



DIVERSITY, ABUNDANCE AND FORAGING BEHAVIOUR OF INSECT POLLINATORS ON MUNGBEAN (*VIGNA RADIATA* L.)

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ABSTRACT

This experiment aimed to assess the diversity, relative abundance and foraging activity of insect pollinators in mungbean (*Vigna radiata* L.) during kharif 2022 at the College of Agriculture and Agricultural Research Station, Jodhpur. Ten species of insect pollinators from six families across two insect orders were recorded. African migrant (*Catopsilia* spp.) was the most dominant species, with a relative abundance of 48.31%, followed by pea blue butterfly (*Lampides boeticus* L.) at 32.86%. The least frequent pollinators were Oriental hornet (*Vespa orientalis* L.) (0.72%) followed by black digger wasp (*Sphex argentatus* F.) (0.80%). Peak foraging activity occurred between 11:00 A.M. and 13:00 P.M. for hymenopterans and between 10:00 A.M. and 13:00 P.M. for lepidopterans. The giant rock bee (*Apis dorsata* F.) spent the most of the time per flower (0.73 seconds), while danaid egg fly (*Hypolimnas bolina* L.) spent the least (0.08 seconds). Weather conditions were observed to influence the abundance of insect pollinators.

Key words: Mungbean, diversity, species composition, abundance, pollinators, foragers, flower visitors, foraging activity, time spent, Lepidoptera, Hymenoptera

Diversified pollinators maintain the resilience and stability of ecosystems (Padhy et al., 2018). Pollination by insects (entomophily) increases the production of many crops. 87% of the total food crops depend entirely on pollinators hence 35% of the global food production is from the crops that depend on pollinators (Klien et al., 2007). The diversity in pollinators abundance acts in such a manner that when one pollinator species declines or faces challenges, other species may step in and continue the vital pollination services, minimizing the impact on plant reproduction and ecosystem functioning. Honey bees being the best pollinators, store honey that can be utilized by human beings for different purposes (Padhy et al., 2018). Mungbean (*Vigna radiata* L.) Wilczek (Leguminosae: Papilionaceae) is the third most important pulse crop of India. There are also some pulses where pollination is gaining importance such as mungbean which is a highly self-pollinated crop (cleistogamous) with 4–5% outcrossing (Van Rheenen, 1964). This study explores the insect pollinators in mungbean.

MATERIALS AND METHODS

The experiment was carried out at the College of Agriculture and Agricultural Research Station, Jodhpur, during kharif 2022. Insect collection was started after 5% flowering (40-45 DAS) and continued till end

of flowering (75-80 DAS) by sweep method using hand net (38 cm diameter: Tempstar, Model: ICN) in mungbean crop throughout the flowering period. Observations were taken on a weekly basis at an hourly interval from 06:00 to 18:00 hrs to record the frequent visiting of insect pollinators on mungbean flowers and they were killed and preserved as dry specimens. The collected insects were differentiated as insect visitors and pollinators by observing their behaviour on flowers. The abundance of the different pollinators recorded on mungbean flower was expressed as mean number of pollinators/ m²/ 5 min. The relative abundance of insect pollinators was correlated with temperature, relative humidity, rainfall and sunshine to know the influence of weather parameters on insect pollinators. Pollinators relative abundance data computed.

RESULTS AND DISCUSSION

Ten insect species belonging to six families of two orders i.e., Hymenoptera and Lepidoptera were found visiting the flowers. Among them, hymenopterans included seven species representing from three families viz., Apidae, Vespidae and Sphecidae. Whereas, lepidoptera comprised of three species belonged to three families viz., Lycaenidae, Pieridae and Nymphalidae (Table 1). Among all the pollinator species, African

migrant (*Catopsilia* spp.) was the most abundant species with the relative abundance of 48.31% followed by pea blue butterfly (*Lampides boeticus* L.) (32.86%), arabian paper wasp (*Polistes wattii* C.) (4.73%), giant rock bee (*Apis dorsata* F.) (4.41%), dwarf honey bee (*Apis florea* F.) (2.75%) and carpenter bee (*Xylocopa fenestrata* F.) (2.35%) visiting in per m²/5 minutes. The oriental hornet (*Vespa orientalis* L.) was least abundant (Table 2). The present result partially agreed with Padhy et al. (2018), who reported eleven species of pollinators on pigeon pea. *Megachile lanata* was the most dominant one (29.1%) followed by *M. disjuncta* (20.5%), *Tetragonula iridipennis* (14.2%), and *Apis cerana indica* (10.95%). Singh et al. (2017) reported 15 species of insects belonging to five families, seven genera and three orders on pigeon pea. The Hymenoptera were the most abundant, whereas lepidopteran and dipteran insects were reported in very small numbers.

The observed population of insect pollinators were correlated with various weather parameters, (Table 3). The recorded population of *Apis dorsata* showed a non-significant and negative correlation with average relative humidity ($r = -0.244$) and average rainfall ($r = -0.166$). Conversely, there was a non-significant

positive correlation with average temperature ($r = 0.124$) and average sunshine ($r = 0.299$). It was noted that an increase in relative humidity and average rainfall was inversely related to the mean population of *A. florea*, *S. argentatus* and *V. orientalis*. In contrast, average temperature and sunshine showed a direct positive correlation and non-significant with the mean population of these species. The population of *P. wattii* exhibited a non-significant and negative correlation with average relative humidity ($r = -0.764$) and average rainfall ($r = -0.710$). However, it was significantly and positively correlated with average temperature ($r = 0.850$) and average sunshine ($r = 0.883$). A non-significant positive correlation was found between *Ropalidia* spp. and average sunshine, while the other factors, including average temperature, relative humidity and rainfall, were non-significantly and negatively correlated. The population of *Catopsilia* spp. showed a non-significant and negative correlation with average relative humidity ($r = -0.767$) and average rainfall ($r = -0.784$), while it was significantly and positively correlated with average temperature ($r = 0.902$) and average sunshine ($r = 0.919$).

The only negative and significant correlation observed was in *L. boeticus* with average rainfall ($r =$

Table 1. Systematic position of key pollinators and predatory wasps associated with mungbean at Jodhpur during kharif, 2022

S.No.	Order	Family	Name of flower visitor
1.	Hymenoptera	Apidae	Giant rock bee, <i>Apis dorsata</i> F.
			Carpenter bee, <i>Xylocopa fenestrata</i> F.
			Dwarf honey bee, <i>Apis florea</i> F.
		Vespidae	Oriental hornet, <i>Vespa orientalis</i> L.
			Arabian paper wasp, <i>Polistes wattii</i> Cameron
			Paper wasp, <i>Ropalidia</i> spp.
2.	Lepidoptera	Sphecidae	Black digger wasp, <i>Sphex argentatus</i> F.
		Pieridae	African migrant, <i>Catopsilia</i> spp.
		Lycaenidae	Pea blue, <i>Lampides boeticus</i> L.
		Nymphalidae	Danaid eggfly, <i>Hypolimnas bolina</i> L.

Table 2. Relative abundance of pollinators in mungbean during inflorescence stage

Species	Number of pollinators visited in different date*						Relative abundance (%)
	21.08.2022	28.08.2022	04.09.2022	11.09.2022	18.09.2022	27.09.2022	
<i>Apis dorsata</i>	4.4± 0.85	5.8± 0.79	9.0± 1.21	4.0± 0.74	4.0± 0.84	3.6± 0.88	4.41
<i>Apis florea</i>	1.4± 0.40	4.8± 0.82	5.2± 1.10	3.4± 0.62	2.4± 0.56	2.0± 0.48	2.75
<i>Vespa orientalis</i>	0.6± 0.28	1.2± 0.46	0.8± 0.35	1.0± 0.37	0.8± 0.30	0.6± 0.28	0.72
<i>Polistes wattii</i>	3.8± 0.82	4.6± 0.82	7.4± 1.36	6.0± 1.12	5.4± 1.00	5.8± 1.08	4.73
<i>Ropalidia</i> spp.	1.0± 0.37	4.6± 1.07	2.4± 0.68	1.4± 0.44	1.6± 0.52	1.0± 0.37	1.72
<i>Sphex argentatus</i>	0.8± 0.30	1.0± 0.37	1.2± 0.42	1.2± 0.34	0.8± 0.30	0.6± 0.21	0.80
<i>Catopsilia</i> spp.	41.6± 2.96	52.8± 3.29	68.6± 3.59	61.0± 3.46	61.2± 3.71	52.0± 3.29	48.31
<i>Lampides boeticus</i>	30.6± 2.86	44.2± 3.42	41.2± 3.29	38.8± 3.10	38.2± 3.06	36.4± 2.96	32.86
<i>Hypolimnas bolina</i>	0.4± 0.17	1.0± 0.32	2.2± 0.52	2.6± 0.51	1.8± 0.39	1.4± 0.36	1.35
<i>Xylocopa fenestrata</i>	0.6± 0.28	3.6± 0.70	5.0± 1.10	3.4± 0.80	2.4± 0.61	1.4± 0.47	2.35

*Total numbers of pollinators visited in a day were observed at an hourly interval; #± Standard deviation of mean

Table 3. Effect of weather parameters on population of insect pollinators in mungbean

Date of observation	Mean Temp. (°C)	Mean RH (%)	Rainfall (mm)	Sunshine (Hrs.)	<i>Apis dorsata</i>	<i>Apis florea</i>	<i>Vespa orientalis</i>	<i>Polistes wattii</i>	<i>Ropalidia</i> spp.	<i>Sphex argentatus</i>	<i>Catopsilia</i> spp.	<i>Lampides boeticus</i>	<i>Hypolimnas bolina</i>	<i>Xylocopa fenestrata</i>
21.08.2022	25.5	77.8	2	4.5	4.4 (2.21)	1.4 (1.38)	0.6 (1.05)	3.8 (2.07)	1 (1.22)	0.8 (1.14)	41.6 (6.49)	30.6 (5.58)	0.4 (0.95)	0.6 (1.05)
28.08.2022	26.15	60.95	0	7.9	5.8 (2.52)	4.8 (2.3)	1.2 (1.3)*	4.6 (2.26)	4.6 (2.26)	1 (1.22)	52.8 (7.3)*	44.2 (6.69)	1 (1.22)	3.6 (2.02)
04.09.2022	28.6	58.6	0	10.4	9 (3.08)	5.2 (2.39)	0.8 (1.14)	7.4 (2.81)	2.4 (1.7)*	1.2 (1.3)*	68.6 (8.31)	41.2 (6.46)	2.2 (1.64)	5 (2.35)
11.09.2022	28.8	62.4	0	8.9	4 (2.12)	3.4 (1.97)	1 (1.22)	6 (2.55)	1.4 (1.38)	1.2 (1.3)	61 (7.84)	38.8 (6.27)	2.6 (1.76)	3.4 (1.97)
18.09.2022	28.55	61.18	0	9.8	4 (2.12)	2.4 (1.7)*	0.8 (1.14)	5.4 (2.43)	1.6 (1.45)	0.8 (1.14)	61.2 (7.85)	38.2 (6.22)	1.8 (1.52)	2.4 (1.7)*
27.09.2022	27.4	58.41	0	9.1	3.6 (2.02)	2 (1.58)	0.6 (1.05)	5.8 (2.51)	1 (1.22)	0.6 (1.05)	52 (7.25)	36.4 (6.07)	1.4 (1.38)	1.4 (1.38)
Coefficient of correlation (r) between population and mean temperature														
0.124 ^{NS} 0.336 ^{NS} 0.113 ^{NS} 0.850* -0.154 ^{NS} 0.408 ^{NS} 0.902* 0.374 ^{NS} 0.967** 0.595 ^{NS}														
Coefficient of correlation (r) between population and mean relative humidity														
-0.244 ^{NS} -0.600 ^{NS} -0.367 ^{NS} -0.764 ^{NS} -0.359 ^{NS} -0.170 ^{NS} -0.767 ^{NS} -0.785 ^{NS} -0.714 ^{NS} -0.690 ^{NS}														
Coefficient of correlation (r) between population and rainfall														
-0.166 ^{NS} -0.614 ^{NS} -0.502 ^{NS} -0.710 ^{NS} -0.394 ^{NS} -0.254 ^{NS} -0.784 ^{NS} -0.824* -0.766 ^{NS} -0.722 ^{NS}														
Coefficient of correlation (r) between population and sunshine														
0.299 ^{NS} 0.551 ^{NS} 0.240 ^{NS} 0.883* 0.187 ^{NS} 0.273 ^{NS} 0.919** 0.670 ^{NS} 0.855* 0.721 ^{NS}														

Data in parenthesis square root transformed values $\sqrt{x + 0.5}$ NS: Non-significant; *Significant at p=0.05%; **: Significant at p=0.01%

-0.824). However, the other factors, including average temperature and sunshine, showed a positive but non-significant correlation ($r = 0.374$ and $r = -0.670$, respectively). A non-significant but negative correlation was found between *L. boeticus* and average humidity ($r = -0.785$). The population of *H. bolina* showed a non-significant and negative correlation with average relative humidity ($r = -0.714$) and average rainfall ($r = -0.766$). Conversely, there was a significant positive correlation with average temperature ($r = 0.967$) and sunshine ($r = 0.855$).

The population of *H. bolina* should a nonsignificant and negative correlation with average relative humidity ($r = -0.714$) and average rainfall ($r = -0.766$). Conversely, there was a significant positive correlation with average temperature ($r = 0.967$) and sunshine ($r = 0.855$). *X. fenestrata* exhibited an inverse relationship with relative humidity and average rainfall, while average temperature and sunshine had a direct positive relationship. Harke et al. (2022) reported that temperature has a positive correlation with the visits of *A. dorsata* and *A. florea*. However, morning and evening relative humidity showed a negative and non-significant relationship with *A. dorsata* in safflower. Altaf et al. (2017) in almond studied that *Xylocopa* spp., lepidopteran and dipteran insects were positively correlated with temperature and sunshine, but rainfall had a negative impact on almond pollination in Dalgate and Badamvari from Srinagar. The present findings differ from previous studies due to variations in climatic conditions between the different studies.

The data of foraging activity and time spent was shown in Table 4 and 5. The foraging activity of *A. dorsata* started with a peak at 11:00 am (1.43 bees/ m²/ 5 min). The findings are also in close agreement with the findings of Chaudhary and Singh (2007), who reported that the foraging activity of *A. dorsata* peaked at 11:00 am (3.5 bees/ m²/ 5 min) on coriander. The foraging activity of *A. florea* started at 10:00 am with a population of 0.27 bees/m²/5 minutes and its peak activity was observed at 11:00 am (1.1 bees/ m²/ 5 min). The present results were in agreement with the findings of Kant et al. (2013), who reported that the foraging activity of *A. florea* was maximum at 10:00-11:00 am. The foraging activity of *X. fenestrata* started at 8:00 am and its peak activity was observed at 11:00 am (1.00 bees/ m²/ 5 min). Similarly, Kumar and Rai (2020) reported the foraging activity of *X. fenestrata* from morning to evening on fennel with peak foraging activity at 11:00 am (4.2 bees/ m²/ min). The population (0.83 wasp/ m²/ 5 min) of *V. orientalis* during the foraging activity was observed once in the day at 12:00 noon, which was in

accordance to Sikdar et al. (2019), who reported that the foraging activity of *V. orientalis* was maximum at 12:00-13:00 hrs (1.43 wasp/ m²/ 3 min) on fennel. The foraging activity of *P. wattii* was at its maximum during the foraging activity at 11:00 am (1.23 wasp/ m²/ 5 min). The findings are in close agreement with Elisei et al. (2008) and Sikdar et al. (2019), who reported that the foraging activity of *Polistes* sp. started at 07:00 am and completed at 17:00 pm, with an activity peak between 10:00 am and 14:00 pm. The foraging activity of *Ropalidia* spp. was observed two times (at 10:00 am and 12:00 noon) in the day and its activity was maximum at 12:00 noon. Similarly *S. argentatus* was also observed two times (at 12:00 noon and 16:00 pm) in the day. The results of both species partially agree with More et al. (2022), who reported wasps were found more active during afternoon hours than in the morning and evening and maximum wasps per plant per minute were found visiting safflower heads at 14:00 pm. The results were also supported by the findings of Sikdar et al. (2019) who reported that maximum wasps were visited at 12:00 noon to 13:00 pm in coriander, fennel and black cumin. The foraging activity of *Catopsilia* spp., *H. bolina* and *L. boeticus* started at 08:00 am. The results are in line with the findings of Hasnat et al. (2015), who reported the peak activity of lepidoptera during 09:00-11:00 am on okra. Contrastingly, Sikdar et al. (2019) reported the maximum activity of lepidopteran insects between 12:00 noon to 13:00 pm in coriander, fennel and black cumin.

The average amount of time spent by *A. dorsata*, *A. florea*, *V. orientalis*, *P. wattii*, *Ropalidia* spp. and *S. argentatus* was more as compared to other flower visiting insects for the lepidopteran insects viz. *Catopsilia* spp., *L. boeticus* and *H. bolina*. Among all, *H. bolina* spent the least amount of time on average (0.08 seconds), whereas *A. dorsata* spent maximum time on average (0.73 sec), followed by *P. wattii* (0.66 sec) and so on. The findings are also in close agreement with the findings of Kumar (2004), who reported that the foraging speed of *A. dorsata* was maximum, followed by *A. mellifera* on juncea and toria. Kumar and Rai (2020) also reported that the foraging speed of *A. dorsata* was maximum being 15.74 sec, followed by *Xylocopa* spp. (13.67 seconds), *A. mellifera* (12.93 seconds), while it was minimum in case of *A. florea* (8.74 sec). The present study has identified ten species of pollinators for mungbean. The foraging activities of pollinators were influenced by the time of the day. Maximum activity of lepidopterans was observed between 10:00-13:00 hrs, and maximum foraging activity of hymenopterans was observed between 11:00 and 13:00

Table 4. Foraging activity of insect pollinators on mungbean

Species	Pollinators visited at different time of the day*													
	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	
<i>Apis dorsata</i>	0±0	0±0	0±0	0±0	0±0	1.43±1.33 (27.92)#	0.53±0.86 (9.09)	0.97±1.27 (18.83)	0.87±1.31 (12.98)	0.8±0.96 (15.58)	0.13±0.43 (2.59)	0.67±0.99 (12.98)	0±0	
<i>Apis florea</i>	0±0	0±0	0±0	0±0	0.27±0.52 (8.33)	1.1±1.40 (34.37)	0.8±1.21 (25)	0±0	0±0	0±0	0.6±0.81 (18.75)	0.43±0.77 (13.54)	0±0	
<i>Vespa orientalis</i>	0±0	0±0	0±0	0±0	0±0	0±0	0.83±0.95 (100)	0±0	0±0	0±0	0±0	0±0	0±0	
<i>Polistes wattii</i>	0±0	0±0	0±0	0±0	0.77±0.92 (13.93)	1.23±1.23 (22.42)	0.33±1.01 (6.06)	1.17±1.61 (21.21)	0±0	0±0	0.97±1.64 (17.57)	1.03±1.49 (18.78)	0±0	
<i>Ropalidia</i> spp.	0±0	0±0	0±0	0±0	0.93±1.31 (46.67)	0±0	1.07±1.34 (53.33)	0±0	0±0	0±0	0±0	0±0	0±0	
<i>Spheg argentatus</i>	0±0	0±0	0±0	0±0	0±0	0±0	0.63±0.85 (67.86)	0±0	0±0	0±0	0.3±0.53 (32.14)	0±0	0±0	
<i>Catopsilia</i> spp.	0±0	0±0	3.17±2.52 (6.29)	7.4±2.76 (13.17)	8.83±2.25 (15.72)	6.77±2.71 (12.04)	6.53±2.36 (11.63)	5.27±2.32 (9.37)	5.1±2.87 (9.07)	4.53±2.45 (8.07)	3.63±2.24 (6.46)	2.67±2.28 (4.74)	1.93±1.93 (3.44)	
<i>Lampides boeticus</i>	0±0	0±0	3.83±2.39 (10.03)	4.7±2.48 (12.29)	4.77±2.36 (12.47)	5.3±2.61 (13.86)	7.03±2.82 (18.39)	4.53±2.16 (11.86)	4.27±2.48 (11.16)	0±0	0±0	3.8±2.62 (9.94)	0±0	
<i>Hypolimnas bolina</i>	0±0	0±0	0.1±0.40 (6.38)	0.33±0.61 (21.28)	0±0	0.67±0.76 (42.55)	0.1±0.40 (6.38)	0.27±0.52 (17.02)	0.1±0.31 (6.38)	0±0	0±0	0±0	0±0	
<i>Xylocopa fenestrata</i>	0±0	0±0	0.1±0.40 (3.65)	0.3±0.75 (7.31)	0.87±1.17 (35.36)	1±1.41 (31.70)	0.48±1.09 (21.95)	0±0	0±0	0±0	0±0	0±0	0±0	

*Observations were taken at weekly interval on five replications; figures in the parenthesis is in %

Table 5. Foraging time spent by major insect pollinators on mungbean flower

Species	Time spent (sec/ flower)						Mean (Seconds/ flower)
	21.08.2022	28.08.2022	04.09.2022	11.09.2022	18.09.2022	27.09.2022	
<i>Apis dorsata</i>	0.43± 1.04 [#]	0.91± 1.68	1.17± 1.95	0.58± 1.45	0.71± 1.59	0.55± 1.34	0.73
<i>Apis florea</i>	0.14± 0.52	0.71± 1.50	0.53± 1.32	0.54± 1.34	0.46± 1.27	0.35± 1.14	0.46
<i>Xylocopa fenestrata</i>	0.03± 0.17	0.14± 0.32	0.11± 0.30	0.11± 0.29	0.09± 0.27	0.05± 0.20	0.09
<i>Vespa orientalis</i>	0.05± 0.30	0.16± 0.78	0.14± 0.78	0.17± 0.78	0.21± 0.96	0.12± 0.68	0.14
<i>Polistes wattii</i>	0.26± 0.69	0.83± 1.84	0.86± 1.77	0.63± 1.45	0.81± 1.76	0.58± 1.33	0.66
<i>Ropalidia</i> spp.	0.11± 0.50	0.41± 1.17	0.37± 1.21	0.24± 0.98	0.27± 1.06	0.18± 0.84	0.26
<i>Sphex argentatus</i>	0.09± 0.45	0.21± 0.96	0.31± 1.24	0.32± 1.12	0.22± 1.03	0.17± 0.78	0.22
<i>Catopsilia</i> spp.	0.62± 0.45	0.63± 0.42	0.69± 0.38	0.65± 0.39	0.50± 0.29	0.43± 0.32	0.59
<i>Lampides boeticus</i>	0.40± 0.42	0.46± 0.39	0.49± 0.43	0.45± 0.41	0.40± 0.35	0.37± 0.36	0.43
<i>Hypolimnas bolina</i>	0.03± 0.16	0.06± 0.22	0.09± 0.27	0.12± 0.29	0.11± 0.38	0.07± 0.22	0.08

Blooming period: 04.09.2022 to 11.09.2022; Standard deviation of mean

hrs. The *Catopsilia* spp. was the most abundant pollinator of mungbean, but hymenopteran species were more numerous. *A. dorsata* spent maximum time on mungbean flowers. Further studies can be conducted to determine the efficiency level of pollinators in mungbean.

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AUTHOR CONTRIBUTION STATEMENT

All authors contributed equally to the conception and design of the study. All authors read and approved the final manuscript.

CONFLICT OF INTEREST

No conflict of interest.

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