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Diversity and Foraging Behaviour of Pollinators on *Sesamum indicum* L.

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***Abstract*:** The experiment was carried out at different altitudinal gradients of Jammu for two consecutive years (2017 and 2018) to study the diversity and foraging behaviour of various pollinators on flowers of *Sesamum indicum* L. The study documented twenty-six (26) species of native pollinators from four major families viz., Apidae, Megachilidae, Halictidae and Sphingidae visiting flowers of *S. indicum* in all the study areas. Megachilid bees, Honey bees, Halictid bees, Ceratina bees, Amegilla bees, Xylocopa bees and Bumble bees were the dominant pollinators, in a decreasing order. Shannon-Weiner Diversity Index and Simpson Index was H= 3.12 and D= 1.80, respectively which indicates high richness of species of entomoforagers among various families. The abundance of various pollinators revealed polynomial pattern of distribution indicating almost even distribution of insects among various pollinator groups with domination of a few groups in terms of flower visitation. Average length of foraging bout was found higher in megachilid bees and honey bees whereas in other cases, moderate foraging bouts were recorded.

***Keywords*:** *Sesamum indicum*, Foraging, Diversity, Native bees, Megachilid bees

Sesame (*Sesamum indicum* L.), belonging to the family Pedaliaceae, is a popular and ancient oilseed crop that has successfully signified its irreplaceable role in human nutrition. Sesame seeds are used to extract oil, and also used for edible purposes at the very same time (El Khier et al 2008). The crop is cultivated in various regions of the world on an area of over 2.023 million hectares. Asia covers about 70% of the world's sesame crop followed by Africa which covers about 26% of the global acreage under this crop. China and India are its largest producers followed by Myanmar and Sudan (Anonymous 2020). About 225 million years ago, the co-evolution of flowering plants and their respective pollinators started (Maiti and Maiti 2011). The flower structure of sesame facilitates cross-pollination wherein, the rate of cross-pollination ranges between 0.5 to 65%, depending on various factors viz., insect activity, environmental conditions, and availability of other vegetation (Rakesh and Lenin 2000). Out of the total pollination activities, more than 85% of activities are performed by insects (Hoshiba and Sasaki 2008) wherein, 80% of the total insect pollination is contributed by bees (Thapa 2006) which serve as the best pollinators. Ashri (2007) reported the rate of cross-pollination between 2.7 and 51.7% in Nigeria. In addition to increasing the yield, cross-pollination also helps to raise quality through a more unified ripening period and an earlier harvesting time. Keeping these facts in view, the present experiment was carried out to study the diversity and foraging behaviour of various pollinators on flowers of *S. indicum* in Jammu, India.

MATERIAL AND METHODS

In different farmers' fields across various landscapes viz., plain areas of Dhiansar in Samba district (32.3750°N, 74.5501°E); steep rainfed landscapes of Sunderbani area in Rajouri district (33.0434°N, 74.4674°E) and elevated rainfed areas of Bajalta in Udhampur district (32.7667°N, 74.9667°E), the present experiment was conducted from July to mid-September (2017 and 2018). Selected patches of *S. indicum*, a widely grown important oilseed of this region, were monitored regularly at peak flowering period (August-September) during the daytime at hourly intervals. Different insect foragers visiting *S. indicum* were collected with aerial nets and stored in insect vials. For visual observation, crops with large number of freshly opened flowers were selected for recording the foraging behaviour and bouts of bees. Line transect method of sampling technique was administered wherein; each line transect was approximately 30 m long. Three different pockets were selected for visual observation with linear distance of 3m within a field. Activity of entomo-foragers was monitored from morning to evening at every hourly interval based on snapshot observation of five minutes in each hour. Distance between visual fields was taken under consideration while continuing the observation. Data generated on foraging activity from each visual field was

pooled in order to obtain a consolidated picture of pollinator activity on *S. indicum*. The collected insects were identified with the help of dichotomous taxonomic keys. Based on observation and record of number of individual foragers, various diversity indices were worked out in order to study the magnitude of pollinator diversity and species richness in the field. The following parameters were used to calculate the species richness and species diversity from the observed data.

Shannon-Wiener diversity:

$$H = \sum_{i=1}^{s} pi \ ln \ pi$$

Where, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations and s is the number of species.

Simpson index:

$$D = 1 / \sum_{i=0}^{n} pi^2$$

Where, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), Σ is still the sum of the calculations, and n is the number of species.

The data generated over two years was pooled for statistical analysis using SPSS 20.0 to compare differences in frequency of occurrence and most dominant insect pollinator of this crop.

RESULTS AND DISCUSSION

A total of twenty-six species of native pollinators belonging to four major families viz., Apidae, Megachilidae, Halictidae (Order- Hymenoptera) and Sphingidae (Order-Lepidoptera) were recorded visiting the flowers of *S. indicum* in the study areas (Table 1). Versatility in foraging insect guild and efficient supply-utilization of available resources to establish a strong plant-pollinator interaction in *S. indicum* was depicted through the generated data in the present study. In all the areas under study, seven species of Megachilid bees viz., *Megachile bicolor, M. lanata, M. hera, M. disjuncta, M. carbonaria, M. cephalotes* and *M. conjuncta* were recorded as the dominant pollinators which was succeeded by three species of honey bees viz., *Apis dorsata*, *A. mellifera* and *A. indica* and five species of Halictidae viz., *Nomia iridipennis, N. curvipes, N. elliotii, N. westwoodi* and *Lassioglossum* sp. Diurnal visitation pattern of insect foragers revealed peak activity time between 1100 to 1300 hours (Fig. 1). Spatial distribution amongst various solitary bee foragers of *S. indicum* revealed the availability of pollinating bees in Jammu region for this important crop. Except for *M. carbonaria* and *N. westwoodi* which were not recorded from Jammu plains, all the other species of Megachilidae and Halictidae along with *Apis* sp. and *Ceratina* sp. were found in all the landscape types. Both the species of *Xylocopa* were not recorded from high altitude sub temperate zone of Sunderbani. *Amegilla* spp. and *Bombus* spp. visited

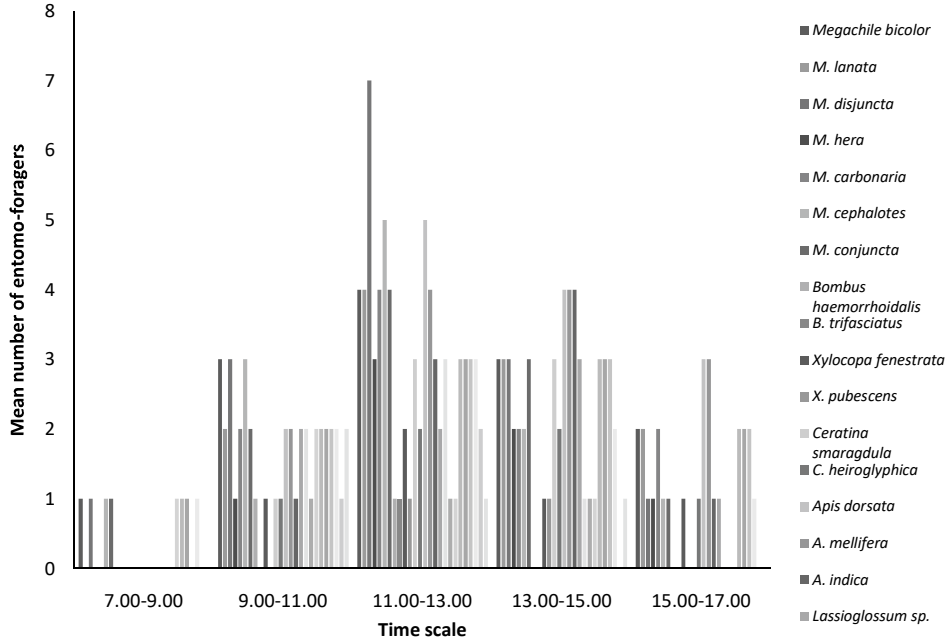

Fig. 1. Diurnal flower visitation pattern of various solitary bees on *S. indicum* in Jammu region

these flowers in almost all the landscape types wherein *A. confusa* was not recorded foraging on *S. indicum* flowers in high altitude area of Sunderbani and *B. trifasciatus* was not recorded from the plains of Jammu (Table 1). Striking plant-pollinator interaction was recorded between the study plant and the flower visitor pool. Whitish-pink tinge colour of flower petals with upside-down bell-shaped structure in morphology, could easily help in visual navigation cue for entomoforagers. Ample content of nectar, and profuse pollen collectively encouraged the visitation of entomo-foragers. Group wise foraging behaviour helped in separating the proficient pollinators from large flower visitor pool recorded from these plants. Species richness of the pollinators of *S. indicum* calculated through Shannon-Weiner Diversity Index was H= 3.12 and through Simpson Index was D= 1.80, which indicated high richness of species of entomoforagers among various families. Abundance of various major flower visiting insects showed polynomial pattern of distribution indicating almost even distribution of insects among various solitary bee groups with domination of a few groups in terms of flower visitation (Fig. 2). Average length of foraging bout, when calculated, was higher in megachilid and honey bees whereas in other cases moderate foraging bouts were recorded (Fig. 3). Of all these insects, megachilid bees and honey bees were the most efficient pollinators as they inserted tongues deep in the flower to collect nectar as compared to other bees which mostly collected nectar from side of the flowers, thereby, acting as nectar thieves. Sesame flowers were of whitish-pink tinge with upside-down bell-shaped structure in morphology. Megachilid bees and honey bees entered the flower to collect nectar and pollen rewards, whereas *Xylocopa* and *Amegilla* sp. collected nectar from sides of the flower. Megachilid bees commenced activities early in the morning at 7.30 am and maximum abundance

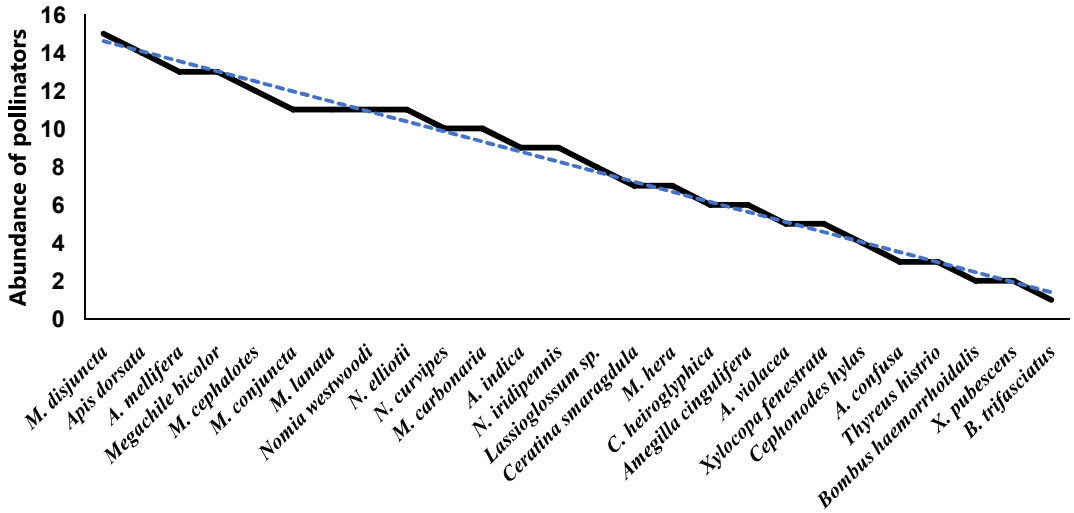

Fig. 2. Distribution of various solitary bee foragers in *S. indicum*

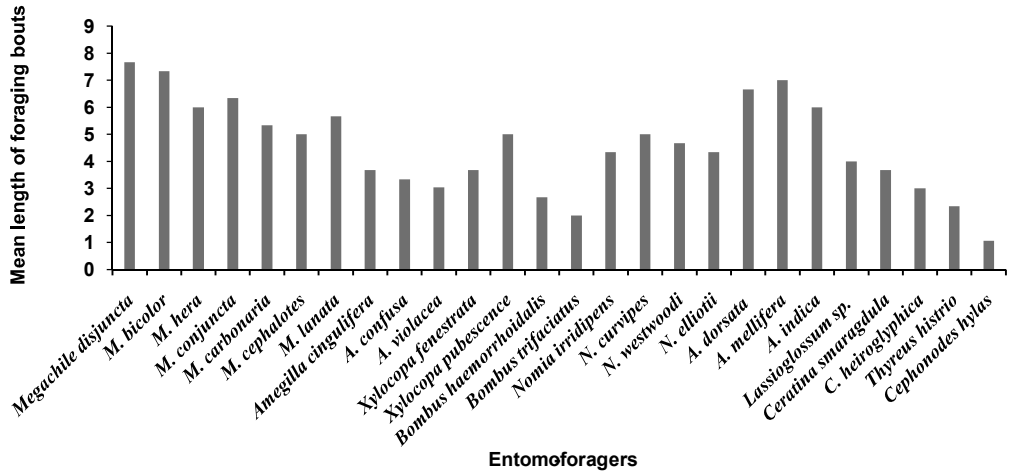

Fig. 3. Comparative pattern of mean foraging length of various bees in flowers of *S. indicum*

was observed between 1100 hrs to 1300 hrs, thereafter the population declined and continued up to 1700 hrs in the evening. In almost all the cases of such major insect visitors, while foraging, their body was found to rub the pollen loaded anthers intensely resulting in a heap of pollen adhered in the ventral parts which were brushed against the rough stigma head of the next flower while foraging in the next, ensuring successful and efficient sternotribic (carrying pollen chiefly on the sterna region of body) pollination. Pashte and Shylesha (2013) also recorded twenty-two species of native pollinators on *S. indicum* among which seventeen species belonged to order Hymenoptera. Kamel et al (2013) collected twenty-nine entomo-foragers on sesamum wherein Hymenoptera was the dominant order with eighteen species. Moreover, Sajjanar and Eswarappa (2015) mentioned the maximum activity of pollinators on sesame during mid-morning hours which is in corroboration with our present study. Abrol et al (2012) observed similar trend in pollinator activity. This strengthens the findings of current study to justify the effective role of native bee guild in pollination of *S. indicum* in this region. Participation of honeybees in crop pollination has been established since pre-historic era of agriculture. In this study too, three species of honeybees, both wild and domesticated, were good foragers on the flower of *S. indicum*, resulting in successful pollination program for this crop.

Table 1. Insect visitors recorded from sesame, *Sesamum indicum* flowers from various landscapes in Jammu

Insect morpho species	Landscape type		
	High altitude sub temperate zone	Elevated land	Plain
Family -Apidae			
Amegilla cingulifera Cockerell	+	+	+
Amegilla confusa Smith	-	+	+
Amegilla violacea Lepeletier	+	+	+
Xylocopa fenestrata Drury	-	+	+
Xylocopa pubescens Spinola	-	+	+
Bombus haemorrhoidalis Smith	+	+	+
Bombus trifasciatus Smith	+	+	-
Apis dorsata Fabricius	+	+	+
Apis mellifera Linnaeus	+	+	+
Apis indica Fabricius	+	+	+
Thyreus histrio Fabricius	-	+	+
Ceratina (Pithitis) smaragdula Fabricius	+	+	+
Ceratina (Pithitis) heiroglaphica Smith	+	+	+
Family -Halictidae			
Nomia iridipennis Smith	+	+	+
Nomia curvipes Fabricius	+	+	+
Nomia elliotii Smith	+	+	+
Nomia westwoodi Gribodo	+	+	-
Lassioglossum sp.	+	+	+
Family -Megachilidae			
Megachile bicolor Fabricius	+	+	+
Megachile lanata Fabricius	+	+	+
Megachile cephalotes Smith	+	+	+
Megachile disjuncta Fabricius	+	+	+
Megachile conjuncta Smith	+	+	+
Megachile hera Bingham	+	+	+
Megachile carbonaria Smith	+	+	-
Family -Sphingidae			
Cephonodes hylas Linnaeus	+	+	+

CONCLUSION

The present study documented the activity of twenty-six species of native pollinators on sesame wherein Megachilid bees were the most dominant pollinators with maximum length of foraging bouts. The peak pollinator activity was recorded between 1100 to 1300 hours. Moreover, the elevated landscape type of Bajalta had the highest species richness of entomo-foragers followed by plain area of Dhiansar and elevated area of Sunderbani, respectively. Present study holds its key importance here, exploring, exploiting and promoting available native bee pollinators of the crop-growing area. Entomophily among zoophilly and in turn, melittophily amongst entomophily has been always regarded as centre of research interest. In Jammu and Kashmir, such kind of explorative research are taking pace with the present study and this, in turn, is also paving way for a new arena of plant-pollinator interaction and pollinator conservation, securing food and nutritional safety, at the same time, assuring reduction of pollinator deficiency in the changing world with climate change.

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