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Priyadarshinee Mohanty

Department of Agricultural

Meteorology, College of

Agriculture, OUAT,

Bhubaneswar, Odisha, India

Amaresh Khuntia

Directorate of Extension

Education OUAT, Bhubaneswar,

Odisha, India

Pravasini Behera

AICRP on Honeybees &

Pollinators, OUAT,

Bhubaneswar, Odisha, India

Foraging activity of Indian honey bee (*Apis cerana indica* F.) in winter season in Odisha condition

Priyadarshinee Mohanty, Amaresh Khuntia and Pravasini Behera

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Abstract

Honeybees are the most economically valuable social insect. The act of gathering pollen and nectar from bee flora is known as foraging behavior for the production of honey. Therefore, foraging is an important activity for the gathering of honey and pollen for feeding the young brood as bee bread. The study was conducted at two different weather conditions in Odisha at AICRP on honeybees and pollinators, OUAT, Bhubaneswar (taken as a coastal entity), and KVK, Semiliguda (taken as an interior pocket) from December 2021 to February 2022 to record the impact of weather parameters on the foraging activity of *Apis cerana indica* F. in the winter season. The foragers were observed to be 20.5, 7.6, and 22.1 numbers per 5 min, and 31, 17.2, and 29.6 foragers/5 min were observed for nectar, pollen, and outgoing foragers, respectively, at Bhubaneswar and Semiliguda conditions. Correlation studies revealed that rainfall only had a significant impact on foraging activity and negative correlation of -0.587*, -0.539*, and -0.580* for nectar, pollen, and outgoing foraging activity respectively at Bhubaneswar while it was not significant effect at Semiliguda. A Positive significant correlation was observed for maximum and minimum temperature with a correlation of more than 0.5 while minimum temperature negatively affected the foraging activity, which was not significant at Bhubaneswar conditions. The regression study showed that Minimum temperature and rainfall were the two parameters contributing 83.8%, 90.7%, and 80.9% for outgoing, nectar, and pollen foragers, respectively, at OUAT, Bhubaneswar. whereas due to minimum temperature, relative humidity (afternoon), and rainfall, the foraging activity was affected by as much as 97.5% and 95.1% for nectar and pollen foragers at Semiliguda, while only minimum temperature and relative humidity (afternoon), affected the foraging activity for outgoing foragers.

Keywords: Weather parameters, *Apis cerana indica* F., foraging activity, standard meteorological week, correlation, regression, temperature, bright sunshine hours, relative humidity (Morning and afternoon), rainfall

1. Introduction

Honeybees are little manipulators that collect pollen and nectar from the flower and use it to make other flowers fertile by helping them in pollination (Dalio, 2015; Kumar *et al.*, 2016) [6]. Collecting nectar and pollen from flowering plants by bees is known as 'foraging activity' (Gary, 1992) [8]. Foraging task in honey bees includes going out for food, recognizing and remembering the location of food sources, carrying and storing food, and interacting with other bees. Several factors outside the colony have an impact on the foraging behaviour such as environmental parameters. When the environment is unfavourable, such as when it's cold, rainy, or snowy, honeybees stop feeding and stop raising their young. Throughout the unfavourable time, they keep busy within the nest, feasting on honey that has been stored. Honeybees experience a wide range of temperatures while foraging, which impacts their thermoregulatory activity. Worker bee foraging behaviour is impacted by the effects of homeostasis. (Cooper, Schaffer 1985; Al-Qarni 2006; Blazyte-Cereskiene *et al.* 2010) [5, 1, 2]. But, temperatures below 10 °C will prevent foraging activity (Joshi, Joshi 2010) [10]. Abiotic factors like temperature, relative humidity, rainfall, no of rainy days, bright sunshine hours, and wind speed may positively or negatively affect the foraging activity. The significance of the relationship between meteorological factors and honey bee flight activity demonstrates different behaviours of honeybees due to different weather conditions (Clarke and Robert, 2018) [4]. Effects of air temperature, humidity, precipitation, minimum and maximum air temperature, as well as wind speed have a significant effect on foraging activity (Pukadija *et al.*, 2007) [15]. The activity of a worker bee at any given time in the colony is affected by the weather conditions (Page and Robinson, 1991) [13]. Climatic change is thought to be a major threat to the pollination service. The declining number of honey bees threatens food security because of the pollination crisis as temporal changes in the foraging rate of bees emphasize on

Corresponding Author:**Priyadarshinee Mohanty**

Department of Agricultural

Meteorology, College of

Agriculture, OUAT,

Bhubaneswar, Odisha, India

studying the effect of weather parameters on the foraging activity of *Apis cerana indica* F.

2. Materials and Methods

The study was conducted to study the effect of various meteorological parameters on the foraging activity of Indian honeybee (*Apis cerana indica* F.) at AICRP on honeybees and pollinators, OUAT, Bhubaneswar, and KVK, Semiliguda of Koraput district presented in (Figure 1) from December 2021 to February 2022. The experimental site at OUAT, Bhubaneswar is situated at 20.29° N and 85.82° E; 45 m above MSL which was considered as a coastal entity, while KVK, Semiliguda, Koraput which is situated at coordinates of 18.42°N and 82.51°E with an average elevation of 903m above MSL was taken as an interior pocket.

The climatic variation regarding the weekly maximum temperature, minimum temperature, morning relative humidity (RH-I), afternoon relative humidity (RH-II), bright sunshine hours (BSH) along with total weekly rainfall, number of rainy days, evaporation and wind speed of OUAT, Bhubaneswar (in Figure 2), and KVK, Semiliguda of Koraput district (in Figure 3) during the investigation (December 2021-February 2022) was taken from the central observatory of the Dept of Agri. Meteorology, OUAT, and Agro meteorological Advisor Service unit of Semiliguda

respectively.

Observation on the foraging activity of the Indian honey bee, *Apis cerana indica* F. was measured on 10 honeybee colonies as per meteorological week at AICRP on honeybees and pollinators, OUAT, Bhubaneswar, and KVK, Semiliguda, Koraput. These studies were recorded at meteorological week intervals during the winter season from December 2021 to February 2022. The bee activity at the hive entrance was recorded 3 times of the day viz., morning (7-8 am), (10-11 am), and evening (3-4 pm). The observation on foraging activity on the colony performance was observed by counting the number of foragers going out and returning to the hive with pollen and nectar for a particular period (Mattu and Verma 1985; Reddy *et al.*, 2015) [12, 17]. The observations were recorded by counting the number of bees coming in and going out by standing near every box for 5 mins. The incoming bees with pollen loads were considered pollen foragers, and those without pollen loads were counted as nectar foragers. The foraging activity of outgoing and incoming foragers (nectar and pollen) was correlated with meteorological parameters, and stepwise regression equations were computed using XLSTAT. The simple linear correlation coefficient, (r) at the 5% and 1% levels of significance were used to compare the two factors and multiple regression equations were constructed.



Fig 1: Location of research work (2021-2022)

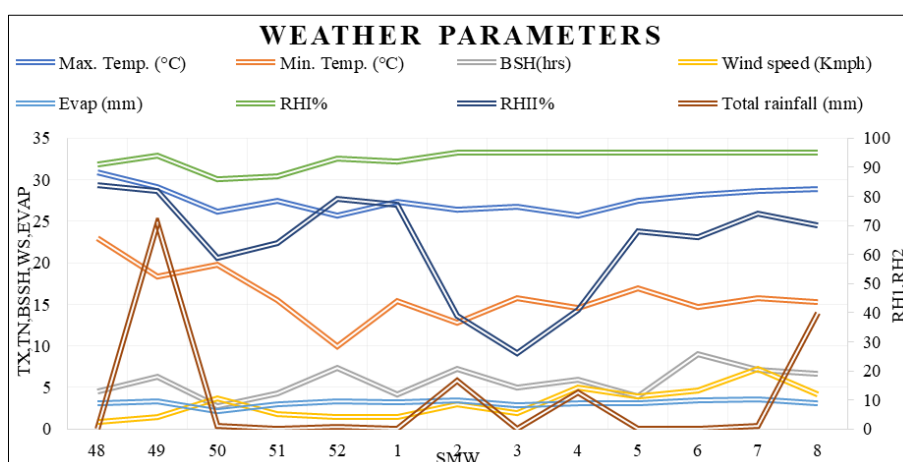


Fig 2: Weekly weather data of OUAT, Bhubaneswar from December 2021 to February 2022

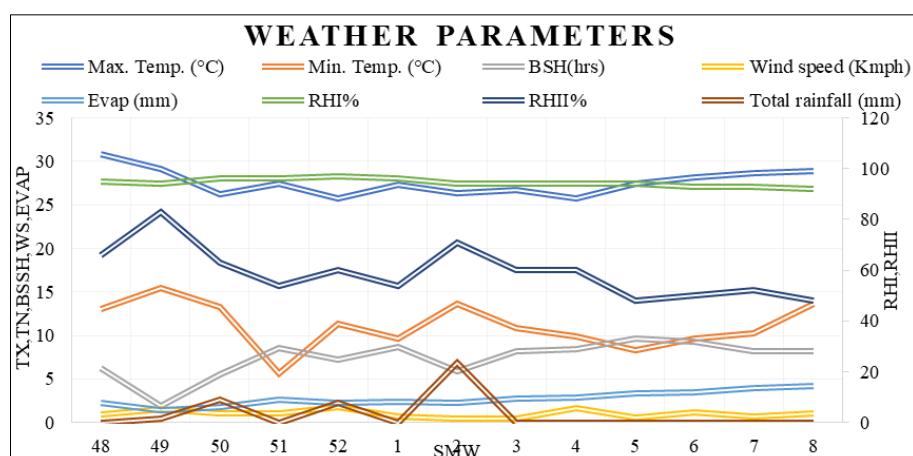


Fig 3: Weekly weather data of KVK, Semiliguda, Koraput from December 2021 to February 2022

3. Results and Discussion

3.1. Effect of foraging activity in the winter season at Bhubaneswar

The winter period extends from December to February. During this season trees like maize, and eucalyptus are in full bloom in Bhubaneswar, whereas trees such as Niger, and sunflower are in full bloom in Semiliguda. Table 1 indicated that during the winter season, the outgoing foragers were found to be higher with 35.4 foragers in 5 minutes in the 48th

met week and the lowest in the 49th met week with only 11.6 no foragers in 5 minutes. The nectar foragers also recorded the highest in the 48th met week and the lowest in the 49th met week having 30.5 and 11.2 foragers per 5 minutes respectively but Pollen gatherers were observed to be the lowest among all groups of worker bees. Pollen foragers with a maximum of 11.5 and 4.9 no of foragers were observed in the 48th and 49th week respectively.

Table 1: Effect of foraging activity of *Apis cerana indica* F. during the winter season at OUAT, Bhubaneswar.

Met Week	Incoming foragers		Outgoing foragers	Weather parameters							
	Nectar Foragers	Pollen Foragers		Max. Temp. (°C)	Min. Temp. (°C)	RH- I (%)	RH- II (%)	Total RF (mm)	BSH (Hrs)	Wv Km/Hr	Evap (mm)
48	30.5	11.5	35.4	29.1	18.3	91	84	0.1	6.3	1.4	3.3
49	11.2	4.9	11.6	26.2	19.8	94	82	70.8	2.7	3.7	2.2
50	22.6	7.2	21.5	27.5	15.5	86	59	1.0	4.3	1.8	3.0
51	14	5.3	16	25.7	10.0	87	64	1.0	7.4	1.5	3.3
52	23.8	8.6	25.6	27.3	15.4	93	79	0.8	4.2	1.5	3.2
1	16.4	6.5	19.5	26.4	12.8	92	77	1.0	7.3	3.0	3.5
2	18.6	6.5	18.1	26.7	15.7	95	39	16.5	5.0	1.9	2.9
3	20.2	7.4	22.3	25.7	14.6	95	26	1.0	6.0	5.0	3.1
4	19.6	6.7	21	27.5	16.9	95	41	12.6	3.9	3.9	3.1
5	24.5	8.2	26.4	28.2	14.7	95	68	1.0	9.0	4.7	3.5
6	22.8	10.4	25.8	28.7	15.8	95	66	1.0	7.1	7.2	3.6
7	22.5	9	22.5	28.9	15.3	95	74	1.1	6.6	4.2	3.1
8	19.5	6.2	21.5	31.2	19.7	95	70	40.0	1.3	4.0	2.9
Mean	20.5	7.6	22.1	27.6	15.7	92.9	63.8	147.9	5.5	3.4	3.1

During the winter season, the highest outgoing foragers were recorded, contributing 44%, followed by nectar gatherers at 40.9% and pollen foragers at 15.1% as presented in Figure 4. The finding of the present study is supported by similar

findings by Hemalatha *et al.*, (2018) [9] reported that nectar foragers contributed 43% in the foraging task while only 16% contribution was made by pollen foragers in the winter season.

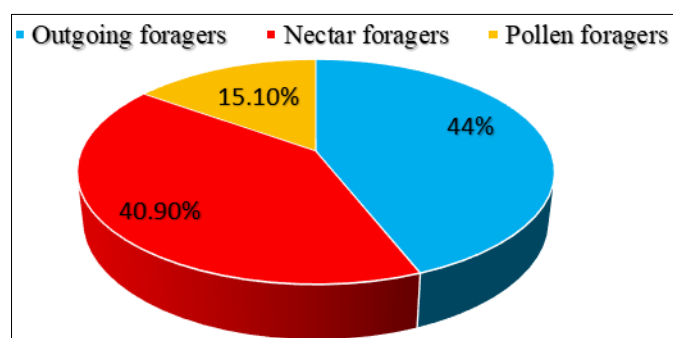


Fig 4: *Apis cerana indica* F. worker bee's contribution in foraging activity during the winter season at OUAT, Bhubaneswar.

3.2. Effect of foraging activity of *Apis cerana indica* F. during the different hours of the day

As observed in Figure 5, for outgoing foragers, the highest activity was observed between 10:00-11:00 am with 27.8 foragers/5 min, followed by 07:00-08:00 am with 23.7 foragers/5 min and the least of 14.7 foragers/5 min at 3-4 pm. Nectar foragers visits were observed at 10:00-11:00 am with an average of 27.3 foragers/5 min followed by 07:00-08:00 am with an average of 20.7 foragers / 5 min and the lowest

visits of 13.3 foragers/5 min at 03:00-04:00 pm as represented in Figure 6. Pollen foragers followed the same trend such that 11.1, 6.6, and 4.8 foragers were observed at 10:00-11:00 am, 07:00-08:00 am, and 03:00-04:00 pm respectively (Figure 7). The present study is in line with Painkra *et al.*, 2021^[14] observed the foraging activity of the Indian bee (*Apis cerana indica* F.) was the highest at 9.00 am (14.71 bees/5 min/plant) and the lowest at 5.00 PM (7.14 bees/5 min/plant).

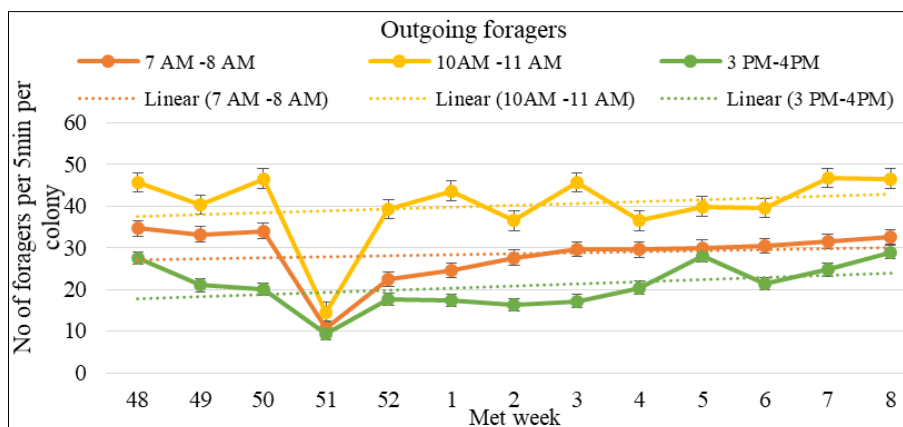


Fig 5: Outgoing foragers foraging activity during different hours of the day during the winter season at OUAT, Bhubaneswar

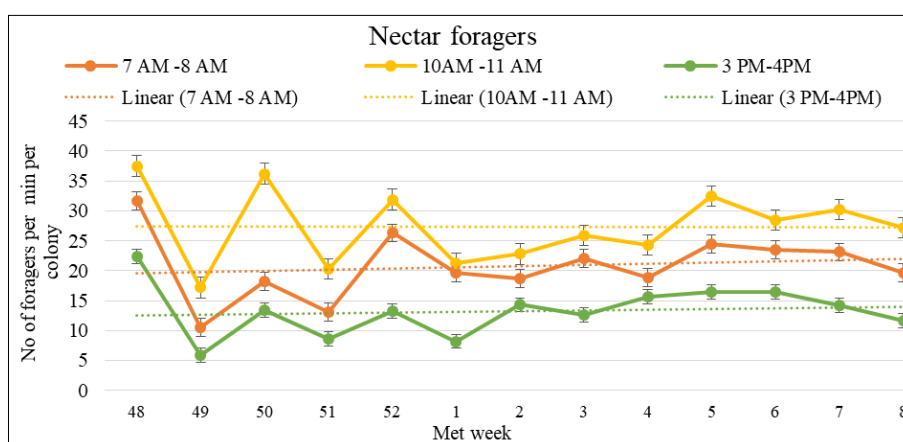


Fig 6: Nectar foragers foraging activity during different hours of the day during the winter season at OUAT, Bhubaneswar

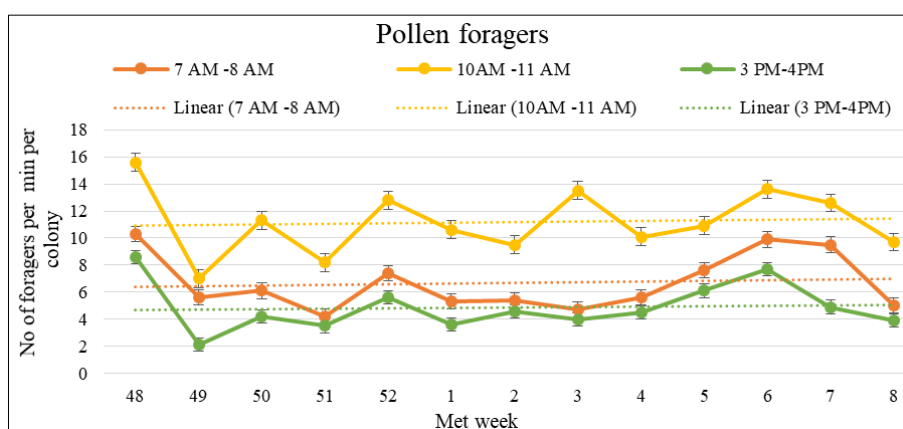


Fig 7: Pollen foragers foraging activity during different hours of the day during the winter season at OUAT, Bhubaneswar

3.3. Correlation between meteorological factors and foraging activities of *Apis cerana indica* F. in the winter season at OUAT, Bhubaneswar.

As revealed in Table 2, outgoing, nectar, and pollen foragers

were positively correlated with maximum temperature with *r*-values of 0.502, 0.536, and 0.420 respectively., which was not found to be significant, Similarly, the minimum temperature was also positively correlated but negatively affecting all the

foraging activities with 'r' value 0.135, 0.161 and 0.140 of outgoing, nectar, and pollen foragers, but the correlation was not significant. The present study finds ample support from Dustmann *et al.*, (1988) [7] observed that the maximum daytime temperature directly impacted the foraging activity of honeybees whereas, the cold snap limited foraging activity and interrupted pollen intake in Germany.

The morning relative humidity has a positive correlation for outgoing, nectar, and pollen-foragers with 'r' values of 0.112, 0.071, and 0.121 respectively but not significant whereas the afternoon relative humidity was also positively correlated with all foragers, with 'r' values of 0.128, 0.124, and 0.210 for outgoing bees, nectar, and pollen-bearing bees respectively, which were also found to be not significant which is corroborated by Reddy *et al.*, observed significant positive relation between relative humidity and foraging activity for outgoing and nectar foragers.

The total rainfall received during the season was 148 mm. There was a significant negative correlation between rainfall and all the foraging activities such as outgoing bees ('r'= 0.580*), nectar-gathering bees ('r'= 0.587*), and pollen-gathering bees ('r'-0.539*) which is in line with Abou-Shaara *et al.* (2012) [19] noted that the foraging activity came down drastically during rain and as both *A. cerana indica* F. and *A. mellifera* were reported to prefer to be in their hives during rain.

The maximum BSH varied from 1.3 to 7.4 hours which was positively correlated for all the foraging activities such as outgoing bees ('r'= 0.318), pollen-gatherers ('r'= 0.365), and nectar-gatherers ('r'= 0.265) but not significant. These above findings are in corroboration with (Zuccoli, 1987) [18] who observed that the intensity of solar radiation was strongly associated with foraging activity.

All the foragers were also positively significant for evaporation with "r" values of 0.569*, 0.501, and 0.575* for outgoing, nectar, and pollen foragers, respectively. Wind velocity was negatively correlated and not significant with r values of -0.012 and -0.016 for the foraging activity of nectar and outgoing foragers but positively correlated with pollen foragers with an R-Value of 0.183.

Table 2: Correlation matrix on the effect of weather factor on the foraging activity of *Apis cerana indica* F. in winter season at OUAT, Bhubaneswar

Meteorological parameters	Incoming Foragers		Outgoing foragers
	Nectar foragers	Pollen foragers	Outgoing foragers
Max T (°C)	0.536	0.420	0.502
Min T (°C)	0.161	0.140	0.135
RH-I (%)	0.071	0.121	0.112
RH-II (%)	0.124	0.210	0.128
Rainfall(mm)	-0.587*	-0.539*	-0.580*
BSH (hours)	0.265	0.365	0.318
Wind speed (km/hr)	-0.012	0.183	-0.016
Evap (mm)	0.501	0.575*	0.569*

*Significantly correlated at 5% level ** significantly correlated at 1% level

3.4. Regression studies of foraging activity of *Apis cerana indica* F. at AICRP on honey bees and pollinators, OUAT, Bhubaneswar in the winter season

As revealed in Table 4 the coefficient of determination (R^2) was 0.838, 0.907, and 0.809 contributing 83.8%, 90.7%, and 80.9% in foraging activity of outgoing, nectar, and pollen foragers respectively due to the impact of min T as well as rainfall in OUAT campus, Bhubaneswar

Table 3: Regression of foraging activity with weather parameters in the winter season at OUAT, Bhubaneswar

winter (Met week 9 th - 21 st)	Foraging Activity	Stepwise regression equation	R ² Value	P Value
	Outgoing foragers	O = -5.765+2.021*MinT-0.323*Rainfall	0.838	0.000
	Nectar foragers	I = -5.76918928242145+1.881*Min T-0.295*Rainfall	0.907	0.0001
	Pollen foragers	P= -1.932+0.646*Min T-0.070*Rainfall	0.809	0.000

3.5. Effect of foraging activity during the winter season at KVK, Semiliguda

It was observed in Table 4 the outgoing foragers performed best in the 8th met week with 36 no of foragers/5 min and least in the 51st met week with 11.5 foragers/5 minutes. Similarly,

for nectar foragers highest results have been recorded in the 8th met week with 42.5 no of foragers/5 mintes and the lowest in the 51st with 11.4 foragers/5 minutes, which was also reflected in the case of pollen foragers with 6.1 and 23.3 foragers/5 minutes in 51st and 8th met week respectively.

Table 4: Effect of foraging activity of *Apis cerana indica* F. during the winter season at KVK, Semiliguda

Mk	Incoming foragers		Outgoing foragers	Weather parameters							
	Nectar Foragers	Pollen Foragers	Outgoing Foragers	Max. Temp. (°C)	Min. Temp. (°C)	RH- I (%)	RH-II (%)	Total RF (mm)	BSH (Hrs)	Wv Km/hr	Evap (mm)
48	37.4	20.9	35.9	26.2	13.0	95	66	0.0	6.3	0.9	2.2
49	31.4	17.4	31.5	24.1	15.4	94	83	1.5	1.9	1.5	1.4
50	35.6	19.8	33.5	24.7	13.3	96	63	9.0	5.5	1.0	1.8
51	11.4	6.1	11.5	23.8	5.7	96	54	0.0	8.5	1.1	2.6
52	29.5	16.3	26.4	25.5	11.3	97	60	7.6	7.2	1.8	2.3
1	29.8	16.5	28.5	25.9	9.6	96	54	0.0	8.7	0.7	2.4
2	26.2	14.5	26.8	25.7	13.7	94	71	23.6	5.9	0.4	2.2
3	34.3	19.1	30.8	24.3	10.8	94	60	0.0	8.2	0.5	2.7
4	29	16.1	26.8	24.8	9.9	94	60	0.0	8.4	1.6	2.9
5	31	17.2	32.6	26.4	8.3	94	48	0.0	9.6	0.6	3.4
6	32.3	18	30.4	26.3	9.7	93	50	0.0	9.3	1.2	3.5
7	32.8	18.2	34.3	27.3	10.3	93	52	0.0	8.2	0.7	3.9
8	42.5	23.3	36	29.7	13.6	92	48	0.0	8.2	1.1	4.2
Mean	31.0	17.2	29.6	25.7	11.1	94.5	59.2	41.7	7.4	1.0	2.7

The highest contribution was made by nectar foragers at 39.8%, followed by outgoing foragers at 38.1%, and the least by pollen foragers at 22.1% as represented in Figure 7.

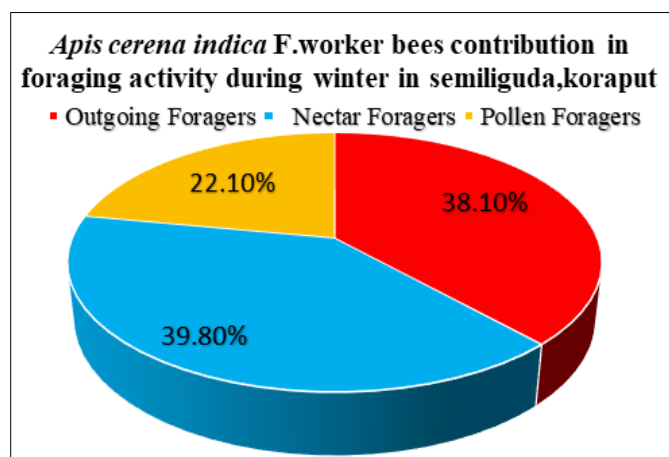


Fig 8: *Apis cerana indica* F. worker bee's contribution in foraging activity during the winter period at KVK, Semiliguda

3.6. Effect of foraging activity of *Apis cerana indica* F. during the different hours of the day at KVK, Semiliguda

As presented in Figure 8, it was observed that the foraging activity during the winter season at Bhubaneswar peaked at 10-11 am for all groups of foragers. For outgoing bees an average of 40 bees/5 min were recorded at 10-11 am, followed by 28.5 bees/5 min at 7-8 am and the lowest of 20.7 bees/5 min at 3-4 pm as presented in Figure 9. The nectar foragers were also seen highly active at 10-11 am where an average of 39.4 bees/5 min were recorded which was followed by 31.1 bees/5 mins at 7-8 am and the least performance was of 22 bees/5 min were recorded at 3-4 pm (Figure 12). Pollen foragers of 25 bees/5 min, 16 bees/5 min, and 10.4 bees/5 min were recorded for 10-11 am, 7-8 am, and 3-4 pm respectively (Figure 10). All the foragers remain the most active at 10-11 am period, which was followed by the 7-8 am period, and the least activity was recorded at 3-4 pm in both locations which are in line with Jyothi (2003) [20] reported on the foraging activity of *Apis cerana indica* F. peaked between 10:00 am and 13:00 pm and dropped after 18:00 pm under the tropical conditions of Karnataka.

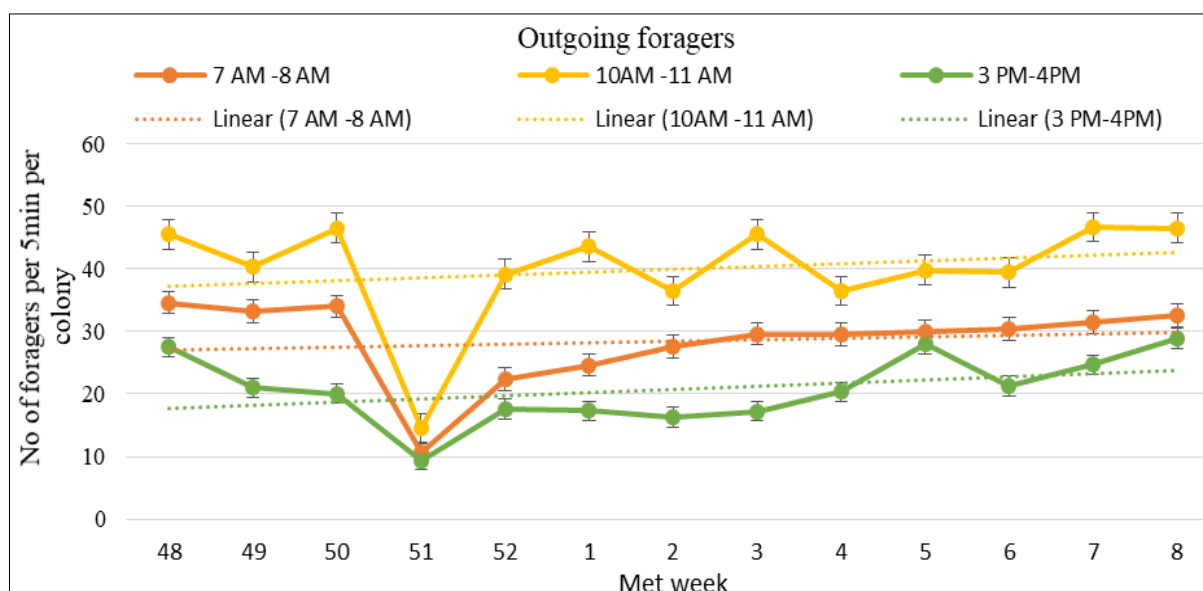


Fig 9: Outgoing foragers foraging activity during different hours of the day during the winter season at KVK, Semiliguda

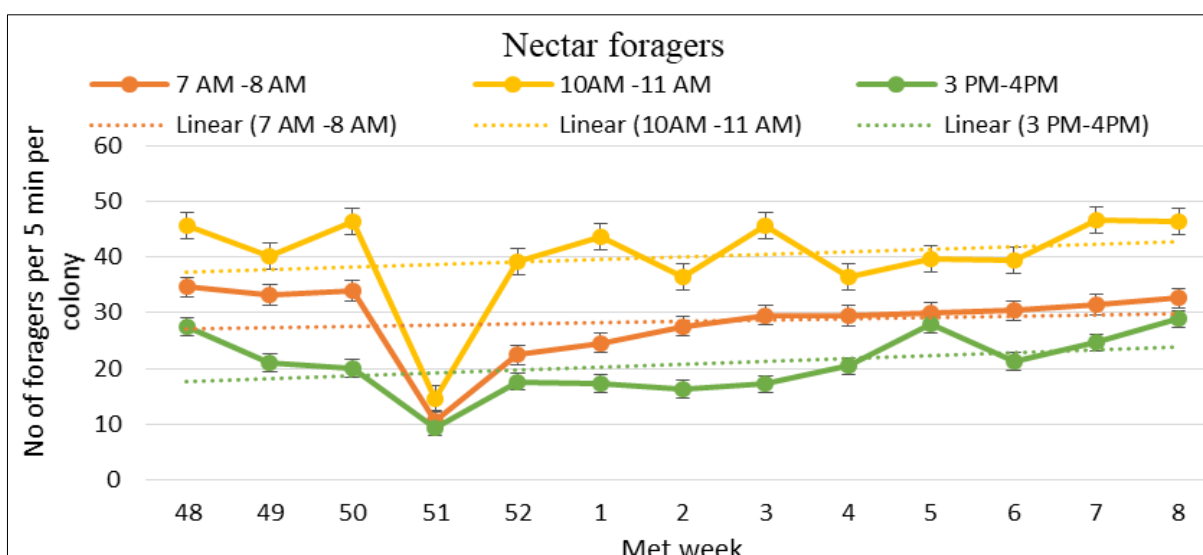


Fig 10: Nectar foragers foraging activity during different hours of the day during the winter season at KVK, Semiliguda

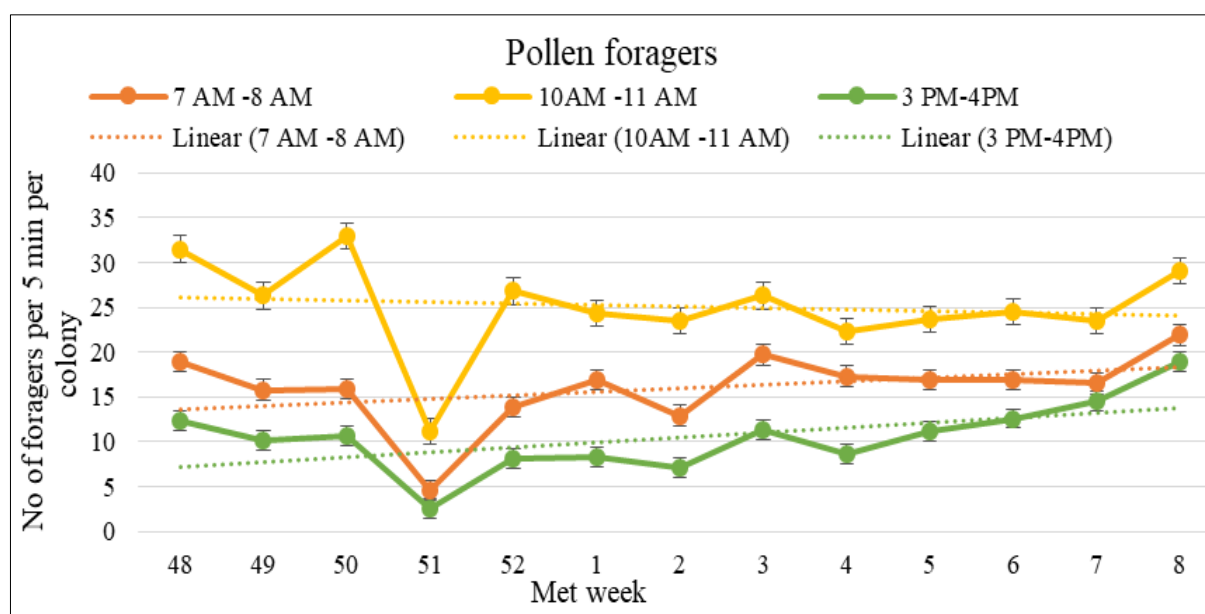


Fig 11: Pollen foragers foraging activity during different hours of the day during winter at KVK, Semiliguda

3.7. Correlation between meteorological factors and foraging activities of *Apis cerana indica* F. during the winter Season at KVK, Semiliguda

As revealed in Table 5, it was observed that the maximum temperatures had a range between 23.8 °C to 29.7 °C with an average of 25.7 °C which had a positive correlation with bees coming with pollen ($r=0.592^*$), nectar ($r=0.606^*$), and outgoing bees ($r=0.568^*$), which was found to be significant only at a 5% level. The minimum temperature that prevailed during the period of study was from 5.7 °C to 13.7 °C, with an average of 11.1 °C, which was also positively correlated with all groups of foragers but negatively affected the foraging activity with an 'r' value of 0.627*, 0.639*, and 0.640* for outgoing, pollen and nectar foragers respectively. Foraging activity increases with increases in temperature and decreases with decreasing temperature. Similar observations are reported by Burrill and Dietz, 1981 [3]. The Relative humidity (morning) varied from 92 to 97% which was negatively correlated with r values of -0.443, -0.431, and, -0.436 for outgoing, nectar, and pollen foragers respectively, whereas afternoon relative humidity varied from 48 to 71%, which was found to be slightly positively correlated with an r value 0.018 for outgoing bees but negatively correlated for bees carrying pollen and nectar having $r = -0.034$, and -0.042 respectively which is in line with Joshi and Joshi (2010) [10] reported that relative humidity showed less effect on the foraging activities of *Apis* species.

The total rainfall received during this season was 42 mm, which resulted in a negative correlation with an r-value of -0.101-0.139 and -0.140 for outgoing foragers, pollen, and nectar gatherers. Reddy *et al.*, (2015) [17] concluded that low temperatures decreased bee activity. Rainfall had hampered the foraging activity while wind speed was found to have no significant effect. This is in agreement with the present study. The BSH was also negatively correlated with foragers with r values of -0.112, -0.115, and -0.166 for nectar, pollen, and outgoing foragers respectively.

The wind speed had a negative effect on foragers having $r = -0.184$, -0.067 and -0.062 for outgoing foragers, pollen, and nectar gatherers respectively which is corroborated by Rashad (1957) [16] observed that change in wind velocity was indirectly related to the population of foraging bees while the other parameters remained roughly constant. Evaporation was positively correlated with all foragers with r values of 0.208, 0.246, and 0.235 for outgoing, nectar, and pollen foragers respectively

Table 5: Correlation matrix on the effect of weather factor on the foraging activity of *Apis cerana indica* F. in winter season at KVK, Semiliguda

Meteorological parameters	Incoming Foragers		Outgoing foragers
	Nectar foragers	Pollen foragers	Outgoing foragers
Max T (°C)	0.606*	0.592*	0.568*
Min T (°C)	0.640*	0.639*	0.627*
RHI (%)	-0.436	-0.431	-0.443
RHII (%)	-0.042	-0.034	0.018
Rainfall (mm)	-0.140	-0.139	-0.101
BSH (hours)	-0.112	-0.115	-0.166
Wind speed (km/hr)	-0.062	-0.067	-0.184
Evap (mm)	0.246	0.235	0.208

*Significantly correlated at 5% level ** Significantly correlated at 1% level

3.8. Regression studies of foraging activity of *Apis cerana indica* F. at AICRP on honey bees and pollinators, OUAT, Bhubaneswar and KVK, Semiliguda in the winter season

At KVK, Semiliguda as revealed in Table 6 the coefficient of determination (R^2) was 0.975 and 0.951 showing as much as 97.5% and 95.1% variation in foraging activity of nectar and pollen foragers respectively due to minimum temperature, rainfall, and afternoon relative humidity, while the coefficient of determination (R^2), of 0.939 showed as much as 93.9% of variation due to rainfall and afternoon relative humidity which negatively affected the foraging activity of outgoing foragers.

Table 6: Regression of foraging activity with weather parameters in the winter season at KVK, Semiliguda

Winter (Met week 49 th -8 th)	Foraging activity	Stepwise regression equation	R ² Value	P Value
	Outgoing foragers	$O = 27.088 + 2.674 * \text{Min T} - 0.459 * \text{RHII}$	0.939	< 0.0001
	Nectar foragers	$N = 25.398 + 3.458 * \text{Min T} - 0.536 * \text{RHII} - 0.339 * \text{Rainfall}$	0.975	< 0.0001
	Pollen foragers	$P = 13.837 + 1.919 * \text{Min T} - 0.293 * \text{RHII} - 0.1907 * \text{Rainfall}$	0.951	< 0.0001

4. Conclusion

In both locations, during winter season the highest contribution was made by outgoing foragers followed by nectar foragers and the least contribution was by pollen foragers. while comparing the variation in foraging activity during the day such that the highest activity was observed at 10-11 am and a second peak was at 7 to 8 am, with the lowest activity at 3-4 pm. Among several weather parameters, only rainfall had a significant and negative correlation with foraging activity at Bhubaneswar. Maximum and minimum temperatures were positively correlated whereas minimum temperature negatively influenced the foraging task. Minimum temperature and rainfall were the two parameters contributing more than 80% for all groups of foragers at Bhubaneswar whereas due to minimum temperature, afternoon relative humidity, and rainfall, the foraging activity was affected as much as 97.5% and 95.1% for nectar and pollen foragers for Semiliguda, but only minimum temperature and afternoon relative humidity affected the foraging activity for outgoing foragers.

5. References

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