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Studies on insect pollinator diversity, species richness, and evenness on Cucumber (*Cucumis sativus* L.) in the Eastern Dry Zone of Karnataka

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ABSTRACT: A study on the diversity of insect pollinators was carried out at the College of Horticulture, Kolar during the summer season of 2020-21 on cucumber (var. Chitra). The crop was raised and maintained to attract insect pollinators. The probability of entomophilous pollination depends upon the diversity of insects. In the present study, a total of 19 insect species was found as pollinators for *Cucumis sativus* (Cucumber) belongs to thirteen families and five insect orders (Hymenoptera, Diptera, Coleoptera, Lepidoptera, and Hemiptera). Of which, Hymenoptera was found to be the most abundant order followed by Diptera. Apidae was found to be the most abundant family followed by Chrysomelidae and Sarcophagidae. The study revealed that *Apis cerana* was found to be a major pollinator, followed by *A. florea* during the entire flowering period. Among the insect pollinators, six species were found foraging for both pollen and nectar, whereas seven species were found foraging for only pollen and six species for only nectar. Shannon index (H) for pollinator diversity was estimated as 0.9159 in four weeks duration of peak flowering, which reflects high species diversity. Simpson index (D) for species richness of insect pollinators was estimated as 0.2162 in four weeks duration of peak flowering indicating the higher abundance of the pollinator species. There is more than a 21 per cent chance of different insect pollinators when randomly captured in the summer season and the Pielous index (J) for species evenness of insect pollinators was estimated as 0.7162 in four weeks duration of peak flowering, indicating moderate evenness during the entire flowering period. Information regarding species eveness of the different insect pollinators is very limited. The following research work helps in filling the gap and also suggest information about the Bioanalytical tool, Pielous index in Eastern dry Zone of Karnataka and other plant- pollinators relationship in cucumber crop.

Keywords: *Cucumis sativus*, evenness on cucumber, faunal diversity, Insect pollinators, species richness.

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the monoecious annual crops belonging to the family Cucurbitaceae, which has been cultivated by man for over 3,000 years (Okonmah, 2011). Considering its economic importance, it ranks fourth after tomatoes, cabbage, and onion in Asia (Eifedeyi and Remison 2010). It is consumed in different ways like salads, vegetables, and sweets. Cucumber possesses antibacterial, antimicrobial, and antifungal characteristics and showed activities like antioxidant, phytochemical and hypoglycaemic activity (Mallick, 2022). Leaves are boiled and mixed with cumin seeds, roasted and powdered, and are administrated for throat infections. Fruits vary in shape, size, and colour and are considered nutritious. The calorific value of the fruit is 30 and has 0.4 per cent protein, 2.5 per cent carbohydrates, 1.5 mg of iron, and 2 mg of vitamin C per 100g fresh weight of fruit (Shrivastava and Roy 2013).

Cucumber is grown over an area of 82,000 hectares with a production of 12,60,000 MT in India. The area under cucumber cultivation is 8,270 hectares with a total production of 1,31,960 MT in Karnataka (NHB, 2018). Being a cross-pollinated crop, it fails to produce fruits when pollination does not occur. The plants may appear to be healthy, growing well, and flowering, but all the flowers drop from the plant. Fruits may appear to start developing but become incomplete or yellow and die completely (Ekeke *et al*., 2018). Generally, cucumber plants are monoecious; produce the staminate and pistillate flowers separately on the same plant. The male (staminate) flowers have very short stems and are borne in clusters of three to five. Whereas female (pistillate) flowers occur singly and can be recognized by the ovary at the base of the flower that develops into the fruit. Both staminate and pistillate flowers produce nectar and many bees visit flowers mainly for nectar collection (Revanasidda and Belavadi 2019). The staminate flowers appear first and are more in number than the pistillate flowers. The staminate flowers are

usually visible 10 days before the first pistillate flower. They normally exceed the pistillate flowers about 10 to 1 in ordinary monoecious variety (Padhiyar and Patel 2021).

The honey bee, *Apis* spp. is of great economic importance in terms of increasing the yield and quality of commercially grown insect-pollinated crops. Insects are the most diversified organisms on earth, comprising beetles, butterflies, flies, grasshoppers, wasps, bees, etc. They play an important role in the conservation of plant germplasm and hence the diversity of both crop and wild flora which further supports the existing fauna. This maintenance of flora balance in nature is the result of an indispensable process (pollination) and the agents are termed pollinators (Avinash *et al*., 2010). Human beings for their livelihood and food production rely on the insect ecosystem for pollination. The characteristics of cucumber fruits are dependent on the method of pollination, pollinators, and time of pollination (El-Kazafy and Yousry 2009; Maria *et al.,* 2010). Pollinators are very crucial to the agro-ecosystem as 75 per cent of the crops depend on insect pollination.

Cucumber crop requires some external agents for successful pollination, due to the presence of separate male and female flowers. Since the flowers are not wind or self-pollinated, they depend on insect pollinators for successful pollination, especially the honey bees. The plant consistently produces a little quantity of pollen that the pollinators are needed for successful pollen transfer from one flower to another to have a good fruit set (Bashir *et al*., 2021). The pistillate flower remains open only for one day, if they are not pollinated during that time the flower terminates and falls from the vine. Fruits do not develop properly when incomplete pollination occurs. Inadequate pollination leads to small, misshapen, or deformed fruits and lower yields (Shah *et al.*, 2015).

MATERIAL AND METHODS

Experiments on insect pollinators diversity, species richness, and evenness of insect pollinators on cucumber were carried out at the College of Horticulture, Kolar (with a latitude of 13.13'33°N and longitude of 78.17'22°E and an elevation of 849 meters above mean sea level) under Eastern Dry Zone of Karnataka. The cucumber crop was raised by using the commercially grown variety Chitra (from Rasi seeds company) in a plot size of 10 × 10 m, with a row-to-row spacing of 2 m and plant-to-plant spacing of 0.9 m by following all the UHS recommended package of practices.

Pollinator fauna, their diversity, and abundance in cucumber. Insect pollinators on cucumber flowers were collected by insect hand net (Belavadi and Ganeshaiah 2013) throughout the blooming period of cucumber at hourly intervals from 06:00 to 18:00 h of the day. Insect collection was started three days after the commencement of flowering and continued till the end of the flowering stage. The collected insects were then killed using ethyl acetate, processed, and preserved as dry specimens. The specimens of pollinators were taxonomically identified by Dr. C.A. Viraktamath, Emeritus Professor of Entomology, and Dr. H.M. Yeshwanth, Assistant Professor of Entomology, Insect Taxonomy Laboratory, Department of Entomology, UAS, GKVK, Bengaluru. Observations were made for different groups of pollinators visiting the cucumber field during flowering from 06:00 to 18:00 h for five minutes in each square meter area from five spots during the peak flowering period (Belavadi and Ganeshaiah 2013). The data was later averaged group-wise to infer the pollinator fauna as well as the dominance of a particular group.

Relative abundance of insect pollinators. The relative abundance of insect pollinator species was determined by using the standard formula (Southwood and Henderson 2000).

$$\text{Relative abundance of species (A)} = \frac{\text{Number of individuals of species (A)}}{\text{Total number of individuals collected}} \times 100$$

Diversity of insect pollinators. The diversity of different species of pollinators visiting cucumber during the peak flowering stage (SMW 18 to 21) of the crop was measured by using Shannon Index (H), Simpson index (D), and Pielous Index (J) (Vyas and Joshi 2013).

Shannon Index for species diversity (H^1)

$$H^1 = -\sum_{i=1}^{s} P\,i\ log10\ Pi$$

Where S= Number of pollinator species

P_i= Proportion of individuals of the abundance of the i^{th} species expressed as a proportion of total cover; $\log_{10}$= log $base_{10}$.

Simpson Index for species richness (D)

$D = \Sigma\ (n/N)^2$

Where n=The total number of a particular species; N=The total number of all species

Pielous index for species evenness (J)

$$J = \frac{H^1}{H^1_{max}} = \frac{-\sum_{i=1}^{s} P\,i\ log10\ Pi}{\log_{10} S}$$

Where S=Number of species

P_i= Proportion of individuals of the abundance of the i^{th} species expressed as a proportion of total cover; $\log_{10}$= log $base_{10}$.

RESULTS

Fauna and diversity of insect pollinators. Nineteen species of insect pollinators were recorded in cucumber during the flowering period at the College of Horticulture (COH), Kolar during the summer season of 2020-21. Among these, seven species belong to the order Hymenoptera, five species to Diptera, two species to Lepidoptera, four species to Coleoptera, and one species from the order Hemiptera (Fig. 1). Of which, the highest number of species belonged to the order Hymenoptera which consisted of five species from the family Apidae (*Apis cerana* Fab., *Apis florea* Fab., *Apis dorsata* Fab., *Ceratina binghami* Cockerell., *Xylocopa fenestrata* Fab); one species each from Megachilidae (*Megachile lanata* Fab.), and Formicidae (*Solenopsis geminata* Fab). Order Diptera consisted of one species

each from the family Stratiomyidae (*Hermetia illucens* L.), Syrphidae (*Eristalis* sp.), Calliphoridae (*Calliphora* sp.), Muscidae (*Musca* sp.), and Sarcophagidae (*Sarcophagi* sp.). Similarly in the order Lepidoptera, one species each from Nymphalidae (*Danaus chrysippus* L.), and Pieridae (*Pieris brassicae* L.), and in order Coleoptera, one species from the family Chrysomelidae (*Aulacophora* sp.) and three species from the family Coccinellidae (*Cheilomenes sexmaculata* Fab., *Coccinella septempunctata* L., *Illeis cincta* Fab.) were recorded. Whereas, in the order Hemiptera one species was recorded from the family Miridae (*Nesidiocoris tenius* Reuter) (Fig. 2). Among all these species of insect pollinators recorded, six species were found foraging for both pollen and nectar, whereas seven species were found foraging for only pollen and six species for only nectar (Table 1) (Fig 3).

Diversity indices of insect pollinators. Studies on diversity indices on cucumber crop (var. Chitra) were conducted at COH, Kolar during the summer of 2020-21 resulted that the Shannon index (H) of insect pollinators diversity was estimated as 0.9159 in four weeks of peak flowering, which reflects high diversity in the study area. Similarly, the Simpson index (D) for species richness of insect pollinators was estimated as 0.2162 in four weeks of peak flowering, indicating that the abundance of the pollinator species is higher and there is more than a 21 per cent chance of different insect pollinators when randomly captured in the summer season. Likewise, the Pielous index (J) for species evenness of insect pollinators was estimated as 0.7162 in four weeks of peak flowering, indicating moderate evenness in COH, Kolar (Table 2).

DISCUSSION

The pollination probability of *Apis cerana* was estimated highest in the sample group of pollinators because of its large size and good foraging activity on flowers (Willmer and Finlayson 2014). The size of insect pollinators and morphological features greatly influence the pollination probability (Willmer and Finlayson 2014). The mean Simpson Index (D) of diversity for insect pollinators represents greater diversity in the region of the study. The value of D varies from 0 to 1 indicating diversity declining value, diversity increases. In the experimental field, the zero value shows infinite diversity while 1 indicates no diversity. The mean Shannon index (H) of insects reflects the dominance of a group in the sample that was the Apidae family and the mean Pielous index of insect pollinators indicates moderate evenness and also implies more evenness leads to more diversity of insect pollinators. Shannon's index will be higher when the diversity is maximum (Selvakumari *et al*., 2022) and Simpson's index will be highest when the abundance of the species is maximum. The present findings are on par with Yogapriya *et al*. (2019) who reported that Shannon's evenness ranged from 0.44 to 0.86 in bitter gourds in Tamil Nadu and indifferent to Prakash and Bijoy (2021) who reported that the Shannon index, Simpson index, and Pielous index were 1.997, 0.8459, and 0.8927 in ash gourd, respectively. The pollination index represents that honey bees have high pollination probability and are actively engaged in cross-pollination services (Prakash and Bijoy 2021). The slight variation in the present study on insect visitors to cucumber and earlier studies on insect pollinators to various cucurbitaceous crops may be due to the type of cucurbit crop, colour of flowers, floral reward, and climatic conditions of the area.

Table 1: Pollinator fauna visiting cucumber flowers at COH, Kolar during 2020-21.

Order	Family	Scientific name	Type of forage	Abundance (n)
Hymenoptera	Apidae	*Apis cerana* Fab.	P, N	3.45
		Apis florea Fab.	P, N	2.38
		Apis dorsata Fab.	P, N	0.42
		Ceratina binghami Cockerell	P, N	0.18
		Xylocopa fenestrata Fab.	P, N	0.18
	Formicidae	*Solenopsis geminata* Fab.	N	0.17
	Megachilidae	*Megachile lanata* Fab.	P	0.17
Diptera	Muscidae	*Musca* sp.	N	0.20
	Sarcophagidae	*Sarcophagi* sp.	N	0.29
	Stratiomyidae	*Hermetia illucens* L.	N	0.17
	Syrphidae	*Eristalis* sp.	P	0.17
	Calliphoridae	*Calliphora* sp.	P, N	0.18
Lepidoptera	Pieridae	*Pieris brassicae* L.	N	0.17
	Nymphalidae	*Danaus chrysippus* L.	N	0.18
Coleoptera	Coccinellidae	*Illeis cincta* Fab.	P	0.18
		Cheilomenes sexmaculata Fab.	P	0.18
		Coccinella septempunctata L.	P	0.18
	Chrysomelidae	*Aulacophora* sp.	P	0.17
Hemiptera	Miridae	*Nesidiocoris tenius* Reuter	P	0.18

Where P: Pollen, N: Nectar

Table 2: Diversity indices of different species of insect pollinators on cucumber under open field conditions (SMW 18 to 21).

Insect pollinators	Abundance (n)	Pi	Pi^2	LogPi	PilogPi
Apis cerana	3.45	0.3750	0.1406	-0.4260	-0.1597
Apis florea	2.38	0.2587	0.0669	-0.5872	-0.1519
Apis dorsata	0.42	0.0457	0.0021	-1.3405	-0.0612
Ceratina binghami	0.18	0.0196	0.0004	-1.7085	-0.0334
Musca sp.	0.18	0.0196	0.0004	-1.7085	-0.0334
Hermetia illucens	0.17	0.0185	0.0003	-1.7333	-0.0320
Illeis cincta	0.17	0.0185	0.0003	-1.7333	-0.0320
Sarcophagi sp.	0.20	0.0217	0.0005	-1.6628	-0.0361
Aulacophora foveicollis	0.29	0.0315	0.0010	-1.5014	-0.0473
Coccinella septempunctata	0.17	0.0185	0.0003	-1.7333	-0.0320
Cheilomenes sexmaculata	0.17	0.0185	0.0003	-1.7333	-0.0320
Pieris brassicae	0.18	0.0196	0.0004	-1.7085	-0.0334
Danaus chrysippus	0.17	0.0185	0.0003	-1.7333	-0.0320
Megachile lanata	0.18	0.0196	0.0004	-1.7085	-0.0334
Calliphora sp.	0.18	0.0196	0.0004	-1.7085	-0.0334
Xylocopa fenestrata	0.18	0.0196	0.0004	-1.7085	-0.0334
Eristalis sp.	0.18	0.0196	0.0004	-1.7085	-0.0334
Solenopsis geminata	0.17	0.0185	0.0003	-1.7333	-0.0320
Nesidiocoris tenius	0.18	0.0196	0.0004	-1.7085	-0.0334
Total	**9.20**		0.2162		-0.9159
S (number of species)=19 Pi = (n/N)	log S = 1.2787 Shannon index (H)= 0.9159 Simpson index (D)= 0.2162 Pielous index (J)= 0.7162		N (Total number of individuals) = 9.20		

Note: (0= Infinite diversity, 1 = No diversity) SMW = Standard meteorological week

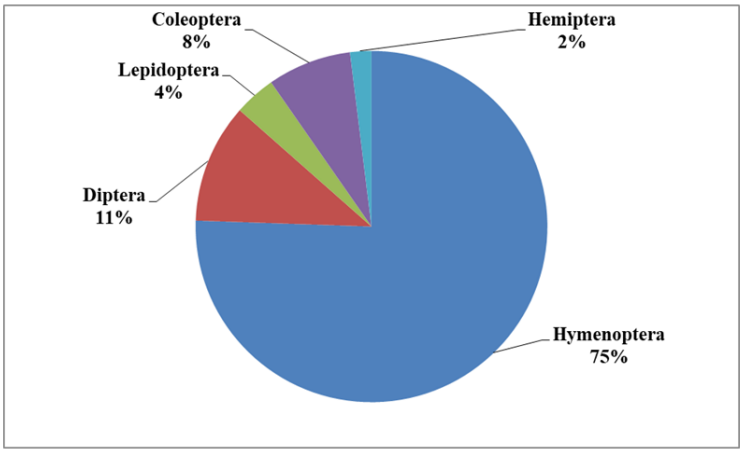

Fig. 1. Per cent relative abundance of insect pollinators (Order wise).

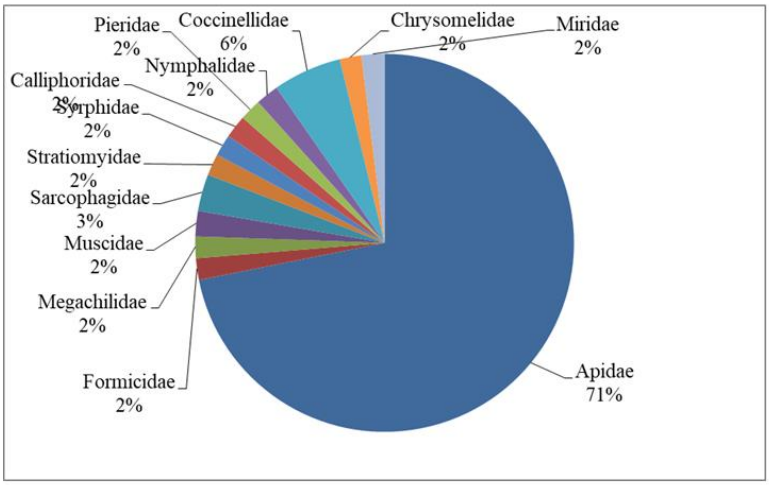

Fig. 2. Per cent relative abundance of insect pollinators (Family wise).

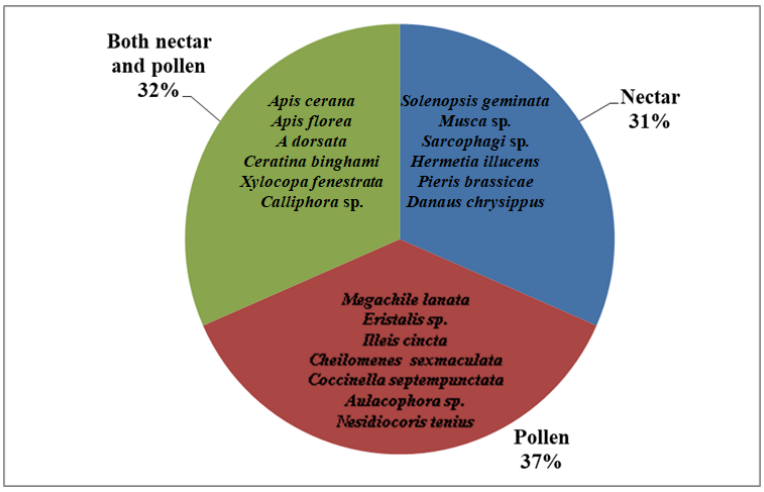

Fig. 3. Per cent relative abundance of insect pollinators based on the type of forage.

CONCLUSIONS

Cucumis sativus attracts more insect pollinators. Bees along with other insect pollinators play an important role in the pollination of cucumber. During this study, we come across 19 species of insect pollinators, which indicates the richness of bee pollinators for this single crop. Other indices also reveal the high diversity of insect pollinators and their dominance in this crop. It was proposed that farmers actively participate in bee farming in their respective fields because, without the presence of insect pollinators, agricultural work cannot be sustained.

FUTURE SCOPE

Studies about other diversity indices of the pollinators, Enhancing the diversity of insect pollinators by the use of commercial scents/ attractants/ food baits for pollination, Commercial exploitation of pollinators for seed production, Standardization of colony density for commercial seed production in cucumber.

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Conflict of Interest. None.

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