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Diversity of insect pollinators and pollination mechanism in sponge gourd, *Luffa cylindrica* (L.) Roem

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ABSTRACT: Sponge gourd, *Luffa cylindrica* (L.) Roem. is a common vegetable crop possessing hermaphrodite flowers. Investigation was carried out to study the diversity of flower visiting insects, abundance and foraging behaviour of insect pollinators, floral attributes like anthesis, flower size, anther dehiscence, flower sex ratio and the mechanism of pollen transfer from staminate to the pistillate flowers on the sponge gourd. A total of 23 species from four insect orders, Hymenoptera, Lepidoptera, Coleoptera and Diptera were recorded from the sponge gourd flowers with hymenopteran pollinators contributing to 17 of such species. Across the 11 species considered as pollinators, 1.67 insects visited 50 flowers per 5 minutes, exhibiting their peak activity during 8.30 to 10.30 am. The bee species, *Tetragonula iridipennis*, *Apis dorsata*, *A. cerana* and *A. mellifera* were recorded as more frequent visitors with a mean abundance of 5.79, 3.84, 2.41 and 1.98 bees/50 flowers/5 min, respectively. Further, *Xylocopa iridipennis* visited maximum number of *Luffa* flowers (range: 12-15) with minimum time spent on a single sitting (5-27 seconds). Whereas, the stingless bee, *T. iridipennis* was found to be visiting the least number of flowers (range: 2-5) in a single visit while spending maximum time on a single flower (110-170 seconds). Significance of commercial cultivation of this summer vegetable crop for beekeeping has also been discussed.

Key words: Foraging behavior, insect abundance, *Luffa cylindrical*, staminate flower, pistillate flower, pollination

The vegetable sponge gourd, *Luffa cylindrica* (L.) Roem., family Cucurbitaceae originated in the tropics of Africa and South East Asia, is also known as dishrag gourd, loofah gourd, smooth gourd, tooria etc (Oboh and Aluyor, 2009; Filipowicz, 2014; Manjunath, 2016). Its fruits are eaten fresh like cucumbers, cooked as a vegetable or used in soups. A colourless, odourless and tasteless oil produced from its seeds can also be used in cooking. The fibrous material inside the mature sponge gourd fruit is commercially used for engine filters, doormats, table mats, mattress or shoulder pad stuffing and for absorbing sound (Azeez *et al.*, 2013). Furthermore, the sponge gourd fruits have been identified as source of several medicinally important groups of compounds (Joshi *et al.*, 2004; Azeez *et al.*, 2013; Partap *et al.*, 2012).

Luffa cylindrica is a trailing or climbing annual that has monoecious inflorescences (Singh, 1958; Bhattacharyya and Chakraborty, 2014). Its plant bears both male- and female flowers which are produced in the leaf axils with 4 to 20 staminate flowers and one pistillate flower in the same axil

(Silva *et al.*, 2012). These flowers open in the early morning and are open only a day (Singh, 1958). Due to their monoecious inflorescence sponge gourd requires transfer of pollen from the staminate to the pistillate flowers. Several insect pollinators, belonging to different orders have been recorded as pollinating agents in cucurbitaceous plants (Thapa, 2002; Agarwal and Rastogi, 2010; Bodlah and Waqar, 2013; Manjunath, 2016). However, the pollination in sponge gourd is reported to be principally assisted by the *Apis* bees (Collinson, 1976; Meléndez-Ramirez, 2002; Stanghellini *et al.*, 2002; Bhattacharyya and Chakraborty, 2014). The limited bloom period for the respective flower makes the pollinator visitation a limiting factor for the successful reproduction (Stanghellini *et al.*, 1997). During rainy periods sponge gourd from its profuse and continuous blossoming provide good nectar and pollen source that help the bees for colony build up and hence has excellent nutritional value. Considering the importance of sponge gourd especially for bees and meager information on its pollinators and pollination mechanism from this region, present study was carried out.

MATERIALS AND METHODS

The study was conducted at G B Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. The observations on insect visitors/pollinators were recorded on ocular basis at an hourly interval from 5.30 am to 1.30 pm for 10 days at full bloom during September- October, 2017. Diversity of the insect visitors was observed and abundance of potential insect pollinators was taken for 5 minutes on 50 flowers at each observational hour. Data on the foraging behaviour (number of flowers foraged per visit, time spent per flower, floral reward etc.) of insect pollinators, floral attributes (flower opening timings, male: female ratio, flower size, colour) and the mechanism of pollen transfer from staminate to the pistillate flowers were also recorded. The pistillate flowers were bagged with muslin cloth to know the pollination requirement.

RESULTS AND DISCUSSION

Diversity of insect visitors

A total of 23 insect species visited on sponge gourd flowers (Table 1), representing orders Hymenoptera (17 species), Lepidoptera (1 species), Diptera (2 species) and Coleoptera (3 species). On the basis of frequency of their visit, the insect visitors were divided into regular and occasional visitors. The regular visitors included the bees- *Tetragonula iridipennis*, *Apis dorsata*, *A. cerana*, *A. mellifera*, *Megachile bicolor*, *Anthophora singulata*, *Anthophora* sp., *Xylocopa iridipennis*, *X. pectifrons* and the ants, *Camponotus* sp. (Hymenoptera); Branded swift skipper/butterfly, *Pelopidas mathias* (Lepidoptera); red pumpkin beetle, *Raphidopalpa foveicollis* and the hadda beetle, *Epilachna dodecastigma* (Coleoptera). The diversity index of different pollinator species showed a diverse fauna of insect pollinators in the *L. cylindrica* crop. The Shannon Wiener diversity index for the regular flower visiting insect was found to be 1.7649. Insects from similar four orders have been reported to visit sponge gourd flowers in other states of India (Agarwal and Rastogi, 2012; Manjunath, 2016) and Nepal (Thapa, 2002).

Abundance of insect pollinators

The data on the abundance of regularly visiting potential pollinators revealed that irrespective of the insect species, 50 flowers of *Luffa* are visited by an average of 1.67 insects per 5 minutes (n= 990; Table 2). Among the insect pollinators, *A. dorsata* was recorded to be first visitor early in the morning at 5.30 am with an abundance of 0.90 bees/5 min/50 flowers followed by *T. iridipennis*, *A. cerana* and the branded swift skipper with an abundance of 0.40, 1.20 and 1.60, respectively at 6.30 am. The peak activity of the insect pollinators was recorded between 8.30 to 10.30 am with highest abundance of 3.11 at 9.30 am (Table 2; Figure 1). Irrespective of the day hours, the stingless bee, *T. iridipennis* had the highest abundance of 5.79 bees/5 min/50 flowers followed by the branded swift butterfly (4.65), *A. dorsata* (3.84), *A. cerana* (2.41), *A. mellifera* (1.98), *M. bicolor* (0.64), *Anthophora* sp. (0.34) and *X. iridipennis* (0.15); respectively. The abundance of insect pollinators on *Luffa* flowers determines the success rate of the whole crop as the time of flowering plays a limiting factor in the pollination of this crop. The maximum diversity of insect pollinators in *Luffa* crop had been recorded twice a day by Manjunath (2016) with the two peaks during 09-12:00 pm and 01-03:00pm in Bangalore. This could be due to relatively lower temperature in southern states during flowering period allowing longer flower opening time for visitation of insect pollinators.

Foraging behavior

Data on the foraging behavior of the insect pollinators (Table 3) revealed that during a single visit an individual *X. iridipennis* foraged maximum number of flowers (range: 12-15) with minimum time spent per flower (range: 5-27s) while an individual of the stingless bee visited minimum number of flowers (range: 2-5) with maximum time spent per flower (110-170s for nectar; 330-485s for pollen collection). Most insect pollinators foraged male flowers for nectar only, however *T. iridipennis* and *Anthophora* sp. collected also pollen, besides collecting nectar. Only some of the insect visitors

Table 1: Diversity of insect visitors on sponge gourd flowers

S. No.	Scientific name	Common name	Family	Order	Consistency of visit	Role of the visitor
1	<i>Anthophora singulata</i>	Digger bee	Apidae	Hymenoptera	Regular	Pollinator
2	<i>Anthophora</i> sp.	Digger bee	-do-	-do-	Regular	Pollinator
3	<i>Apis cerana</i>	Indian honey bee	-do-	-do-	Regular	Pollinator
4	<i>Apis dorsata</i>	Rock bee	-do-	-do-	Regular	Pollinator
5	<i>Apis mellifera</i>	European honey bee	-do-	-do-	Regular	Pollinator
6	<i>Tetragonula iridipennis</i>	Stingless bee	-do-	-do-	Regular	Pollinator
7	<i>Xylocopa austuans</i>	Carpenter bee	-do-	-do-	Occasional	Pollinator
8	<i>Xylocopa iridipennis</i>	Carpenter bee	-do-	-do-	Regular	Pollinator
9	<i>Xylocopa pectifrons</i>	Carpenter bee	-do-	-do-	Regular	Pollinator
10	<i>Ceratina sexmaculata</i>	Small carpenter bee	-do-	-do-	Occasional	Pollinator
11	<i>Thyreus takaonis</i>	Cuckoo bee	-do-	-do-	Occasional	Pollinator
12	<i>Megachile anthracina</i>	Leaf cutter bee	Megachilidae	-do-	Occasional	Pollinator
13	<i>Megachile bicolor</i>	Leaf cutter bee	-do-	-do-	Regular	Pollinator
14	<i>Megachile disjuncta</i>	Leaf cutter bee	-do-	-do-	Occasional	Pollinator
15	<i>Nomia</i> sp.	Alkali bee	Halictidae	-do-	Occasional	Pollinator
16	<i>Camponotus</i> sp.	Ant	Formicidae	-do-	Regular	Nectar feeder
17	<i>Campsomeriella collaris</i>	Scolid wasp	Scollidae	-do-	Occasional	Pollinator
18	<i>Pelopidas mathias</i>	Branded swift skipper	Hespiridae	Lepidoptera	Regular	Pollinator
19	<i>Metasyrphus</i> sp.	Syrphid fly	Syrphidae	Diptera	Occasional	Pollinator
20	<i>Syrphus corollae</i>	Syrphid fly	-do-	-do-	Occasional	Pollinator
21	<i>Raphidopalpa foveicollis</i>	Red pumpkin beetle	Crysomellidae	Coleoptera	Regular	Phytophagous
22	<i>Epilachna dodecastigma</i>	Hadda beetle	Coccinellidae	-do-	Regular	Phytophagous
23	<i>Mylabris</i> sp.	Blister beetle	Meloidae	-do-	Occasional	Phytophagous

foraging male flowers for nectar or pollen or both also visited pistillate flowers for nectar collection. Such insects included *T. iridipennis*, *A. dorsta*, *A. cerana*, *A. mellifera*, *Anthophora* sp. and the branded swift skipper. All insect pollinators except the carpenter bees, *Xylocopa* species foraged the flowers either from the top or from the side of the stamens. The bees of *Xylocopa* species collected nectar while holding the stamens and sitting on them. The stingless bees and the ants collected the exudates from the floral buds.

Floral attributes and pollination mechanism

The lemon yellow coloured flowers (both male & female) start opening early in the morning between 4.30-5.30am and are completely open by 6.0-7.0am, depending upon the temperature. The diameter of the staminate flowers varied from 5-10 cm (av. =7.4 cm) while that of the pistillate varied from 7.5-10.5 cm (av. =8.5 cm). The number of staminate flowers varied from 6 to 24 in a bunch and open for a day only in a dangling manner. Anther dehiscence and nectar secretion initiates soon after opening of the

flower and the pollen & the nectar remain available for next 5-7 hrs. The petals of the flowers start wilting at about 12.0 noon and all the staminate flowers are shed same day by 6.30-7.00pm evening while the pistillate flowers though get closed after pollination but remain attached to the long tubular ovary secreting exudates from the sepals for several days. The daily average ratio of male to female flowers was 20:1.

In the monoecious *L. cylindrica* plant, transfer of

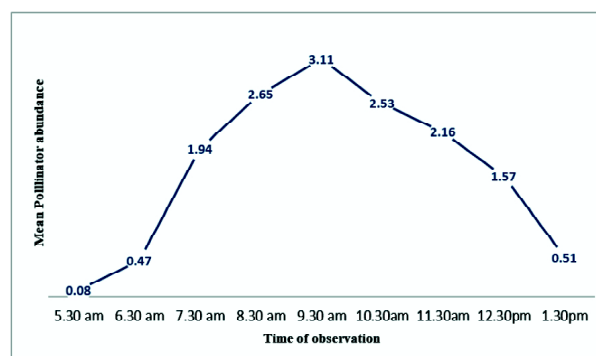


Fig. 1: Mean abundance of pollinators during different day hours

Table 2: Abundance of insect pollinators on sponge gourd flowers

Insect species	Average number of insects/5min/50 flowers at different day hours									Mean*
	5.30am	6.30 am	7.30 am	8.30 am	9.30 am	10.30 am	11.30 am	12.30pm	1.30pm	
<i>A. singulata</i>	0.00	0.10	0.20	0.00	0.40	0.00	0.20	0.10	0.00	0.11
<i>Anthophora sp.</i>	0.00	0.00	0.80	0.90	0.60	0.40	0.40	0.00	0.00	0.34
<i>A. cerana</i>	0.00	1.20	2.60	3.10	5.20	4.00	2.50	2.00	1.10	2.41
<i>A. dorsata</i>	0.90	2.40	4.70	6.00	6.40	6.50	3.50	2.70	1.50	3.84
<i>A. mellifera</i>	0.00	0.00	2.40	2.90	3.60	3.20	3.40	1.60	0.70	1.98
<i>M. bicolor</i>	0.00	0.00	1.40	1.40	1.50	0.50	0.80	0.20	00	0.64
<i>M. disjuncta</i>	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.02
<i>T. iridipennis</i>	0.00	0.40	5.00	9.40	11.20	9.00	8.60	7.00	1.50	5.79
<i>X. iridipennis</i>	0.00	0.00	0.30	0.30	0.20	0.30	0.20	0.10	0.00	0.15
<i>X. pectifrons</i>	0.00	0.00	0.10	0.10	0.00	0.00	0.10	0.00	0.00	0.03
<i>P. mathias</i>	0.00	1.60	5.80	7.60	7.80	6.50	6.30	5.00	1.30	4.65
Mean**	0.08	0.47	1.94	2.65	3.11	2.53	2.16	1.57	0.51	1.67#

*Mean of 90 observations (9hrs× 10 days); **Mean of 110 observations (one hr× 10 days× 11 species); #Mean of 990 observations (9hrs× 10 days× 11 species)

Table 3: Foraging behavior of different insect pollinators on sponge gourd flowers

Insect species	No. of flowers foraged per visit (range)		Time spent per flower (sec)	Floral reward		Working position while foraging in relation to stamens/pistils
	Staminate	Pistillate		Nectar	Pollen	
<i>A. singulata</i>	6-8	Nil	20-52	+	-	Top/side
<i>Anthophora sp.</i>	4-7	0-1	15-73	+	+	Side/top
<i>A. cerana</i>	5-6	0-2	37-84	+	-	Top/side
<i>A. dorsata</i>	8-10	0-2	45-112	+	-	Side/top
<i>A. mellifera</i>	6-8	0-1	32-96	+	-	Side/top
<i>M. bicolor</i>	5-8	nil	30-75	+	+	Top/side
<i>M. disjuncta</i>	4-5	nil	15-40	+	-	Top/side
<i>T. iridipennis</i>	2-4	0-1	110-170 (nectar); 330-485 (pollen)	+	+	Top/side
<i>X. iridipennis</i>	12-15	nil	5-27	+	-	Top
<i>X. pectifrons</i>	7-10	nil	12-23	+	-	Top
<i>P. mathias</i>	6-7	0-1	126-280			Side/top

pollen from the staminate to the stigma of pistillate flower is essential for the development of the fruits as none of the five pistillate flowers developed in to fruit when covered with the muslin cloth bags before their opening. This transfer of the pollen from male to female flower is performed chiefly by the bees. Off the 20 species visiting sponge gourd flowers for pollen and nectar, only six insect species were observed to visit both staminate and pistillate flowers. Many individuals of these six species too were seen to discriminate male from the female ones and many a times avoided foraging female flowers. The six species were- the honey bees, *A. dorsata*, *A. cerana*, *A. mellifera*; the stingless bee, *T. iridipennis*; the digger bee, *Anthophora sp.* and the branded swift skipper, *Pelopidas mathias*. The pollination occurs

when the bees dusted with pollen visit female flowers for nectar. Similarly, the branded swift having loose pollen grains on legs and the proboscis may also transfer the pollen from male to the female flowers. The pollination efficiency of these insect visitors can be determined by their abundance, number of loose pollen grains carried on their bodies and the frequency. In our study, while approaching the pistillate flowers, most individuals of these insect species landed on the petals and collected nectar from the base of the jointed pistils by entering their body (*Tetragonula* & *Anthophora sp.*) or the head (the honey bees) or the proboscis (small branded swift) in the space around and between the pistils and the petals without coming in direct contact with the jointed stigmas. However, some of the foragers

also sit on the top of the jointed pistils and in effort to search nectar, work on the pistils before actually taking nectar. Such individuals of the six insect species appeared to be more efficient pollinators. The carpenter bees though were not observed to visit female flowers for nectar collection, yet their foraging behavior on sponge gourd flowers suggested their potential role in pollination mechanism of this plant. The carpenter bees always collected nectar from the staminate flowers while holding the stamens from the top and thus large numbers of the pollen grains stick to the ventral body surface and the legs. Interestingly, after foraging 2-3 flowers for nectar, an individual carpenter bee especially *X. iridipennis*, while in flight, removed the pollens from its body and cast off thousands of yellow coloured pollen grains with their legs before approaching other flowers. During this process many pollen grains may be shed or drifted on to the stigmas in pistillate flowers thus facilitating the pollination process. The discarded pollen grains from the insect body can easily be seen on the green leaves of the plant.

CONCLUSION

Present studies conclude that the vegetable sponge gourd, *Luffa cylindrica* owing to its profuse and prolonged flowering, is an attractive foraging resource, yielding good amount of nectar and pollen for productive insects like the honey bees and other insects especially the bees which are helpful in pollination of many crops including the sponge gourd. Commercial cultivation of sponge gourd in this region would be of greater significance for the beekeepers due to its prolonged flowering from August to October, providing good build up for the colonies so as to harness higher honey yields from the brassica crop. On the basis of abundance, foraging behaviour and visitation of the insect visitors on staminate and pistillate flowers, it is further concluded that the honey bees, *Apis dorsata*, *A. cerana* and *A. mellifera*, the stingless bees, *Tetragonula iridipennis*, the digger bees, *Anthophora* sp., the carpenter bees, *Xylocopa* species and the branded swift, *P. mathias* play significant role in pollination of sponge gourd flowers.

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