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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(6): 4868-4872

www.thepharmajournal.com
Received: 24-04-2023
Accepted: 30-05-2023

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Biodiversity and activity period of insect pollinators in cucumber *Cucumis sativus* L.

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Abstract
The studies on diversity of insect pollinators revealed that the activity period of stingless bee was observed during both year of experimentation. However, in case of Apis bees the higher activity of *A. florea* was seen followed by activity of *A. dorsata* and *A. cerana* during Kharif season of 2018 and 2019. The pollinators of hymenoptera order were the most abundant followed by lepidoptera. Non-Apis bees were also act as promising pollinators in cucumber crop. The activity period of stingless bee was observed during both year of experimentation.

Keywords: Biodiversity, activity period

Introduction
Cucumber (*Cucumis sativus* L.) is a plant in the order of Cucurbitales belonging to the Cucurbitaceae family. It is in the group of dicotyledon with stem in the form of creeping vine consisting of yellow flowers. Cucumbers have crisp texture, high water content, and can be cultivated all year round. Production is highest during February and March. Propagation is done by planting seeds are commonly used for plate decoration. Cucumber contains erepsin enzyme that aids digestion of protein. Sajjanar *et al.* (2004) [9] reported that the 24 species of insects found visiting the cucumber (*C. sativus*) bloom, predominantly by hymenoptera. Among bees, A. dorsata was the most frequent visitor that started activity around 06:00 h, whereas all other insect visitors started foraging activity by 08:00 h. Rubina (2010) [8] recorded that the cucumber flowers were visited by 28 species of insect pollinators, of which 20 species belong to order hymenoptera, two species to diptera, four species to lepidoptera and two species to coleoptera. Honey bee species *viz*., *A. cerana*, *A. florea*, *A. dorsata* and *T. iridipennis* constituted 84.88 percent of the total insect pollinators compared to 15.11 percent of other pollinators.

Materials & Methods
Diversity of insect pollinators
For diversity study, insect visitors like rock bee, Indian bee, little bee, stingless bee, solitary bees and butterflies on cucumber crop were observed during its peak activity period of the day (*i.e.* middle of the day) for its abundance and diversity study. Groupwise diurnal insect pollinators from cucumber flowers were recorded.

Abundance of insect pollinators
The population of major insect pollinators like; rock bees, Indian bees, little bees, stingless bees, solitary bees and butterflies found on flowers in the cucumber plot was recorded during entire blooming period by counting numbers of different visitors visited flowers at 1 m × 1 m area using quadrate made from the iron rod. The species wise counts of individual flower visiting insects were recorded for 10 minutes from each of four different spots of cucumber crop measuring one square meter area with an interval of one week starting from initiation of flowering to cessation of flowering during both the years of study. The data thus obtained were summed up and utilised for working out the abundance of different pollinators in cucumber crop.
Relative abundance is the number of individuals of a given species of pollinators as a percentage of all of the individuals in the study area. The relative species abundance was calculated by using the following formula.

$$\text{Relative abundance (\%)} = \frac{N_i}{N_A} \text{ X } 100$$

Where,
Ni = Total numbers of individual species
N_A = Total number of pollinators

Species richness
Species richness is the number of different species represented in an ecological community. From the recorded data on cucumber flower visitations, species richness for insect pollinators was worked out. The number of different kinds of insect pollinators' species in the study area was considered as a measure of the richness of pollinators in the study area. The more species present in the area, the 'richer' the area with diverse kinds of pollinators.

Species diversity index
Shannon-Wiener species diversity index
In order to study the proportion of each species within the pollinators' community of the study area, the diversity index for insect pollinators was worked out using the Shannon-Wiener species diversity index formula (Shannon, 1948) [14].

$$\text{Species Diversity index (H}') = -\sum_{i=1}^{k} \times 1\text{npi}$$

Where,
pi = Proportion of i^{th} species in the total sample
pi = *fi*/n
fi = Number of specimens of the i^{th} species
n = Total number of the specimen in the sample
k = Total number of species
1n = Natural logarithm ($\log_e$)

Species evenness
Evenness compares the similarity of the population size of each of the species present in the study area. In order to estimate the equitability component of diversity; the species evenness of a community was calculated by Pielou's evenness index (Pielou, 1966) [15].

$$\text{Pielou's evenness index (J)} = \frac{H}{H_{max}}$$

Where,
H = number derived from the Shannon diversity index
H_{max} = maximum possible value of H

$$H_{max} = -\sum_{i=1}^{n} \times \ln N$$

Where,
N = the total number of species

Results & Discussion
Diversity of insect pollinators, relative abundance, species diversity index and species evenness
The observations of diurnal insect pollinators were recorded from commencement of flowering in cucumber to cessation of flowering from the uncovered cucumber crop with an interval of a week during both seasons *i.e. Kharif* 2018 and *Kharif* 2019. The data of both years 2018 and 2019 was summed up and analysed. The results thus obtained are presented in Table 1. The results presented in Table 1 showed that a total of 761 insect pollinators were sampled during *Kharif* season of 2018 and 2019; among the hymenopteran, *Tetragonal laeviceps* (319) was found the most abundant with 27.91 percent abundance in cucumber crop followed by *Apis florea* (266) with 23.27 percent and *Apis dorsata* (238) with 20.82 percent abundance as very common bee species. Whereas, *Apis cerana indica* (141) with 12.34 percent richness as common bee species visited the cucumber crop during both nthe year of study. However, 10.15 percent abundance of solitary bees with the population of 116 solitary bees were also appeared as common to rare diurnal pollinators of cucumber crop. Nevertheless, butterflies (63) population with 5.51 percent abundance in Cucumber crop was recorded as rare pollinators of cucumber crop.
Based on summed up data of Apis bees and non-Apis bees presented in Table 1, showed that the Apis bees were acquired 56.43 percent share of observed insect pollinators and remained on top with the most abundant insect pollinators of cucumber. However, non-Apis bees attained 38.06 percent part of insect pollinators. The hymenopteran pollinator was remained abundant pollinators with 94.49 percent sharing. However, lepidopteran pollinators also appeared in cucumber crop during blooming period with the presence of 5.51 percent of total observed insect pollinators during 2018 and 2019 from cucumber crop.

Table 1: Biodiversity of insect pollinators in cucumber at Navsari during *Kharif*-2018 and 2019

Sr. No.	Name of insect pollinator	Total Population	Abundance (%)
Hymenoptera			
1	*Apis dorsata* (Fabricius, 1793)	238	20.82
2	*Apis cerana indica* (Fabricius, 1793)	141	12.34
3	*Apis florea* (Fabricius, 1787)	266	23.27
A. Apis bees		645	56.43
4	*Tetragonala laeviceps*	319	27.91
5	Solitary bees	116	10.15
B. Non-Apis bees		435	38.06
Hymenopteran pollinators (A + B)		1080	94.49
6	Butterflies	63	5.51
Lepidopteran pollinators		63	5.51
Total		1143	100
Shanon index-1.79 Evenness- 0.93			

Shannon's diversity index and species evenness of insect pollinators of cucumber crop was recorded as 1.79 and 0.93, respectively. The species evenness index (0.93) with a great extent moving towards one indicated huge species inequatability within the insect pollinator's community.
The results of present study are more or less in close agreement with the work of Prakash (2002) [6] who reported 82 percent hymenopteran pollinators from the cucumber crop. Sajjanar *et al.* (2004) [9] also recorded hymenopteran pollinators as predominant visitors of cucumber crop. Eswarappa *et al.* (2005) [1] reported bee fauna like *A. dorsata*, *A. cerana*, *A. florea* and *T. iridipennis* comprised more than 82.00 percent of the total insect pollinators. Michelson *et al.* (2017) [4] observed the hymenopteran pollinators as the predominant order with 97.48 percent of the total visits in

Citrullus lanatus. Revanasidda and Belavadi (2019) [7] also reported hymenopteran pollinators from muskmelon as abundant pollinators with 81.25 percent bans lepidopteran with 12.5 percent pollinator's share. Zinzuvzdiya and Ghetiya (2020) [13] also reported dominance of hymenopteran pollinators from agricultural landscape area of South Gujarat, India.

Considering the recorded lepidopteran pollinators of present work, it is also similar with their work, as the lepidopteran pollinators were also reported from different crops at its bloom stage by Prakash (2002) [6], Sajjanar *et al.* (2004) [4] and Sathreesha (2010) [10] from cucumber; Eswarappa *et al.* (2005) [1] from chow-chow, Kumar (2006) [3], Ali *et al.* (2014) from pumpkin, Patel (2007) [5], Subhakar *et al.* (2011) from bitter gourd, Revanasidda and Belavadi (2019) [17] from muskmelon. Zinzuvzdiya and Ghetiya (2020) [13] also reported nine species of lepidoptera order as the most common diurnal pollinators from agricultural landscape area of South Gujarat.

Activity period of bees in cucumber

The observations of bee visit were recorded from the open plots of cucumber crop at full bloom stage during *Kharif* season of 2018 and 2019. The results thus obtained are presented in Table-2 and 3 as well as depicted in Figure 1 and 2.

The commencement of activity of *A. dorsata* in uncovered field crop was recorded at 08:05 h during *Kharif* 2018 (Table 2 Fig 1). The activity of *A. dorsata* was increased continuously and reached at its peak activity at 13:05 h with 6.8±1.3 bees/m^2/5 minutes, then after activity was declined at 14:05 h (4.2±1.9 bees/m^2/5 minutes) and found to be active till 15:05 h with 0.6±0.4 bees/m^2/5 minutes. The activity of *A. dorsata* was ceased from 16:05 h. Similarly, *A. florea* started its activity at 07:05 h in open field cucumber crop and its activity was slowly increased till 12:05 h with peak activity 9.0±1.6 bees/m^2/5 minutes. Then after, its activity was declined and remained active upto 15:05 h with 0.6±0.3 bees/m^2/5 minutes. The activity of *A. dorsata* was ceased from 16:05 h. While in the case of *A. cerana* the activity was commenced from 08:05 h in open field of cucumber with 2.6±0.9 bees/m^2/5 minutes and reached at its peak activity at 10:05 h (5.2±0.8 bees/m^2/5 minutes) then the activity declined gradually and ceased after 13:05 h with last observed value of 0.8±0.6 bees/m^2/5 minutes.

Table 2: Activity period of pollinators in Cucumber during *Kharif* 2018

Time (Hours)	Number of visitors / m^2 / 5 minutes (Average± SD) #				
	Open crop				Covered crop
	A. dorsata	*A. cerana*	*A. florea*	Stingless bee	Stingless bee
06:05	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
07:05	0.0±0.0	0.0±0.0	0.6±0.5	0.0±0.0	0.2±0.4
08:05	0.2±0.4	1.6±0.9	1.0±1.0	0.4±0.5	1.8±0.8
09:05	2.6±1.1	2.4±1.1	2.0±0.6	1.0±1.0	5.0±1.6
10:05	5.4±1.5	4.2±0.8	6.2±1.3	7.4±1.1	6.0±1.6
11:05	5.6±1.1	1.2±0.8	7.4±1.1	10.6±1.8	11.2±2.4
12:05	6.6±1.1	0.8±0.8	9.0±1.6	13.6±2.1	10.8±2.4
13:05	6.8±1.3	0.6±0.9	7.0±1.6	10.0±1.6	8.8±1.3
14:05	4.2±1.9	4.2±1.9	2.8±3.1	5.4±2.1	4.0±1.6
15:05	0.4±0.9	0.8±0.8	0.6±1.3	1.8±0.8	0.8±0.8
16:05	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
17:05	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
18:05	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0

Note: # Mean of five observations SD: Standard deviation

In case of stingless bee, *T. laeviceps* the activity was commenced from 07:05 h with 0.8±0.2 bees/m^2/5 minutes in uncovered cucumber crop, and gradually its activity was increased and reached at its topmost level of activity at 12:05 h with 13.6±2.1 bees/m^2/5 minutes. The stingless bee was remained more active between 10:05 to 13:05 h in open crop. The activity was stopped at 17:05 h. It was commonly observed that after withering of cucumber flower stingless bees were found to be rested on leaves as well as at the base of petiole of flower bud as well as withered flower.

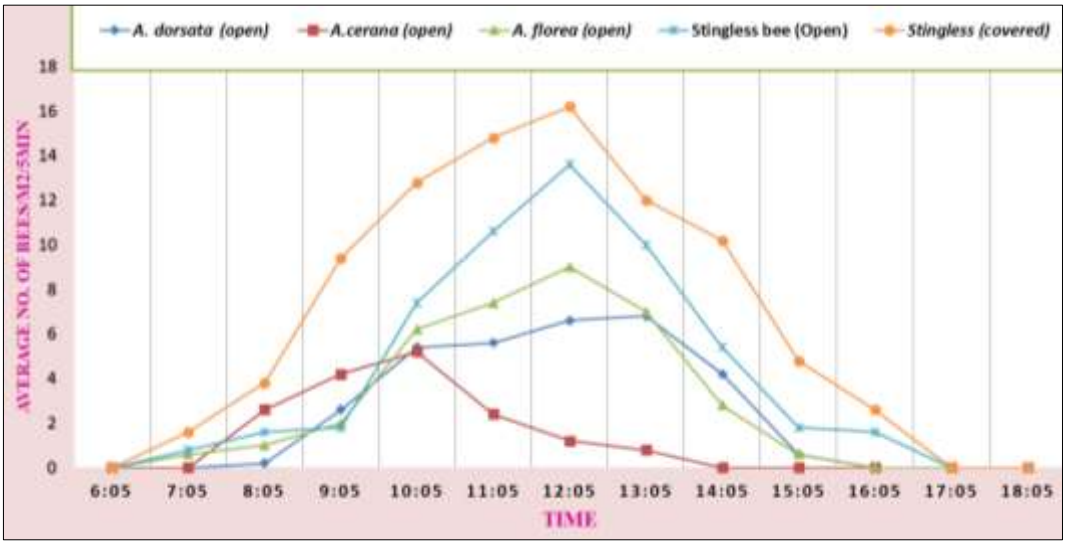

Fig 1: Activity period of pollinators in Cucumber during *Kharif* 2018

Similarly, under confined cucumber crop, the activity was commenced from 07:05 h with 1.6±0.4 bees/m^2/5 minutes, and gradually its activity was increased and reached at its topmost level of activity at 12:05 h with 16.2±2.4 bees/m^2/5 minutes. The stingless bee was remained more active between 09:05 to 14:05 h in covered crop. The activity was stopped at 17:05 h. It was commonly observed that after withering of cucumber flower stingless bees were found to be rested on

leaves as well as at the base of petiole of flower bud and withered flower too.

The commencement of activity of *A. dorsata* in uncovered field crop was recorded at 08:05 h during *Kharif* 2019 (Table 3 and Fig 2). The activity of *A. dorsata* was increased continuously and reached at its peak activity at 13:05 h with 8.6±1.3 bees/m^2/5 minutes, then after activity was declined at 14:05 h (3.4±1.1 bees/m^2/5 minutes). The activity of *A. dorsata* was ceased from 15:05 h. Similarly, *A. florea* started its activity at 07:05 h in open field cucumber crop and its activity was slowly increased till 12:05 h with peak activity 10.4±1.6 bees/m^2/5 minutes. Then after, its activity was declined and remained active up to 14:05 h with 0.6±0.3 bees/m^2/5 minutes. The activity of *A. florea* was ceased from 15:05 h. While in the case of *A. cerana* the activity was commenced from 08:05 h in open field of cucumber with 3.4±0.4 bees/m^2/5 minutes and reached at its peak activity at 10:05 h (6.4±0.6 bees/m^2/5 minutes) then the activity declined gradually and ceased after 12:05 h with last observed value of 1.8±0.6 bees/m^2/5 minutes.

In case of stingless bee, *T. laeviceps* the activity was commenced from 07:05 h with 1.8±0.4 bees/m^2/5 minutes in uncovered cucumber crop, and gradually its activity was increased and reached at its topmost level of activity at 12:05 h with 14.2±2.1 bees/m^2/5 minutes. The stingless bee was remained more active between 10:05 h to 13:05 h in open crop. The activity was stopped at 17:05 h. It was commonly observed that after withering of cucumber flower stingless bees were found to be rested on leaves as well as at the base of petiole of flower bud as well as withered flower.

Table 3: Activity period of pollinators in Cucumber during *Kharif* 2019

Time (Hours)	Number of visitors / m^2 / 5 minutes (Average± SD) #				
	Open crop				Covered crop
	A. dorsata	*A. florea*	*A. cerana*	Stingless bee	Stingless bee
06:05	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
07:05	0.0±0.0	0.6±0.4	0.0±0.0	1.8±0.4	2.2±0.4
08:05	0.6±0.2	1.8±0.7	3.4±0.4	2.6±0.4	3.8±0.8
09:05	2.2±1.0	3.4±0.8	3.8±0.4	3.8±0.6	10.8±1.2
10:05	5.8±1.2	6.2±1.0	6.4±0.6	8.4±1.0	14.4±1.3
11:05	6.2±1.1	8.8±0.8	5.4±1.0	12.4±1.2	15.6±2.1
12:05	6.8±0.8	10.4±1.6	1.8±0.6	14.2±2.1	18.6±2.4
13:05	8.6±1.3	7.0±1.6	0.0±0.0	12.0±1.6	14.0±1.4
14:05	3.4±1.1	2.8±1.1	0.0±0.0	7.4±1.2	10.2±1.2
15:05	0.0±0.0	0.0±0.0	0.0±0.0	1.8±0.8	3.6±0.4
16:05	0.0±0.0	0.0±0.0	0.0±0.0	1.2±0.4	1.8±0.4
17:05	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
18:05	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0

Similarly, under confined cucumber crop, the activity was commenced from 07:05 h with 2.2±0.4 bees/m^2/5 minutes, and gradually its activity was increased and reached at its topmost level of activity at 12:05 h with 18.6±2.4 bees/m^2/5 minutes. The stingless bee was remained more active between 09:05 to 14:05 h in covered crop. The activity was stopped at 17:05 h. It was commonly observed that after withering of cucumber flower stingless bees were found to be rested on leaves as well as at the base of petiole of flower bud and withered flower too.

Overall, more activity of stingless bee was observed during both year of experimentation. However, in case of Apis bees the higher activity of *A. florea* was seen followed by activity of *A. dorsata* and *A. cerana* during *Kharif* season of 2018 and 2019.

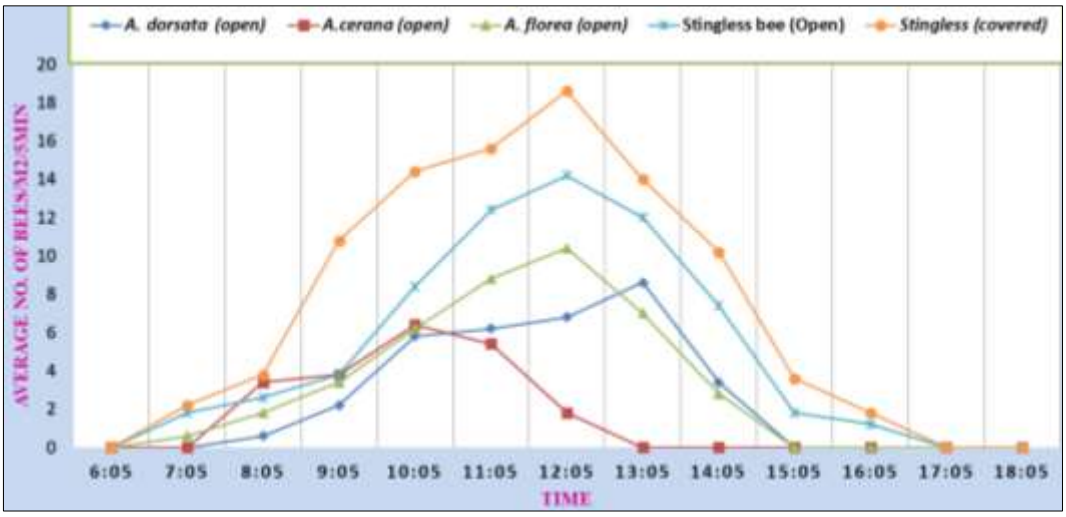

Fig 2: Activity period of pollinators in Cucumber during *Kharif* 2019

The results of present findings are more or less in confirmation with the results of Sajjanar *et al*. (2004) [9] who recorded peak activity of *A. dorsata* by 13:00 h with bee visits of 6.89 bees/m^2/5 min in cucumber crop. The activity of

different bee species in either open plots or caged plots of chow chow was found the maximum at 10:00 to 11:00 h by (Eswarappa *et al*., 2005) [1]. Patel (2007) [5] showed peak foraging activity of all the pollinators at 12:00 h of the day, while foraging activity was less during 14:00 h and 18:00 h of the day in cucumber field at Dharvad. According to Taha and Bayoumi (2009) [12] the bee activity was on flowers stopped after 14:00 h in watermelon at Egypt as all flowers closed in the crop. Rubina (2010) [8] recorded the maximum foraging activity of *A. cerana*, *A. florea* and *T. iridipennis* at 12:00 h under caged condition of cucumber crop. The maximum activity of outgoing stingless bees was recorded at 12:00 h by Gadhiya (2015) [2] at Navsari, Gujarat under poly house condition.

In contrast to results of present research, Kumar (2006) [3] observed the maximum foraging activity of *A. cerana indica* in pumpkin at 09:00 h, which might be due to change of season.

Conclusion

The pollinators of hymenoptera order were the most abundant followed by lepidoptera. Non-Apis bees were also act as promising pollinators in cucumber crop. The activity period of stingless bee was observed during both year of experimentation. However, in case of Apis bees the higher activity of A. florea was seen followed by activity of A. dorsata and A. cerana during Kharif season of 2018 and 2019.

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