Indian Journal of Entomology 85(Special Issue) May 2023: 101-107 eRef. No. NWRABNRG21 DoI. No.: 10.55446/IJE.2023.1170

RELATIVE ABUNDANCE OF DIFFERENT *APIS* SPP. ON RAPESEED-MUSTARD

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ABSTRACT

Abundance of insect pollinators on rapeseed-mustard showed that bees were most abundant on *Brassica rapa* L. var. toria i.e. 15.15, 18.47, 21.02 and 15.11 bees/ m^2/ 10 min and least abundant on *Brassica nigra* i.e. 8.43, 9.53, 11.30 and 8.47 bees/ m^2/ 10 min at 1000 h, 1200 h, 1400 h and 1600 h, respectively. At 1000 h, *Apis mellifera* was observed as the most abundant pollinator (13.94 bees/ m^2/ 10 min) followed by *A. cerana* (11.23 bees/ m^2/ 10 min), *A. dorsata* (10.50 bees/ m^2/ 10 min) and *A. florea* (8.30 bees/ m^2/ 10 min) and the same trend was also followed at 1200 h, 1400 h and 1600 h. The comparative mean abundance of *Apis* spp. on different varieties/ genotypes of rapeseed-mustard revealed that bees were most abundant on variety TH 68 (16.77 bees/ m^2/ 10 min) and least abundant on Nigra (9.12 bees/ m^2/ 10 min). Also *A. mellifera* had maximum (15.50 bees/ m^2/ 10 min) mean comparative density across the varieties/genotypes followed by *A. cerana* (12.90 bees/ m^2/ 10 min), *A. dorsata* (12.25 bees/ m^2/ 10 min) and *A. florea* (9.37 bees/ m^2/ 10 min). The activity of different honey bees varied with time i.e. maximum abundance of *A. mellifera*, *A. cerana*, *A. dorsata* and *A. florea* was reported at 1200 to 1400 h and it was least abundant at 1000 h and 1600 h of the day.

Key words: Abundance, *Apis cerana*, *A. dorsata*, *A. florea*, *A. mellifera*, pollinator, rapeseed, mustard, *Brassica* spp.

India is the fourth largest rapeseed-mustard producer in the world after European Union, Canada and China. At national level, rapeseed-mustard is cultivated over an area of 6.12 million hectare having production of 9.26 million tonnes and productivity of 1511 kg/ ha (Annonymous, 2020a). This crop accounts about one-third of the oil produced in India, making it the country's key edible oilseed crop. Haryana is the second most important rapeseed-mustard producing state in the country with an area of 0.51 million ha, production of 0.95 million tonnes and productivity of 1830 kg/ ha (2016-2017) which is highest in the country (Annonymous, 2020b). Rapeseed-mustard crop in India includes conventionally grown native species, namely brown sarson (*Brassica campestris* L. var. brown sarson), toria (*B. campestris* L. var. toria), yellow sarson (*B. campestris* L. var. yellow sarson), Indian mustard [*B. juncea* (L.) Czernj & Cosson], black mustard [*B. nigra* (L.) Koch] and taramira (*Eruca sativa* Mill) along with non-native species like white mustard (*Sinapis alba* L.), gobhi sarson (*B. napus* L.) and Ethiopian mustard/ karanrai (*B. carinata*).

The different *Brassica* spp. requires external pollinating agents like insects for transfer of the pollen grains from anther to stigma. Among various insect pollinators that visited *B. juncea* flowers, honey bees viz. *Apis dorsata, A. cerana, A. mellifera* and *A. florea* constituted the major proportion (Abrol, 2007a) and reported to be sympatric in existence on rapeseed mustard crop (Chaudhary, 2006). Brassica oilseed crops provide abundant floral resources, producing nectar with relatively high concentrations of sugars and huge quantities of pollen, which makes them attractive to a wide variety of insect pollinators (Thom et al., 2016). Insect pollination ensures uniform ripening and earlier pod setting, increased seed germination and seed oil content in *Brassica* oilseed crops (Bartomeus et al., 2014 and Abrol, 2007b). Ahmed and Rehman (2002) observed that pollination of rapeseed crop (*B. campestris* var. toria) by insect foragers gave maximum (9.16 q/ha) yield which was 133.33% higher than the self-pollinated treatment. Manning and Wallis (2005) found that placing hives of honey bees (*A. mellifera* L.) in canola (*B. napus* L.) at a density of approximately one hive/ ha resulted in 20% seed yield increase, whereas the yield declined in plots located more than 200 m from the apiary. A total of eight insect pollinators belonging to three different orders viz., Hymenoptera, Diptera and Coleoptera were found visiting on mustard flowers. The highest contribution of relative abundance (%) and average insect population was observed in the order Hymenoptera as 84.64% with 22.15 insect pollinators/ m^2/ min, respectively (Singh et al., 2018).

The information available on the abundance of different *Apis* spp. on new genotypes of various *Brassica* spp. is very meager. Besides the research on the resource partitioning by *Apis* spp. on various *Brassica* spp. has not been fully exploited. Therefore, to bridge over the gap of information, the present study was planned to study abundance of major insect pollinator i.e. *Apis* spp. on *Brassica juncea*, *B. napus, B. rapa*, *B. carinata*, *B. nigra* and *Eruca sativa.*

MATERIALS AND METHODS

The study was executed during 2019-20 in the research area of Oilseeds Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar, Haryana. It lies in the semi-arid, subtropics at $29^0$10' N latitude and $75^0$46' E longitude and at an altitude of 215.2 meters above mean sea level.

Eleven genotypes of different *Brassica* spp. of rapeseed-mustard selected for present study. The cultivars studied are RH 725, RH 0502, DRMRIJ-31 (GIRIRAJ) and RCH-1 of *B. juncea* L.*,* HNS 0901 of *B. napus* L., YSH-401, BSH-1 and TH 68 of *B. rapa* L., HC-212 of *B. carinata* Braun, NIGRA of *B. nigra* Koch and T27 of *Eruca sativa* Mill.

All genotypes were sown and raised as per recommended Package of Practices of CCS HAU, Hisar. The sowing was done on 13th October 2019 with three replications. The abundance of major flower pollinators on different *Brassica* spp. flowers was recorded by visual observations from per square meter area of crop for 10 minutes for three consecutive sunny days at two-hour interval starting from 1000 to 1600 h using a hand tally counter. Data obtained were analyzed subjecting to randomized block design using online software OPSTAT. The weather data for parameters such as relative humidity, atmospheric temperature, rainfall, sunshine hours and wind speed was collected from the observatory of the Department of Agro-meteorology, CCS HAU, Hisar and was correlated with foraging behavior of different *Apis* spp. The data was statistically analyzed using Pearson's method.

RESULTS AND DISCUSSION

Abundance of *Apis* spp. at 1000 h on various rapeseed-mustard varieties/genotypes

At 1000 h (Table 1), bees were most abundant on variety TH 68 (15.15 bees/ m^2/ 10 min) and least abundant on Nigra, T-27 (8.43 bees/ m^2/ 10 min). The mean density of *A. mellifera* was maximum (13.94 bees/ m^2/ 10 min) followed by *A. cerana* (11.23 bees/ m^2/ 10 min), *A. dorsata* (10.50 bees/ m^2/ 10 min) and *A. florea* (8.30 bees/ m^2/ 10 min) and all varied statistically from each other. *A. mellifera* population was found maximum on variety TH 68 (22.93 bees/ m^2/ 10 min) and the population varied from 10.20-16.87 bees/ m^2/ 10 min in all other varieties/ genotypes with significant variation. *A. cerana* population vary from 8.87-14.47 bees/ m^2/ 10 min and all these varieties/ genotypes vary significantly from each other except genotype HNS 0901 which was found statistically at par with variety T-27. *A. dorsata* was most abundant on genotype HC-212 (15.20 bees/ m^2/ 10 min). Further, the population of *A. florea* was most abundant on variety TH 68 (11.33 bees/ m^2/ 10 min) and its population varied from 5.00-10.53 bees/ m^2/ 10 min on rest of the varieties/genotypes.

Abundance of *Apis* spp. at 1200 h on various rapeseed-mustard varieties/genotypes

At 1200 h (Table 2), bees were most abundant on variety TH 68 (18.47 bees/ m^2/ 10 min) and least abundant in Nigra (9.53 bees/ m^2/ 10 min). The mean density of *A. mellifera* was maximum (16.76 bees/ m^2/ 10 min) followed by *A. cerana* (13.87 bees/ m^2/ 10 min), *A. dorsata* (12.91 bees/ m^2/ 10 min) and *A. florea* (10.15 bees/ m^2/ 10 min) and all vary statistically from each other. Here, *A. mellifera* population was found maximum on variety TH 68 (26.80 bees/ m^2/ 10 min) and the population in all other varieties/ genotypes varied non-significantly from 13.27-19.80 bees/ m^2/ 10 min. *A. cerana* was most abundant on variety TH 68 (18.33 bees/ m^2/ 10 min) and their population varied from 7.47-17.00 bees/ m^2/ 10 min in different varieties/ genotypes. Population of *A. dorsata* was higher on variety BSH-1 (19.20 bees/ m^2/ 10 min) and it varied from 9.93-14.60 bees/ m^2/ 10 min on other varieties/ genotypes. *A. florea* was most abundant on variety TH 68 (14.13 bees/ m^2/ 10 min) and its population in rest of the varieties/genotypes varied non-significantly from 6.80-12.53 bees/ m^2/ 10 min.

Abundance of *Apis* spp. at 1400 h on various rapeseed-mustard varieties/genotypes

At 1400 h (Table 3), bees were most abundant on variety TH 68 and least abundant in Nigra (11.30 bees/ m^2/ 10 min). The mean density of *A. mellifera* was maximum (19.57 bees/ m^2/ 10 min) followed by *A. cerana* (15.87 bees/ m^2/ 10 min), *A. dorsata* (14.89 bees/ m^2/ 10 min) and *A. florea* (11.54 bees/ m^2/ 10 min) and all varied statistically from each other. *A. mellifera* population was found maximum on variety TH

Table 1. Abundance of *Apis* spp. on different varieties/genotypes of rapeseed-mustard at 1000 h at Hisar during 2019-20

Pollinator	No. of honey bees/ m²/ 10 min											Mean
	RH 725	RH 0502	HNS 0901	YSH 401	BSH-1	TH 68	HC-212	NIGRA	T-27	GIRIRAJ	RCH-1	
A. mellifera	15.60* (4.07)**	12.40 (3.65)	16.40 (4.17)	16.87 (4.22)	13.53 (3.81)	22.93 (4.89)	11.00 (3.46)	10.20 (3.34)	10.53 (3.39)	11.53 (3.54)	12.67 (3.70)	13.97 (3.84)
A. cerana	10.60 (3.40)	12.07 (3.61)	8.93 (3.15)	11.67 (3.55)	9.27 (3.20)	13.67 (3.82)	12.60 (3.68)	7.20 (2.86)	8.87 (3.14)	14.20 (3.90)	14.47 (3.93)	11.23 (3.48)
A. dorsata	11.13 (3.48)	9.87 (3.29)	9.53 (3.24)	8.67 (3.10)	14.87 (3.98)	12.67 (3.69)	15.2 (4.02)	9.40 (3.22)	9.13 (3.18)	7.53 (2.92)	7.53 (2.92)	10.50 (3.37)
A. florea	7.67 (2.94)	8.00 (3.00)	8.20 (3.03)	10.00 (3.31)	9.47 (3.23)	11.33 (3.51)	10.53 (3.39)	6.93 (2.81)	7.47 (2.91)	6.73 (2.78)	5.00 (2.45)	8.30 (3.04)
Mean	11.25 (3.48)	10.58 (3.39)	10.77 (3.40)	11.80 (3.55)	11.78 (3.56)	15.15 (3.98)	12.33 (3.64)	8.43 (3.06)	9.00 (3.16)	10.00 (3.29)	9.92 (3.25)	
CD (p=0.05)	(0.203)	(0.035)	(0.039)	(0.028)	(0.048)	(0.03)	(0.04)	(0.032)	(0.037)	(0.115)	(0.123)	(0.023)
SE (m)	0.057	0.01	0.011	0.008	0.014	0.008	0.011	0.009	0.01	0.032	0.035	0.008
CD (p=0.05) for varieties/genotypes						(0.037)						
SE (m)						0.013						

*Each value represents a mean of 5 observations; **Figures in parentheses are the means of √n+1 transformation

Table 2. Abundance of *Apis* spp. on different varieties/genotypes of rapeseed-mustard at 1200 h at Hisar during 2019-20

Pollinator	No. of honey bees/ m²/ 10 min											Mean
	RH 725	RH 0502	HNS 0901	YSH 401	BSH-1	TH 68	HC-212	NIGRA	T-27	GIRIRAJ	RCH-1	
A. mellifera	18.93* (4.46)**	15.80 (4.09)	19.73 (4.55)	19.80 (4.56)	16.60 (4.19)	26.80 (5.27)	13.53 (3.81)	12.53 (3.67)	13.27 (3.78)	13.40 (3.80)	13.93 (3.86)	16.76 (4.19)
A. cerana	13.47 (3.80)	13.73 (3.83)	13.33 (3.78)	15.27 (4.03)	13.00 (3.74)	18.33 (4.39)	15.07 (4.00)	7.47 (2.90)	9.53 (3.25)	16.40 (4.17)	17.00 (4.24)	13.87 (3.83)
A. dorsata	13.60 (3.82)	12.07 (3.61)	12.40 (3.65)	10.80 (3.43)	19.20 (4.49)	14.60 (3.94)	17.67 (4.32)	10.47 (3.38)	11.33 (3.51)	9.93 (3.31)	9.93 (3.31)	12.91 (3.71)
A. florea	9.47 (3.23)	9.47 (3.23)	11.27 (3.49)	11.93 (3.59)	11.93 (3.59)	14.13 (3.87)	12.53 (3.67)	7.67 (2.94)	8.27 (3.04)	8.13 (3.02)	6.80 (2.79)	10.15 (3.32)
Mean	13.87 (3.83)	12.77 (3.70)	14.18 (3.88)	14.45 (3.91)	15.18 (4.01)	18.47 (4.38)	14.70 (3.96)	9.53 (3.23)	10.60 (3.39)	11.97 (3.57)	11.92 (3.55)	
CD (p=0.05)	(0.164)	(0.022)	(0.043)	(0.051)	(0.051)	(0.051)	(0.038)	(0.14)	(0.085)	(0.148)	(0.138	(0.035)
SE (m)	0.046	0.006	0.012	0.014	0.014	0.014	0.011	0.04	0.024	0.042	0.039	0.013
CD (p=0.05) for varieties/genotypes						(0.059)						
SE (m)						0.021						

*Each value represents a mean of 5 observations; **Figures in parentheses are the means of √n+1 transformation

Table 3. Abundance of *Apis* spp. on different varieties/ genotypes of rapeseed-mustard at 1400 h at Hisar during 2019-20

Pollinator	No. of honey bees/ m²/ 10 min											
	RH 725	RH 0502	HNS 0901	YSH 401	BSH-1	TH 68	HC-212	NIGRA	T-27	GIRIRAJ	RCH-1	Mean
A. mellifera	22.07*	18.60	23.13	23.47	20.40	30.00	15.87	14.33	15.53	14.87	17.00	19.57
	(4.80)**	(4.42)	(4.91)	(4.94)	(4.62)	(5.56)	(4.10)	(3.91)	(4.07)	(3.98)	(4.24)	(4.51)
A. cerana	16.27	16.00	15.67	17.53	15.60	20.53	15.73	8.87	10.93	18.47	18.93	15.87
	(4.15)	(4.12)	(4.08)	(4.30)	(4.07)	(4.64)	(4.09)	(3.14)	(3.45)	(4.41)	(4.47)	(4.09)
A. dorsata	14.60	13.73	14.53	12.67	22.4	16.87	20.13	12.53	13.47	11.40	11.40	14.89
	(3.95)	(3.83)	(3.94)	(3.69)	(4.83)	(4.22)	(4.59)	(3.67)	(3.80)	(3.52)	(3.52)	(3.96)
A. florea	10.53	10.13	11.67	13.80	13.73	16.67	14.87	9.47	9.60	8.33	8.13	11.54
	(3.39)	(3.34)	(3.59)	(3.84)	(3.83)	(4.20)	(3.98)	(3.23)	(3.26)	(3.06)	(3.02)	(3.52)
Mean	15.87	14.62	16.25	16.87	18.03	21.02	16.65	11.30	12.38	13.27	13.87	
	(4.08)	(3.93)	(4.12)	(4.20)	(4.34)	(4.66)	(4.19)	(3.49)	(3.65)	(3.74)	(3.81)	
CD (p=0.05)	(0.08)	(0.032)	(0.041)	(0.03)	(0.041)	(0.026)	(0.058)	(0.047)	(0.083)	(0.148)	(0.118)	(0.020)
SE (m)	0.023	0.009	0.012	0.008	0.012	0.007	0.016	0.013	0.023	0.042	0.033	0.007
CD (p=0.05) for varieties/genotypes						(0.033)						
SE (m)						0.012						

*Each value represents a mean of 5 observations; **Figures in parentheses are the means of $\sqrt{n+1}$ transformation

68 (30.00 bees/ m²/ 10 min) and the population varied significantly from 14.33-23.47 bees/ m²/ 10 min in all other varieties/ genotypes. *A. cerana* was most abundant in variety TH 68 (20.53 bees/ m²/ 10 min) and their population varied from 8.87-18.93 bees/ m²/ 10 min in different varieties/genotypes and all these varieties/ genotypes varied significantly from each other except HNS 0901, HC-212 and BSH-1 which were found at par. Population of *A. dorsata* was most abundant on variety BSH-1 (22.40 bees/ m²/ 10 min) with statistical variations and its population varied from 12.53-16.87 bees/ m²/ 10 min in all other varieties/genotypes. *A. florea* was most abundant on variety TH 68 (16.67 bees/ m²/ 10 min) and its population in rest of the varieties/ genotypes varied significantly from 8.13-14.87 bees/ m²/ 10 min except varieties YSH 401 and BSH-1 which were at par with each other.

Abundance of *Apis* spp. at 1600 h on various rapeseed-mustard varieties/genotypes

At 1600 h (Table 4), bees were most abundant on variety TH 68 (15.11 bees/ m²/ 10 min) and least abundant on Nigra and T-27 (8.47and 9.31 bees/ m²/ 10 min, respectively) and all these varieties/genotypes were found at par with each other. The mean density of *A. mellifera* was maximum (14.69 bees/ m²/ 10 min) followed by *A. cerana* (12.03 bees/ m²/ 10 min), *A. dorsata* (11.30 bees/ m²/ 10 min) and *A. florea* (8.74 bees/ m²/ 10 min) and they varied statistically from each other. *A. mellifera* population was found maximum on variety TH 68 (18.73 bees/ m²/ 10 min) and the population varied non-significantly from 9.13-15.07 bees/ m²/ 10 min in all other varieties/ genotypes. *A. cerana* population was most abundant on variety TH 68 (11.27 bees/ m²/ 10 min) and in all other varieties/ genotypes their populations varied from 7.93-11.00 bees/ m²/ 10 min with non-significant variation except BSH-1, Nigra, T-27, Giriraj and RCH-1 which vary significantly from each other. Population of *A. dorsata* was most abundant on variety BSH-1 (15.07 bees/ m²/ 10 min) and it varied non-statistically from 7.67-10.33 bees/ m²/ 10 min in all other varieties/genotypes. *A. florea* was most abundant on variety TH 68 (9.93 bees/ m²/ 10 min) and its population varied non-significant from 6.07-8.67 bees/ m²/ 10 min in all other varieties/ genotypes except TH 68 and HNS 0901.

Comparative mean abundance of *Apis* spp. on different varieties/genotypes of rapeseed-mustard

Comparative mean abundance (Table 5) of honey bees was highest in variety TH 68 (16.77 bees/ m²/ 10

Table 4. Abundance of *Apis* spp. on different varieties/genotypes of rapeseed-mustard at 1600 h at Hisar during 2019-20

Pollinator	No. of honey bees/ m²/ 10 min											
	RH 725	RH0502	HNS0901	YSH 401	BSH-1	TH 68	HC-212	NIGRA	T-27	GIRIRAJ	RCH-1	Mean
A. mellifera	13.27* (3.77) **	11.87 (3.58)	15.00 (3.99)	14.53 (3.94)	15.07 (4.00)	18.73 (4.44)	9.67 (3.26)	8.93 (3.15)	9.13 (3.18)	9.73 (3.27)	11.53 (3.54)	14.69 (3.92)
A. cerana	9.80 (3.26)	10.60 (3.40)	9.33 (3.21)	10.67 (3.41)	10.20 (3.34)	11.27 (3.50)	11.00 (3.46)	6.40 (2.72)	7.93 (2.98)	11.60 (3.55)	13.33 (3.79)	12.03 (3.58)
A. dorsata	10.33 (3.36)	9.27 (3.20)	7.87 (2.97)	9.13 (3.18)	15.07 (4.00)	9.87 (3.29)	14.00 (3.87)	7.47 (2.90)	7.80 (2.96)	7.67 (2.94)	7.67 (2.94)	11.30 (3.47)
A. florea	6.93 (2.81)	7.20 (2.86)	6.20 (2.68)	8.67 (3.10)	8.60 (3.09)	9.93 (3.29)	9.07 (3.17)	6.07 (2.65)	6.80 (2.79)	6.60 (2.75)	5.53 (2.56)	8.74 (3.09)
Mean	12.13 (3.58)	11.20 (3.46)	11.65 (3.50)	12.64 (3.65)	13.98 (3.83)	15.11 (3.95)	12.87 (3.70)	8.47 (3.05)	9.31 (3.19)	10.33 (3.33)	10.93 (3.40)	
CD (p=0.05)	(0.384)	(0.031)	(0.034)	(0.026)	(0.048)	(0.035)	(0.048)	(0.043)	(0.049)	(0.033)	(0.093)	(0.062)
SE (m)	0.109	0.009	0.01	0.007	0.014	0.01	0.014	0.012	0.014	0.009	0.026	0.022
CD (p=0.05) for varieties/genotypes						(0.103)						
SE (m)						0.037						

*Each value represents a mean of 5 observations; **Figures in parentheses are the means of √n+1 transformation

Table 5. Comparative mean abundance of *Apis* spp. on different varieties/ genotypes of rapeseed-mustard at Hisar during 2019-20

Pollinator	No. of honey bees/ m²/ 10 min											
	RH 725	RH 0502	HNS 0901	YSH 401	BSH-1	TH 68	HC-212	NIGRA	T-27	GIRIRAJ	RCH-1	Mean
A. mellifera	17.47* (4.30)**	14.67 (3.96)	18.57 (4.42)	18.67 (4.43)	14.16 (3.88)	24.61 (5.05)	12.51 (3.67)	11.50 (3.53)	12.11 (3.62)	12.38 (3.65)	13.78 (3.84)	15.50 (4.04)
A. cerana	12.60 (3.69)	13.10 (3.76)	11.82 (3.58)	13.78 (3.84)	13.10 (3.74)	15.95 (4.11)	13.60 (3.81)	7.48 (2.90)	9.31 (3.21)	15.16 (4.02)	15.93 (4.11)	12.90 (3.71)
A. dorsata	12.47 (3.67)	11.23 (3.50)	11.08 (3.48)	10.31 (3.36)	17.88 (4.33)	13.50 (3.80)	16.75 (4.21)	9.97 (3.31)	10.43 (3.37)	12.00 (3.60)	9.13 (3.17)	12.25 (3.62)
A. florea	8.84 (3.14)	8.70 (3.11)	9.33 (3.22)	11.10 (3.47)	10.93 (3.44)	13.01 (3.74)	11.75 (3.56)	7.53 (2.91)	8.03 (3.00)	7.45 (2.89)	6.36 (2.71)	9.37 (3.21)
CD (p=0.05)						(0.036)						(0.011)
SE (m)						(0.013)						(0.004)
Mean	12.84 (3.70)	11.93 (3.58)	12.70 (3.67)	13.47 (3.78)	14.02 (3.86)	16.77 (4.18)	13.65 (3.82)	9.12 (3.17)	9.98 (3.31)	11.75 (3.55)	11.30 (3.46)	
CD (p=0.05)						(0.018)						
SE (m)						(0.008)						

*Each value represents a mean of 5 observations; **Figures in parentheses are the means of √n+1 transformation

min) and lowest in Nigra (9.12 bees/ m^2/ 10 min). The mean density of *A. mellifera* was maximum (15.50 bees/ m^2/ 10 min) followed by *A. cerana* (12.90 bees/ m^2/ 10 min), *A. dorsata* (12.25 bees/ m^2/ 10 min) and *A. florea* (9.37 bees/ m^2/ 10 min) and they varied statistically from each other. *A. mellifera* population was found maximum on variety TH 68 (24.61 bees/ m^2/ 10 min) and the population in all other varieties/ genotypes varied from 12.11-18.67 bees/ m^2/ 10 min with significant variation except genotype HNS 0901 and variety YSH 401 which were found at par with each other. *A. cerana* was most abundant on variety TH 68 (15.95 bees/ m^2/ 10 min) and the population in different varieties/genotypes varied significantly from 7.48-15.93 bees/ m^2/ 10 min except TH 68 and RCH-1 which were at par with each other. Population of *A. dorsata* was most abundant on variety BSH-1 (17.88 bees/ m^2/ 10 min respectively) and its population in rest of the varieties/genotypes (9.97-13.50 bees/ m^2/ 10 min) varied statistically. *A. florea* was most abundant on variety TH 68 (13.01 bees/ m^2/ 10 min) and its population in rest of the varieties/genotypes varied significantly from 7.45-11.75 bees/ m^2/ 10 min.

The present observations corroborate with earlier findings. Sihag (1990) and Jhajj et al. (1996) recorded that bees started foraging at 0900-1000 h, reached a highest at 1200-1400 h and started reducing at 1500 h and the activity ceased at 1700 h of the day. The similar results were obtained by Vishwakarma and Chand (2017) reported that among the different pollinators *A. mellifera* was observed most frequent on flowers of mustard which backing 24.94% of pollination in experimental genotypes. Abrol and Bajiya (2017) found that *A. mellifera* was highest (%) 28.09, 28.31 in comparing 25.10, 25. 48 of *A. cerana*, 18.00, 18.09 of *A. dorsata*, 8.53, 7.90 of *A. florea* and 5.55, 5.71 of *X. fenestrate*. Akhtar et al. (2018) recorded the abundance of managed *A. mellifera* was maximum (87.76%) followed by *A. florea* (1.11%) and *A. dorsata* (0.98%) and peak activity of the insect pollinators was observed at the mid of the day i.e. 12:00 pm. The activity of managed *A. mellifera* started to increase from the third week of blooming (20th Jan. 2015) and reached to maximum in the sixth week (10th Feb. 2015). Pudasaini et al. (2015) observed *A. mellifera* was most dominated and abundant (36.34%); succeeded by *A. florea* (12.45%), *A. cerana* (11.14%), *A. dorsata* (5.68%), *Andrena* spp. (3.71%), *Megachilus* spp. (0.66%).

Correlation of abundance of *Apis* spp. with weather parameters

The abundance of all four *Apis* spp. had non-significant correlation with maximum and minimum temperature during the different stage of flowering (Table 6). Correlation between abundance of honey bee species was highest at maximum temperature and it was least at minimum temperature. Relative humidity showed significant positive correlation with abundance of three honey bee species i.e. *A. mellifera, A. cerana, A. dorsata* but in case of *A. florea* showed non-significant correlation with morning relative humidity and analysis of relative humidity resulted significant positive correlation with abundance of all four honey bees in the evening. Wind speed had significant positive correlation with *Apis* spp. and sunshine hours were showing non-significant correlation with different parameters.

The present results are in agreement by Abrol and Bajiya (2017) who found that foraging activity of honey bees was positively correlated with temperature. Akhtar et al. (2018) reported that honey bees showed significantly strong and positive correlation with temperature. Kunjwal et al. (2014) revealed that abundance of pollinators was increased with rising of average daily maximum temperature (r =0.631) and it also rise with effective sunshine hours (r = 0.696). The variation in results is because, the abundance of floral visitors depends upon weather parameters like temperature, RH, wind velocity, rainfall and many other crop dependent factors, and that varies according

Table 6. Correlation of abundance of honey bees with meteorological parameters

Weather parameters	No. of honey bees/ m^2/ 10 min			
	A. mellifera	*A. cerana*	*A. dorsata*	*A. florea*
Max. Temp	0.505	0.544	0.554	0.520
Min. Temp	0.411	0.445	0.458	0.431
RH (M)	0.814*	0.817*	0.817*	0.803
RH (E)	0.903*	0.888*	0.885*	0.886*
Wind Speed (km/ h)	0.952**	0.942**	0.942**	0.945**
Sunshine (hrs)	0.250	0.299	0.302	0.274

*Significant at p = 0.1 **Significant at p = 0.05

to time and space. Each species was found to have its specific ecological threshold below which activity does not occur normally.

The mean population of the *Apis* spp. exhibited certain temporal peaks and lows reflecting the reward presence, ideal temperature zones and pollination. As the honey bee species' abundance is temporal, so will be the pollination efficiency, that varies greatly amongst these species based on many factors, including body size, loose pollen grain carrying capacity, foraging speed, foraging rate, foraging behavior and overall abundance. It is thus, important to analyze such interactions for individual bees.

ACKNOWLEDGEMENT

The authors are thankful to the Head, Department of Entomology, Chaudhary Charan Singh Haryana Agricultural University, Hisar for the provision of necessary facilities, valuable suggestions and encouragement for the current investigation.

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(Paper presented: February, 2021;
Peer reviewed, revised and accepted: April, 2022; Online Published: May, 2023)
Online published (Preview) in www.entosocindia.org and indianentomology.org (eRef. No. NWRABNRG21)