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Impact of Weather Factors (Temperature and Relative Humidity) on the Relative Abundance of two Honey bees (*Apis*) Species on Mustard (*Brassica juncea*) and Sunflower (*Helianthus annus*)

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Abstract
Honey bees are regarded as the best insect pollinator (Chitka; 2022, Hung *et al*. 2018). By promoting genetic variation in plants through cross pollination, different species of honey bees have been contributing to biodiversity and enhancement of crop yields and other plant products. They not only enhance the production but also contributing in setting up a vibrant ecosystem upon which humanity depends. Of late, environmental upheavals like global warming and climate change tend to alter the abiotic factors like temperature and relative humidity. Impact of the changes on the foraging behaviour of honey bees must be assessed to ascertain whether these factors are affecting the relative abundance of honey bees and thereby their pollinating capability. The current research work has been undertaken keeping in view these goals. Two important edible oil crops, *B. juncea* (mustard) and *H. annus* (sunflower) are mainly pollinated by honey bee species *Apis nmellifera* and *Apis florea* around Muzaffarpur town. So relative abundance of these two honey bee species have been studied. The result shows that population of *Apis mellifera* ands *Apis florea* on *Brassica juncea* show positive correlation with temperature and negative correlation with relative humidity. But the negative correlation of *Apis mellifera* with relative humidity was relatively less pronounced.

Keywords: Foraging behaviour, honey bee, relative abundance, and relative humidity.

Introduction

Indian mustard *(Brassica juncea)* commonly called sarson / rai and sunflower *(Helianthus annus)* are important oilseed crops in India. Mustard is the major rabi (winter) oilseed crop in Bihar. As far as oilseed economy (of India) is concerned it stands next to the groundnut. Sunflower (Helianthus annus) an annual oilseed, is significant cash crop (Fernandez- Martinez *et al*; 2010) [14] that can be grown both as a rabi (winter) or Kharif (monsoon) crop. In Asia, India is the second largest sunflower growing country after China.

The agro-climatic conditions of Bihar provide suitable environment for mustard and sunflower cultivation. Mustard cultivation mainly concentrated (although it is cultured across the state) in the districts like Muzaffrpur, Vaishali, Champaran, Bhagalpur, Munger, Patna, Nalanda, Saran and Siwan. As far as sunflower is concerned Bihar is expanding in its cultivation. The major districts for sunflower cultivation in Bihar are Samastipur, Muzaffarpur, Nalanda, Vaishali, Purnea, Bhagalpur. Findings reveal that the flowers of mustard and sunflower attract a wide variety of insects. Among them honey bees are considered as the best pollinaters (Chittka 2022, Hung *et al* 2018). Lehrman (2007) [10, 17, 22].

Reported importance of Apis mellifera both for pollination and for honey production. Honey bees collectively formed the most predominant group of pollinators as high as 97.87% of sunflower & 97.58 % of mustard (Virakamath, Patil, Murasing & Guruprasad, 2002). Arya, Sihag and Yadav (1994) [4, 32] stated that A. mellifera was most common visitor of sunflower, foraging both for nectar & pollen. Honey bees are ecofriendly, provide free ecosystem services and ensure uniform maturity and early harvest of the crop (Anil 2015) [3] with seeds of better quality. Thus an investigation was conducted in the Muzaffarpur district of Bihar-India to investigate the impact of temperature and humidity on the relative abundance of *A. mellifera* and *A. florea*, on mustard *(Brassica juncea)* and sunflower *(Helianthus annus)*.

Materials and Methods

The present research work was performed chiefly at University department of Zoology (B. R. A. Bihar University) Muzaffarpur. The field study was made at Mushari block of Muzaffarpur district Bihar. The study was made during two consecutive years 2022 [10]-23 and 2023-24.

To study the relative abundance of *A. mellifera* and *A. florea*, yellow and brown mustards and sunflowers were grown with recommended agronomical package and practices. The crops were grown during 2022- 23 and 2023-24. The details of crops grown are as follows:

S.No.	Crops	Cultivers	Date of sowing	Seed rate	Spacing (in cm)
1	B. Juncea	Varuna	5th Nov	5Kg./ha	30x15
2	H. annus	Modern	20thJul	8Kg./ha	45x20

Crop research Program

Design: Factorial RBD
Replication: Three
Plot size: 2.5 m x 5.00 m

When crops came to bloom, the number of foragers *Apis mellifera* and *Apis florea* foraging for nectar / pollen or both were counted for 10 minutes in an area of one square meter marked randomly in experimental plots. Numbers of foragers were recorded at 900h, 1100h, 1300h and 1500h of the day at weekly intervals. The dates on which crops were observed are given below:

Crop	Date of Observation	
	2022-23	**2023-24**
Brassica juncea	20.12.22	20. 12. 23
	27.12.22	27. 12. 23
	05.01.23	05. 01. 24
	12.01.23	12. 01. 24
Helianthus annus	28. 01. 23	28. 01. 24
	04. 02. 23	04. 02. 24
	11. 02. 23	11. 02. 24
	18. 02. 23	18. 02. 24

On different dates and at different times, the temperature and relative humidity were recorded.

The abundance of *Apis mellifera* and *Apis florea* was correlated with mean temperature and mean relative humidity. Methods of Statistical analysis outlined by Panas and Sukhatme (1967) [26] were followed to work out the correlation and regression equations. The data were statistically analyzed in factorial RBD. All data are mean. Significance level at $P < 0.05$.

Result and discussion

Observations on *Brassica juncea*

The data on relative abundance of *Apis mellifera* and *Apis florea* recorded at different hours of the day on different dates in the year 2022-23 and 2023-24 are presented in Table1(a). On different hours of the day the population of *Apis mellifera* was found greater than those of *Apis florea*. In the fourth to fifth week of December, the mean populations of both the species- *Apis mellifera* and *Apis florea* were highest. However, in the second to third week of January the mean populations were recorded lowest.

Table 1: (a) Relative abundance (No. of bees/10 minute/m^2) of *Apis mellifera* and *Apis florea* on *Brassica juncea* at different hours of the day during two constitutive years 2022 [10]-23 and 2023-24.

Month	Week	Species	*Mean population at different hours of the day (h)					Avg. temp (°C)	Avg.RH (%)
			900h	1100h	1300h	1500h	Mean		
Year: 2022-2023									
December	IV	*Apis mellifera*	38.34	25.10	47.68	24.69	33.95		
		Apis florea	6.85	5.90	11.50	4.50	7.19	13.8	79.0
		Mean	22.60	15.50	29.59	14.60	20.57		
	V	*Apis mellifera*	51.50	43.20	61.35	31.51	46.89		
		Apis florea	13.50	10.10	16.20	6.80	11.65	16.3	78.6
		Mean	32.50	26.65	38.78	19.16	29.27		
January	II	*Apis mellifera*	30.50	21.50	42.30	18.07	28.09		
		Apis florea	10.50	8.50	12.50	6.40	9.48	13.7	79.0
		Mean	20.50	15.00	27.40	12.24	18.72		
	III	*Apis mellifera*	49.35	46.30	54.50	40.28	47.61		
		Apis florea	10.60	9.50	12.35	8.25	10.18	16.3	76.0
		Mean	29.96	27.90	33.43	24.27	28.89		
		Grand Mean	26.39	21.26	32.30	17.56	24.38		
Year 2023-2024									
December	IV	*Apis mellifera*	61.30	56.25	71.15	41.20	57.48		
		Apis florea	16.50	15.30	18.50	13.30	15.90	18.9	64.0
		Mean	38.90	35.78	44.83	27.25	36.69		
	V	*Apis mellifera*	46.15	44.30	51.15	34.30	43.98		
		Apis florea	10.67	8.50	14.50	7.30	10.24	15.4	73.5
		Mean	28.41	26.40	32.83	20.80	27.11		
January	II	*Apis mellifera*	37.33	32.50	39.30	27.45	34.15		
		Apis florea	12.50	10.40	15.50	8.30	11.68	13.7	74.5
		Mean	24.92	21.45	27.40	17.88	22.92		
	III	*Apis mellifera*	35.33	30.50	37.30	25.30	32.11		
		Apis florea	9.50	7.40	9.50	5.40	7.95	13.0	75.3
		Mean	22.42	18.95	23.40	15.35	20.03		
		Grand Mean	28.66	25.64	32.11	20.32	26.68		

There were significant variation (P =0.05) in the population of *Apis mellifera* with year, date, hour and interaction effects of year × hour, year × date, hour × date and year × hour × date. While in the case of *Apis florea*, the influence of year, hour, date, interaction effect of year x hour and hour x date on the population abundance were statistically significant (P =0.05) except the interaction effects of year × date and year × hour × date. Table 1(b).

Table 1: (b) *Means of three replications

Factors	Apis mellifera		Apis florea	
	SEM(±)	CD(P =0.05)	SEM(±)	CD(P =0.05)
Year	0.29	0.79	0.16	0.43
Hour	0.4	1.12	0.22	0.61
Date	0.4	1.12	0.22	0.61
Year x hour	0.57	1.58	0.31	0.87
Yrae x date	0.57	1.58	NS	NS
Hour x date	0.81	2.24	0.4	1.22
Year x Hour x date	1.14	3.16	NS	NS
CV (%)	4.89		10.22	

During both the years (i.e. 2022 [10]-2023 and 2023-2024), on *Brassica juncea* the honey bees activities were recorded at their peak at 1300h followed by 900h, whereas the lowest activities were recorded at 1500h. Mamood, Ray and Erickson (1996) [23] observed that *Apis mellifera* foraged in flowers most actively between 1100h and 1300h, with a peak at 1300h. Sihag and Khatkar (1999) observed that the peak activity of Apis species on mustard were between 1100h to 1300h. These results can be explained on the basis of the fact that pollen grains were mainly available in the morning hours (Burgstaller, 1989; Rana,Raj and Kaushik, 1997) [7, 30].

Correlation coefficient and multiple regression equations have been calculated to investigate the influence of temperature and relative humidity on Apis mellifera and Apis florea in the year 2022 [10]-23 and 2023-24. The population of *Apis mellifera* and *Apis florea* on *Brassica juncea* showed positive and highly significant correlations with temperature and exhibit negative and significant correlations with relative humidity (Table2). The standard regression coefficient suggests that the populations of *Apis mellifera* and *Apis florea* are dependent on temperature and relative humidity. Similar observations made by Kumar & Singh (2005) [21]. The regression model revealed that the combined contributions of temperature and relative humidity to abundance of *Apis florea and Apis mellifera* were 98.4% and 86.6% respectively. The R^2 value of *A. mellifera* (0.866**) and *A.florea* (0.984**) are highly significant and exhibit their contribution to abundance. Similar results were obtained by Cirusdarescu (1972), Aboral and Bhat (1987) and Kumar and Singh (2005) [1, 11, 21].

Table 2: Correlation coefficients and multiple regression equations between mean population *(A. meliifera and A. florea)* and weather parameters on *Brassica juncea.*

Independent variable (X)	Dependent variable (Y)	
	***Apis mellifera* (Y_1)**	***Apis florea* (Y_2)**
Temperature (°C) (X_1)	0.891**	0.992**
Relative humidity (X_2)	- 0.829**	-0.732*

Multiple regression equation

$Y_1 = 77.062 + 2.81\ X_1 - 0.998\ X_2$ ($R^2 = 0.866$** Adj. $R^2 = 0.813$**)

$Y_2 = -5.397 + 1.117\ X_1 - 0.015\ X_2$ ($R^2 = 0.984$** Adj. $R^2 = 0.977$**)

**Significant at 1% probability level

*Significant at 5% probability level

Observations on *Helianthus annus*

The observations made with *Helianthus annus* on different hours of the day revealed that the peak activities of *Apis mellifera* and *Apis florea* were at 1100h followed by 1300h and 0900h respectively. The minimum activities were recorded at 1500hours. Table 3(a). In the fifth week of January the population abundance of *Apis mellifera* and *Apis florea* were recorded minimum on *Helianthus annus*, whereas in the second week of February it was noticed maximum. As the flowering was advanced, the relative abundance of Apis mellifera and Apis florea increased. In the second week of February the relative abundance reached its peak and then declines in the third week of February as the flowering reached its maturity. Table 3(a).

Table 3: (a) Relative abundance (No. of bees/10 minute/m2) of *Apis mellifera* and *Apis florea* on *Helianthus annus* at different hours of the day during two consecutive years 2022 [10]-23 and 2023-24.

Month	Week	Species	*Mean population at different hours of the day (h)					Avg. temp (°C)	Avg.RH (%)
			900h	1100h	1300h	1500h	Mean		
Year: 2022-2023									
January	V	*Apis mellifera*	42.53	56.51	33.51	31.33	40.97		
		Apis florea	10.50	13.53	11.23	6.75	10.50	15.9	72.9
		Mean	26.52	35.02	22.37	19.04	25.74		
February	I	*Apis mellifera*	50.50	63.80	52.20	39.56	51.52		
		Apis florea	11.53	16.73	14.35	8.97	12.90	16.6	65.5
		Mean	31.02	40.27	33.28	24.27	32.26		
	II	*Apis mellifera*	69.50	91.67	82.50	58.50	75.54		
		Apis florea	18.53	24.87	21.53	11.63	19.14	19.1	59.5
		Mean	44.02	58.27	52.02	35.07	47.34		
	III	*Apis mellifera*	60.50	78.35	72.50	51.60	65.74		
		Apis florea	16.33	20.74	12.25	9.78	14.78	18.5	63.0
		Mean	38.42	49.50	42.38	30.69	40.26		
		Grand Mean	34.99	45.78	37.51	27.27	36.39		
Year 2023-2024									
January	V	*Apis mellifera*	36.93	40.75	30.12	26.50	33.58		
		Apis florea	7.50	9.35	7.36	6.55	7.69	14.5	75.0
		Mean	22.22	25.05	18.74	16.53	20.64		
February	I	*Apis mellifera*	43.55	56.50	46.50	36.85	45.85		
		Apis florea	10.52	15.53	13.52	20.35	14.98	17.1	66.0
		Mean	27.04	36.02	32.01	28.60	30.42		
	II	*Apis mellifera*	67.35	85.38	81.36	53.50	71.90		
		Apis florea	17.35	22.52	20.35	9.42	17.41	18.6	62.5
		Mean	42.35	53.95	50.86	31.46	44.66		
	III	*Apis mellifera*	59.10	81.20	68.46	45.85	63.65		
		Apis florea	14.53	18.75	16.85	9.35	14.89	17.8	64.0
		Mean	38.82	49.98	42.66	27.60	39.27		
		Grand Mean	32.10	41.25	35.57	26.05	33.74		

The effects of year, hour, date and the interaction of effect of hour × date on the population of *Apis mellifera* were statistically significant (P = 0.05), whereas interaction effects of year × hour, year × date and year × hour × date were non-significant. However, in case of *Apis florea* the effect of year, hour, date, interaction effects of year × hour, year × date, hour × date and year × hour × date were significant (P =0.05). Table 3(b).

The relative abundance of honey bees was highest at midday and minimum during early and late hours of the day. The above findings support the reports of kumar (2000), Kumar and Singh (2005) [18, 21].

Table 3(b): *Means of three replications

Factors	*Apis mellifera*		*Apis florea*	
	SEM(±)	CD(P =0.05)	SEM(±)	CD(P =0.05)
Year	0.5	1.39	0.13	0.35
Hour	0.71	1.97	0.18	0.49
Date	0.71	1.97	0.18	0.49
YearX hour	NS	NS	0.25	0.7
Yrae x date	NS	NS	0.25	0.7
Hour X date	1.42	3.94	0.36	0.99
YearXHourX date	NS	NS	0.5	1.4
CV (%)	6.21		6.21	

The correlation coefficients (Table no.4) of *Apis mellifera* and *Ais florea* populations on *Helianthus annus* were positive and highly significant with temperature. The activity of Apis florea was negative and highly significantly correlated with relative humidity, whereas the correlation coefficient of the *Apis mellifrea* population was negative and non significant with relative humidity. The mathematical regression models to predict the activity of *Apis mellifera* and *Apis florea* were developed which revealed that combined contributation of temperature and relative humidity to population of *Apis mellifera* and *Apis florea* were 94.2% and 94.7% respectively. Multiple regression equation model suggests that temperature is mainly responsible for variations in population of *Apis species* as the regression coefficients of temperature are positive with each species.

Table 4: Correlation coefficients and multiple regression equations between mean population *(A. meliifera and A.florea)* and weather parameters on *Helianthus annus.*

Independent variable (X)	Dependent variable (Y)	
	Apis mellifera (Y_1)	*Apis florea* (Y_2)
Temperature ((°C) (X_1)	0.968**	0.972**
Relative humidity (X_2)	- 0.660 NS	- 0.903**

Multiple regression equation

$Y_1 = -138.291 + 10.485\ X_1 + 0.234\ X_2$ ($R^2 = 0.942$** Adj. $R^2 = 0.918$**)

$Y_2 = -18.332 + 2.002\ X_1 - 0.040\ X_2$ ($R^2 = 0.947$** Adj. $R^2 = 0.918$**)

**Significant at 1% probability level

*Significant at 5% probability level

Conclusion

On the basis of the result discussed above it can be concluded that on both oilseed crops *Apis mellefera* activity was the highest in the morning and the lowest in the afternoon. At the time of flowering the maximum activity was observed. The relative abundance of *Apis mellifera* was greater than those of *Apis florea* on *Brassica juncea* and *Helianthus annus*. The population abundance of *Apis mellifera* and *Apis florea* were positively and significantly correlated with temperature but negatively and significantly correlated with relative humidity.

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