International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 04-01-2024, Accepted: 21-01-2024, Published: 05-02-2024
Volume 9, Issue 2, 2024, Page No. 5-9

Diversity and relative abundance of honey bee species (Hymenoptera: Apidae) on black mustard (*Brassica nigra*) in agroecosystems of Nainital district, Uttarakhand

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Abstract
Investigation was carried out on diversity and relative abundance of *Apis* species on *Brassica nigra* during blooming period (February- April 2023) in croplands of Khurpatal (Site I) and Mangoli (Site II) villages, located in hilly areas of district Nainital, Uttarakhand. Diversity studies revealed that two *Apis* species—*Apis dorsata* and *Apis cerana indica*—visited the black mustard flowers. The number of honey bees (irrespective of species) foraging were comparatively higher during full bloom rather than the onset and end of flowering. Among the two species observed, the maximum population per m^2/10 min (by sweep net method) was found to be of *A. cerana indica* (34.78) and (36.2) at Site I and Site II, respectively. However, the population per m^2/10 min of *A. dorsata* was found to be (6.86) and (7.18) at Site I and Site II, respectively. Both the diversity indices i.e., Shannon diversity index and Evenness index was found to be highest in Mangoli village (H= 0.4554) (E= 0.657) followed by Khurpatal village (H= 0.4516) (E= 0.6516). However, Margalef's index appeared to be higher in Khurpatal village (d= 0.1316) followed by Mangoli village (d= 0.130). Besides, *A. mellifera* and *A. florae* also contribute in pollination services but these were not observed in the croplands during the study period.

Keywords: Agroecosystems, *Brassica nigra*, diversity, honey bees, relative abundance

Introduction
In India, honeybees were conventionally reared for honey production for many centuries and they are indeed a major pollinator which helps in increasing crops productivity. There are only 5 per cent of the forest plants that doesn't require an obligatory pollinator for their pollination whereas insects pollinate around 95% of plants [34]. Approximately 90% of them are pollinated by insects [3, 27]. The diet of entire human population is composed of almost one-third of insect-pollinated plants, with honey bees pollinating 80% of those plants [6]. Many workers have recognized bees as the major pollinators of the crops [1, 2, 21, 25, 33]. In India foraging behavior of *Apis* sp. has been recorded by different workers on different crops in different localities [11, 16, 35].
Brassica flowers, because of their bright yellow color and fragrance, are very attractive for pollinators. Additionally, they are a good supply of pollen and nectar [19]. According to the estimation, 80% of the insect pollination is performed by bees in wild as well as in commercial crops [4]. Honeybees have also been recognized as the recurrent visitor of mustard blossoms [7].
Despite having amazing vegetation, Nainital was not thoroughly investigated to identify the precise honeybee population. Beekeepers are unable to fully utilize their domesticated honey bees because farmers and indigenous people lack knowledge of the potential of honey bees to increase crop yield. The goal of the current study was to assess the diversity and number of honey bees in regions of Nainital.

Materials and Methods
Study Area
The study area was croplands of Nainital district, located in southern Uttarakhand, northern India. It is located at 79.58°E 29.36°N and has an average elevation of 1948m (6,385 ft) asl. The town is known for its beautiful views of the highlands of the outer Himalayas. It has plenty of legends and myths surrounding its history. Naini Lake, a large natural lake is considered the main landmark of the area. A survey was made to select the study sites.

Sampling Sites
According to the survey, four *Apis* species were selected i.e., *A. dorsata*, *A. cerana indica*, *A. mellifera*, and *A. florea*. Further, two sampling sites were selected for the study. (Figure- 1)

Fig 1: Study Area

Site I. Khurpatal: The first site was Khurpatal village in Nainital district, Uttarakhand, India. It is situated 10 km away from Nainital hill station. It is located at 29.37°N and 69.42°E, at an average elevation of 1635m asl.

Site II. Mangoli: The second site was Mangoli village, in Nainital district in Uttarakhand, India. It is situated 17 km

away from Nainital hill station. It is located at 29.35°N and 79.40°E, at an average elevation of 520m asl.

Out of all the agricultural commodities grown in these villages, such as, *Coriandrum sativum* (Coriander), *Pisum sativum* (Green Peas), *Brassica nigra* (Black Mustard), *Daucus carota* (Carrot) and *Raphanus sativus* (Radish). *Brassica nigra* (Black Mustard) was selected as it was the most preferred food by the honey bees.

Fig 2: Sampling Sites

Specimen Collection and Identification

Quadrates of 1 m^2 were placed in the crop field and manual counting of honey bee visitation was done at the start of each hour for 10 min. Observations were recorded for five days of flowering period, using a stopwatch (with an accuracy of 0.01 second) following the method given by Free [8]. Honey bees visiting the respective blossoms were collected with sweep nets [9]. Sweepings were made at hourly intervals i.e., 900-1000, 1000-1100. 1100-1200, 1200-1300, 1300-1400, 1400-1500, 1500-1600, 1600-1700, 1700-1800 and 1800-1900 hr [17]. The collected insects were kept in ethyl acetate-soaked cotton jars. Later were set into wooden boxes and labelled. These were identified as per available literature.

Statistical Analysis

$$\text{Relative abundance of Species} = \frac{Number\ \ of\ indi viduals\ \ of\ species\ \ (A)}{Total\ number\ \ of\ all\ honey\ \ bees} \times 100$$

Shannon-Wiener diversity Index

$$H(S) - \sum_{i=1}^{s} pi\ lnpi$$

Evenness Index

$$E = {}^{H}/_{\ln S}$$

Margalef's Index

$$d = \frac{(S-1)}{lnN}$$

Results & Discussion

Diversity: The analysis of honey bee diversity on *Brassica nigra* flowers is presented in Table 1. Two species of honey Bee were found on the study area *viz*., Indian hive bee *A. cerana indica* and Rock bee *A. dorsata*. Out of which, *A. cerana indica* was the major visitor contributing 3472 individuals followed by *A. dorsata* with 704 individuals. No specimen of *A. mellifera* and *A. florea* were observed during the study period. The diversity indices; Shannon Wiener's diversity index was maximum at Site II (H= 0.4554) followed by Site I (H= 0.4516). Similarly, Evenness (E) was highest at Site II (E= 0.6570) followed by Site I (E= 0.6516). However, Margalef Index was found to be maximum at Site I (d= 0.1316) followed by Site II (d= 0.1300).

Table 1: Diversity indices of Honey bee species at Nainital

	Site I (Khurpatal)	Site II (Mangoli)
No. of Species	2	2
Individuals	1990	2186
Shannon (H)	0.4516	0.4554
Evenness (E)	0.6516	0.657
Margalef (d)	0.1316	0.130

Relative Abundance of Honey bee species on Black Mustard flowers: A total of 4176 individuals of different honeybees were recorded during the study. 1990 specimens were observed in Khurpatal whereas, 2186 specimens were observed in Mangoli village. *A. cerana indica* was found to be the dominant species (83.14%) followed by *A. dorsata* (16.85%). (Figure- 3).

(a) **(b)**

Fig 3: Honey bee species foraging on *Brassica nigra* (Black Mustard): (a) *Apis cerana* (b) *Apis dorsata*

Data on relative abundance of honey bees on *B. nigra* flowers at different hr of the day is calculated and presented in Table 2 (Site I) and Table 3 (Site II). Irrespective of different bee species, highest population was recorded during 1300-1400 hr of the day (12.45 bees/m^2/10 min) at Site I and (12.95 bees/m^2/10 min) at Site II. Lowest population was recorded during 0900-1000 hr i.e., (9.0 bees/m^2/10 min) at Site I and (9.15 bees/m^2/10 min) at Site II.

Table 2: Abundance of bee species on *B. nigra* throughout the day during February- April 2023 at Nainital (Site I)

Bee Species	Bees/m^2/10 min during different day hr											
	0900-1000	1000-1100	1100-1200	1200-1300	1300-1400	1400-1500	1500-1600	1600-1700	1700-1800	1800-1900	Mean (±SE)	SD
A. cerana	30.6	32.8	33.6	34.2	40.4	40.2	36.2	34.0	33.0	30.8	34.58±1.08	3.42
A. dorsata	5.4	5.4	7.2	7.2	9.4	9.2	7.0	6.2	5.8	5.8	6.86±0.46	1.45
Mean	18.0	19.1	20.4	20.7	24.9	24.7	21.6	19.9	19.4	18.3	-	-

Table 3: Abundance of bee species on *B. nigra* throughout the day during February- April 2023 at Nainital (Site II)

Bee Species	Bees/m^2/10 min during differernt day hr											
	0900-1000	1000-1100	1100-1200	1200-1300	1300-1400	1400-1500	1500-1600	1600-1700	1700-1800	1800-1900	Mean (±SE)	SD
A. cerana	31.8	33.4	35.0	38.2	42.0	41.4	39.0	35.6	33.8	31.8	36.2±1.18	3.75
A. dorsata	4.8	6.4	6.0	7.2	9.8	9.4	7.6	8.0	6.8	5.8	7.18±0.49	1.57
Mean	18.3	19.9	20.5	22.7	25.9	25.4	23.3	21.8	20.3	18.8	-	-

Reagrdless of different hr of observation, *A. cerana indica* per m^2/10 min was observed to be maximum at both the sites *viz*; 34.58 and 36.2 bees, at Site I and Site II, respctively. However, number of *A. dorsata* was recorded to be 6.86 and 7.18 bees.

Data in Table 4 and Table 5 revealed that the abundance of honey bees per m^2/10 min was maximum at full bloom stage at both the sites, 10.95 bees (08/03/23) at Site I and 11.3 bees (09/03/23) at Site II. While at the comencement and cessation of flowering, comparatively lower number of honey bees were recorded, 9.07 bees (10/02/23) and 10.45 bees (11/02/23) at Site I and Site II, repectively.

Table 4: Relative Abundance of bee species on *B. nigra* at different dates of observation during February- April 2023 at Nainital (Site I)

Date of observation	Bees/m^2/10 min				
	A. cerana	*A. dorsata*	*A. mellifera*	*A. florea*	Mean
10/02/23	30.9	5.4	0	0	18.15
23/02/23	35.5	6.8	0	0	21.15
08/03/23	36.1	7.7	0	0	21.9
21/03/23	35.6	7.3	0	0	21.45
03/04/23	34.8	7.1	0	0	20.95
Mean	34.58	6.86	0	0	-

Table 5: Relative Abundance of bee species on *B. nigra* at different dates of observation during February- April 2023 at Nain ital (Site II)

Date of Observation	Bees/m^2/10 min				
	A. cerana	*A. dorsata*	*A. mellifera*	*A. florea*	Mean
11/02/23	35.3	6.5	0	0	20.9
24/02/23	36.2	7.2	0	0	21.7
09/03/23	37.1	8.1	0	0	22.6
22/03/23	36.6	7.6	0	0	22.1
04/04/23	35.8	6.4	0	0	21.1
Mean	36.2	7.1	0	0	-

The richness and abundance of honey bee species plays an important role in pollination of *B. nigra*. In our study, *A. cerana indica* was observed to be the dominant species (83.14%) followed by *A. dorsata* (16.85%). These results are in accordance with Rahman (1940) [26], who reported that this bee was available at more than 2000 meters of elevation asl. Our findings are also supported by Koeniger (1976) [15] who reported that *A. cerana* is found in colder areas like Northern China, and high mountain areas of Himalayas. Nainital is located in the Kumaon foothills of outer Himalayas.

Highest population of honey bees were recorded during

1300-1400 hr of the day (12.45 bees/m^2/10 min) at Site I and (12.95 bees/m^2/10 min) at Site II. Lowest population was recorded during 0900-1000 hr i.e., (9.0 bees/m^2/10 min) at Site I and (9.15 bees/m^2/10 min) at Site II. The results are in conformity with the earlier findings of Kapil and Brar (1971) [12], who revealed that *A. dorsata* and *A. cerana indica* commenced foraging at 0700- 1000 hr on mustard and rapeseed, and the highest foraging activity was recorded between 1230 and 1400 hr and ceased by 1700 hr. Schinohara (1987) [30] concluded from his research that *Apis* were the most frequent visitors, primarily in the afternoon. The results are also in accordance with Mishra *et al.* (1988) [23], who revealed that the highest population of Honey bee species was observed between 1300-1400 hr of the day on mustard flowers. The foraging activity of *A. cerana indica* and *A. dorsata* started between 0900-1000 hr and ceased at 1800-1900 hr. According to them *A. cerana indica's* highest foraging activity was noted between 1300 and 1400 hr on mustard flowers in Solan, Himachal Pradesh, India. Kasina (2007) [13] measured the highest *Apis* density on sunflower between 10:00 a.m. and 2:00 p.m. Nderitu *et al.* (2008) [24] confirms that hymenopteran species activities on plum were maximum around 1300-1400 hr, and then dropped. Relative abundance peaked at 12:00 pm. Singh (2008) [32] recorded the maximum foraging activity of *Apis* species at 1200 hr, followed by 1000, 1400 and 1600 hr on parental lines of *Brassica napus.* Wadhwa and Sihag (2015) [37] reported that irrespective of insect species, the abundance on flowers was lesser in the morning time at 700 hr- 1000 hr and reached at peak level in the afternoon, 1300 hr. They observed a slight decrease in abundance between 1500 and 1700 hr in the evening.

Analysis of abundance at different days of observation revealed that maximum population of honey bees was recorded during full bloom stage (11.17 bees/m^2/10 min) on 01/03/23 at Site I, while it was (11.37 bees/m^2/10 min) on 10/03/23 at Site II. However, least population was observed at onset of bloom (9.22 bees/m^2/10 min) which was at par with cessation time (9.67 bees/m^2/10 min) at Site I. While at Site II, (10.02 bees/m^2/10 min) at the onset of bloom and (10.85 bees/m^2/10 min) by the end of bloom were obseerved. Our results are in accordance with the earlier findings of Kendell and Smith (1975) [14], Willson and Price (1977) [39], Schaffer and Schaffer (1979) [28], Schemske (1980) [29], and Dhaliwal and Atwal (1985) [5] that at full bloom stage, there are maximum number of flowers and so greater number of pollinators visit these flowers, which helped maximize pollination. Mishra *et al.* (1976) [22], Verma (1990) [36] and Mattu and Mattu (2010) [20] also reported that honeybees constituted a major proportion of insect pollinators on crops in Shimla hills. According to several recent research, both domesticated and wild native bees play a vital part in crop pollination. (Winfree *et al.* 2007) [40].

Conclusion

According to our investigation, mustard crop receives the greatest number of honey bee visits during its full bloom stage since there are more flowers available at that time. Consequently, it is evident that number of flowers affects the number and visits of pollinators, which in turn affects the degree of pollination. A few species of *A. dorsata* are found in the study area. The presence of this species at high altitude could be possibly due to habitat loss, climate change, and pollution in foothills, plains, and urban areas and this may have somewhat increased the average temperature of the study area and availability of *A. dorsata*. The possible reason of non- availability of *A. mellifera* and *A. florea* in the study area could be because of high altitude and lower temperature during the study period.

Acknowledgement

The authors are thankful to beekeepers of Nainital district, Mr. Jagdish Chandra Shah, and Mr. Tej Singh Mehra for their help in the field survey. We are also grateful to Head, Department of Zoology, D. S. B. Campus, Kumaun University, Nainital, for providing the necessary facilities.

References

1. Abd Rabou *et al*. Predators of scale insects (Hemiptera) and their role in control in Egypt. *Acad. J. Biol. Sci*,2012:5(3):203-9.
2. Arora GS. Lepidoptera: fauna of conservations area: fauna of Nanda Devi Biosphere Reserve. *Zool. Survey*,1997:IN.9:67-88.
3. Buchman LS, Nabhan PG. The forgotten pollinators. Island press, Wahington DC, USA, 1996, 292.
4. Corbet SA, Williams IH, Osborne JL. Bees and the pollination of crops and wild flowers in the European Community. *Bee World*,1991:72(2):47-59.
5. Dhaliwal JS, Atwal AS. Effect of age of crop, plant spacing, soil moisture and phosphatic fertilizers on bee activity on *Brassica* crop. *Inter India Publi*, 1985, 91-101.
6. FAO, Pollination of cultivated plants in the tropics. *Agric. Serv. Bull*,1995:118:98.
7. Free JB, Nuttall PM. The pollination of oil seed rape (*Brassica rape*) and the behavior of bees on the crop. *J Agric Sci*,1968:71:91–4.
8. Free JB. Insect pollination of crops. London, UK: Academic Press, 1993, 684.
9. Gadagkar R, Chandrashekhara K, Nair P. Insects' species diversity in tropics: sampling method and case study. *Bombay Nat Hist Soc*,1990:87(3):328-53.
10. Hill MO. Diversity and its evenness, a unifying notation, and its consequences. Ecology,1973:54:(2):427-32.
11. Joshi PC, Sharma R. Population density and secondary net production of above ground Entomofauna of a cropland field, *Uttar Pradesh. Zool*,1998:18(1):1-4.
12. Kapil RP, Brar HS. Foraging behaviour of *Apis florea* F. in relation to *Brassica campestris* var. toria. In: Proceedings XXII *International Apiculture Congress*, Moscow, 1971, 335.
13. Kasina M. *et al*. Sunflower pollinators in Kenya: Does diversity influence seed yield? African Crop Science Conference Proceedings,2007:8:1149-1153.
14. Kendell DA, Smith BD. The forging behavior of honey bee on ornamental *Malus* spp. used as pollinizers in apple orchards. *J Appl Ecol*,1975:12:465-71.
15. Koeniger N. Interspecific competition between Apis florea and Apis mellifera in the tropics. Bee World,1976:57(3):110-112.
16. Kumar R, Chaudhary OP, Lenin JK. Studies on the foraging behavior of honey bees and their role as pollinators of sunflower (*Helianthus annuus* L.). *Indian Bee J*,1994:56:207-210.

17. MacKay PA, Knerer G. Seasonal occurrence, and abundance in a community of wild bees from an old field habitat in southern Ontario. The Can Entomol,1979:111(3):367-76.
18. Margalef's R. Temporal succession and spatial heterogeneity in phytoplankton. In: Perspectives in Marine biology, Berkeley: University Calif. Press, 1970, 323-47.
19. Masierowska ML. Floral nectaries and nector production in brown mustard Evolution,2003:238:97-107.
20. Mattu VK, Raj H, Thakur ML. Foraging behavior of honeybees on apple crop and its variation with altitude in Shimla hills of western Himalaya. International Journal of Science and Nature,2012:3:296–301.
21. Michener C. The bees of the world. Johns Hopkins University Press, 2000.
22. Mishra RC, Dogra GS, Gupta PR. Some observations on insect pollinators of apple. Indian Bee Journal,1976:38:20-22.
23. Mishra RC, Kumar J, Gupta JK. The effect of mode of pollination on yield and oil potential of *Brassica campestris* L. Var. sarson with observations on insect pollinators. Journal of Apicultural Research,1988:27(2):186-189.
24. Nderitu J, Nyama SYO, Ka M, Sina ML. Diversity of sunflower pollinators and their effect on seed yield in Makueni District, Eastern Kenya. Spanish Journal of Agricultural Research,2008:6(2):271-278.
25. Palot MJ, Radhakrishnan C. New larval food plants of *Euploea* core (Cramer) (Lepidoptera: Insect), *Zoos Print J*,2001:16(10):614.
26. Rahman KA. Insect pollinations of toria (*Brassica napus* L. var Dichotoma prain) and sarsoon (*Brassica campestris* L. var sarson Prain) at Lyallpur. Indian Journal of Agricultural Sciences,1940:10(3):422-442.
27. Richards AJ. Plant breeding systems. New York: Chapman Hall, 1986, 135-88.
28. Schaffer WM, Schaffer MV. The adaptive significance of variations in reproductive habit in the Aguacate II: Pollinator foraging behaviour and selection for increased reproductive expenditure. Ecology,1979:60:1051-1069.
29. Schemske DW. Floral ecology and humming bird pollination of *Combretum farinosum* in Coste Rice. *Bitropica*,1980:12:169-171.
30. Schinohara RK. Importancia da polinizaçao entomofila na cultura do girassol-Zootecnia, São Paulo,1987:25(3):275-287.
31. Shannon CE, Wiener W. The Mathematical theory of communications, University of lllinois Press, Champaigh, 1963.
32. Singh J. Foraging frequency and pattern of movement of different *Apis* spp. On parental lines of *Brassica napus* L. *Entomon*,2008:33(2):91-99.
33. Taha EA, Bayoumi YA. The value of honey bees (*Apis mellifera*, L.). As pollinators of summer seed watermelon (*Citrullus lanatus colothynthoides* L.) in Egypt. *Acta Biol Szegediensis*,2009:53(1):33-7.
34. Tewari GN, Singh K. Role of pollinators in vegetable seed production. Indian bee journal, 1983, 45-51.
35. Verma LR, Dutta PC. Foraging behavior of *Apis cerana indica* and *Apis mellifera* in pollinating apple flowers. *J. Apic. Res*,1986:25:197-201.
36. Verma LR. Beekeeping. In: Integrated mountain development: economic and scientific perspectives. ICIMOD senior fellowship series, (V50B). Oxford and IBH Publishing Co. Pvt. Ltd, India, 1990, 4. ISBN 81-204-0538-2
37. Wadhwa N, Sihag RC. Melittophilous mode of pollination predominates in European plum (*Prunus domestica* L.) in the semi-arid environment of Northwest India. Asian Journal of Agricultural Research,2015:9(5):189-207.
38. Williams *et al.* Variation in native bee faunas and its Implication for Detecting Community Changes. *Conserv Ecol*,2001:5(1):7.
39. Willson M, Price PW. The evolution of inflorescence size in Asclepias (*Asclepiadaceae*). Trop Agric,1977:54:353-56.
40. Winfree RNM, Williams J, Duschoff, Kremen C. Native bees provide insurance against ongoing honey bee losses. Ecology Letters,2007:10:1105-1113.