| Bee species | Time spent/flower (sec) | | | | |
|---|---|---|---|---|---|
| | 0600-0800 | 0800-1000 | 1000-1200 | 1600-1800 | Mean |
| *Apis dorsata* | 11.97 | 12.57 | 10.50 | 9.28 | 11.08 |
| *Apis mellifera* | 12.78 | 13.01 | 10.00 | 8.75 | 11.13 |
| *Apis cerana* | 8.71 | 9.42 | 8.38 | 8.21 | 8.68 |
| *Musca domestica* | 14.50 | 15.07 | 14.21 | 11.85 | 13.91 |
| *Eristalis tenax* | 14.00 | 14.35 | 11.21 | 10.64 | 12.55 |
| *Episyrphus balteatus* | 12.71 | 13.64 | 12.64 | 11.50 | 12.62 |
| *Syrphus corollae* | 12.00 | 12.14 | 11.50 | 9.71 | 11.33 |
| *Melanostoma orientale* | 10.75 | 11.21 | 10.21 | 9.20 | 10.34 |
| **Mean** | 12.18 | 12.68 | 11.08 | 9.89 | 11.46 |
| | | | | **SE(m)** | **C.D. (p=0.05)** |
| Bee species | | | | 0.27 | 0.78 |
| Day hours | | | | 0.19 | 0.55 |
| Bee species x day hours | | | | 0.55 | 1.56 |
| **CV** | | | | 12.92 | |

**Table 5. Diversity of insect pollinators on apricot (*Prunus armeniaca*) at Horticulture Research Centre (Pantnagar) during February**

| Sr. No. | Scientific Name | Order | Family | Foraging Activity | Status |
|---|---|---|---|---|---|
| 1. | *Apis dorsata* | Hymenoptera | Apidae | P,N | VF |
| 2. | *Apis mellifera* | Hymenoptera | Apidae | P,N | VF |
| 3. | *Apis cerana* | Hymenoptera | Apidae | P,N | VF |
| 4. | *Musca domestica* | Diptera | Muscidae | P | F |
| 5.. | *Eristalis tenax* | Diptera | Syrphidae | N | F |
| 6.. | *Episyrphus balteatus* | Diptera | Syrphidae | N | F |
| 7. | *Syrphus corollae* | Diptera | Syrphidae | N | F |

*P=Pollen gatherers, N= Nectar gatherers, VF = Very frequent, F = Frequent, R = Rare*

**Table 6. Average time spent by different insect species on *Prunus armeniaca* flowers at different hours of day during February at Pantnagar**

| Bee species | Time spent/flower (sec) | | | | |
|---|---|---|---|---|---|
| | 0600-0800 | 0800-1000 | 1000-1200 | 1600-1800 | Mean |
| *Apis dorsata* | 12.24 | 13.00 | 9.71 | 9.64 | 11.15 |
| *Apis mellifera* | 12.28 | 13.51 | 10.00 | 8.87 | 11.16 |
| *Apis cerana* | 8.44 | 8.64 | 8.07 | 7.77 | 8.23 |
| *Musca domestica* | 13.64 | 14.85 | 13.07 | 12.28 | 13.46 |
| *Eristalis tenax* | 13.64 | 14.35 | 10.78 | 10.35 | 12.28 |
| *Episyrphus balteatus* | 12.78 | 13.71 | 12.42 | 12.00 | 12.73 |
| *Syrphus corollae* | 13.85 | 12.71 | 12.28 | 10.07 | 12.23 |
| **Mean** | 12.41 | 12.97 | 10.90 | 10.14 | 11.60 |
| | | | | **SE(m)** | **C.D. (p=0.05)** |
| Bee species | | | | 0.27 | 0.76 |
| Day hours | | | | 0.20 | 0.57 |
| Bee species x day hours | | | | 0.54 | 1.52 |
| **CV** | | | | 12.46 | |

**Table 7. Diversity of insect pollinators on Plum (*Prunus cerasifera*) at Horticulture Research Centre (Pantnagar) during February**

| Sr. No. | Scientific Name | Order | Family | Foraging Activity | Status |
|---|---|---|---|---|---|
| 1. | *Apis dorsata* | Hymenoptera | Apidae | P,N | VF |
| 2. | *Apis mellifera* | Hymenoptera | Apidae | P,N | VF |
| 3. | *Apis cerana* | Hymenoptera | Apidae | P,N | VF |
| 4. | *Trigona* spp. | Hymenoptera | Apidae | P,N | F |
| 5. | *Eristalis tenax* | Diptera | Syrphidae | P | F |
| 6. | *Episyrphus balteatus* | Diptera | Syrphidae | P | F |
| 7. | *Syrphus corolla* | Diptera | Syrphidae | N | F |
| 8. | *Melanostoma orientale* | Diptera | Syrphidae | N | F |
| 9. | *Musca domestica* | Diptera | Muscidae | P | F |
| 10. | *Vespa orientalis* | Hymenoptera | Vespidae | - | F |

*P=Pollen Gatherers, N= Nectar Gatherers, VF = Very Frequent, F = Frequent, R = Rare*

**Table 8. Average time spent by different insect species on *Prunus cerasifera* flowers at different hours of day during February -March at Pantnagar**

| Bee species | Time spent/flower (sec) | | | | |
|---|---|---|---|---|---|
| | 0600-0800 | 0800-1000 | 1000-1200 | 1600-1800 | Mean |
| *Apis dorsata* | 11.94 | 12.14 | 9.81 | 9.42 | 10.83 |
| *Apis mellifera* | 12.00 | 12.68 | 9.14 | 8.92 | 10.68 |
| *Apis cerana* | 8.64 | 8.78 | 7.85 | 7.57 | 8.21 |
| *Trigona spp.* | 13.07 | 13.85 | 11.92 | 9.35 | 12.05 |
| *Eristalis tenax* | 11.57 | 12.14 | 11.14 | 10.57 | 11.35 |
| *Episyrphus balteatus* | 12.85 | 13.00 | 9.64 | 8.85 | 11.08 |
| *Syrphus corollae* | 11.28 | 11.50 | 10.07 | 8.85 | 10.42 |
| *Melanostoma orientale* | 10.07 | 10.42 | 9.57 | 8.62 | 9.67 |
| *Musca domestica* | 13.64 | 14.78 | 12.64 | 11.85 | 13.23 |
| **Mean** | 11.67 | 12.14 | 10.20 | 9.33 | 10.84 |
| | | | | **SE(m)** | **C.D. (p=0.05)** |
| Bee species | | | | 0.27 | 0.77 |
| Day hours | | | | 0.18 | 0.51 |
| Bee species x day hours | | | | 0.55 | 1.55 |
| **CV** | | | | 13.60 | |

### 3.4 Average Time Spent by Different Insect Species on *Prunus cerasifera* Flowers at Different Hours of Day during February -March at Pantnagar

The data on foraging speed *i.e.* time spent by different insect species on *Prunus cerasifera* flowers at different hours of day during February to March 2013 at Pantnagar have been presented in Table 8 revealed that in *Apis dorsata, Apis mellifera* and *Apis cerana* mean foraging speed (time spent/ flower in seconds) 9.42 to 12.14, 8.92 to 12.68 and 7.57 to 8.78 seconds respectively, while in case of *Trigona* spp. (9.35 to 13.85), *Eristalis tenax* (10.57 to 12.14), *Episyrphus balteatus* (8.85 to 13.00), *Syrphus corollae* (8.85 to 11.50), *Melanostoma orientale* (8.62 to 10.42) and *Musca domestica* had 11.85 to 14.78 second respectively. *Musca domestica* was observed to spend maximum time (average 13.23 second per flower) was significantly higher followed by *Trigona* spp. (12.05 second), *Eristalis tenax* (11.35 second), *Episyrphus balteatus* (11.08 second) *Apis dorsata* (10.83 second), *Apis mellifera* (10.68 second), *Syrphus corollae* (10.42 second), *Melanostoma orientale* (9.67 second), and lowest time spent by *Apis cerana* (8.21 second). Bhatia *et al* [9] reported 34 species of insects from litchi flowers at Himachal Pradesh of which maximum belonged to the order Diptera followed by Hymenoptera and Coleoptera; whereas Jarlan *et*

*al* [10] reported *Eristalis tenax* (Syrphidae) as one of the most efficient pollinator of Litchi flowers. Eardley and Mansell [11] conducted a survey in two litchi orchards in South Africa and recorded many insects other than honey bees visiting flowers and were responsible for pollination in litchi and in present study the many insect pollinators recorded on Litchi bloom. Bhalla *et al.* [12] considered syrphid-flies as the most common insect pollinators visiting on flowers of plum, peach and almond trees in Himachal Pradesh, India. They observed the hover-fly, *Eristalis* spp. as the predominant species and effective pollinator which worked maximum hours throughout the flowering season of Litchi. They also observed that peach flowers attracted on an average of 70 honey bees per branch per 10 minute as compared with 39 on plum and 32 on almond.

The mean time spent by these insect species during 0800-1000 h of the day (12.14 seconds/flower) was significantly higher than the mean time spent by these insect species during 1000-1200 (10.20 seconds/flower) and at 1600-1800 h (9.33 seconds/ flower).

**Table 9. Diversity of insect pollinators on Litchi (*Litchi chinensis*) at Horticulture Research Centre (Pantnagar) during March**

| Sr. No. | Scientific Name | Order | Family | Foraging Activity | Status |
|---|---|---|---|---|---|
| 1. | *Apis dorsata* | Hymenoptera | Apidae | P,N | VF |
| 2. | *Apis mellifera* | Hymenoptera | Apidae | P,N | VF |
| 3. | *Apis cerana* | Hymenoptera | Apidae | P,N | VF |
| 4. | *Apis florea* | Hymenoptera | Apidae | P,N | VF |
| 5. | *Trigona* spp. | Hymenoptera | Apidae | P,N | F |
| 6. | *Musca domestica* | Diptera | Muscidae | P | R |
| 7. | *Eristalis tenax* | Diptera | Syrphidae | N | F |
| 8. | *Episyrphus balteatus* | Diptera | Syrphidae | N | F |
| 9. | *Syrphus corollae* | Diptera | Syrphidae | N | F |
| 10. | *Metasyrphus latifascialis* | Diptera | Syrphidae | N | F |
| 11. | *Melanostoma orientale* | Diptera | Syrphidae | N | F |
| 12. | *Vespa orientalis* | Hymenoptera | Vespidae | - | F |

*P=Pollen Gatherers, N= Nectar Gatherers, VF = Very Frequent, F = Frequent, R = Rare*

**Table 10. Average time spent by different inset species on *Litchi chinensis* flowers at different hours of day during March- April at Pantnagar**

| Bee species | Time spent/flower (sec) | | | | |
|---|---|---|---|---|---|
| | 0600-0800 | 0800-1000 | 1000-1200 | 1600-1800 | Mean |
| *Apis dorsata* | 11.68 | 12.42 | 7.94 | 7.42 | 9.87 |
| *Apis mellifera* | 12.14 | 12.37 | 9.71 | 9.28 | 10.87 |
| *Apis cerana* | 8.71 | 9.21 | 8.21 | 8.07 | 8.55 |
| *Apis florea* | 13.85 | 14.00 | 11.57 | 11.28 | 12.67 |
| *Trigona spp.* | 12.85 | 13.92 | 11.07 | 10.00 | 11.96 |
| *Musca domestica* | 13.14 | 13.92 | 12.71 | 10.00 | 12.44 |
| *Eristalis tenax* | 13.85 | 15.14 | 12.07 | 12.00 | 13.26 |
| *Episyrphus balteatus* | 12.78 | 14.21 | 13.07 | 10.64 | 12.67 |
| *Syrphus corollae* | 13.85 | 14.14 | 13.57 | 11.40 | 13.24 |
| *Metasyrphus latifascialis* | 13.85 | 13.92 | 11.92 | 11.28 | 12.75 |
| *Melanostoma orientale* | 13.92 | 14.14 | 11.64 | 11.50 | 12.80 |
| **Mean** | 12.78 | 13.40 | 11.22 | 10.26 | 11.92 |
| | | **SE(m)** | | **C.D. (p=0.05)** | |
| Bee species | | 0.31 | | 0.86 | |
| Day hours | | 0.18 | | 0.52 | |
| Bee species x day hours | | 0.62 | | 1.72 | |
| **CV** | | 13.77 | | | |

### 3.5 Average Time Spent by Different Inset Species on *Litchi chinensis* Flowers at Different Hours of Day during March- April at Pantnagar

In *Litchi chinensis* the foraging speed *i.e.* time spent by different insect species at different day hours during March to April 2012 at Pantnagar have been presented in Table 10 revealed that in *Apis dorsata* mean foraging speed (time spent/ flower in seconds) 7.42 to 12.42 and in case of *Apis mellifera, Apis cerana*, *Apis florea* and *Trigona* spp*.* it was 9.28 to 12.37, 8.07 to 9.21, 11.28 to 14.00, 10.00 to 13.92 seconds respectively. In *Musca domestica* it was *(*10.00 to 13.92), *Eristalis tenax* (12.00 to 15.14), *Episyrphus balteatus* (10.64 to 14.21), *Syrphus corollae* (11.40 to 14.14), *Metasyrphus latifascialis* (11.28 to 13.92) and *Melanostoma orientale* (11.50 to 14.14). The maximum time (average 13.26 second) per flower was spent by *Eristalis tenax* followed was significantly higher than all *Apis* bees. *Syrphus corollae* spent (13.24 second), *Melanostoma orientale* (12.80 second), *Metasyrphus latifascialis* (12.75 second), *Apis florea* (12.67 second) and *Musca domestica* (12.44 second) *Trigona* spp*.* (11.96 second), *Apis mellifera* (10.87 second), *Apis dorsata* (9.87 second) and lowest time spent by *Apis cerana* (8.55 second). Mishra and Yazdani [13] have reported that in Bihar region *A. cerana indica* Fab. was the most dominant forager on litchi followed by *A. dorsata* Fab. Various insect spp. belonging to the different order namely, Diptera, Hymenoptera and Lepidoptera were also recorded as a visitor on litchi crop.

The mean time spent by these insect species was significantly higher (13.40 second) at 0800-1000 h than the mean time spent by these insect species during 0600-0800 h (12.78 second/ flower) after that the time spent by these species during 0600-0800 h (12.78 second/ flower) and 0800-1000 h (13.40second/ flower) were also significantly higher than the 1000-1200 (11.22 second/ flower) and 1600-1800 h (10.26 second/ flower) and it is significant too at the time of 1000-1200 h compare to the 1600-1800 h.

The similar findings were observed by Pandey and yadava [14], who recorded that the Apoidea (*Apis* and *Mellipona* spp.) comprised 98-99 per cent of total insect visitors to the litchi flowers. Most visits were made during morning hours between 8:00 AM to 11:00 AM which correlated with the maximum anther dehiscence [15,16].

## 4. CONCLUSION

The study on biodiversity and foraging behaviour of major insect pollinators on some fruit crops were carried out on 05 different forage plant species. A total of 12 insect species of pollinators belonging to four families and 2 orders were collected. The hymenopterans and dipterans were the major floral visitors. Hymenopterans comprising of 06 species from 2 families, *viz.* Apidae (*Apis dorsata, Apis mellifera, Apis cerana, Apis florea* and *Trigona spp.*), Vespidae (*Vespa orientalis* ) They were followed in order of diversity by Dipterans (6 species from 2 families) *viz.* Syrphidae (*Eristalis tenax, Episyrphus balteatus, Syrphus corollae, Metasyrphus latifascialis* and *Melanostoma orientale*), Muscidae (*Musca domestica*). Amongst the family Apidae the *Apis dorsata, Apis mellifera, Apis cerana,* showed a wide range of forage plants as they were found visiting on all the 05 forage plants. Amongst the family Syrphidae *Eristalis tenax, Episyrphus balteatus, Syrphus corolla* were found in all these 05 fruit plants. Mean average time spent per flower by these insects was maximum during 08AM-10AM and lowest time spent by these insects during 04PM to 06 PM on these fruit crops.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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