**Diversity and Foraging Behaviour of Honey bee (*Apis mellifera*) in Relation to Abiotic Factor Under Open Field Condition in Linseed Crop**

**Abstract**

The present study entitled “Diversity and Foraging Behaviour of Honey bee (*Apis mellifera*) in Relation to Abiotic Factor Under Open Field Condition in Linseed crop” was carried out on Linseed variety “Sharda” at the Entomology research field situated at Heera Puri Research Farm, Institute of Agriculture and Natural Sciences, Deen Dayal Upadhyaya Gorakhpur University Gorakhpur, Uttar Pradesh during the *Rabi* season 2023- 2024. The linseed variety “Sharda” was sowing in the field using three replications with division 8 treatment including plot size (4m×3m) by using randomized block design. The observation was started in morning (8000 h.) to evening (1700 h.) for conduct to understand the effect of abiotic factors on the foraging intensity, foraging rate and foraging speed of *Apis mellifera*. The results revealed that the maximum foraging intensity was observed (11.57 bees/m2/minute) in 18th SW during the period of 1000-1200 hours whereas the minimum foraging intensity was observed (3.83 bees/m2/minute) in 13th SW during the time interval of 1500-1700 hours. However, the results were observed that the foraging rate has been maximum (10.51flowers/minute) in 16th SW during the period of 1000-1200 hours, whereas the minimum foraging rate was observed (3.76 flowers/minute) during the period of 1500- 1700 hours in 13th SW. Furthermore, the maximum foraging speed was observed (6.18 second/flower) in 18th SW during the period of 8000-1000 hours. Whereas the minimum time spend per flower was observed (1.02 second/flower) in 20th SW during the period of 1500- 1700 hours. The data revealed that the correlation coefficient of relative abundance, foraging rate and foraging speed of honey bee was positive correlated to the weather parameter (Tmax. & Tmin.) whereas the negative correlated with the relative humidity during (morning and evening) and rainfall.

**Keywords:** *Apis mellifera*,foraging behaviour, correlation, regression, abiotic factor.

**INTRODUCTION**

The sole species in the family Linaceae with commercial and agronomic significance is linseed, also known as flax (*Linum usitatissimum* L.), an important oilseed crop that is a member of the Order Malpighiales and family Linaceae. The family comprises 14 genera and over 200 species (Tadesse *et al*., 2009). Within the field crop category, oilseed crops are the second most important factor influencing agricultural economy, after cereals. The growth rates of seasonal oilseed crops, such as sunflower, safflower, Niger, and linseed, are low because these crops are regarded as secondary sources of vegetable oil; flax stem is used to prepare fiber for the linen industry (Sutar *et al*., 2022). Approximately 80% of the total amount of linseed oil produced in India is used by industries to make a variety of products, such as paints, varnish, oilcloth, linoleum, and printing ink, with the remaining 20% being used by farmers (Dash *et al*., 2017). Linseed seeds contain 33-43% oil of drying type and 24% protein. Oil of linseed includes big amount of unsaturated fatty acids; it is extensively utilized in paint industries. Linseed oil has 75% linoleic acid and 17% linoleic acid (Arshad *et al*., 2000). It is utilized as feed (oil cakes), food (dietary fibers, minerals, and omega-3 fatty acids), and medicine (it has anti-inflammatory, phytoestrogen, and antioxidant qualities) (Toure and Xueming, 2010) and (Chopra and Badiyala, 2016). Globally, 32.63 lakh hectares of linseed are grown, yielding 31.82 lakh tons with an average productivity of 975 kg per hectare (Anonymous, 2019). Canada holds the top spot in the world for flax seed production and exports, having done so since 1994. In India, the crop occupies 1.8 lakh ha, producing and producing 1.1 lakh tonnes and 671 kg/ha, respectively. The top four states for linseed production are Madhya Pradesh, Jharkhand, and Odisha, which account for 65% of the total area and 64% of the total production (Anonymous, 2020). Although linseed is typically thought of as a self-pollinating crop, cross-pollinating has been shown to boost vigor and output. Insects often perform cross-pollination, and they are primarily responsible for increasing fruit set through pollination services (Eradasappa and Mohana, 2016). A valuable social insect are honey bees. Honey bees are essential to agricultural crop pollination (Muttu *et al*., 2012). Farmers see honeybees as their favorite social insects. Because they yield honey as well as other goods like bee wax, propolis, and venom, these are extremely important. Pollination is the honeybee's most prized activity. About 81% of crops that are pollinated by insects are produced by honey bees, who are a significant pollinator among all insect pollinators. Honey bees acquire pollen by flying from blossom to blossom on all the flowering plants in the field. Pollination is the process by which pollen is transported. Crop productivity increases as a result of honey bee pollination (Muhammad *et al*., 2019). In Russia, the results of honeybee pollination indicated a 19% increase in seeds per capsule, a 22% rise in seed weight overall, and a 2.2% weight increase per seed. It is impossible to discount the importance of honey bees as pollinators in raising agricultural crop yields (Nest *et al*., 2012). About 51 million hectares of cross-pollinated crops, which are mostly visited by bees in search of pollen, nectar, or both, make up half of India's total land area (Gatoria *et al*., 1996). The importance of bees as pollinators grows along with the woods; in this day and age of industrial agriculture, natural pollinator habitats are being destroyed in addition to the widespread use of pesticides that harm natural foes. Furthermore, as the number of people in India rises, the amount of forest area-which serves as many wild bug species' ideal natural habitat-is diminishing. Today, both native *Apis cerana indica* and foreign *Apis mellifera* are used in beekeeping in India. In addition to increasing output, bee pollination enhances the quality of several seed species, such as linseed, which matures uniformly and yields a crop earlier. For linseed to be more productive, bee colonies must be available during the crop's flowering phase. Because linseed is a rich supply of nectar and pollen, it draws a wide variety of insect pollinators, such as honeybees. Even at the current level of land usage for linseed farming, a nationwide planned bee pollination program greatly helps to meet worldwide demand and foreign exchange (Navatha *et al*., 2012). Keeping in view the use of honeybee and other pollinators to increase the yield both quantitatively and qualitatively, the present study is planned to understand the Foraging behaviour and relative abundance of honey bee species in Linseed flowers and Impact on weather parameter on foraging behaviour of honey bees.

**MATERIALS AND METHODS**

The field experiment was carried out at the Entomology research field situated at Heera Puri Research Farm, Institute of Agriculture and Natural Sciences, Deen Dayal Upadhyaya Gorakhpur University Gorakhpur. Gorakhpur is situated in eastern region of Uttar Pradesh and situated within latitude 26.7547610 N and longitude 83.3840370 E. with an altitude of 75 meters above the mean sea level. The research filed is under Agro climatic Zone IV north eastern plain region. Gorakhpur has humid subtropical dry winter climate. The region typically receives about 108.83 millimetres (4.28 inches) of precipitation mostly concentrated from middle June to September with occasional showers in winters, has 86.46 rainy days annually. The relative humidity of Gorakhpur is around 68% although it varies from 38% during summer (May) to 84% during the monsoon (August). The hot season lasts for around 3 months from March to last June with average daily temperature above 34.44˚C. The hottest month of the year in Gorakhpur region is June with an average high of 36.11˚ C and low of 27.22˚ C, the cool season last for around 2 months from December to February with an average daily temperature below 24.44˚C and the coldest month of the year in Gorakhpur is January with an average low of 10˚C and high of 21.66˚C. The metrological data were obtained from the nearby Metrological observatory. The experimental site was uniform with sandy loam garden soil having medium fertility and fairly good drainage. Soil is medium in organic carbon and nitrogen. The *PH* value of the soil is 6.5-7.5. Soil is medium in organic carbon and nitrogen. The recommended Linseed variety Sharda was sown in a plot size of 4m×3m, with row to row and plant to plant spacing of 20cm and 10cm, respectively.

**Foraging intensity, foraging rate and foraging speed**

Foraging intensity, foraging rate and foraging speed of *Apis mellifera* was observed at different hours of the day from 08:00-17:00 hours at two hours intervals weekly from one square meter area from the locations already marked randomly in the crop. Simultaneously, weather parameters were also recorded and relationship between weather parameters and insect visitors were worked out using statistical methods.

**Relative abundance of *Apis mellifera* on *Linum usitatissimum* L.**

Abundance (number of bees/m2/minute) of Honey bees visiting on Linseed flower- heads were recorded at different hours of the day starting from 08:00 h in the morning to 17:00h in the evening at an interval of two hours. Observations were recorded at the open pollinated plots. For studying the relative abundance, population of insect pollinators was recorded by taking direct count on flower heads of the plants covering an area of one square meter in each replication. Five such places were selected randomly for taking insect counts.

## Foraging rate of *Apis mellifera* on *Linum usitatissimum* L.

Foraging rates of *Apis mellifera* were recorded in terms of number of flowers visited per minute by an individual bee using the method given by Kumar and Rao (1991). At each time, foragers were marked and their movement was followed as long as possible. During the course of their movement, total number of flower visited per minute was calculated for *Apis* spp. The number of flower visited per minute included the flying time from one flower to another flower.

## Foraging speed of *Apis mellifera* on *Linum usitatissimum* L.

Foraging speed of *A. mellifera* was evaluated through the time spent on a single flower by the foragers. Total of three bees of *Apis mellifera* were observed for recording foraging speed. Handling time i.e. the time spent to insert the proboscis and suck up the nectar or brushing/collecting pollen was considered as the time spent per flower which was recorded with the help of a stop watch.

**Data analysis**

To assess the foraging behavior we used the theory of Karl Pearson correlation coefficient. The correlation between two variables X and Y is typically represented by the symbol ‘r’. It is a numerical indicator of the linear relationship between two variables and is calculated as the product of the standard deviations of the two variables X and Y and the covariance between X and Y. The data of pollinators behavior were subjected to statistical analysis using analysis of variance (ANOVA), followed by means comparison with Least Significant Difference (LSD) at P = 0.05.

**RESULTS AND DISCUSSION**

**Foraging intensity of *Apis mellifera* on Linseed (*Linum usitatissimum* L.) crop during the year of 2024.**

Foraging intensity (number of pollinators visited/m2/minute) of Honey bees on *Linum usitatissimum* L. variety Sharda flowers was recorded at weekly interval (March, 2024 - May, 2024) during different time intervals between (0800-1700 h) of the day. Table 1 and figure 1 demonstrate the foraging intensity of *A. mellifera* on linseed crop over different standard weeks and time intervals in 2024. The weekly mean intensity of honey bees varied from 5.04 to 9.11 bees/m2/minute corresponding to the 13th and 18th SW of blooming, respectively. The minimum foraging intensity was observed 3.83 bees/m2/minute during the period of 1500-1700 hours in 13th SW of blooming. Whereas the maximum foraging intensity was observed 11.57 bees/m2/minute during the time intervals of 1000-1200 hours followed by 9.52 bees/m2/minute during the period of 1300-1500 hours in 18th SW. Whereas in 15th SW which was statistically at par with 16th SW and in case of 14th SW which was statistically at par with 19th SW in same period of time 0800-1000 hours. In the same way in 19th SW was statistically at par with 20th SW during the period of 1500-1700 hours.

(Singh *et al*., 2020) found a similar result when they studied the abundance of *A. mellifera* (4.31 bees/m2/minute), *A. dorsata* (2.57 bees/m2/minute), and *A. cerana indica* (1.98 bees/m2/minute), all of which were nearby to the current findings. (Usman *et al*., 2018)similarly showed that the greatest activity of *A. mellifera* occurred between 1000- 1500 hours (Pradeep, 2018) reported that the foraging intensity of bees ranged from 4.16 to 16.08 bees/m2/minute for *A. mellifera* and from 1.02 to 2.69 bees/m2/minute for *A. dorsata* during full blooming phases of crop, which is consistent with the findings of the current study. According to (Painkra, 2019), the highest population of *A. mellifera* was found at 1200 hours (6.57 bees/5min/m2), followed by 1000 hours (4.97 bees/5min/m2), and the lowest population was found at 0800 hours (1.85 bees/5min/m2). (Chaudhary, 2006), (Kant *et al*., 2013), (Patil and Pastagia, 2016) all reported the foraging intensity of *A. mellifera* and *A. cerana indica*, which agrees with the current findings. (Singh *et al*., 2017) found that *A. mellifera* (3.83/m2/minute), *A. dorsata* (2.41/m2/minute), and *A. cerana indica* (1.83 /m2/minute) have the highest foraging intensity, which is similar to the results of our study. (Meena *et al*., 2015), (Bhowmik *et al*., 2017) and (Amin *et al*., 2018)are some of the researchers that agree with our findings.

**Foraging rate of *A. mellifera* on Linseed (*Linum usitatissimum* L.) crop during the year of 2024.**

Table 2 and figure 2 show the data on the number of flowers visited per minute by *A. mellifera* on linseed flowers. The weekly mean foraging rate of *A. mellifera* on linseed flowers recorded during different SW varied from 3.76 to 10.51 flowers visited/minute respectively, corresponding to the 13th and 18th SW of the blooming period. After gradually increasing to the greatest level during the peak flowering time, i.e. the 18th SW among 10.51 flowers visited/minute it gradually decreased to 3.76 flowers visited/minute as the flowering 13th SW came to a close. The mean foraging rate of *A. mellifera* bees throughout different day hours ranged from 4.78 to 9.67 flowers visited per minute, in virtue of 13th to 18th SW and the foraging rate of honey bee was statistically at par in 13th and 14th SW during the period of 1000- 1200 hours followed by 17th SW and 15th SW during the period of 1000- 1200 hours respectively.

The findings of (Dalio, 2018), who noted that the Asian bee, *A. cerana*, visited more flowers per minute (18.10), followed by *A. mellifera* (17.36) and *A. dorsata* (13.87), provided support for the present investigation's conclusions. *A. florea* had a relatively modest foraging rate (7.53flowers/min). According to (Srivastava *et al*., 2017), *A. dorsata* had the highest mean 68 foraging rate (5.35 ± 0.33 flowers/min), followed by *A. mellifera* (4.87 ± 0.34 flowers/min), *A. cerana* (1.75 ± 0.23 flowers/min), and *A. florea* (0.11 ± 0.09 flowers/min) with the lowest mean foraging rate. *A. cerana, A. mellifera, A. dorsata*, and *A. florea* were found to have their average maximum foraging rates during the hours of 1100–1300, 1300–1500, 1100–1300, and 0900–1100, respectively, according to (Vishwakarma and Chand, 2017). (Devi *et al*., 2016) found that *A. cerana* (12.67) had the highest foraging rate (18.54 flowers visited/minute) in the broccoli bloom, followed by *A. mellifera* (12.07), *A. dorsata* (10.55), and *A. florea* (1.89). They also found that the mean foraging rate (regardless of the species of honey bee) varied throughout the day, peaking between 1100–1300 h. (10.74) and lowest between 1700–1900 hours (7.31).

**Foraging speed of *A. mellifera* on Linseed (*Linum usitatissimum* L.) crop during the year of 2024.**

The data on time spent per flower by *A*. *Mellifera* on Linseed flowers have been presented in Table 3 and figure 3 Foraging speed of *A*. *Mellifera* on Linseed flowers observed during different weeks over the times revealed that the weekly mean foraging speed ranged between 1.02 to 6.18 seconds/flower corresponding to 20th and 18th SW of the blooming period, respectively. The maximum time spent per flower by *A. mellifera* (6.18 second/flower) whereas second highest (6.09second/flower) was in 18th SW during the period of 0800-1000 and 1000-1200 hours whereas least time spent by *A*. *mellifera* (1.02 second/flower) was recorded at 1500-1700 hours during 20th SW of the observation. The weekly mean foraging speed of *A. mellifera* was varied from 1.67 to 4.35 second/flower corresponding to the 20th and 18th SW of full blooming period.

However, *A. mellifera* had the fastest foraging speed, (2.25 s) and (2.24 s) at 12:00 pm and 2:00 pm), on brown mustard flowers, followed by *A. dorsata* (1.05 s) at 2:00 pm and *A. cerana* (0.74 s) at 4:00 pm, according to (Kunjwal *et al.,* 2014). When measured simultaneously at 1200-1400 hours, the minimum time spent per flower by *A. mellifera, A. cerana indica,* and *A. dorsata* was 2.38 seconds, 2.02 seconds, and 2.97 seconds; on *B. juncea*, however, *A. florea* spent the least amount of time per flower (4.23 seconds) during 0800-1000 hours. In contrast to the current findings, **(**Devi *et al*.,2011) from Orissa observed that *A. mellifera* spent 2.20 to 2.80 seconds on mustard flowers on average throughout 1200 h, and that the minimum amount of time was spent on the plant during 1600 h.

**Table 1 Foraging intensity of *A. mellifera* on Linseed ( Linum usitatissimum L.) crop during the year of 2024.**

|  |
| --- |
|  Average numbers of honey bee/m²/minute during four different time intervals of the day |
| Std. week |  Time hr. |
| 0800-1000 | 1000-1200 | 1300-1500 | 1500-1700 |  Mean |
| 13th | 4.01(2.22) | 6.37(2.67) | 5.96(2.63) | 3.83(2.19) | 5.04 |
| 14th | 5.36(2.50) | 5.69(2.58) | 5.26(2.49) | 4.06(2.23) | 5.09 |
| 15th | 6.26(2.67) | 6.46(2.72) | 7.34(2.88) | 4.27(2.29) | 6.08 |
| 16th | 6.29(2.68) | 7.19(2.85) | 6.95(2.81) | 6.22(2.68) | 6.66 |
| 17th | 9.44(3.22) | 8.35(3.03) | 8.18(3.02) | 5.18(2.48) | 7.79 |
| 18th | 8.62(3.07) | 11.57(3.54) | 9.52(3.24) | 6.75(2.78) | 9.11 |
| 19th | 5.30(2.50) | 6.00(2.64) | 7.86(2.97) | 5.52(2.55) | 6.17 |
| 20th | 4.87(2.40) | 5.20(2.48) | 7.13(2.84) | 5.50(2.54) | 5.68 |
| Mean | 6.27 | 7.10 | 7.28 | 5.17 | 6.45 |
| CD at 5% | 0.45 | 0.58 | 0.35 | 0.19 |  |
| SEm± | 0.14 | 0.18 | 0.11 | 0.06 |  |
| SE(d) | 0.21 | 0.26 | 0.16 | 0.09 |  |
| CV(%) | 9.70 | 11.64 | 7.07 | 4.51 |  |

* Each value represents mean of 3 observations
* Figures in parentheses are the means of $\sqrt{(x+1)}$ transformation

**Table 2 Foraging rate of *A. mellifera* on Linseed ( Linum usitatissimum L.) crop during the year of 2024.**

|  |
| --- |
| A Number of flowers visited by honey bee/ minute during four different time intervals of the day |
| Std. week | Time hr. |
| 0800-1000 | 1000-1200 | 1300-1500 | 1500-1700 | Mean |
| 13th | 4.12(2.21) | 5.64(2.90) | 5.62(2.57) | 3.76(2.17) | 4.78 |
| 14th | 6.02(2.63) | 5.57(2.44) | 5.27(2.50) | 3.90(2.20) | 5.19 |
| 15th | 8.05(2.99) | 8.27(3.06) | 7.05(2.83) | 5.98(2.63) | 7.34 |
| 16th | 9.0393.15) | 9.59(3.36) | 7.30(2.88) | 6.11(2.66) | 8.00 |
| 17th | 7.57(2.91) | 8.64(3.31) | 9.20(3.18) | 8.32(3.03) | 8.43 |
| 18th | 10.42(3.37) | 10.51(3.40) | 10.27(3.35) | 7.47(2.90) | 9.67 |
| 19th | 9.73(3.26) | 9.18(3.07) | 10.02(3.31) | 7.33(2.88) | 9.06 |
| 20th | 6.96(2.79) | 6.82(2.75) | 8.56(3.08) | 6.47(2.73) | 7.20 |
| Mean | 7.74 | 8.03 | 7.91 | 6.17 | 7.46 |
| CD at 5% | 0.66 | 0.52 | 0.29 | 0.42 |  |
| SEm± | 0.21 | 0.17 | 0.09 | 0.14 |  |
| SE(d) | 0.30 | 0.24 | 0.13 | 0.19 |  |
| CV(%) | 12.88 | 9.71 | 5.57 | 9.14 |  |

* Each value represents mean of 3 observations
* Figures in parentheses are the means of √n+1 transformation

**Table 3 Foraging speed of *A. mellifera* on Linseed (Linum usitatissimum L.) crop during the year of 2024.**

|  |
| --- |
| Time spent by honey bee/flower (seconds) during four different time intervals of the day |
| Std week | Time hr. |
| 0800-1000 | 1000-1200 | 1300-1500 | 1500-1700 | Mean |
| 13th | 1.62(1.61) | 2.85(1.95) | 2.45(2.42) | 2.25(1.78) | 2.29 |
| 14th | 2.91(1.94) | 3.05(2.01) | 2.75(1.92) | 2.41(1.82) | 2.78 |
| 15th | 3.38(2.08) | 3.18(2.04) | 3.78(2.18) | 2.32(1.80) | 3.17 |
| 16th | 4.07(2.24) | 3.42(2.08) | 4.08(2.25) | 1.90(1.68) | 3.37 |
| 17th | 4.86(2.39) | 4.90(2.42) | 2.84(1.95) | 2.07(1.74) | 3.67 |
| 18th | 6.18(2.67) | 6.09(2.66) | 2.44(1.85) | 2.70(1.91) | 4.35 |
| 19th | 3.94(2.16) | 3.45(2.09) | 2.07(1.72) | 1.71(1.63) | 2.79 |
| 20th | 2.17(1.77) | 1.53(1.58) | 1.96(1.69) | 1.02(1.40) | 1.67 |
| Mean | 1.62 | 3.56 | 2.80 | 2.05 | 3.01 |
| CD at 5% | 0.62 | 0.36 | N/A | N/A |  |
| SEm± | 0.20 | 0.12 | 0.28 | 0.12 |  |
| SE(d) | 0.28 | 0.17 | 0.40 | 0.18 |  |
| CV(%) | 16.69 | 9.86 | 24.81 | 12.90 |  |

* Each value represents mean of 3 observations
* Figures in parentheses are the means of √n+1 transformation

**Impact of abiotic factors on the foraging intensity of *A. mellifera* on Linseed (*Linum usitatissimum* L.) crop during 2024.**

The correlation of abundance of *A. mellifera* on linseed crop was worked out with weather parameters viz., temperature (maximum and minimum), relative humidity (morning and evening), presented in table 4 The data revealed that the correlation of abundance of *A. mellifera* with temperature (maximum, minimum) was positive correlated during the period of 0800-1000 hours and 1000-1200 hours (r = 0.613, r = 0.410, r = 0.407, r = 0.173), while at 1300-1500 hours Tmax. was significantly correlated (r=0.751) and highly significant during the period of 1500-1700 hours (r=0.861). However Relative humidity was negative correlated in both (morning and evening) during the period of 0800-1700hours (r= -0.632, r = -0.299, r = -0.726, r = -0.881, r = -0.538, r = -0.136, r = -0.592, r = -0.559). Among the all-weather parameters Tmax., Tmin., had positive impact on the foraging intensity of honey bee on linseed crop and negatively effect on relative humidity.

The regression of abundance of *A. mellifera* on linseed crop was worked out with weather parameters viz., temperature (maximum and minimum), relative humidity (morning and evening), presented in table 4.a during the period of 0800- 1000 hours following regression equation was developed to predict the intensity of *A. mellifera,*

Y = 23.356-0.192X1-0.097X2-0.292X3+0.174X4

The regression equation revealed that the various abiotic factors were to be most influencing factor, which contributed (R2= 0.492) 49.2 per cent variation in honey bee population/m2/minute, whereas at the time of 1000-1200 hours using regression

Y =8.141+0.277X1-0.318X2-0.268X3+0.233X4

The regression equation revealed that the various abiotic factors were to be most influencing factor, which contributed (R2=0.446) 44.6 per cent variation in honey bee population/m2/minute, as well as during the period of 1300- 1500 hours for regression

Y =23.537-0.255X1+0.015X2-0.292X3+0.192X4

The regression equation revealed that the various abiotic factors were to be most influencing factor, which contributed (R2=0.709) 70.9 per cent variation in honey bee population/m2/minute, including at the time intervals of 1500- 1700 hours Following regression equation

Y= -22.961+0.687X1-0.074X2+0.120X3-0.073X4

The regression equation revealed that the various abiotic factors were to be most influencing factor, which contributed (R2=0.780) 78 per cent variation in honey bee population/m2/minute.

Bee activity and temperature were found to have a significantly strong and positive correlation (r= 0.766) by (Akhtar *et al*., 2018), whereas rainfall and relative humidity showed a significantly negative correlation (r= -0.715) and a significantly negative correlation (r= -0.759) respectively. According to (Abrol and Bajiya, 2017), temperature and the foraging activity of honey bees were found to be positively connected, while temperature and air humidity, wind speed, and rainfall pattern were negatively correlated. According to (Maity *et al*., 2014), the number of pollinators rose as the average daily maximum temperature climbed (r = 0.631) and the number of effective sunshine hours increased (r = 0.696). However, there was a negative association (r = –0.736 and –0.837, respectively) between the honeybee population and relative humidity and wind speed.

**Impact of abiotic factors on the foraging rate of *A. mellifera* on Linseed (*Linum usitatissimum* L.) crop during 2024.**

The correlation of foraging rate of *A. mellifera* on linseed crop was worked out with weather parameters viz., temperature (maximum and minimum), relative humidity (morning and evening), presented in table 5 The data has been observed that the correlation of foraging rate of *A. mellifera* with temperature (maximum) was positive significant correlated (r = 0.790, r = 0.712), however temperature (minimum) has been positive correlated (r = 0.625, r = 0.555), during the period of 0800-1000 hours and 1000-1200 hours. While at 1300-1500 hours Tmax. was highly significant correlated (r=0.837). However relative humidity was negative significant correlated in morning (r= -0.789, r = -0.760, r = -0.786) and negative correlated in evening (r= -0.675, r = -0.684, r = -0.665) during the period of 0800-1500 hours, along with relative humidity obtain negatively highly significant correlated during the period of 1500- 1700 hours (r = -0.915, r = -0.852). Among the all-weather parameters Tmax., Tmin., had positive impact on the foraging rate of honey bee on linseed crop and negatively effect on relative humidity.

The regression of foraging rate of *A. mellifera* on linseed crop was worked out with weather parameters viz., temperature (maximum and minimum), relative humidity (morning and evening), shown in table 5.a during the period of 0800- 1000 hours following regression equation was developed to predict the rate of *A. mellifera,*

Y = 31.639-0.463X1+0.176X2-0.421X3+0.265X4

While regression equation revealed that the various abiotic factors were to be most influencing factor, which contributed (R2= 0.736) 73.6 per cent variation in honey bee flowers visited/minute, whereas at the time of 1000-1200 hours using regression

Y =21.161-0.166X1-0.001X2-0.240X3+0.122X4

The regression equation revealed that the various abiotic factors were to be most influencing factor, which contributed (R2=0.615) 61.5 per cent variation in honey bee flowers visited/minute, as well as during the period of 1300- 1500 hours for regression

Y =31.353-0.681X1+0.534X2-0.439X3+0.302X4

The regression equation revealed that the various abiotic factors were to be most influencing factor, which contributed (R2=0.820) 82 per cent variation in honey bee flowers visited/minute, including at the time intervals of 1500- 1700 hours Following regression equation

Y= 24.928-0.466X1+0.297X2-0.278X3-0.144X4

The regression equation revealed that the various abiotic factors were to be most influencing factor, which contributed (R2=0.883) 88.3 per cent variation in honey bee flowers visited/minute.

(Kumar, 1999) reported similar results on the relationship between *Apis* spp. and meteorological parameters on sunflower. The fore mentioned conclusions were also confirmed by other researchers (Cirusdarescu, 1972; Abrol and Bhat, 1987; Sihag *et al*., 1999a and Kumar, 2000). Similar results were obtained by (Abrol and Bhat, 1987) and (Cirusdarescu, 1972). The population of honeybees and temperature were also found to positively correlate by (Oitiz Sanchez and Tinaut 1994). (Sihag *et al*., 1994) an also found that, across all honeybee species in oilseed, bee activity was considerably and positively connected with temperature, but negatively and significantly correlated with relative humidity.

**Impact of abiotic factors on the foraging speed of *A. mellifera* on Linseed (*Linum usitatissimum* L.) crop during 2024.**

The correlation of foraging speed of *A. mellifera* on linseed crop was worked out with weather parameters i.e., temperature (maximum and minimum), relative humidity (morning and evening), presented in table 6 The data was observed that the correlation of foraging speed of *A. mellifera* upon temperature (maximum, minimum) was positive correlated during the period of 0800-1000 hours and 1000-1200 hours (r = 0.698, r = 0.498, r = 0.398, r = 0.221), while at 1300-1500 hours as well as 1500- 1700 hours Tmax., Tmin., was negatively correlated (r = -0.147, r = -0.275, r = -0.282, r = -0.498). However relative humidity was negative correlated in both (morning and evening) during the period of 0800-1700 hours (r= -0.639, r = -0.496, r = -0.317, r = -0.177, r = -0.132, r = -0.258, r = -0.316, r = -0.406).Among the all-weather parameters Tmax., Tmin., had positive impact during morning and negative impact on afternoon period of time on the foraging speed of honey bee on linseed crop and negatively effect on relative humidity.

The regression of foraging speed of *A. mellifera* on linseed crop was worked out with weather parameters viz., temperature (maximum and minimum), relative humidity (morning and evening), shown in table 6.a during the period of 0800- 1000 hours following regression equation was developed to predict the speed of *A. mellifera,*

Y = 24.052-0.394X1+0.113X2-0.359X3+0.252X4

While regression equation revealed that the various abiotic factors were to be most influencing factor, which contributed (R2= 0.629) 62.9 per cent variation in honey bee second/flower, whereas at the time of 1000-1200 hours using regression

Y =32.744-0.360X1+0.154X2-0.413X3+0.309X4

The regression equation revealed that the various abiotic factors were to be most influencing factor, which contributed (R2=0.391) 39.1 per cent variation in honey bee second/flower, as well as during the period of 1300- 1500 hours for regression

Y =-3.473+0.349X1-0.384X2+0.156X3-0.157X4

The regression equation revealed that the various abiotic factors were to be most influencing factor, which contributed (R2=0.568) 56.8 per cent variation in honey bee second/flower, including at the time intervals of 1500- 1700 hours Following regression equation

Y= 17.322-0.286X1-0.042X2-0.158X3+0.121X4

The regression equation revealed that the various abiotic factors were to be most influencing factor, which contributed (R2=0.526) 56.2 per cent variation in honey bee second/flower.

**Table 4 Correlation co-efficient matrix(r) between foraging intensity of *Apis mellifera* L. on Linseed (Linum usitatissimum L.) with weather parameters during the year 2024.**

|  |  |
| --- | --- |
| Time hr. | Weather Parameter |
| Tmax. | Tmin. | Rh max. | Rhmin. |
| 0800-1000 | 0.613 | 0.410 | -0.632 | -0.538 |
| 1000-1200 | 0.407 | 0.173 | -0.299 | -0.136 |
| 1300-1500 | 0.751\* | 0.523 | -0.726 | -0.592 |
| 1500-1700 | 0.861\*\* | 0.727\* | -0.881 | -0.559 |

\* (Correlation is significant at the 0.05 level)

\*\*(Correlation is significant at the 0.01 level)

**Table 4.a Multiple regression equation between dependent and independent variables during the year 2024.**

|  |  |  |
| --- | --- | --- |
| Time hr. | Multiple equation | Coefficient of determination(R2) |
| 0800-1000 | 23.356-0.192X1-0.097X2-0.292X3+0.174X4 | 0.492 |
| 1000-1200 | 8.141+0.277X1-0.318X2-0.268X3+0.233X4 | 0.446 |
| 1300-1500 | 23.537-0.255X1+0.015X2-0.292X3+0.192X4 | 0.709 |
| 1500-1700 | -22.961+0.687X1-0.074X2+0.120X3-0.073X4 | 0.780 |

X1- Maximum Temperature oC X2- Minimum Temperature oC

X3- Relative Humidity (Max.) X4- Relative Humidity (Min.)

**Table 5 Correlation co-efficient matrix(r) between foraging rate of *Apis mellifera* L. on Linseed (Linum usitatissimum L.) with weather parameters during the year 2024.**

|  |  |
| --- | --- |
| Time hr. | Weather Parameter |
| Tmax. | Tmin. | Rh max. | Rhmin. |
| 0800-1000 | 0.790\* | 0.625 | -0.789\* | -0.675 |
| 1000-1200 | 0.712\* | 0.555 | -0.760\* | -0.684 |
| 1300-1500 | 0.837\*\* | 0.770\* | -0.786\* | -0.665 |
| 1500-1700 | 0.840\*\* | 0.775\* | -0.915\*\* | -0.852\*\* |

\* (Correlation is significant at the 0.05 level)

\*\*(Correlation is significant at the 0.01 level)

**Table 5.a Multiple regression equation between dependent and independent variables during the year 2024.**

|  |  |  |
| --- | --- | --- |
| Time hr. | Multiple equation | Coefficient of determination(R2) |
| 0800-1000 | 31.639-0.463X1+0.176X2-0.421X3+0.265X4 | 0.736 |
| 1000-1200 | 21.161-0.166X1-0.001X2-0.240X3+0.122X4 | 0.615 |
| 1300-1500 | 31.353-0.681X1+0.534X2-0.439X3+0.302X4 | 0.820 |
| 1500-1700 | 24.928-0.466X1+0.297X2-0.278X3-0.144X4 | 0.883 |

X1- Maximum Temperature oC X2- Minimum Temperature oC

X3- Relative Humidity (Max.) X4- Relative Humidity (Min.)

**Table 6 Correlation co-efficient matrix(r) between foraging speed of *Apis mellifera* on Linseed (Linum usitatissimum L.) with weather parameters during the year 2024.**

|  |  |
| --- | --- |
| Time hr. | Weather Parameter |
| Tmax. | Tmin. | Rh max. | Rhmin. |
| 0800-1000 | 0.698 | 0.498 | -0.639 | -0.496 |
| 1000-1200 | 0.398 | 0.221 | -0.317 | -0.177 |
| 1300-1500 | -0.147 | -0.275 | -0.132 | -0.258 |
| 1500-1700 | -0.282 | -0.498 | 0.316 | 0.406 |

\* (Correlation is significant at the 0.05 level)

\*\* (Correlation is significant at the 0.01 level)

**Table 6.a Multiple regression equation between dependent and independent variables during the year 2024.**

|  |  |  |
| --- | --- | --- |
| Time hr. | Multiple equation | Coefficient of determination(R2) |
| 0800-1000 | 24.052-0.394X1+0.113X2-0.359X3+0.252X4 | 0.629 |
| 1000-1200 | 32.744-0.360X1+0.154X2-0.413X3+0.309X4 | 0.391 |
| 1300-1500 | -3.473+0.349X1-0.384X2+0.156X3-0.157X4 | 0.568 |
| 1500-1700 | 17.322-0.286X1-0.042X2-0.158X3+0.121X4 | 0.526 |

X1- Maximum Temperature oC X2- Minimum Temperature oC

X3- Relative Humidity (Max.) X4- Relative Humidity (Min.)

**CONCLUSION**

Foraging intensity, foraging rate and foraging speed is important factors for determining of pollination efficiency of any bee species. It was concluded that the weekly observation of foraging intensity, foraging rate and foraging speed of *Apis mellifera* has been minimum in evening during the period of 1500-1700 hours. Whereas foraging intensity and foraging rate was observed maximum in forenoon during the period of 100-1200 hours but maximum foraging speed obtain in early morning during the period of 0800-1000 hours. The correlation co-efficient between foraging intensity, rate and speed of *Apis mellifera* was observed that the temperature (maximum and minimum) has been positive correlated during the period of 0800-1700 hours, whereas the relative humidity (morning and evening) has been negative correlated during the period of 0800-1700 hours. Since bee pollination of Linseed is the most efficient and affordable way to increase crop productivity and improve the production seeds, this study will be offer instructions for pollination of crop by honey bee is useful for farmers in open field condition in relation to abiotic factor.

**REFERENCES**

1. Abrol, D.P. and Bajiya, M.P. (2017). Flower-visiting insect pollinators of mustard (*Brassica napus*) in Jammu Region. *Journal of Pharmacognosy and Phytochemistry*, 6(5), 2380-2386.
2. Abrol, D.P., and Bhat, A.A. (1987). Influence of atmospheric conditions and flora; rewards on diurnal pattern, floral visitation rates and pollinating effectiveness of *Apis cerana indica* Fab. *Foragers Res. Dev. Reporter*, 4, 13- 15.
3. Akhtar, T., Aziz, M.A., Naeem, Md., Ahmed, M.S. and Bodlah, I. (2018). Diversity and Relative Abundance of Pollinator Fauna of Canola (*Brassica napus* L. var. Chakwal Sarsoon) with Managed *Apis mellifera* L. in Pothwar Region, Gujar Khan, Pakistan. *Pakistan Journal of Zoology*, 50(2), 567-573.
4. Amin, M. R., Nishat, M. J. A., Afroz, M., and Ghosh, P. (2019). Apiculture for sustainable agriculture: Bangladesh perspective. *Bangladesh Journal of Ecology*, *1*(1), 47-52.
5. Anonymous. (2019-2020). *Linseed Annual Report*,ICAR-IIOR.
6. Anonymous. (2020-2021). *Linseed Annual Report*, ICAR-IIOR.
7. Arshad, M.S., Suhail, A., and Hussian, S. A. (2000). Insecticidal mortality, foraging behaviour and pollination role of honeybee (*Apis mellifera* L.) on Brassica (*Brassica campestris* L.).  *Pakistan Journal of Zoology*, 32(4), 369-372.
8. Bhowmik, B., Mitra, B. and Bhadra, K. (2014). Diversity of insect pollinators and their effect on the crop yield of Brassica juncea L., NPJ-93, from southern West Bengal. *International Journal of Recent Scientific Research*, 5(6), 1207-1213.
9. Bhowmik, B., Sarita, S., Alok, S. K. B., and Kakali, B. (2017). Role of insect pollinators in seed yield of coriander (*Coriandrum sativum* L.) and their electroantennogram response to crop volatiles. *Agricultural Research Journal*, *54*(2), 227-235.
10. Bhushan, S., Kumar, S., Kumar, S., Choudhary, V.k., Choudhary, A.K., and Ram, S. (2021). The study of heterosis and inbreeding depression for seed yield and its attributes in linseed (*Linum* *usitatissimum* L.) *The Pharma Innovation Journal*, 10(10), 2265-2270.
11. Chaudhary, O. P., Mishra, S. and Jage Singh, J. S. (2007). Diversity, temporal abundance, foraging behaviour of floral visitors and effect of different modes of pollination on coriander (*Conundrum sativum* L.).
12. Chaudhary, O.P., and Singh, J. (2007). Diversity, Temporal Abundance, foraging behaviour of Floral visitors and effect of Different modes of pollination on Coriander (*Coriander Sativum* L.). *Journal of Species and Aromatic Crops*, 16 (1).
13. Chopra, P., and Badiyala, D. (2016). Influence of sowing time on performance of linseed (*Linum usitatissimum* L.) varieties under mid hill conditions of Himachal Pradesh. *Journal of Oilseeds Research*, 33(4), 256-258.
14. Cirusdarescu, G. (1972). Pollination of lucerne and factors influencing their activity in the south-eastern part of Birsei depression. *Annals University* *Bucuresti Biologe Anim*, 20, 71-81.
15. Dalio, J.S. (2018). Foraging Frequency of *Apis* Species on Bloom of *Brassica napus* L. *The International Journal of Engineering and Science*, 7(2), 28-33.
16. Dash, J., Naik, B., and Mohapatra, U. (2017). Linseed: A valuable crop plant. *International Journal of Advanced Research*, 5(3), 1428-1442.
17. Devi, H.S., Sontakke, B.K., Mohapatra, L.N. and Padhi, J. (2011). Foraging activities of Italian bee, *Apis mellifera* L. on mustard under coastal conditions of Orissa. *Journal of Plant Protection and Environment*, 8(1), 34-38.
18. Devi, H.S., Sontakke, B.K., Mohapatra, L.N. and Padhi, J. (2011). Foraging activities of Italian bee, *Apis mellifera* L. on mustard under coastal conditions of Orissa. *Journal of Plant Protection and Environment*, 8(1), 34-38.
19. Devi, S., Ombir, Sumit and Singh, Y. (2016). Abundance and foraging behaviour of major insect pollinators on seed crop of broccol (*Brassica oleracea* L. var. *italica Plenck*) LPH-1. *Journal of Applied and Natural Science*, 8(3), 1493-1496.
20. Eradasappa, E., and Mohana, G.S. (2016). Role of pollination in improving productivity of cashew – A review. *Agricultural Reviews*, 37(1), 61-65.
21. Gatoria, G.S., Singh, B., and Jhaji, H.S. (1996). Need to revise or separately fix the standards for *A. mellifera* apiary honey. Facts based on some case studies. *National bee keeping experience exchange conference*, *29 -31 May*, *1995*, *Punjab Agriculture University, Ludhiana*.
22. Kant, K., Singh, B., Meena, S.R., Ranjan, J.K., Mishra, B.K., Solanky, R.K. and Kumar, M. (2013). Relative abundances and foraging behaviour of honey bee Species on minor seed spice crops. *International Journal of Seed Spices*, 3(2), 51- 54.
23. Kumar, J. and Rao, K.V.K. (1991). Pollinating efficiency of some bee visitors to the carrot (*Daucus carota* L.) crop in mid hills of Himachal Pradesh (India). *Indian Bee Journal*, 53 (1-4), 34-38.
24. Kumar, J., Rao, K.V.K. and Gupta, J.K. (1994). Pollination efficiency of bees visiting blossoms of *Brassica campestris* L. var. toria in mid hills of Himachal Pradesh, India. *Indian Bee Journal*, 56, 202-206.
25. Kumar, M., Singh, R. and Chand, H. (2000). Foraging activity of honeybees on different varieties of sunflower. *Indian Bee Journal*, 62 (3-4), (63-64).
26. Kumar, N., and Singh, R. (2005). Relative abundance of Apis spp. on *rabi* season sunflower (*Helianthus annus* L.). *Journal of Entomological Research*, 29(1), 65-69.
27. Kunjwal, N., Kumar, Y. and Khan, M.S. (2014). Flower-visiting insect pollinators of brown mustard, *Brassica juncea* (L.) Czern and Coss and their foraging behaviour under caged and open pollination. *African Journal of Agricultural Research*, 9(16), 1278-1286.
28. Maity, A., Chakrabarty, S.K. and Yadav, J.B. (2014). Foraging behaviour of honeybees (*Apis spp*.) (Hymenoptera, Apidae) in hybrid seed production of Indian mustard (*Brassica juncea*). *Indian Journal of Agricultural Sciences*, 84(11), 1389-1394.
29. Mattu, V., Raj, H., and Thakur, M. (2012). Foraging behavior of honeybees on apple crop and its variation with altitude in Shimla hills of western Himalaya, India. *International Journal Scientific Nature*, (3), 269-301.
30. Meena, K. (2015). Diversity Dimensions of India and Their Organization Implications: An Analysis, *International Journal of Economics & Management Sciences*, 4(6), 1000261.
31. Navatha, L., Sreedevi, K., Chaitanya, T., Prasad, P.R., and Naidu, M.V.S. (2012). Species richness and foraging activity of insect visitors in linseed (*Linum usitatissimum* L.). *International journal of agriculture environment,* 5(4), 465-471.
32. Nest, B.N.V., and Moore, D. (2012). Energetically optimal foraging strategy is emergent property of time-keeping behavior in honey bees. *Behavioral Ecology*, 23, 649-658.
33. Ortiz-Sánchez, J. A., and Tinaut, A. (1994). Effect of insect pollination on the production of a hybrid sunflower variety (*Helianthus annuus* L.) in southern Spain.
34. Painkra, G. P. (2019). foraging behavior of italian honey bee, *apis mellifera* (hymenoptera-apidae) in broccoli flowers. *Journal of Plant Development Sciences*,11(11), 681-683.
35. Patil, P. N. and Pastagia, J. J. (2016). Effect of bee pollination on yield of coriander, *Coriandrum sativum Linnaeus*. *international journal of plant protection*, 9(1), 79-83.
36. Pradeep, A. (2018). foraging behavior of honeybee pollination in coriander and mustard (Doctoral dissertation, Birsa Agricultural University, Ranchi, Jharkhand-6).
37. Razzaq, A., Abbasi, K. H., Jamal, M., Aslam, A., Malik, K., and Ullah, M. A. (2019). Evaluation of Pollination by Honeybee (*Apis Mellifera* L.) on Canola (*Brassica Napus* L.) Produce. *Biomedical Journal of Scientific and Technical Research*, *22*(4), 16833-16836.
38. Sanchez- Ortiz, J. A. and Tinaut, A. (1994). Effect of insect pollination on the production of a hybrid sunflower variety (*Helianthus annuus* L.) in southern Spain. *Entomofauna*, 15 (34), 397-404.
39. Sihag, R. C. and Khatkar, S. (1999a). Foraging Pattern of three Honeybees on Eight Cultivars of oilseed crops. *International Journal of Tropical Agriculture*, 17 – 14.
40. Sihag, R. C. and Khatkar, S. (1999b). Foraging Pattern of three Honeybees on Eight Cultivars of oilseed crops. *International Journal of Tropical Agriculture*, 17 – 14.
41. Singh, H., Chhuneja, P. K., Singh, J., and Sandhu, A. C. S. K. (2020). *Apis mellifera* Linnaeus contribution in augmenting seed yield of *Brassica carinata* A. Braun. *Journal of Entomology and Zoology Studies*, *8*, 1949-1953.
42. Singh, V., Dubey, V. K., Rana, N. and Chandrakar, G. (2018). The relative diversities and abundance of different insect pollinators on Mustard. *International Journal of Current Microbiology and Applied Sciences*, 6, 672-676.
43. Srivastava, K., Sharma, D., Singh, S. and Ahmad, H. (2017). Foraging behaviour of honeybees in seed production of *Brassica oleracea* var. *Italica Plenck*. *Bangladesh Journal of Botany*, 46(2), 675-681.
44. Sutar, H.B., and Patil, R.G. (2022). Insecticidal Effects on Pollinating Attributes of Linseed Foragers. *Research Journal of Agricultural Sciences an International Journal*,13(06),1802-1806.
45. Tadesse, T., Singh, H., and Weyessa, B. (2009). Correlation and path coefficient analysis among seed yield traits and oil content in Ethiopian Linseed germplasm. *International Journal of Sustainable Crop Production*, 4, 8-16.
46. Toure, A., and Xueming, X. (2010). Flax seed lignans: source, biosynthesis, metabolism, antioxidant activity, bio-active components, and health benefits. *Comprehensive Reviews in Food and Science and Food Safety*, 9(3), 261-269.
47. Umar, m., Aqeel, A., Hassan, W.U., Bashir, N.H., Ullah, I., Nazir, T., and Hanan, A. (2018). Evaluation of foraging activity and pollen collection by *Apis mellifera* L*.* on linseed crop at different day timings. *Journal of Entomology and Zoology Studies*, 7(1), 264-269.
48. Usman, M., Amin, F., Najm-Ul-Saqib., Sohail, K., Shah, F. S. and Aziz, A. (2018). Incidence of different insect visitors and their relative abundance associated with coriander (Coriandrum sativum) in district Charsadda, *Pure Appl. Biol*., 7(2), 539-546.
49. Vishwakarma, R., and Chand, P. (2017). Foraging activity of insect pollinators and their impact on yield of Rapeseed-mustard. *Bioinfolet*, 14(3), 222-227.