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Diversity and Relative Abundance of Insect Pollinators on Pigeon Pea (*Cajanus cajan* L.) in Gajapati District of Odisha

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ABSTRACT

Background: Many cross pollinated flowering plants rely on pollinators for reproduction and survival. The pigeon pea (arhar), *Cajanus cajan* L., is the India's most important pulse crop. It attracts pollinators because to its cross pollination nature, possible nectar and pollen source, attractive colour and scent of the seeds and timing of blossoming. As a result, a complete research of pigeon pea insect pollinator fauna shall be used to conserve those fauna for increasing pigeon pea pollination effectiveness.

Methods: Diversity of different pollinating agents associated with the crop pigeon pea by observing their abundance, diversity, percentage contribution, dominance status and diversity following the statistical diversity indexes were recorded during *Kharif*, 2021-22 in the state of Odisha where the insect pollinators' fauna was recorded through fixed plot survey.

Result: *Megachille lanata* (Fabricius) was found to be the most dominant pollinator throughout the flowering period among seven different pollinators of order Hymenoptera. *M. lanata* and *Megachille disjuncta* (Fabricius) shown higher foraging activity *i.e.* 6.02 bees/5 min/m^2 and 4.25 bees/5 min/m^2 respectively. Subdominant class represented maximum species among different dominant status classes exhibited. Very less diversity was observed throughout the season but still more diversity has been observed at mid flowering stags during 10:00-11:00 AM..

Key words: Arhar, *Megachille lanata*, Pigeon pea, Pollinators' diversity.

INTRODUCTION

A pollinator is an organism that helps transfer of pollen from the male reproductive organs (stamen) to the female reproductive organs (pistil) of flowers, facilitating the process of fertilization and subsequent seed production in flowering plants. This transfer of pollen is crucial for the reproduction and survival of many plant species. Diversified pollinators maintain the resilience and stability of ecosystems. 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. Honeybees being the best pollinator, store honey that can be utilized by human being in different purposes. The pigeon pea/arhar, *Cajanus cajan* L., is the second-most produced legume in the Fabaceae family and the most significant pulse crop in India. Pigeon pea being often cross pollinated is well known to attract pollinators due to several characteristics of its flowers and reproductive strategy. Some of the reasons for which pigeon pea attracts pollinators are cross pollination, potential nectar and pollen source, attractive colour and sent of the seeds and the timing of blooming are the major one. Pigeon pea in grown in an area of 47.17 lakh hectares with a production capacity of 41.37 lakh tons in whole India. The state Karnataka ranks the first in area cultivated while the production is the highest in Maharashtra where Odisha could cultivate 1.35 lakh hectare with a production capacity of 1.37 lakh tons (Annual Report, 2022). To increase the productivity of pigeon pea in Odisha condition, pollinators should be conserved in the natural ecosystem for resourceful pollination. Therefore, an investigation has been made on diversity of different pollinating agents associated with the

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crop pigeon peaby observing at Gajapati district of Odisha and analyzed their abundance, percentage contribution, dominance status and diversity index.

MATERIALS AND METHODS

The present study has been undertaken during cropping seasons of *kharif*, 2021-22 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, Gajapati, Odisha. The soil type of the experimental plot was red lateritic with the average soil pH of 6.5. The seeds of HYV pigeon pea cv. Asha was grown with the inter and intra row spacing maintained at 50 cm and 30 cm respectively and the plot size was of 2 m×2 m. The crop with same agronomic dimensions grown in twenty replication for the current and other research studies. A recommended dose of N_2: P_2O_5: K_2O at 20:40:20 kg/ha was applied. Necessary agronomic practices were followed to maintain proper plant population and normal growth of plants. A prophylactic spraying of the insecticide profenophos @ 2 ml/lit against the infestation of early season pests at 60 day after sowing prior to onset of flowering was applied to keep the crop away from pest infestation.

In order to study the diversity of different insect pollinators visiting pigeon pea flowers observations were taken during the flowering period of the crop. Collection of pollinators was done at 10 days interval during the early, mid and late flowering period in thirty sweeps per day at 07:00 hr. to 08:00 hr., 10:00 hr. to 11:00 hr.,13:00 hr. to 14:00 hr. and 16:00 hr. to 17:00 hr. by using a sweeping net of 40 cm diameter. The different time periods were fixed at alternative time intervals. After collection of the pollinators they were killed by using the ethyl acetate solution and dried to preserve as per Borror and De Long (1981). Identification of the pollinators was done by matching with previously identified fauna of pollinators (Identified by the Department of Entomology, OUAT, Bhubaneswar, Odisha). Diversity of pollinators was recorded by separating them based on their order and family.

Observations on the foraging activity of different insect pollinators visiting on the flowers of pigeon pea were made during the early flowering *i.e*. at 10 per cent flowering stage coinciding with 69 DAS, followed by 30 per cent flowering stage coinciding with 79 DAS, 89 DAS and 99 DAS, followed by mid flowering *i.e*. at 50 per cent flowering stage coinciding with 109 DAS, 119 DAS and 129 DAS, followed by late flowering *i.e*. at 70 per cent flowering stage coinciding with, 139 DAS, 149 DAS and 159 DAS during different day intervals as mentioned before. The observations were taken based on the number of pollinators visiting pigeon pea flowers per 1 m^2 per 5 minute at randomly selected 10 spots within the field and the mean data was arrived for the final result. The data were computed for study of the activity of pollinators during the cropping period and for estimation of activity of pollinators.

The dominance status of various taxa of the pollinators were described on the basis of relative abundance which determines the percentage of specimens of a given species in the total number of organism collected and the index of dominance was described with the following classes of domination (Jakiewicz, 2003).

<1 % = Subrecedent; 1-9% = Recedent.
10-20 % = Sub-dominant; 21-30% = Dominant.
31-60 % = Eudominant; > 60 % = Superdominant.

For statistical analysis of diversity studies, three different statistical tools were used for scientific conclusions, those are Simpson's Index of Diversity, Shannon-Weiner Index and Sorenson's coefficient were worked based on the methods suggests by Simpson (1949) and Shannon-weiner index (1949).

Simpson's index (D)

It means the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species) and the formula for calculating D as follows.

$$D = \frac{\Sigma n\,(n - 1)}{N\,(N - N)}$$

Where,
n = Total number of organisms of a particular species.
N = Total number of organism of all species.

A part from this, Simpson's index of diversity (SID): 1-D, Simpson's reciprocal index: 1/D and evenness was also calculated.

$$D = \frac{1}{\Sigma_{i=1}^{s} p_i^2}$$

$$\text{Evenness } (E_D) = \frac{D}{D_{max}} = \frac{1}{\Sigma_{i=1}^{s} p_i^2} \times \frac{1}{s}$$

Where,
D = Simpson's diversity index.
P_i = Proportion of S made up of the i^{th} species.
S = Total number of species in the community (richness).

Shannon-weiner index (H′)

Shannon-weiner index (1949) is a very widely used diversity index for comparing diversity between various habitats (Clarke and Warwick, 2001). Shannon-Weiner Index assumes that individuals are randomly sampled from an independently large population and all the species are represented in the sample. The value of Shannon Weiner Diversity Index usually ranges between 1.5 and 3.5 and rarely surpasses 4.5. A value near 4.6 would indicate that the numbers of individuals are evenly distributed between all the species. Mathematically, Shannon-Wiener Index is:

$$H' = \frac{s}{i = 1} - \sum Pi \log 2\ pi$$

Where,
Pi = The proportion of the i^{th} species (n_i/N).
s = The number of species.

RESULTS AND DISCUSSION

The present study revealed that the activity of different pollinators started at 10 per cent flowering stage coinciding with 69 DAS and continued till the late flowering stage *i.e.* 159 DAS. A great majority of pigeon pea plants flowered between 89 DAS to 129 DAS and the diversified activities of pollinators mostly observed during the period were recorded.

Studies on pollinator diversity on pigeon pea crop revealed the occurrence of two out of the seven Hymenopteran pollinators families associated with the flowers were Apidae and Megachilidae. Pigeon pea crop was visited by three species of honeybees *i.e. Apis dorsata* Fabricius*, Apis cerana indica* Fabricius and *Tetragonula iridipennis* Smith. Along with the bee species some other hymenopterans were also observed foraging on pigeon pea *viz*., two of the leaf cutting bees (*Megachile lanata* Fabricius and *Megachile disjuncta* Fabricius) and two bumble bee species (*Xylocopa latipes* Drury and *Xylocopa aestuans* Linnaeus) (Table 1). Padhy *et al*. (2018) also observed 11 different insect pollinators in Odisha condition which followed similar trend while Singh (2017) with six and seven species of insect pollinators (Singh, 2016) throughout blooming stage of pigeon pea in Nagaland stating the highest frequency of visit was done by the *M. lanata* followed by *Amegilla zonata* Linnaeus*, M. relata* Smith, *M. monticola* Smith*, M. conjuncta* Smith*, X. tenuiscapa* Westwood and *Nomia* sp. More diversified insect pollinator activities reported earlier with 15 (Singh *et al*., 2017), 24 (More *et al*., 2015) and with the highest of 30 species (Rashmi *et al*., 2010) might be attributed to the cropping diversity and cultivation practices.

Family Apidae having 71.43 per cent share was found to be the most dominant one followed by Megachilidae having 28.57 per cent per cent share which are active and conspicuous during the cropping season and the illustrations are presented in Fig 1. Report of Singh (2016) recording four species of Megachilidae, two of Apidae and a species of Halictidae is in close agreement with the present findings except that the occurrence of Halictidae as against the observation of Rashmi *et al.* (2010) reporting six species under Apidae, five under Megachilidae, four under Xylocopidae, three under Vespidae, one under Sphecidae, Scoliidae and Formicidae, Lepidopterans representing Nymphalidae and Papilionidae, Dipterans with Tachinidae and Coleopterans comprising Chrysomelidae. Diversity and abundance of pollinators at Bengaluru (Rashmi *et al*., 2010) and Nagaland (Singh, 2017) might be due to agro-ecological and geographical suitability for the pollinators.

Among the pollinators *M. lanata* constitute 34.33 per cent of the total foragers and beingthe most dominant among the bee species visiting pigeon pea flower followed by *M. disjuncta* (24.25%), *T. iridipennis* (13.74%), *A. c. indica* (13.27%), *X. latipes* (13.12%), *X. aestuans* (1.38%) and *A. dorsata* (0.20%) were also observed visiting on pigeon pea (Fig 2). Singh (2017) also reported that *M. lanata* was the most dominant bee species followed by other *Megachile* sp.of pigeon pea crop. Similar results have been reported by Brar *et al.* (1992) at Punjab, that the most abundant species was *M. lanata* (28%) followed by *A. dorsata* (23%) and *A. mellifera* (22%). Other investigations made by Ahmad and Srivastava (2002) and Azevedo *et al.* (2007) and also Chaudhary and Jain (1978) reporting the predominance *M. lanata*in pigeon pea are in support of the present finding.

A. c. indica was recorded to be the most abundant pollinator of pigeon pea at Bengaluru (Rashmi *et al*., 2010) while *A. florea* at Maharashtra (More *et al*., 2015) and *A. mellifera* at Jammu and Kashmir (Singh *et al*., 2017). These species could not be recorded in appreciable number during the current investigation at Gajapati, Odisha condition astonishingly with complete absence of *A. mellifera*. This variation is mostly due to variations in agro-ecological condition and human intervention involving practice of beekeeping in the region.

Table 1: Diversity of insect pollinators of pigeon pea in Gajapati district of Odisha during *Kharif* (2021-22).

Common name	Scientific name	Family	Order
Indian hive bee	*Apis cerana indica* Fabricius	Apidae	Hymenoptera
Rock bee	*Apis drosata* Fabricius	Apidae	Hymenoptera
Leaf cutting bee	*Megachile lanata* Fabricius	Megachilidae	Hymenoptera
Leaf cutting bee	*Megachile disjuncta* Fabricius	Megachilidae	Hymenoptera
Stingless bee	*Tetragonula iridipennis* Smith	Apidae	Hymenoptera
Carpenter bee	*Xylocopa latipes* Drury	Apidae	Hymenoptera
Carpenter bee	*Xylocopa aestuans* Linnaeus	Apidae	Hymenoptera

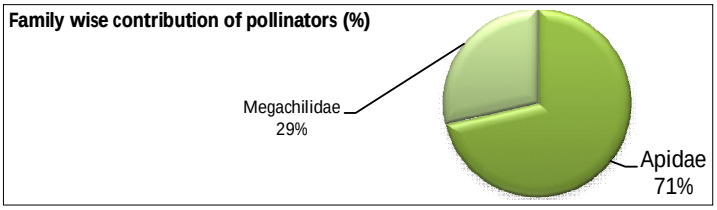

Fig 1: Family wise share of pollinator's of pigeon pea in Gajapati district of Odisha during *Kharif* (2021-22).

M. lanata was recorded as the most dominant pollinator foraging at a rate of 6.02 bees/5 min/m^2 and their abundance was more during 13:00-14:00 hr (11.10 bees/5 min/m^2) followed by 10:00 to 11:00 Hr (9.77 bees/5 min/m^2) and 07:00 to 08:00 Hr (3.13 bees/5 min/m^2) and least was observed during 16:00-17:00 Hr. *i.e.* 04:00-05:00 Hr (0.07 bees/5 min/m^2). *M. disjuncta* (4.25 bees/5 min/m^2) was found to be the second most dominant pollinator followed by *T. iridipennis* (2.41 bees/5 min/m^2), *A. c. indica* (2.33 bees/5 min/m^2), *X. latipes* (2.30 bees/5 min/m^2), *X. aestuans* (0.24 bees/5 min/m^2) and *A. dorsata* (0.04 bees/5 min/m^2) was found to be the least foraging pollinator among all in pigeon pea (Table 2). Singh (2017) reported six species of bee pollinators where *M. lanata* (17.33 and 17.00 bees/m^2/5 min

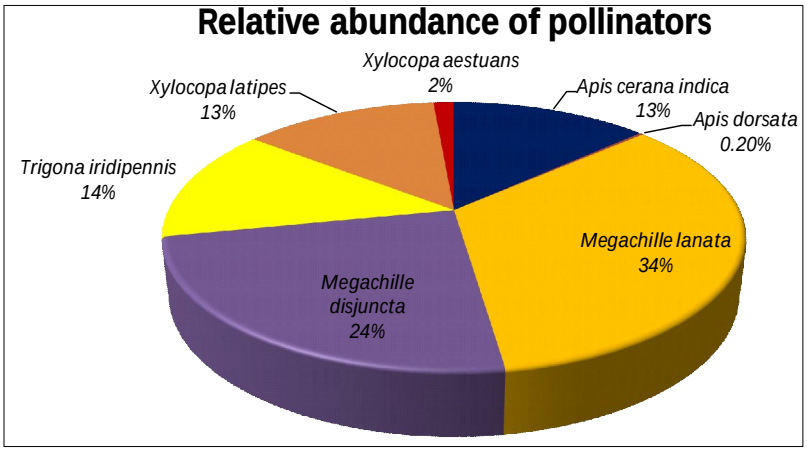

Fig 2: Relative abundance of pollinator's associated with pigeon pea in Gajapati district of Odisha during *Kharif* (2021-22).

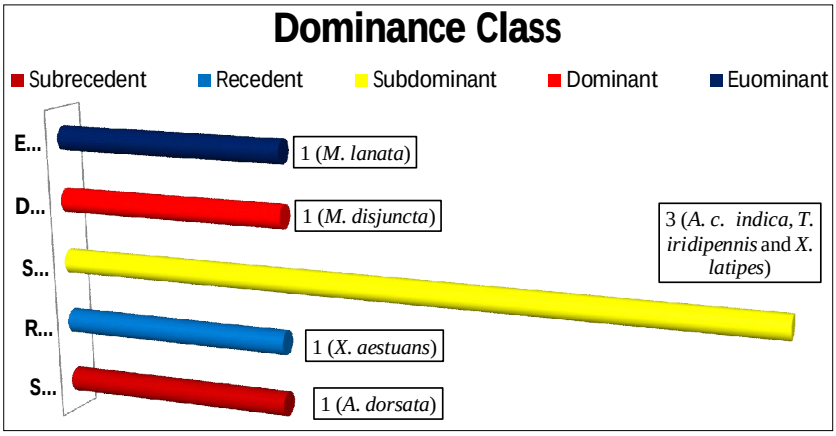

Fig 3: Dominance status of pollinators with different classes associated with pigeon pea in Gajapati district of Odisha during *Kharif* (2021-22).

Table 2: Foraging activities of different insect pollinators during all flowering stage of pigeon pea in Gajapati district of Odisha during *Kharif* (2021-22).

Name of the species	Pollinators visiting per 5 minute per m^2				Mean±SD
	07:00-08:00	10:00-11:00	13:00-14:00	16:00-17:00	
Apis cerana indica	1.60	3.50	3.57	0.63	2.33±1.26
Apis drosata	0.00	0.00	0.17	0.00	0.04±0.07
Megachille lanata	3.13	9.77	11.10	0.07	6.02±4.57
Megachille disjuncta	2.80	7.47	6.47	0.27	4.25±2.88
Tetragonula iridipennis	1.50	4.77	3.37	0.00	2.41±1.81
Xylocopa latipes	1.93	4.00	3.23	0.03	2.30 ± 1.50
Xylocopa aestuans	0.03	0.17	0.77	0.00	0.24 ± 0.31
Mean	1.57	4.24	4.10	0.14	

Table 3: Species diversity and evenness of bee pollinators with respect to different days of pigeon pea in Gajapati district of Odisha during *Kharif* (2021-22).

	No. of species	Simpsons index (D)	Simpsons index of diversity (SID) (1-D)	Simpson's reciprocal index (I/D)	Evenness (E)
69 DAS	4	0.28	0.72	3.57	0.83
79 DAS	5	0.26	0.74	3.88	0.73
89 DAS	7	0.27	0.73	3.72	0.52
99 DAS	7	0.25	0.75	3.94	0.56
109 DAS	6	0.26	0.74	3.89	0.63
119 DAS	6	0.28	0.72	3.63	0.60
129 DAS	7	0.27	0.73	3.74	0.53
139 DAS	6	0.20	0.80	5.01	0.81
149 DAS	6	0.37	0.63	2.73	0.45
159 DAS	5	0.46	0.54	2.16	0.43
07:00-08:00	6	0.21	0.79	4.67	0.76
10:00-11:00	6	0.23	0.77	4.37	0.72
13:00-14:00	7	0.24	0.76	4.12	0.58
16:00-17:00	4	0.46	0.54	2.18	0.52
Early	7	0.26	0.74	3.81	0.53
Mid	7	0.25	0.75	4.00	0.57
Late	6	0.29	0.71	3.49	0.58

Table 4: Shannon-weiner index of bee pollinators with respect to different days of pigeon pea in Gajapati district of Odisha during *kharif* (2021-22).

	No. of species	Shannon index	Evenness (E)
69 DAS	4	1.30	0.33
79 DAS	5	1.40	0.28
89 DAS	7	1.48	0.21
99 DAS	7	1.46	0.21
109 DAS	6	1.47	0.24
119 DAS	6	1.42	0.24
129 DAS	7	1.47	0.21
139 DAS	6	1.66	0.28
149 DAS	6	1.31	0.22
159 DAS	5	1.02	0.20
07:00-08:00	6	1.58	0.26
10:00-11:00	6	1.56	0.26
13:00-14:00	7	1.59	0.23
16:00-17:00	4	0.94	0.23
Early	7	1.47	0.21
Mid	7	1.52	0.22
Late	6	1.46	0.21

in 2011 and 2012 respectively) was found to have peak activity during 10:00 to 12:00 hr. which closely corroborates with the present findings.

The dominance status of various pollinator taxa was determined by calculating the percentage of specimens of a specific species in the total number of organisms collected and the results were as follows.

M. lanata falls under eudominant class while *M. disjuncta* under dominant. *A. c. indica*, *T. iridipennis* and *X. latipes* falls under subdominant class. *X. aestuans* and *A. dorsata* falls under class recedent and subrecedent respectively (Fig 3).

In the current study, the diversity of the pollinators are estimated through the Simpson's Index of diversity during various flowering stages (69-159 DAS) of the crop revealed the number of species varying between 4 and 7 with the Simpson's Index ranging from 0.20 to 0.46. The Simpson's index of diversity was ranging from 0.54 to 0.80 and Simpson's reciprocal Index was ranging from 2.16 to 5.01. In general the diversity was almost uniform because of the evenness of the species. The diversity of the pollinators are estimated through the Simpson's index of diversity during various timing of a day (*i.e*. 07:00 hr, 10:00 hr, 13:00 hr and 17:00 hr) of the crop revealed that the number of species varies between 4-7 with the Simpson's index of diversity ranging from 0.54-0.79 and diversity at all early, mid and late flowering (0.71-0.75) as mentioned in the Table 3.

The Shannon-Weiner Index estimated values during various flowering days (69-159 DAS) of the crop varied from 1.02 to 1.66 expressing the diversity of the pollinators during various timing of a day (*i.e*. 07:00 hr, 10:00 hr, 13:00 hr and 17:00 hr) of the crop with the Shannon-Weiner Index ranging from 0.94 to 1.59. The diversity of the pollinators during different flowering stages varied from 1.46 to 1.52. (Table 4).

CONCLUSION

The present investigation concludes that the pigeon pea flowers attracted seven different pollinators of family Apidae

and Megachilidae belonging to order Hymenoptera. The species *M. lanata* was found to be most dominant one throughout the flowering period while *X. latipes* shown its peak activity during late flowering stage. The subdominant class represented maximum species among different dominant status classes. Though the results shown very less diversity but still more diversity has been observed at mid flowering stags during 10:00-11:00 hr. Thus pigeon pea can be regarded as a major bee flora for its dietary source of pollen and nectar.

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Conflict of interest: None.

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