Diversity of floral visitors and foraging behaviour of major bee species on buckwheat (*Fagopyrum esculentum* M.)

ABSTRACT

Buckwheat flowers attract a diverse range of insect floral visitors contributing to pollination. This study aims to assess their diversity, dominance and foraging behaviour of major bee species on the pin and thrum morphs of buckwheat during different blooming phases.A total of 46 insect species visited buckwheat flowers, which included both *Apis* and non-*Apis* species, out of which 21 species were from Hymenoptera, 14 species from Diptera, six from Lepidoptera,three from Hemiptera and two from Coleoptera.The Berger-Parker dominance index for floral visitors on pin morph and thrum morph of buckwheat varied among different blooming phase with *Apis cerana* F. being the most dominant visitor throughout blooming phase. The diversity of floral visitors was highest during maximum bloom phase on pin and thrum morph as compared to initial and late blooming phases.Irrespective of blooming phases, the diversity of floral visitors was maximum on thrum morph as compared to pin morph.Among the dominant bee floral visitors, foraging rate of *A. cerana*was highest during maximum blooming phase.The foraging duration of*A. florea*for collection of nectar and pollen from pin and thrum morphs was highest among the major bee floral visitors recorded during maximum bloom phase. Effective pollination requires the peak foraging activity of dominant bee species during the maximum bloom phase.

Keyword**:** Diversity, Floral visitors, Foraging duration, Foraging rate, Nectar and Pollenforaging activity.

1. Introduction

Common buckwheat (*Fagopyrum esculentum*M.) also known as buckwheat, belongs to flowering plants of Polygonaceae family. It is a pseudocereal used in the same way as cereals but does not belong to the grass family. Buckwheat is cultivated for its grain-like seeds and as a cover crop. Buckwheat is an OldWorld crop which is believed to have originated in China (Ohnishi, 1998). Around 5000–6000 years ago, the first Buckwheat was sown in China (Tang *et al.*, 2009; Luitel *et al*., 2021). It was introduced into the New World by European settlers in 17th century (Treadwell and Huang, 2008). Due to its multifood use as a pseudocereal with a higher nutritional content than many conventional cereals and its use as a functional food with

industrial applications, leads to promising future on a global scale (Liu *et al*., 2008 and Tang *et al*., 2009).

Buckwheat protein has dietary fibre like effects which induces low digestibility and improves intestinal functions thus, protecting against constipation and colon carcinogenesis (Kato *et al*., 2000). It has higher anti-oxidant properties superior to most cereals (Zielinski and Kozlowska, 2000). Buckwheat protein product suppresses gallstone formation and reduces cholesterol level (Tomotake *et al.*, 2000). Rutin content in buckwheat is supposed to provide protection against harmfull effects of radioactive rays often experienced in high altitude areas and persons handling radioactive material. However, excessive consumption may result in itching with development of rashes in some individuals (Joshi and Paroda, 1991). Buckwheat has high capacity to take up phosphorus from a calcium bound source and has the ability to reduce the weed biomass due to allelopathic effect (Iqbal *et al*., 2002).

In 2021, the area of buckwheat cultivation in the world was 19,88,545 ha. with a seed yield of over 18,75,067 tonnes (Plazek *et al*., 2023). The area of buckwheat cultivation varies every year due to unstable seed yield.

A total of 12 insect species, of which three species were from Apidae viz. *A. florea* F., *A. cerana* F., *A. dorsata* F. belonged to Hymenoptera, one species each was from Syrphidae (*Episyrphus* sp.), Muscidae (*Musca* sp.), Calliphoridae (*Lucilia* sp.), Sarcophagidae (*Sarcophaga* sp.) belonged to Diptera, two species from Nymphalidae (*Danaus chrysippus* L. and *Hypolimnas bolina* L.), one species each from Lycaenidae (*Euchrysops cnejus* F.) and Noctuidae (*Helicoverpa armigera* H.) under Lepidoptera and *Lygaeus kalmii* S. (Lygaeidae) under Hemiptera were recorded on buckwheat flowers. Hymenopterans (61.49%) were the most abundant pollinators followed by Diptera (25.00%), Lepidoptera (12.16%) and Hemiptera (1.35%) at Dharwad, Karnataka (Kambrekar *et al*., 2018).

Singh (2008), recorded that *Apis cerana* F. started foraging activity early morning hours (06.14 ± 0.004 h) and ceased at late in the evening (17.28 ± 0.011 h). The total duration of foraging activity was 10:00 h and the average duration of each foraging trip was 4.5 ± 0.146 min at Kathmandu, Nepal.The highest numbers of *Apis cerana* F. were observed at 11 AM (9.28±2.62) and 1 PM (6.57±2.72), with the lowest at 7 AM and 5 PM. The highest numbers of *A. dorsata* F. were observed at 1 PM (4.83±1.60) and 11 AM (3±0.90) but showed no activity at 7 AM. *A. florea* F. had peak activity at 11 AM (2.45±0.64) and 1 PM (1.25±0.72) and no activity at 7 AM and 5 PM. *A. mellifera* L. had the highest numbers at 11 AM

(3.8±1.4) and 1 PM (1.47±1.31), with no activity at 7 AM and 5 PM. Foraging activity was highest around late morning and early afternoon at Dhaka, Bangladesh (Akter *et al.*, 2023).

In Karnataka at Dharwad, Kambrekar, *et al.*, (2018) studied only on insect species visiting the buckwheat flowers.The objective of the study is to assess the diversity and dominance of insect floral visitors and foraging behaviour of major bee species throughout the different blooming phases of buckwheat. Further the study aims to analyse the variations in visitor diversity between pin and thrum morphs, identify dominant floral visitors and evaluate their foraging rates and foraging durations with respect to pollen and nectar collection for better understanding of pollinator dynamics during different blooming phases.

2. MATERIALS AND METHODS

Study area

The study was conducted in the experimental plot at ICAR-National Bureau of Agricultural Insect Resources, Yelahanka, Bengaluru at 874 MSL, 13°09' N 77°56' E situated in the South Eastern Dry Zone of Karnataka during 2023-24.

Flowering phases of the crop:

The flowering period of the crop which occurred from 3rd January to 29th February, 2024, was categorised into three flowering phases, based on the number of flowers opened per inflorescence in the plant.

Initial Bloom Phase: At this initial phase, a single plant was bearing 3-4 inflorescences and this phase where anthesis of 25 per cent floral buds occurred was categorized as initial bloom phase *i.e.*, from 3rd to 18th January, 2024, with a total duration of 15 days.

Maximum Bloom Phase: During this phase, the anthesis of more than 50 per cent of the floral buds occurred in the inflorescence, then it was categorized as maximum bloom phase *i.e.*, from 19th January to 3rd February, 2024, with a total duration of 16 days.

Late bloom Phase: This phase showed anthesis in remaining 25 per cent of the floral buds in the inflorescence, *i.e.*, from 4th February to 29th February, 2024, with a total period of 26 days, followed by pod set in flowers of initial and maximum bloom phase, with a total duration of 1-2 weeks.

Documentation of flower visitors on buckwheat inflorescence

The crop was raised in a Randomized Block Design at NBAIR, Attur in December2023**.** Flower visitors were collected by using sweep net sampling technique at regular intervals and in different times of a day during different phases of flowering period of the crop. The collected flower visitors were transferred to a poison bottle containing cotton wad which was soaked in ethyl acetate (70 %) to kill the insect floral visitors. Insects collected from sweep samples were brought to the laboratory, mounted by using insect pins, properly dried and preservedfor future identification. Identification of floral visitors was done by using the taxonomic keys in consultation with insect taxonomist, Department of Agril. Entomology, UAS, GKVK, Bengaluru.

Determination of pollen and nectar gatherers

Among the floral visitors, most frequent visiting species and type of floral resource (nectar/pollen) they collected were recognized during these observations for further studies on foraging behaviour (Belavadi and Ganeshaiah., 2013). Those floral visitors collected and stored the pollen in their corbicula are considered as pollen gatherers and those collected only nectar by inserting their proboscis in to the nectaries of flowers are treated as nectar gatherers.

Shannon-Wiener index of diversity (H)

The frequency of visits by each species was recorded to identify the most abundant insect species effecting buckwheat pollination. Pollinator count data was used to compute the Shannon- Wiener diversity index (H), by using the following formula:

$$H = - \Sigma Pi \times \ln Pi$$

where, 'H' is the Shannon-Wiener Index of diversity

'Pi' is the proportion of the i^{th} species of pollinator.

Berger-Parker dominance index

The dominant species on any given sampling day was determined by the Berger-Parker dominance index 'd', which gives the proportion of the total numbers of individuals in a sample that is due to the dominant species and was calculated by using the following formula:

$$d = ni / NT$$

where, 'd' is the index of dominance

'ni' is the number of individuals of the i^{th} species on sampling date

'NT' is the total number of individuals in the sample.

Foraging rate (number of florets visited per bee per minute) of major bee floral visitors

The fresh individual major beefloral visitors were tracked for collection of floral rewards for the period of one minute and the number of florets visited during this period was counted and expressed in terms of number of florets visited by the individual bees species per minute. The same observation was replicated four times from 06:00 to 18:00 hrs at one-hour interval.

Foraging duration (Time spent by individual foragers on each flower)

The individual honey bee species during maximumblooming phase were carefully observed at hourly intervals starting from 06:00 upto18:00 hrs and the duration taken starting from arrival on a particular flower till its departure after foraging of pollen and nectar from pin and thrummorph were recorded by using a digital stop watch. The duration taken by four different honey bee species at hourly intervals was recorded and the mean was calculated. The time spent was expressed in seconds per flower.

3. RESULTS AND DISCUSSION

Documentation of flower visitors on buckwheat inflorescence

Totally fourty-six species of floral visitors, which included *Apis* and non-*Apis* species were collected and documented at different blooming phases of buckwheat during 2023-24. Of these, twenty-one species were Hymenopteran*sviz.*, *Apis cerana* Fab.,*A. mellifera* L.**,***A. dorsata* Fab. and *A. florea* Fab., were the *Apis* species, whereas, *Braunsapis* sp., *Ceratina sutepensis* Cockerell and *Xylocopa* sp. were the non-*Apis* species which belonged to Apidae, foraged for nectar and pollen. *Cerceris hortivaga* K., *Cerceris vagans* R. and *Tachysphere* sp. belonged to Crabronidae,which foraged for nectar. *Campsomariella collaris collaris* F. and *C. annulata* F. belonged to Scoliidae, which foraged for nectar. *Labus* sp., *Delta conoideum* G. and *Polistes stigma tamulus* F. which foraged for nectar and they belonged to family Vespidae. *Chrysis angolensis* R. belonged to family Chrysididae and foraged for nectar. *Seladonia* sp. and *Hoplonomiawestwoodi* belonged to Halictidae and they foraged for nectar and pollen. *Camponotus pennsylvanicus* (De Geer), *C. cinctellus* G. and *Formica* sp. belonged to family Formicidae and they foraged for nectar (Table 1).

Fourteen species under order Diptera *viz.*, *Chrysomya marginallus* W. and *C. megacephala* F. belonged to family Calliphoridae, which foraged for nectar. *Syritta*

*orientalis*M., *Eristalis obliqus* W., *Serratoparagus* sp., *Paragus tibialis* F., *Sphaerophoria sulphuripes* T. and *Halophilus pendulus* L. belonged to family Syrphidae, which foraged for nectar. *Odontomyia ochropa* T. and *Hermetia illucens* L. belonged to family Stratiomyidae and they foraged for nectar. *Stomorhina* sp., *Rhinia* sp. and *Stomorhinaxanthogaster* W. belonged to family Rhiniidae and foraged for nectar (Table 1).

Six species of Lepidopterans*viz*., *Danaus chrysippus* L., *Phalanta phalantha* D. and *Hypolimnas bolina* L. belonged to family Nymphalidae and they foraged for nectar. *Eurema hecabe* L. belonged to family Pieridae, which foraged for nectar. L*ampides boeticus* L. and *Castalius rosimon* F. belonged to family Lycaenidae which foraged for nectar (Table 1).

Three species of Hemiptera among which*Cletus trigonus* T. belonged to family Coreidae, which foraged for nectar,*Riptortus linearis* L. belonged to family Alydidae, which foraged for nectar and *Halyomorpha* sp.belonged to family Pentatomidae, which foraged for nectar (Table 1). Two species of Coleopterans*viz*., *Micraspis discolor* F.and *Coccinella* sp.belonged to family Coccinellidae, which foraged for pollen (Table 1). These findings were supported by the reports of Jacquemart *et al.,* (2007) who recorded 49 different insect species, belonging to 18 families, of which Diptera and Hymenoptera were the predominant visitors.

Berger-Parker dominance index (d) of floral visitors on pin morph of buckwheat at initial, maximum and late bloom phases during 2024

The Berger-Parker dominance index values for floral visitors on pin morph varied among initial (0.006-0.340), maximum (0.006-0.293) and late (0.010-0.330) bloom phaseof buckwheat.*Apis cerana* F.wasthe most dominant insect floral visitor with the highest 'd' value of 0.340, followed by *A. florea* Fab. (0.240) and *A. mellifera* L. (0.125).*Odontomyia ochropa* T.,*Chrysomya marginallus*W. and *Eurema hecabe*L. (0.006) were the least dominant floral visitors duringinitial bloom phase.The maximum (166.67) abundance (1/d) values were observed in*Odontomyia ochropa* T.,*Chrysomya marginallus*W. and *Eurema hecabe* L. whereas minimum (2.94) abundance (1/d) value was seen in *Apis cerana* F.duringinitial bloom phase. During maximum bloom phase, *A. cerana Fab.* was the most dominant floral visitor with highest 'd' value of 0.293, followed by *A. florea* Fab. (0.261) and *A. mellifera* L. (0.153). *Danaus chrysippus* L. and *Eurema hecabe*L. were the least dominant floral visitors with each having 'd' value of 0.006.The maximum (166.67) abundance (1/d) values were observed in*Danaus chrysippus* L. and *Eurema hecabe*L. whereas minimum (3.41) abundance (1/d) value was seen in *Apis cerana* F.duringmaximum bloom phase.Similarly, *A. cerana* Fab. was the most dominant floral visitor with the highest 'd' value of 0.330, followed by *A. florea* Fab.

(0.231) and *A. mellifera* L. (129). *Micraspis discolor*F.,*Hypolimnas bolina*L. and *Coccinella* sp. were the least dominant visitors during late bloom phase, with each having 'd' value of 0.010 (Table 2).The maximum (100.00) abundance (1/d) values were observed in *Micraspis discolor*F.,*Hypolimnas bolina*L. and *Coccinella* sp.whereas minimum (3.03) abundance (1/d) value was seen in *Apis cerana* F. during late bloom phase. These findings were supported by Ali *et al*. (2023), who recorded23 species of buckwheat pollinators belongs to four orders of class Insecta among which highest number of floral visitors on buckwheat was recorded in Hymenoptera (40%) followed by Diptera (33%), Lepidoptera (20%) and Coleoptera (7%).

Berger-Parker dominance index (d) of floral visitors on thrum morph of buckwheat at initial, maximum and late bloom phases during 2024

The Berger-Parker dominance index values for floral visitors on thrum morph varied among initial (0.006-0.294), maximum (0.008-0.314) and late (0.006-0.284) bloom phase of buckwheat.*Apis cerana* F.wasmost dominant insect floral visitor with the highest 'd' value of 0.294, followed by *A. florea* Fab.(0.232) and *A. mellifera* L. (0.131).*Odontomyia ochropa* T.and *Paragus tibialis* F.(0.006) were the least dominant floral visitors duringinitial bloom phase. The maximum (166.67) abundance (1/d) values were observed in *Odontomyia ochropa* T.and *Paragus tibialis* F.whereas minimum (3.40) abundance (1/d) value was seen in *Apis cerana* F. during initial bloom phase. During maximum bloom phase, *A. cerana Fab*.was the most dominant floral visitor, with highest 'd' value of 0.314 followed by *A. florea* Fab. (0.235) and *A. mellifera* L. (0.134).*C. marginallus*W.,*M. discolor*F.,*C. hortivaga*K.,P*halanta phalantha*D. and *Eurema hecabe*L. were the least dominant floral visitors with each having 'd' value of 0.008.The maximum (125.00) abundance (1/d) values were observed in *C. marginallus*W.,*M. discolor*F.,*C. hortivaga*K.,*Phalanta phalantha*D. and *Eurema hecabe*L. whereas minimum (3.18) abundance (1/d) value was seen in *A. cerana* F. during maximum bloom phase. Similarly, *A. cerana* Fab.was the most dominant floral visitor, with the highest 'd' value of 0.284,followed by *A. florea* Fab. (0.238) and *A. mellifera* L. (144).*Micraspis discolor*F. was the least dominant visitor during late bloom phase, with 'd' value of 0.006.The maximum (166.67) abundance (1/d) value was observed in *M. discolor*F., whereas minimum (3.52) abundance (1/d) value was seen in *Apis cerana* F. during late bloom phase (Table 3).

Table 1: Floral visitors of buckwheat (*Fagopyrum esculentum* M.) during flowering period (2023-24)

Sl No.	Order	Family	Species	Reward collected
1		Crabronidae	*Cerceris hortivaga* K.	N
2			*Cerceris vagans* R.	N
3			*Tachysphere* sp.	N
4			*Apis cerana* F.	N+P
5	Hymenoptera	Apidae	*Apis mellifera* L.	N+P
6			*Apis dorsata* F.	N+P
7			*Apis florea* F.	N+P
8			*Xylocopa* sp.	N+P
9			*Braunsapis* sp.	N+P
10			*Ceratina sutepensis* Cockerell	N+P
11		Scoliidae	*Campsomariella collaris collaris* F.	N
12			*Campsomariella annulata* F.	N
13		Vespidae	*Delta conoideum* G.	N
14			*Labus* sp.	N
15			*Polistes stigma tamulus* F.	N
16		Chrysididae	*Chrysis angolensis* R.	N
17		Halictidae	*Seladonia* sp.	N+P
18			*Hoplonomia westwoodi*	N+P
19		Formicidae	*Camponotus pennsylvanicus* (De Geer)	N
20			*Camponotus cinctellus* G.	N
21			*Formica* sp.	N
22	Diptera	Calliphoridae	*Chrysomya marginallus* W.	N
23			*Chrysomya megacephala* F.	N
24		Syrphidae	*Syritta orientalis* M.	N
25			*Eristalis obliqus* W.	N
26			*Serratoparagus* sp.	N
27			*Paragus tibialis* F.	N
28			*Sphaerophoria sulphuripes* T.	N
29			*Halophilus pendulus* L.	N
30		Stratiomyidae	*Odontomyia ochropa* T.	N
31			*Hermetia illucens* L.	N
32		Rhiniidae	*Stomorhina* sp.	N
33			*Rhinia* sp.	N
34			*Stomorhina xanthogaster* W.	N
35		Muscidae	*Musca* sp.	N
36	Lepidoptera	Nymphalidae	*Danaus chrysippus* L.	N
37			*Phalanta phalantha* D.	N
38			*Hypolimnas bolina* L.	N
39		Pieridae	*Eurema hecabe* L.	N
40		Lycaenidae	*Lampides boeticus* L.	N
41			*Castalius rosimon* F.	N
42	Hemiptera	Coreidae	*Cletus trigonus* T.	N
43		Alydidae	*Riptortus linearis* L.	N
44		Pentatomidae	*Halyomorpha* sp.	N
45	Coleoptera	Coccinellidae	*Micraspis discolor* F.	P
46			*Coccinella* sp.	P

'd' value of floral visitors at different Phases of Bloom

Note: N-Nectar; P-Pollen

Table 2: Berger-Parker dominance index (d) of floral visitors on pin morph of buckwheat at initial, maximum and late bloom phases during 2024

	Pin					
	Initial		Maximum		Late	
	d	1/d	d	1/d	d	1/d
Apis cerana	0.340	2.94	0.293	3.41	0.330	3.03
Apis mellifera	0.125	8.00	0.153	6.54	0.129	7.75
Apis florea	0.240	4.17	0.261	3.83	0.231	4.33
***Rhinia* sp.**	0.016	62.50	0.000	0.000	0.000	0.000
Eristalis obliqus	0.019	52.63	0.027	37.04	0.015	66.67
Chrysomya marginallus	0.006	166.67	0.009	111.11	0.013	76.92
Campsomariella collaris	0.009	111.11	0.009	111.11	0.000	0.000
***Serratoparagus* sp.**	0.009	111.11	0.000	0.000	0.000	0.000
Syritta orientalis	0.037	27.03	0.042	23.81	0.042	23.81
Sphaerophoria sulphuripes	0.031	32.26	0.034	29.41	0.030	33.33
Odontomyia ochropa	0.006	166.67	0.000	0.000	0.000	0.000
Cerceris vagans	0.022	45.45	0.000	0.000	0.000	0.000
Halophilus pendulus	0.028	35.71	0.009	111.11	0.000	0.000
Danaus chrysippus	0.016	62.50	0.006	166.67	0.000	0.000
Eurema hecabe	0.006	166.67	0.006	166.67	0.013	76.92
***Tachysphere* sp.**	0.009	111.11	0.000	0.000	0.000	0.000
Ceratina sutepensis	0.025	40.00	0.018	55.56	0.000	0.000
***Seladonia* sp.**	0.016	62.50	0.000	0.000	0.000	0.000
Camponotus cinctellus	0.022	45.45	0.009	111.11	0.020	50.00
Camponotus pennsylvanicus	0.019	52.63	0.021	47.62	0.023	43.48
Paragus tibialis	0.000	0.000	0.000	0.000	0.000	0.000
***Stomorhina* sp.**	0.000	0.000	0.000	0.000	0.000	0.000
Micraspis discolor	0.000	0.000	0.009	111.11	0.010	100.00
***Haplonomia* sp.**	0.000	0.000	0.030	33.33	0.033	30.30
Polistes stigma tamulus	0.000	0.000	0.006	166.67	0.000	0.000
***Labus* sp.**	0.000	0.000	0.009	111.11	0.000	0.000
Castalius rosimon	0.000	0.000	0.003	333.33	0.013	76.92
Cerceris hortivaga	0.000	0.000	0.009	111.11	0.000	0.000
Campsomariella annulata	0.000	0.000	0.012	83.33	0.000	0.000
Hypolimnas bolina	0.000	0.000	0.006	166.67	0.010	100.00
Phalanta phalantha	0.000	0.000	0.006	166.67	0.000	0.000
***Braunsapis* sp.**	0.000	0.000	0.018	55.56	0.000	0.000
Chrysomya megacephala	0.000	0.000	0.000	0.000	0.017	58.82
***Formica* sp.**	0.000	0.000	0.000	0.000	0.013	76.92
Lampides boeticus	0.000	0.000	0.000	0.000	0.020	50.00
***Coccinella* sp.**	0.000	0.000	0.000	0.000	0.010	100.00

'd' value of floral visitors at different Phases of Bloom

Thrum

Table 3: Berger-Parker dominance index (d) of floral visitors on thrum morph of buckwheat at initial, maximum and late bloom phases during 2024

Floral visitors	Initial		Maximum		Late	
	d	1/d	d	1/d	d	1/d
Apis cerana	0.294	3.40	0.314	3.18	0.284	3.52
Apis mellifera	0.131	7.63	0.134	7.46	0.144	6.94
Apis florea	0.232	4.31	0.235	4.26	0.238	4.20
***Rhinia* sp.**	0.008	125.00	0.013	76.92	0.000	0.000
Eristalis obliqus	0.022	45.45	0.020	50.00	0.022	45.45
Chrysomya marginallus	0.017	58.82	0.008	125.00	0.013	76.92
Campsomariella collaris	0.014	71.43	0.010	100.00	0.000	0.000
***Serratoparagus* sp.**	0.011	90.91	0.000	0.000	0.000	0.000
Syritta orientalis	0.038	26.32	0.026	38.46	0.022	45.45
Sphaerophoria sulphuripes	0.035	28.57	0.043	23.26	0.041	24.39
Odontomyia ochropa	0.006	166.67	0.000	0.000	0.000	0.000
Cerceris vagans	0.022	45.45	0.000	0.000	0.000	0.000
Halophilus pendulus	0.017	58.82	0.013	76.92	0.016	62.50
Danaus chrysippus	0.011	90.91	0.010	100.00	0.000	0.000
Eurema hecabe	0.008	125.00	0.008	125.00	0.019	52.63
***Tachysphere* sp.**	0.008	125.00	0.000	0.000	0.000	0.000
Ceratina sutepensis	0.034	29.41	0.018	55.56	0.000	0.000
***Seladonia* sp.**	0.014	71.43	0.015	66.67	0.000	0.000
Camponotus cinctellus	0.025	40.00	0.010	100.00	0.028	35.71
Camponotus pennsylvanicus	0.028	35.71	0.000	0.000	0.022	45.45
Paragus tibialis	0.006	166.67	0.000	0.000	0.000	0.000
***Stomorhina* sp.**	0.014	71.43	0.000	0.000	0.000	0.000
Micraspis discolor	0.000	0.000	0.008	0.000	0.006	166.67
***Haplonomia* sp.**	0.000	0.000	0.035	28.57	0.031	32.26
Polistes stigma tamulus	0.000	0.000	0.010	100.00	0.000	0.000
***Labus* sp.**	0.000	0.000	0.013	76.92	0.000	0.000
Castalius rosimon	0.000	0.000	0.010	100.00	0.016	62.50
Cerceris hortivaga	0.000	0.000	0.008	125.00	0.000	0.000
Campsomariella annulata	0.000	0.000	0.013	76.92	0.000	0.000
Hypolimnas bolina	0.000	0.000	0.010	100.00	0.009	111.11
Phalanta phalantha	0.000	0.000	0.008	125.00	0.000	0.000
***Braunsapis* sp.**	0.000	0.000	0.015	66.67	0.000	0.000
Chrysomya megacephala	0.000	0.000	0.000	0.000	0.013	76.92
***Formica* sp.**	0.000	0.000	0.000	0.000	0.016	62.50
Lampides boeticus	0.000	0.000	0.000	0.000	0.022	45.45
***Coccinella* sp.**	0.000	0.000	0.000	0.000	0.009	111.11

Shannon-Wiener Index of diversity (H) of floral visitors (No./4 inflorescence/5mins) in buckwheat during different bloom phase, 2024

The diversity of floral visitors was highest during maximum blooming phase on pin (2.18) and thrum morph (2.29) compared to initial (2.13 & 2.28) and late blooming (2.17 &

2.27) phases. Irrespective of blooming phases the diversity of floral visitors was maximum on thrum morph compared to pin morph (Table 4&5). These findings were supported by Akter *et al.* (2023), who recorded that the Shannon-Wiener diversity index in buckwheat under open field condition for genus and species was 1.57 and 1.43 respectively at Dhaka, Bangladesh.

Number of flowers visited by *Apis* species of honey bees (No. of florets/4 bees/min) in open plot during different bloomingphases of buckwheat

In all the blooming phases, *A. cerana* started visiting the florets from 07:00-08:00 hrs (51, 52 and 51 florets/4 bees/min) and the number of florets visited increased gradually and reached maximum during 10:00-11:00 hrs (85, 68 and 63 florets/4 bees/min). Thereafter, the number of florets visited declined upto 13:00-14:00 hrs and then number of florets visited increased at 14:00-15:00 hrs (50, 51 and 50 florets/4 bees/min). Visitation of florets by *A. cerana*completelyceased from 16:00-18:00 hrs. These findings were supported by Rahman and Rahman (2000), who stated that the foraging activity of *A. cerana* F. was highest during 09:00 to 10:00 hrs with maximum number of 9.2 foragers/ m2/ min

A. florea started visiting the florets from 07:00-08:00 hrs (12, 14 and 18florets/4 bees/min) and the number of florets visited increased gradually and reached maximum during 09:00-10:00 hrs (53, 50 and 61 florets/4 bees/min). Thereafter, the number of florets visited declined upto 12:00-13:00 hrs and then number of florets visited increased at 13:00-14:00 hrs (36, 40 and 46 florets/4 bees/min).Florets visitation by *A. florea* ceased completelyfrom 16:00-18:00 hrs in all the blooming phases.

Florets visitation by*A. mellifera* started from 08:00-09:00 hrs (5, 49 and 49florets/4 bees/min) and the number of florets visited increased gradually and reached maximum during 10:00-11:00 hrs (92, 92 and 81 florets/4 bees/min). Thereafter, the number of florets visited declined upto 13:00-14:00 hrs and then number of florets visited increased at 14:00-15:00 hrs (57, 57 and 55 florets/4 bees/min).Florets visitation by *A. mellifera* ceasedcompletelyfrom 16:00-18:00 hrs in all the blooming phases.These findings were supported byAryal *et al.*(2016),who stated that the *Apis cerana* F. started their foraging activity from 8.24 ± 0.5 AM to 5.18 ± 0.2 PM while *A. mellifera* L. started foraging activity from 8.29 ± 0.5 AM to 4.56 ± 0.5 PM at Chitwan, Nepal.

Irrespective of blooming phases none of the bees from *Tetragonula iridipennis*visited the florets in open plot of buckwheat.

The mean number of flowers visited by*A. cerana* Fab (55.89, 58.56 and 54.56florets/4 bees/min) was highest compared to*A. mellifera* L. (44.63, 55 and 52.50florets/4 bees/min)and

A. florea Fab(29.44, 34.11 and 33.67florets/4 bees/min), this might be due to variation of foraging rate in terms of handling of floral rewards by the *Apis* species (Table 6).

Number of flowers visited by *Apis* species of honey bees (No. of florets/4 bees/min) in caged plot during different bloomingphases of buckwheat

In all the blooming phases, *A. cerana* started visiting the florets from 07:00-08:00 hrs (52, 52 and 50florets/4 bees/min) and the number of florets visited increased gradually and reached maximum during 10:00-11:00 hrs (102, 92 and 90 florets/4 bees/min). Thereafter, the number of florets visited declined at 13:00-14:00 hrs and then number of florets visited increased at 14:00-15:00 hrs (51, 69 and 79 florets/4 bees/min). Visitation of florets by *A. cerana*completelyceased from 16:00-18:00 hrs. These findings were supported by Dhakal (2003), who observed that *A. cerana* F. started foraging on buckwheat at 7.03±0.22 AM and ceased at 4.51±0.15 PM while, *A. mellifera* L. started foraging at 7.29±0.28 AM and ceased at 4.48±0.13 PM.

Florets visitation by*A. mellifera* started from 08:00-09:00 hrs (47, 56 and 51florets/4 bees/min) and the number of florets visited increased gradually and reached maximum during 10:00-11:00 hrs (89, 92 and 91 florets/4 bees/min). Thereafter, the number of florets visited declined at 12:00-13:00 hrs and then number of florets visited increased at 13:00-14:00 hrs (61, 66 and 60 florets/4 bees/min).Florets visitation by *A. mellifera* ceasedcompletelyfrom 16:00-18:00 hrs in all the blooming phases.These findings were supported by Aryal *et al.*, (2016), who recorded highest number of flowers visited by *A. cerana* F. at 10 AM. The number of flowers visited by *A. cerana* and *A. mellifera* was the lowest at 4 PM for both species of honeybees at Chitwan, Nepal.

Irrespective of blooming phases none of the *Tetragonula iridipennis*beesvisited the florets in caged plot of buckwheat.

The mean number of flowers visited by*A. cerana* Fab (62.44, 75.11 and 68.78florets/4 bees/min) was highest compared to*A. mellifera* L. (52.75, 63 and 58.88florets/4 bees/min),this might be due to variation of foraging rate in terms of handling of floral rewards by the *Apis* species. Non visitation of florets by *Tetragonula iridipennis*either in open or in caged plot might be due to the release of volatile compounds either from floral rewards or from parts of the plant (Table 7).

Table 4: Shannon-Wiener Index of diversity (H) of floral visitors (No. /4 inflorescence/5mins) on pin morph of buckwheat during different bloom phases(2024)

Initial blooming phase		Maximum blooming phase		Late blooming phase	
Floral visitors	**Total**	**Floral visitors**	**Total**	**Floral visitors**	**Total**
Apis cerana	109	*Apis cerana*	98	*Apis cerana*	100
Apis mellifera	40	*Apis mellifera*	51	*Apis mellifera*	39
Apis florea	77	*Apis florea*	87	*Apis florea*	70
Rhinia sp.	5	*Eristalis obliqus*	9	*Chrysomya megacephala*	5
Eristalis obliqus	6	*Chrysomya marginallus*	3	*Chrysomya marginallus*	4
Chrysomya marginallus	2	*Campsomariella collaris*	3	*Camponotus pennsylvanicus*	7
Campsomariella collaris	3	*Micraspis discolor*	3	*Camponotus cinctellus*	6
Serratoparagus sp.	3	*Syritta orientalis*	14	*Formica* sp.	4
Syritta orientalis	12	*Haplonomia* sp.	10	*Lampides boeticus*	6
Sphaerophoria sulphuripes	10	*Polistes stigma tamulus*	2	*Eurema hecabe*	4
Odontomyia ochropa	2	*Sphaerophoria sulphuripes*	10	*Castalius rosimon*	4
Cerceris vagans	7	*Labus* sp.	3	*Hypolimnas bolina*	3
Halophilus pendulus	9	*Castalius rosimon*	1	*Coccinella* sp.	3
Danaus chrysippus	5	*Cerceris hortivaga*	3	*Micraspis discolor*	3
Eurema hecabe	2	*Halophilus pendulus*	3	*Eristali obliqus*	6
Tachysphere sp.	3	*Danaus chrysippus*	2	*Syritta orientalis*	8
Ceratina sutepensis	8	*Eurema hecabe*	2	*Haplonomia* sp.	10
Seladonia sp.	5	*Ceratina sutepensis*	6	*Ceratina sutepensis*	5
Camponotus cinctellus	7	*Camponotus pennsylvanicus*	7	*Sphaerophoria sulphuripes*	13
Camponotus pennsylvanicus	6	*Campsomariella annulata*	4	*Campsomariella collaris*	3
		Camponotus cinctellus	3		
		Hypolimnas bolina	2		
		Phalanta phalantha	2		
		Braunsapis sp.	6		
Total	**321**	**Total**	**334**	**Total**	**303**
Shannon Wiener index 'H' value	**2.13**	**Shannon Wiener index 'H' value**	**2.18**	**Shannon Wiener index 'H' value**	**2.17**

Table 5: Shannon-Wiener Index of diversity (H) of floral visitors (No. /4 inflorescence/5mins) on thrum morph of buckwheat during different bloom phases(2024)

Initial blooming phase		Maximum blooming phase		Late blooming phase	
Floral visitors	**Total**	**Floral visitors**	**Total**	**Floral visitors**	**Total**
Apis cerana	105	*Apis cerana*	124	*Apis cerana*	91
Apis mellifera	47	*Apis mellifera*	53	*Apis mellifera*	46
Apis florea	83	*Apis florea*	89	*Apis florea*	76
Rhinia sp.	3	*Rhinia* sp.	5	*Chrysomya megacephala*	4
Eristalis obliqus	8	*Eristalis obliqus*	8	*Chrysomya marginallus*	4
Chrysomya marginallus	6	*Chrysomya marginallus*	3	*Camponotus pennsylvanicus*	7
Campsomariella collaris	5	*Campsomariella collaris*	4	*Camponotus cinctellus*	9
Serratoparagus sp.	4	*Micraspis discolor*	3	*Formica* sp.	5
Syritta orientalis	15	*Syritta orientalis*	15	*Lampides boeticus*	7
Paragus tibialis	2	*Haplonomia* sp.	14	*Eurema hecabe*	6
Sphaerophoria sulphuripes	12	*Polistes stigma tamulus*	4	*Castalius rosimon*	5
Odontomyia ochropa	2	*Sphaerophoria sulphuripes*	14	*Hypolimnas bolina*	3
Stomorhina sp.	5	*Labus* sp.	5	*Coccinella* sp.	3
Cerceris vagans	8	*Castalius rosimon*	4	*Micraspis discolor*	2
Halophilus pendulus	6	*Cerceris hortivaga*	3	*Halophilus pendulus*	5
Danaus chrysippus	4	*Halophilus pendulus*	5	*Eristali obliqus*	7
Eurema hecabe	3	*Danaus chrysippus*	4	*Syritta orientalis*	7
Tachysphere sp.	3	*Eurema hecabe*	3	*Haplonomia* sp.	10
Ceratina sutepensis	12	*Ceratina sutepensis*	7	*Ceratina sutepensis*	5
Seladonia sp.	5	*Seladonia* sp.	6	*Sphaerophoria sulphuripes*	13
Camponotus cinctellus	9	*Campsomariella annulata*	5	*Campsomariella collaris*	5
Camponotus pennsylvanicus	10	*Camponotus cinctellus*	4		
		Hypolimnas bolina	4		
		Phalanta phalantha	3		
		Braunsapis sp.	6		
Total	**357**	**Total**	**395**	**Total**	**320**
Shannon Wiener index 'H' value	**2.28**	**Shannon Wiener index 'H' value**	**2.29**	**Shannon Wiener index 'H' value**	**2.27**

Table 6: Number of florets visited by major bee floral visitors (No. of florets/4 bees/min.) in open plot during different blooming phase of buckwheat, 2024

***Apis* species**	**Initial bloom phase**				**Maximum bloom phase**				**Late bloom phase**			
Time (hrs)	***A. c***	***A. f***	***A. m***	***T. i***	***A. c***	***A. f***	***A. m***	***T. i***	***A. c***	***A. f***	***A. m***	***T. i***
06:00-07:00	0.00	0.00	0.00	---	0.00	0.00	0.00	---	0.00	0.00	0.00	---
07:00-08:00	51.00	12.00	0.00	---	52.00	14.00	0.00	---	51.00	18.00	0.00	---
08:00-09:00	65.00	21.00	5.00	---	67.00	24.00	49.00	---	62.00	45.00	49.00	---
09:00-10:00	65.00	53.00	12.00	---	99.00	50.00	51.00	---	79.00	61.00	50.00	---
10:00-11:00	85.00	36.00	92.00	---	68.00	39.00	92.00	---	63.00	45.00	81.00	---
11:00-12:00	49.00	35.00	65.00	---	49.00	38.00	65.00	---	51.00	35.00	62.00	---
12:00-13:00	46.00	34.00	46.00	---	47.00	36.00	46.00	---	47.00	26.00	43.00	---
13:00-14:00	46.00	36.00	43.00	---	46.00	40.00	43.00	---	45.00	46.00	41.00	---
14:00-15:00	50.00	33.00	57.00	---	51.00	32.00	57.00	---	50.00	20.00	55.00	---
15:00-16:00	46.00	5.00	37.00	---	48.00	34.00	37.00	---	43.00	7.00	39.00	---
16:00-17:00	0.00	0.00	0.00	---	0.00	0.00	0.00	---	0.00	0.00	0.00	---
17:00-18:00	0.00	0.00	0.00	---	0.00	0.00	0.00	---	0.00	0.00	0.00	---
Mean	**55.89**	**29.44**	**44.63**	**---**	**58.56**	**34.11**	**55.00**	**---**	**54.56**	**33.67**	**52.50**	**---**
SE (m)±	**4.43**	**4.83**	**9.92**	**---**	**5.76**	**3.41**	**6.09**	**---**	**3.82**	**5.73**	**4.88**	**---**
Florets visited/bee	**13.97**	**7.36**	**11.15**	**---**	**14.64**	**8.52**	**13.75**	**---**	**13.63**	**8.41**	**13.13**	**---**

A. c- *Apis cerana* ***A. f-*** *Apis florea* ***A. m-*** *Apis mellifera* ***T. i-*** *Tetragonula iridipennis*

Table 7: Number of florets visited by major bee floral visitors (No. of florets/4 bees/min.) in caged plot during different blooming phase of buckwheat, 2024

Apis species Time (hrs)	Initial bloom phase			Maximum bloom phase			Late bloom phase		
	A. c	***A. m***	***T. i***	***A. c***	***A. m***	***T. i***	***A. c***	***A. m***	***T. i***
06:00-07:00	0.00	0.00	---	0.00	0.00	---	0.00	0.00	---
07:00-08:00	52.00	0.00	---	52.00	0.00	---	50.00	0.00	---
08:00-09:00	68.00	47.00	---	54.00	56.00	---	52.00	51.00	---
09:00-10:00	99.00	49.00	---	90.00	88.00	---	65.00	85.00	---
10:00-11:00	102.00	89.00	---	92.00	92.00	---	90.00	91.00	---
11:00-12:00	49.00	37.00	---	88.00	63.00	---	83.00	61.00	---
12:00-13:00	47.00	43.00	---	85.00	35.00	---	81.00	34.00	---
13:00-14:00	46.00	61.00	---	83.00	66.00	---	54.00	60.00	---
14:00-15:00	51.00	55.00	---	69.00	58.00	---	79.00	47.00	---
15:00-16:00	48.00	41.00	---	63.00	46.00	---	56.00	42.00	---
16:00-17:00	0.00	0.00	---	0.00	0.00	---	0.00	0.00	---
17:00-18:00	0.00	0.00	---	0.00	0.00	---	0.00	0.00	---
Mean	**62.44**	**52.75**	**---**	**75.11**	**63.00**	**---**	**68.78**	**58.88**	**---**
SE (m)±	**7.52**	**5.85**	**---**	**5.36**	**6.84**	**---**	**5.17**	**7.10**	**---**
Florets visited/bee	**15.61**	**13.19**	**---**	**18.77**	**15.75**	**---**	**16.94**	**14.72**	**---**

A. c*- Apis cerana* ***A. f****- Apis florea* ***A. m****- Apis mellifera****T. i****- Tetragonula iridipennis*

Nectar foraging duration of *Apis* species of honeybees on pin and thrum morphs of buckwheatduring maximum bloom phase

The times spent for collection of nectar from pin and thrum morphs of buckwheat by the honey bees varied significantly during different hours of the day (Table 8).

The foragers of *A. cerana* spent least foraging duration (3.25sec/flower) on the pin morph during 09:00-10:00 hrs for nectar collection. The duration for nectar foraging gradually increased and reached a maximum (4.50sec/flower) during 12:00 to 13:00 hrs and then declined to 3.00seconds per flowerduring15:00-16:00 hrs. The foragers of *A. florea*spent least foraging duration (3.50sec/flower) on the pin morph during 08:00-09:00 hrs for nectar collection. The duration for nectar foraging gradually increased and reached a maximum (12.75sec/flower) during 12:00 to 13:00 hrs and then declined to 7.00 seconds per flowerduring15:00-16:00 hrs. Similarly, the foraging duration of *A. mellifera* for nectar collection gradually increased from 08:00-09:00 hrs (3.25sec/flower) and reached a maximum (6.75sec/flower) during 11:00 to 12:00 hrs and then declined to 3.00seconds per flower during 15:00-16:00 hrs. The *A. florea* Fab. spent maximum mean foraging duration for the collection of nectar (8.06±2.91sec/flower) compared to *A. mellife*ra L. (4.25±1.41sec/flower) and *A.cerana* Fab.(3.59±0.48sec/flower).

The foragers of *A. cerana* spent least foraging duration (4.00sec/flower) on the thrum morphduring 08:00-09:00 hrs for nectar collection. The duration for nectar foraging gradually increased and reached a maximum (5.00sec/flower) during 09:00 to 10:00 hrs and then declined to 4.25seconds per flowerduring15:00-16:00 hrs.These findings were supported by Rahman and Rahman (2000) who stated that the time spent (3.2 sec/floret) was maximum during 09:00 to 10:00 hrs indicating that was the best time for foraging. The foraging activity declined gradually during the evening hours of the day attaining minimum of 0.8 at 16:00 hrs at Jorhat, Assam.

The foragers of *A. florea*spent least foraging duration (8.75sec/flower) on the thrum morph during 09:00-10:00 hrs for nectar collection. The duration for nectar foraging gradually increased and reached a maximum (10.50sec/flower) during 10:00 to 11:00 hrs and then declined to 8.75seconds per flowerduring15:00-16:00 hrs. Similarly, the foraging duration of *A. mellifera* gradually increased from 08:00-09:00 hrs (3.25sec/flower) and reached a maximum (5.00sec/flower) during 12:00 to 13:00 hrs and then declined to 4.25seconds per flower during 15:00-16:00 hrs. *A. florea* Fab. spent maximum mean foraging duration for the collection of nectar (8.44±1.22sec/flower) compared to *A. mellife*ra L. (4.13±0.68sec/flower)

and *A.cerana* Fab.(4.09±0.55 sec/flower). The variation in the nectar foraging duration of honey bee species either from pin/thrum morph among different hours might be due to the variation in size of proboscis of honey bee species for sucking of nectar from the flowers and also due to preferential quantity and TSS concentration of nectar or the bigger species (*A. mellifer*a L.) may be more efficient/quicker compared to the smaller species (*A. florea* Fab.) in gathering the nectar.The study by Waddington and Herbst (1987), revealed that both the time a bee takes to visit a flower (Inouye, 1980) and sometimes (i.e., when the corolla is deep in relation to proboscis length) the amount of nectar taken from the flower depend on proboscis length. The shape of the bees body matches the shape of flowers influences how much effort it takes and how much nectar it gathers, which in turn affects how the bee chooses to forage.

Pollen foraging duration of *Apis* species of honeybees on pin and thrum morphs of buckwheatduring maximum bloom phase (2024)

The time spent for collection of pollen from pin and thrum morphs of buckwheat by the honey bees varied significantly among the different hours of the day (Table 9).

The foragers of *A. cerana* spent least foraging duration (2.50sec/flower) on the pin morphduring 09:00-10:00 hrs for pollen collection and maximum (4.50sec/flower) during 10:00 to 11:00 hrs. The foragers of *A. florea* spent least foraging duration (5.25sec/flower) on the pin morphduring 07:00-08:00 hrs for pollen collection and maximum (7.75sec/flower) during 08:00 to 09:00 hrs. The foragers of *A. mellifera* spent least foraging duration (3.50sec/flower) on the pin morphduring 08:00-09:00 hrs for pollen collection and maximum time (5.00sec/flower) during 10:00 to 11:00 hrs.The *Apis florea* Fab. spent maximum mean foraging duration for the collection of pollen(6.65±0.91sec/flower) compared to *Apis mellifer*a L. (4.15±0.55sec/flower) and *Apis cerana* Fab. (3.60±0.82sec/flower).

The foragers of *A. cerana* spent least foraging duration (2.75sec/flower) on the thrum morphduring 11:00-12:00 hrs for pollen collection and maximum (3.75sec/flower) during 09:00 to 10:00 hrs.These findings were supported by Singh (2008), who recorded that the time spent by *A. cerana* F. on the buckwheat inflorescence at 09.00 AM was longest (24 ± 3 min) and it decreased at 12.00 PM (20 ± 3 min) and it reached to 16 ± 3 min. at 15.00 PM on buckwheat flowers at Kathmandu, Nepal.The foragers of *A. florea* spent least foraging duration (5.75sec/flower) on the thrum morph during 07:00-08:00 hrs for pollen collection and maximum (7.75sec/flower) during 09:00 to 10:00 hrs. The foragers of *A. mellifera* spent least foraging duration (3.25sec/flower) on the thrum morph during 07:00-10:00 hrs for pollen collection and maximum (4.25sec/flower) during 11:00 to 12:00 hrs.The *Apis florea* Fab.

spent maximum mean foraging duration for the collection of pollen(6.60±0.78sec/flower) compared to *Apis mellife*ra L. (3.55±0.41sec/flower) and *Apis cerana* Fab. (3.10±0.38sec/flower).The variation in the pollen foraging duration of honey bee species either from pin/thrum morph during different hours of the day might be due to variation in the amount of pollen offered by the flowers to bee species.

Table 8: Nectar foraging duration of *Apis* species of honeybees on pin and thrum morphs during maximum blooming phase of buckwheat

***Apis* species** **Time (hrs)**	**Pin morph**			**Thrum morph**		
	A. cerana	***A. florea***	***A. mellifera***	***A. cerana***	***A. florea***	***A. mellifera***
06:00-07:00	0.00^{c}	0.00^{d}	0.00^{d}	0.00^{c}	0.00^{d}	0.00^{d}
07:00-08:00	0.00^{c}	0.00^{d}	0.00^{d}	0.00^{c}	0.00^{d}	0.00^{d}
08:00-09:00	3.50^{ab}	3.50^{cd}	3.25^{bc}	4.00^{ab}	9.00^{ab}	3.25^{bc}
09:00-10:00	3.25^{b}	7.00^{bc}	4.00^{bc}	5.00^{a}	8.75^{ab}	4.75^{ab}
10:00-11:00	4.00^{ab}	10.50^{ab}	3.25^{bc}	3.50^{b}	10.50^{a}	4.25^{abc}
11:00-12:00	3.50^{ab}	9.75^{ab}	6.75^{a}	4.50^{ab}	8.25^{abc}	4.25^{abc}
12:00-13:00	4.50^{a}	12.75^{a}	5.25^{abc}	4.25^{ab}	8.50^{abc}	5.00^{a}
13:00-14:00	3.75^{ab}	8.25^{abc}	5.50^{ab}	4.00^{ab}	6.25^{c}	3.00^{c}
14:00-15:00	3.25^{b}	5.75^{bc}	3.00^{c}	3.25^{b}	7.50^{bc}	4.25^{abc}
15:00-16:00	3.00^{b}	7.00^{bc}	3.00^{c}	4.25^{ab}	8.75^{ab}	4.25^{abc}
16:00-17:00	0.00^{c}	0.00^{d}	0.00^{d}	0.00^{c}	0.00^{d}	0.00^{d}
17:00-18:00	0.00^{c}	0.00^{d}	0.00^{d}	0.00^{c}	0.00^{d}	0.00^{d}
Mean±SD	**3.59±0.48**	**8.06±2.91**	**4.25±1.41**	**4.09±0.55**	**8.44±1.22**	**4.13±0.68**
F test	*	*	*	*	*	*
SE (m)±	**0.43**	**1.77**	**0.80**	**0.46**	**0.83**	**0.59**
CD @5%	**1.23**	**5.10**	**2.29**	**1.32**	**2.40**	**1.70**
CV	**35.73**	**65.96**	**56.14**	**33.66**	**29.62**	**43.09**

Note: *-Significant at p=0.05

Table 9: Pollen foraging duration of *Apis* species of honeybees on pin and thrum morph during maximum blooming phase of buckwheat

***Apis* species** **Time (hrs)**	**Pin morph**			**Thrum morph**		
	A. cerana	***A. florea***	***A. mellifera***	***A. cerana***	***A. florea***	***A. mellifera***
06:00-07:00	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}
07:00-08:00	3.00^{b}	5.25^{b}	4.25^{ab}	3.00^{ab}	5.75^{b}	3.25^{a}
08:00-09:00	4.00^{a}	7.75^{a}	3.50^{b}	3.00^{ab}	6.00^{ab}	3.50^{a}
09:00-10:00	2.50^{b}	6.50^{ab}	4.00^{ab}	3.75^{a}	7.75^{a}	3.25^{a}
10:00-11:00	4.50^{a}	7.00^{ab}	5.00^{a}	3.00^{ab}	6.75^{ab}	3.50^{a}
11:00-12:00	4.00^{a}	6.75^{ab}	4.00^{ab}	2.75^{b}	6.75^{ab}	4.25^{a}
12:00-13:00	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}
13:00-14:00	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}
14:00-15:00	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}
15:00-16:00	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}
16:00-17:00	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}
17:00-18:00	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}
Mean±SD	**3.60±0.82**	**6.65±0.91**	**4.15±0.55**	**3.10±0.38**	**6.60±0.78**	**3.55±0.41**
F test	*	*	*	*	*	*
SE (m)±	**0.34**	**0.76**	**0.38**	**0.31**	**0.68**	**0.47**
CD @5%	**0.96**	**2.19**	**1.08**	**0.91**	**1.96**	**1.35**
CV	**44.70**	**54.96**	**43.52**	**48.75**	**49.51**	**63.40**

Note: *-Significant at p=0.05

4. CONCLUSION

Forty-six insect floral visitors were documented during different bloom phases, which werebelonged to 5 insect orders and 19 families. *Apis cerana* F. being the most dominant visitorthroughout blooming phase. The diversity of floral visitors was highest during maximum bloom phase on pin and thrum morph as compared to initial and late blooming phases. Among the dominant bee floral visitors,*A. cerana*visited more number of florets followed by *A. mellifera*and *A. florea*during maximum blooming phase.The foraging duration of *A. florea*for collection of nectar and pollen from pin and thrum morphs was highest among the major bee floral visitors recorded during maximum bloom phase. Based on foraging rate,it is suggested for the farmer to keep *A. cerana* and *A. mellifera* bee hives for better pollination.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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