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Comparative Foraging Behavior of Apis cerana indica and Apis dorsataon Brassica cropin the Agroecosystems ofWestern Himalayan Region, Uttarakhand

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Abstract: The research conducted in the Black Mustard fields of Mangoli village (540m), situated in the Nainital district, and provides a valuable and significant perspective on the foraging behavior of honey bee pollinators visiting the flowers of Brassica crops. Apis cerana exhibited a significantly longer foraging duration, achieved its peak activity level, and took more time to complete a single foraging trip on Black mustard inflorescences compared to Apis dorsata. Conversely, A. dorsata demonstrated a higher visitation rate, visiting a significantly greater number of flowers per minute. The findings revealed that the highest frequency of flower visits occurred at 1100 hours. The average foraging rate was highest for A. cerana indica (10.2 bees/minute), followed by A. dorsata (2.3 bees/minute). Furthermore, the visitation rate peaked for A. dorsata at 10.3 flowers/minute, while A. indica followed closely at 8.75 flowers/minute. The average time spent by both Apis species on individual flowers at various times of the day was recorded at 0.330 seconds for A. dorsata and 0.773 seconds for A. indica.

Keywords: Foraging, Apis cerana indica, Apis dorsata, Pollination, Brassica nigra

Introduction

The interplay between plants and pollinators is pivotal in connecting intricate food webs within ecosystems and driving co-evolution among insect-plant species [1]. The rich diversity of pollinators is essential for the successful production of seeds in flowering plants. These pollinators provide a critical ecosystem service that underpins the reproductive success of many plants. Their roles extend beyond mere pollination; they are integral to maintaining the health and stability of most terrestrial ecosystems, ensuring a robust food web and promoting biodiversity[3].Research indicates that approximately 90% of flowering plant species rely on insect pollination, with bees being the primary pollinators for most angiosperms globally. The absence of this service could lead to the collapse of interconnected species and processes in natural and agricultural ecosystems, significantly impacting agricultural productivity. Therefore, pollination is a vital ecological service provided by

pollinators, with direct implications for agricultural productivity.The Brassica nigra plant bears a cluster of bright yellow flowers with a strong aroma, which effectively attracts numerous pollinators. Research by Kunjwalet al. (2014) [4] highlights the pivotal role of honey bees in the pollination process of Brassica plants. Given the crucial role pollinators play in the survival and proliferation of diverse plant species, their presence is vital to both the conservation of ecosystems and the effective use of agricultural resources. This study aims to explore the complex behaviors of honey bees as they interact with Brassica nigra crops, a significant player in agricultural economics. By examining these interactions, this research uncovers valuable insights into the dynamics of honey bee pollination and its impact on crop yield. Ultimately, it aims to provide practical recommendations for farmers to optimize pollination strategies and enhance the productivity of Brassica crops.

Materials and Methods

Experimental Location

The research was conducted on Black Mustard in the farmlands of Mangoli village, a location chosen for its representative characteristics of the Western Himalayan Region, Uttarakhand. The crop's vegetation period spanned from November 2022 to May 2023. The study area was located at an average elevation of 540 m above sea level, with coordinates of 29.35°N, 79.40°E. Located 18 kilometers southwest of Nainital, this village offers a valuable opportunity for ecological research, particularly in pollination ecology. The area is rich in diverse flora and fauna, creating an ideal environment for studying the interactions between plants and their pollinators.

Foraging Behavior

Throughout the research, various aspects of the foraging behavior of two honey bee species, specificallyApis cerana indica and Apis dorsata, were meticulously observed and recorded. This included visitation frequency, visitation rate, stay time, and foraging time.All observations were documented at hourly intervals throughout the blooming season, from the start of flowering through peak bloom to the end. We tallied the number of honey bees, calculated the average population, and identified the dominant species. The aspects were meticulously observed and recorded, ensuring the reliability of our findings.The collected data were consolidated, tabulated, and then analyzed using analysis of variance (ANOVA), with significance tested at the 5% level.

Results

Studies on the foraging behavior of honeybees, Apis cerana and Apis dorsata, regarding visitation frequency, visitation rate, and stay time, have been summarized in Tables 1 and 2.Apis cerana indica (Fig. 1) and Apis dorsata (Fig. 2) were observed

foraging on Black Mustard inflorescences from 0800 h to 1700 h throughout the crop's flowering period.

Figure2. Apis cerana indica

Figure3. Apis dorsata

Table1. Foraging activity of Apis cerana indica on Brassica nigra at hourly intervals

Time (hours)	Visitation Frequency	Visitation Rate	Stay Time
0800-0900	5.35	4.85	0.276
0900-1000	5.55	5.25	0.383
1000-1100	6.50	5.90	0.480
1100-1200	10.20	8.75	0.773
1200-1300	7.4	6.35	0.567
1300-1400	7.2	6.30	0.588
1400-1500	7.25	6.25	0.605
1500-1600	8.85	7.8	0.702
1600-1700	5.8	5.25	0.515
1700-1800	5.35	4.7	0.483

CD (P=0.05)	**0.584**	**0.701**	**0.046**
SEM	0.203	0.244	0.016

Table2. Foraging activity of Apis dorsata on Brassica nigra at hourly intervals

Time (hours)	Visitation Frequency	Visitation Rate	Stay Time
0800-0900	0.800	5.1	0.082
0900-1000	1.0	6.65	0.118
1000-1100	1.15	7.6	0.168
1100-1200	2.3	10.3	0.330
1200-1300	1.05	7.75	0.189
1300-1400	1.05	7.6	0.207
1400-1500	1.05	7.6	0.216
1500-1600	1.75	9.1	0.266
1600-1700	1	6.35	0.144
1700-1800	1	6	0.127
CD (P=0.05)	**0.382**	**1.20**	**0.027**
SEM	0.133	0.418	0.009

Both species exhibited significant variations in their total visitation counts, visitation rates, and duration of stay. Apis cerana indica was recognized as the dominant species within the study area. The visitation frequency (number of bees/flower/minute) for A. indica reached its peak at 1100h, with 10.20 bees/min, followed by a count of 8.85 bees/min recorded at 1500h. The frequency of flower visitation declined as the day progressed towards evening. At 0900h and 1600h, a lower number of bees was documented, precisely 5.55 bees/min and 5.8 bees/min, respectively. The lowest population was noted at 0800h, registering 5.35 bees/min. The maximum visitation rate (flowers visited/minute) was recorded at 1100h, reaching 8.75 bees/min, whereas the minimum rate was observed at 1700h at 4.7 bees/min. Furthermore, the stay time (duration spent on each flower/minute) for A. cerana indica was 0.702 sec and 0.276 sec, the highest and lowest, respectively.

Apis dorsata initiated foraging activities on Black mustard blooms at 0800h, with a recorded rate of 0.80 bees/minute. The highest population of foraging bees was documented at 1100h, reaching 2.3 bees/minute, followed by 1.75 bees/minute at 1500h. Notably, a lower population was recorded at 1000h, with a count of 1.15 bees/minute. The lowest population was again observed at 0800h, maintaining a count of 0.80 bees/minute. The visitation rate peaked at 1100h (10.3 bees/minute) and reached its minimum at 0800h (5.1 bees/minute). In addition, the duration of time that Apis dorsata spent on individual flowers was recorded at a maximum of 0.330 seconds per minute and a minimum of 0.082 seconds per minute.

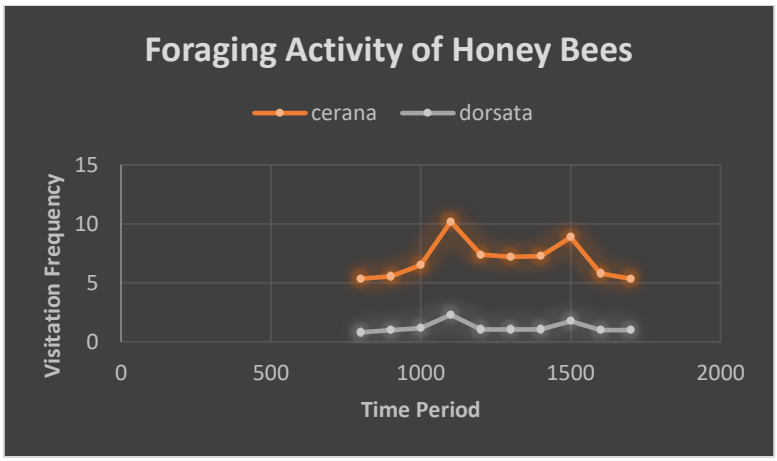

Fig4. Graphical Representation of Foraging Activity of Bee Species A.cerana and A.dorsata during different hours of the day.

Discussion

The current findings align closely with those of Mupadeet al. (2009) [5], who noted that honey bees began visiting the crop at 0800 h, reached peak numbers between 1300 and 1600 h, and gradually decreased from 1600 to 1800 h. This pattern is consistent with the findings of Oh and Woo (1990) [6], who identified a similar trend in the foraging behavior of two honey bee species that increased during the morning hours, reaching a peak before slightly declining and then rising again in the evening, only to decrease again afterwards, although foraging activity persisted even beyond that point. They observed that insect activity sharply rises after sunrise, gradually declines throughout the day, and ceases before sunset.

Our conclusions are in line with those of previous researchers. Kumar and Singh (2008) [7] found that Apis dorsata exhibited peak foraging activity on safflower crops at 1100 h and had the lowest activity at 1500 h. Meanwhile, Singh (2008) [8] noted that the highest foraging activity of Apis species occurred at 1200 h. Painkraet al. (2014) [9, 10] also found that the foraging activity of Apis cerana indica peaked at 1100 h (51.10 bees/5min/m^2) and was at its lowest at 1700 hours (3.5 bees/5min/m^2), while Apis dorsata showed maximum activity at 1100 hours (8.20 bees/5min/m^2) and the least activity at 1500 h (2.10 bees/5min/m^2). Yucel and Duman (2005) [11] reported that honeybee workers foraged on onion plants between 0815 and 1630 h, with the peak activity occurring between 1100 and 1200 h.

Our results correspond closely as well with those of Painkraet al. (2014) [12], who found the peak foraging activity for Apis indica was at 1100 h (115.00 bees/5min/m^2), while for Apis dorsata, it was also at 1100 h (30.00 bees/5min/m^2). The lowest activity level was recorded at 1700 h (5.00 bees/5min/m^2).In other of his studies, Painkra (2016) [13] noted the foraging behavior of rock bees, Apis dorsata, visiting Lajwanti grass, with peak visitation between 1000 and 1100 h, followed by a low between 1600 and 1700 h, and then activity at 0800 to 0900 h.

Another study by Painkra (2018) [14] observed the foraging behavior of Apis dorsata on Ageratum conyzoides. The highest activity was observed at 1100 h (2.77 bees/5min/m2), and the lowest at 1700 h (0.72 bees/5min/m^2).

Our research shows that A. dorsata achieves an impressive flower visitation rate of 10.3 flowers/minute, surpassing that of A. indica at 8.75 flowers/minute. This finding reinforces the insights of Mostajeranet al. in 2006 [15], who observed that bees with larger wings tend to have enhanced flying capabilities than those with smaller wings. This suggests that rock bees, characterized by their relatively larger wings, can effectively visit more flowers in a shorter timeframe. Moreover, A. dorsata, with its larger body size, exhibits a notably higher pollen deposition rate than other familiar floral visitors, underscoring its significant role in pollination.

Utilizing pollinators, especially honey bees, is widely recognized as one of the most cost-effective and environmentally sustainable approaches to boost the productivity of crops that depend on cross-pollination. By facilitating pollen transfer between flowers, these industrious insects play a crucial role in increasing fruit and seed production, ultimately enhancing agricultural yields and supporting ecosystem health (Free 1970, Pateel and Sattagi 2007). [16, 17]. Numerous studies have consistently shown that the yield can be boosted by as much as 50-60% in fruit and plantation crops, 45-50% in sunflower, sesame, and niger, and by 100-150% in cucurbit crops through effective pollinator management (Melnichenko AN, Khalifman IA., 1960) [18].

Scientists have proposed an intriguing idea: the combination of heavy morning dew and brisk cold winds might be causing a dip in foraging activity. This fascinating insight has its roots in studies dating back to the 1920s (Wilson, 1926, 1929; Free, 1960) [19-21], inviting us to consider how weather conditions can influence animal behavior.

Conclusion

Recent findings indicate that mustard flowers are highly attractive to various species of Apis. These bees are particularly effective at collecting pollen due to their specialized structures, such as pollen baskets. Among the different species, Apis cerana indica and Apis dorsata are identified as the primary visitors to mustard flowers. These findings not only deepen our understanding of bee behavior but also invite us to consider how we might enhance conditions to support their foraging efforts, preserving the delicate balance of our ecosystem.

However, it is crucial for farmers to exercise caution when using insecticides to manage insect pests, as these chemicals can adversely affect beneficial insect populations, including honeybees. Therefore, it is recommended that farmers adopt a more rational approach to insecticide use or consider implementing biological control methods. It also underscores the need for further research in this area to fully

comprehend the complexities of pollination ecology and to develop effective strategies for the conservation and utilization of agricultural resources.This area of study presents opportunities for further research and exploration.

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