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DIVERSITY OF POLLINATORS ON SUNFLOWER

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ABSTRACT

Sunflower crop was grown during rabi 2021 and summer 2022 at the M S Swaminathan School of Agriculture, Centurion University of Technology and Management, Gajapati, Odisha. Investigation has been made on diversity of different pollinating agents associated with sunflower by observing their abundance, diversity, percentage contribution following the statistical diversity indices. The present study revealed eighteen different pollinators associated with sunflower. The Indian honey bee, *Apis cerana indica* (F) was recorded as the most dominant hymenopteran pollinator followed by the rock bee *Apis dorsata* (F) from family Apidae. The foraging activity of *A. c. indica* was observed to be maximum during mid flowering stage (1.72± 1.23 and 2.78± 1.81 bees/ capitulum/ min in 1st and 2nd season, respectively) with highest activity during 01:00-02:00 PM (3.02 bees/ capitulum/min.) and 10:00 to 11:00 AM (4.42 bees/ capitulum/ min) during first and second seasons respectively. The Apidae family members' i.e. *A. c. indica* and *A. dorsata* have attained eudominant and other pollinators were belonging mostly to the recedent and subrecedent classes based on dominance status. The diversity indices showed mid flowering stage attracted the most diversified group of pollinators.

Key words: *Apis cerana indica*, *Apis dorsata*, *Tetragonula iridipennis*, butterflies, relative abundance, dominance status, diversity index, ecology, Simpson's index, Shannon-Weiner Index (H')

Pollinators can be of any means of transferors such as bees, butterflies, birds, bats and other insects that play a crucial role in ecosystems and agriculture by facilitating the transmission of pollen from the male to the female parts of a flower. This phenomenon is known as pollination and results in several significant benefits for both the environment and human society. The diversity of pollinators refers to the wide variety of animal species that participate in the pollination which leads to fertilization and subsequent seed and fruit production. This process is essential for the reproduction and survival of many plant species, including those that are vital for human food production and ecosystem health. The diversity of pollinators provides several advantages and benefits to ecosystems, plants, and human societies. The presence of diversified pollinators maintains the resilience and stability of ecosystems. Apart from this, pollinators contribute to genetic diversity within plant populations. The relative abundance of different pollinators is proportional representation or frequency of various pollinator species within a given ecosystem or area. It describes the numerical or population density of different pollinators and their respective contributions to the pollination process. Understanding the relative abundance of pollinators is important for assessing the overall health and functioning of pollination networks. Among all of the pollinators, honey bees are regarded as the best because they not only help in pollination but also stores honey which can be utilized by human beings.

Insect pollination contributes 9.5% of economic value of agricultural production used directly for human food according to Gallai et al. (2009). The western honey bee has been widely used as pollinators since the application of pollination services began according to Valido et al. (2019). Honey bees are considered as the excellent pollen vectors as majority of the foragers land on the outer ring of the florets and then move to inner rings where fresh pollen is available, before flying to next head. In addition, their movements between capitula are always indiscriminate which enhanced pollen movement according to Toit and Holm (1992). Honey bees along with birds and bats contribute around 35% yield towards agriculture production (F.A.O., 2023). Sunflower *Helianthus annuus* (L) is an important oilseed and a valuable crop. It has bright

and showy flowers that produce large amounts of nectar and pollen, making them highly attractive to pollinators, particularly bees and butterflies. Apart from this, the sunflower's inflorescence, which is made up of multiple tiny flowers arranged in a large disk, provides a generous landing platform for pollinators. Therefore, an investigation has been made on diversity of pollinating agents associated with sunflower by observing their abundance, diversity, and contribution following the statistical diversity indexes.

MATERIALS AND METHODS

The present study has been undertaken during two seasons i.e. first season (September-December, 2021) and second season (January-April, 2022) in the Experimental Station of Entomology located in the upland area of Experimental Research Field, M S Swaminathan School of Agriculture, Paralakhemundi, Centurion University of Technology and Management, Odisha. Apart from this, three other areas were also used for research. Those were the farmers' field of Kashinagar block, Gumma Block and Goshani block of Gajapati District of Odisha where three villages from each location were selected. The MSSSoA was coming under block Goshani. Keen observation has been taken on diversity of pollinators, their abundance, and contribution and dominance status. Following methods were used- Data has been collected on composition and abundance of pollinators from different agroecosystems of Gajapati district through visual observation at 05 days interval during the two cropping seasons during 2021-23. The identification of the pollinators was done from a large number of samples following fixed plot survey in selected experimental sites. The collected adult insects were killed by using chloroform and dry preserved through pinning/pointing in the laboratory of Department of Entomology, MSSSoA. The specimens were identified referring the identified specimen maintained in collections of AICRP on Honey bees and pollinators, OUAT, Bhubaneswar. The common name, scientific name, family, order, habitat of the specimens were recorded with their foraging behaviour. The dominance status of various taxa of the pollinators were described on the basis of relative abundance which determines the % of specimens of a given species in the total number of organism collected and the index of dominance was described following classes of dominance (Jakiewicz, 2003). For statistical analysis of diversity of pollinators, Simpson's index of diversity (Simpson, 1949) and Shannon-Weiner index (Shannon-Weiner Index, 1949) were used.

RESULTS AND DISCUSSION

Eighteen different pollinators were found foraging on sunflower in Gajapati district of Odisha. The present study conducted at MSSSoA, CUTM, Goshani block, in the first season revealed that the crop sunflower is visited by pollinators were belonging to order Hymenoptera and Lepidoptera. The adult lepidopteran pollinators were coming towards the plants as a source of nectar. According to Table 1, sunflower crop is visited by three species of honey bees, two species each of leaf cutter bees and wasps. Apart from the hymenopteran pollinators, eight lepidopteran adult pollinators were also found visiting sunflower. Studies on pollinator diversity in the second season revealed that the crop sunflower is visited by pollinators belonging to only Hymenoptera. Sunflower crop is visited by similar hymenopteran pollinators observed in first season with addition to *Apis florea* (F) and *Amegilla zonata* (L).

The data from two other blocks of Gajapati district. that the pollinators were similar revealed in case of Gumma block where European bees, *Apis mellifera* (F) was observed which was not observed in other two blocks (Table 1). Nayak et al. in 2021 at Bhawanipatna, Odisha recorded two honey bee species i.e. *A. dorsata* and *A. c. indica* and one bumble bee (*Xylocopa* sp). Yasmeen et al. in 2021 found a total of eight species of pollinators. A total of 14 pollinator insects species was recorded on sunflower belonging to the orders Hymenoptera and Lepidoptera (Adeoye and Pitan, 2020). Similarly, Mehmood et al. (2018); Basak and Mandal (2018) identified 7 and 18 different major insect pollinators, respectively. Bhowmik and Bhadra (2015) identified seventeen pollinators. Hussain et al. (2015) at Swabi Khyber Pakhtunkhwa, North Western Pakistan recorded fifteen species of pollinators belonging to 11 genera, 8 families and three orders. Rasheed et al. (2015) in Islamabad identified twelve different species of insect pollinators. Krishna et al. (2014) at Parbani, Maharashtra also revealed that *A. mellifera, A. c. indica* and *A. florea* were the major pollinators associated with sunflower. Goswami et al. (2013) at Pantnagar, Uttarakhand recorded 12 species of insect pollinators visiting sunflower. Jadhav et al. (2011) at Tirupati identified twenty species of insect pollinators associated with sunflower. Nderitu et al. (2008) at Eastern Kenya observed 14 insects species visiting sunflower floral heads. Kasina et al. (2007) at Makueni district, Eastern Ken recorded 14 insect species associated with sunflower. Mahavir (1999) at Haryana, Swaminathan and Bharadwaj (1982) at

Table 1. Pollinators' diversity on sunflower in Gajapati District, Odisha (2021-2022)

Sl. No.	Common name	Scientific name	Block Goshani		Block Kashinagar, 2022	Block Gumma, 2022
			First season, 2021	Second season, 2022		
Family: Apidae; Order: Hymenoptera						
1	Indian hive bee	*Apis cerana indica* F.	1	1	1	1
2	Rock bee	*Apis dorsata* F.	2	2	2	2
3	European bee	*Apis mellifera* L.	-	-	-	3
4	Stingless bee	*Tetragonula iridipennis* Smith	3	3	3	4
5	Little bees	*Apis florea* F.	-	4	-	-
6	Carpenter bee	*Xylocopa latipes* Drury	4	5	4	5
7	Carpenter bee	*Xylocopa aestuans* L.	5	6	-	-
8	Digger bee	*Amegilla zonata* L.	-	7	-	-
Family: Vespidae; Order: Hymenoptera						
9	Oriental hornet	*Vespa orientalis* L.	6	8	-	-
10	Wasp	*Vespa tropica* L.	7	-	-	-
Family: Nymphalidae; Order: Lepidoptera						
11	Tawny coster	*Acraea terpsicore* L.	8	-	-	-
12	Common crow	*Euploea core* Cramer	9	-	-	-
13	Grey pansy	*Junonia atlites* L.	10	-	-	-
14	Blue glassy tiger	*Idiopsis vulgaris* Butler	11	-	-	-
15	African monarch	*Danaus chrysippus* L.	12	-	-	-
16	Lemon pansy	*Junonia lemonias* L.	13	-	-	-
Family: Pieridae; Order: Lepidoptera						
17	Common/Lemon emigrant	*Catopsilia pomona* F.	14	-	-	-
Family: Crambidae; Order: Lepidoptera						
18	Cucumber moth	*Diaphania indica* Saunders	15	-	-	-

Udaipur, Rajasthan, Satyanarayan and Seetharam (1982) at Bangalore, Karnataka and Arya et al. (1994) at Hisar, Haryana identified 15, 10, 21 and 20 pollinators, respectively.

The studies conducted at MSSSoA during first season revealed that the order Lepidoptera (53.33%) was having more diversified species as compared to order Hymenoptera (46.67). From Lepidoptera, family Nymphalidae (40%) consisted highest number (6) followed by Pieridae (6.67%) and Crambidae (6.67%). From Hymenoptera, Apidae (33.33%) was the dominant one (5) followed by Vespidae. Whereas, in the second season one and only order Hymenoptera were found visiting the sunflowers on majority basis. Family Vespidae constituted 14.29% while family Apidae found the major by contributing 85.71% of pollinators. In the first season, Indian honey bees*, Apis cerana indica* constitute 30.81% of the total foragers and it remained the most dominant among the bee species visiting sunflower flower followed by *Apis dorsata* (Fabricius) (23.65%)*, Tetragonula iridipennis* (19.56%), *Xylocopa latipes* (Drury) (5.68%), *Acraea terpsicore* (Linnaeus) (2.64%), *Junonia lemonias* (L) (2.44%)*, Xylocopa aestuans* (2.44%), *Catopsilia pomona* (1.99%)*, Vespa orientalis* (1.64%)*, Junonia atlites* (1.59%), *Idiopsis vulgaris* (1.54%)*, Diaphania indica* (1.54%)*, Vespa tropica* (1.54%)*, Danaus chrysippus* (1.49%) and *Euploea core* (1.44%) were also observed. In the second season also Indian honey bees*, A. c. indica* remained the most dominant among the bee species visiting sunflower flower constituting 33.94% followed by *A. dorsata* (30.38%)*, T. iridipennis* (22.51%), *A. zonata* (8.49%) *X. latipes* (1.63%), *V. orientalis* (1.60%) and *X. aestuans* (1.46%).

Yasmeen et al. (2021) observed *A. mellifera*, *A. dorsata*, *A. c. indica*, *T. iridipennis*, *Vespa tropica* and Hesperidae as the major sunflower visiting species. Adeoye and Pitan (2020) revealed that the hymenopterans belonged to five families namely: Apidae, Halticidae, Anthophoridae, Megachilidae and Vespidae while the families Nymphalidae, Danaidae and Erebidae were the lepidopterans. The most common pollinators were *Trigona* sp (61.00%), *A. mellifera* (15.58%), *Dactylurina staudine* (13.23%) and *Acreazetes* (4.13%). The results showed that Hymenoptera (93.38%) were the most dominant insects

in the study, followed by Lepidoptera (6.62%) which is in line with the present investigation. Basak and Mandal (2018) revealed *A. dorsata* as the most dominant pollinator followed by followed by *A. c. indica*.

Present results revealed that the population of *A. c. indica* was the maximum with 1.72 bees/ capitulum/ 5 min similar results were obtained. In the second season also, *A. c. indica* remained major pollinator 2.78 bees/ capitulum/5 min followed by *A. dorsata* (2.49 bees/capitulum/5 min) and *T. iridipennis* (1.84 bees/ capitulum/ 5 min). Other pollinators also visited with very less foraging activity (Table 2); *X. latipes* was very less in numbers during early and mid flowering stages but more during late flowering stage; *A. c. indica* was found to be more prevalent during 01:00-02:00 PM in the first season (3.02 bees/capitulum/ 5 min) whereas it was more abundant during 10:00-11:00 AM in the second season (4.42 bees/capitulum/ 5 min). *A. dorsata* was found to be more prevalent during 10:00-11:00 AM in the first season (2.34 bees/ capitulum/ 5 min) whereas it was more abundant during 10:00-11:00 AM in the second season (3.69 bees/ capitulum/ 5 min). *T. iridipennis* shown higher tendency during 10:00-11:00 AM in both of the seasons i.e. 1.67 bees/capitulum/5 min and 2.74 bees/ capitulum/ 5 min in first and second season respectively. Hemanth et al. (2020) with *A. cerana* showed peak activity time from 11.00 to 12.00; followed by *A. cerana* (2.87 bees/ capitulum/ 5 min); when 51- 75% of disc florets opened the foragers of *A. cerana* (3.73 bees/ capitulum/ 5 min) was seen at mid flowering. During full bloom, *A. cerana* foragers recorded mean number of foragers with 4.25 bees/ capitulum/ 5 min. In general the number of *A. cerana* foragers increased with disc florets opening/ capitulum. During the present investigation, similar rising trend of *A. c. indica* count was observed with increase in number of disc florets.

Fifteen pollinators were observed which can be categorized in to five out of six classes of dominance. In the first season, majority of the pollinators came under recedent constituted 10 numbers (*A. terpsicore*, *E. core*, *J. atlites*, *I. vulgaris*, *D. chrysippus*, *J. lemonias*, *C. pomona*, *D. indica*, *V. orientalis* and *V. tropica*) followed by subrecedent (*X. latipes* and *X. aestuans*) and dominant (*A. c. indica* and *A. dorsata*) each constituting two numbers followed by sub dominant (*T. iridipennis*) having only one species covering four classes of dominance classes during early flowering stage. During mid flowering stage majority of the 12 numbers of pollinators came under recedent (*X. latipes*, *X. aestuans*, *A. terpsicore*, *E. core*, *J. atlites*, *I. vulgaris*, *D. chrysippus*, *J. lemonias*, *C. Pomona*, *D. indica, V. orientalis* and *V. tropica*) followed by 2 dominant (*A. dorsata* and *T. iridipennis*) and eudominant having only one species covering three classes of dominance status. During late flowering stage majority of the 7 numbers of pollinators came under subrecedent (*E. core, J. atlites, I. vulgaris, D. chrysippus, J. lemonias, D. indica* and *V. tropica*) followed by 4 numbers of recedent (*X. aestuans, A. terpsicore, C. pomona* and *V. orientalis*), 3 numbers of subdominant (*A. dorsata, T. iridipennis and X. latipes*) and eu-dominant having only one species i.e. *A. c. indica* covering four classes of dominance classes. It is further observed that *A. c. indica* is having eudominant class status in both mid flowering and late flowering stages.

In the second season, seven pollinators were observed categorized into five out of six classes of dominance. Majority came under subrecedent (*X. latipes*, *X. aestuans* and *V. orientalis*) followed by eudominant (*A. c. indica* and *A. dorsata*) followed by dominant (*T. iridipennis*) and recedent (*A. zonata*) covering four classes of dominance status in the early flowering stage. During mid flowering stage majority came under subrecedent (*X. latipes* and *X. aestuans*) and dominant (2 numbers) (*A. c. indica* and *T. iridipennis*); followed by eudominant (*A. dorsata*), subdominant (*A. zonata*) and recedent (*V. orientalis*). During late flowering stage majority under recedent were (*T. iridipennis, X. latipes, X. aestuans, V. orientalis* and *A. zonata*) followed by subdominant and eudominant (*A. dorsata* and *A. c. indica*, respectively). In the first season, diversity of pollinators estimated through the Simpson's index of diversity during various flowering stages (45-84 DAS) revealed that the number of species varies between 5- 14 with the Simpson's Index, Simpson's index of diversity and Simpson's reciprocal Index ranging from 0.13 to 0.26, 0.78 to 0.87 and 3.80 to 7.51, respectively. The diversity during various timing of a day (*i.e.* 07:00 hr, 10:00 hr, 13:00 hr and 17:00 hr) revealed that the number of species varies between 7- 15 with Simpson's index of diversity ranging from 0.77-0.81 and diversity at all early, mid and late flowering (0.77-0.84). In the second season, diversity during various flowering stages (48-88 DAS) revealed that the number of species varies between 3-7 with the Simpson's Index, Simpson's index of diversity and Simpson's reciprocal Index ranging from 0.25 to 0.37, 0.63 to 0.75 and 2.70 to 4.87, respectively. The

Table 2. Relative abundance of insect pollinators during all flowering stages in sunflower

First season (September-December, 2021)						Second season (January-April, 2022)					
Species	Number of pollinators				Mean ± SD	Species	Number of pollinators				Mean± SD
	07:00-08:00 AM	10:00-11:00 AM	01:00-02:00 PM	04:00-05:00 PM			07:00-08:00 AM	10:00-11:00 AM	01:00-02:00 PM	04:00-05:00 PM	
Apis cerana indica	1.28	2.36	3.02	0.22	1.72± 1.23	*Apis cerana indica*	3.37	4.42	3.12	0.20	2.78± 1.81
Apis dorsata	0.88	2.34	2.00	0.06	1.32± 1.05	*Apis dorsata*	2.81	3.69	3.28	0.17	2.49± 1.59
Tetragonula iridipennis	1.30	1.67	1.40	0.00	1.09 ± 0.74	*Tetragonula iridipennis*	2.24	2.74	2.31	0.07	1.84± 1.20
Xylocopa latipes	0.22	0.38	0.62	0.04	0.32± 0.25	*Xylocopa latipes*	0.07	0.19	0.26	0.02	0.13± 0.11
Xylocopa aestuans	0.07	0.11	0.32	0.04	0.14± 0.13	*Xylocopa aestuans*	0.08	0.16	0.24	0.00	0.12± 0.10
Acraea terpsicore	0.16	0.22	0.21	0.00	0.15± 0.10	*Vespa orientalis*	0.06	0.09	0.29	0.09	0.13± 0.11
Euploea core	0.07	0.10	0.16	0.00	0.08± 0.07	*Amegilla zonata*	1.16	1.13	0.39	0.10	0.69± 0.53
Junonia atlites	0.07	0.12	0.17	0.00	0.09± 0.07						
Idiopsis vulgaris	0.03	0.16	0.16	0.00	0.09± 0.08						
Danaus chrysippus	0.10	0.13	0.10	0.00	0.08± 0.06						
Junonia lemonias	0.12	0.24	0.18	0.00	0.14± 0.10						
Catopsilia pomona	0.10	0.22	0.11	0.01	0.11± 0.09						
Diaphania indica	0.11	0.13	0.10	0.00	0.09± 0.06						
Vespa orientalis	0.10	0.10	0.11	0.06	0.09± 0.02						
Vespa tropica	0.08	0.07	0.11	0.09	0.09± 0.02						
Mean	0.31	0.56	0.58	0.03		Mean	1.40	1.77	1.41	0.09	

diversity during various timing of a day (*i.e.* 07:00 hr, 10:00 hr, 13:00 hr and 17:00 hr) varies between 6-7 species with Simpson's index ranging from 0.73-0.80 and at all early, mid and late flowering (0.69-0.74). In general the diversity was almost uniform because of the evenness of the species.

The Shannon-Weiner Index values during various flowering days (45-84 DAS) ranges from 1.43 to 2.24 in the first season and 1.06-1.56 during different flowering durations (48-88 DAS) in the second season. The diversity of pollinators during various timing of a day (*i.e.* 07:00 hr, 10:00 hr, 13:00 hr and 17:00 hr) was with Shannon-Weiner Index ranging from 1.64 to 1.96 and 1.42 to 1.63 in the first and second season, respectively. The diversity during flowering stages varied from 1.82 to 2.13 and 1.24 to 1.49 in the first and second seasons respectively. Shannon-Weiner Index at 70 DAS (1.57) and 68 DAS (1.32), 01:00 PM (1.64) and 10:00 AM (1.42) and mid flowering stage (1.82 and 1.24) have shown more diversity in first and second season, respectively. Hymenoptera and Lepidoptera were evenly distributed within the experimental field with a value range of 0.90 - 0.96 (Adeoye and Pitan, 2020). Thus, a wide variety of insect species, notably those belonging to order Hymenoptera are extremely attracted towards sunflower capitulum. *Apis cerana indica* was the dominant one followed by *A. dorsata*. *Apis cerana indica and A. dorsata* have attained eudominant status whereas others mostly having recedent and subrecedent status.

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AUTHOR CONTRIBUTION STATEMENT

DP, CRS and SB conceived and designed research. DP conducted experiments. DP and CRS analyzed data. DP wrote the manuscript. CRS and SB reviewed the manuscript and approved the final manuscript.

CONFLICT OF INTEREST

No conflict of interest.

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