STUDY ON INSECT DIVERSITY AND POLLINATION EFFECT ON THE YIELD OF ELEPHANT APPLE

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Abstract

An experiment was conducted from June to November 2021 at the Sher-e-Bangla Agricultural University in Dhaka to find out the insect diversity and pollination effects on the yield of elephant apple. Six flower visiting insects (*Apis cerana*, *Apis dorsata*, *Xylocopa* sp., *Vespa* sp., *Camponotus copressus* and *Syrphes* sp.) from five insect families (Apidae, Vespidae, Anthophoridae, Formicidae, and Syrphidae) under two orders (Hymenoptera and Diptera) were observed. Apidae (33.33%), Vespidae (16.67%), Formicidae (16.67%), Syrphidae (16.67%), and Anthoporidae (16.67%) visited flowers. *Apis dorsata* was the most frequent insect pollinator (47.62%), with 5.00 per flower on average. The Shannon-Wiener diversity index for species was 1.562. The highest foraging duration was recorded for *Apis dorsata* at 1.4 minutes per flower. Without netting and with netting, elephant apple plants produced 7.00 and zero (0.00) fruit per branch, respectively. Plants without netting had 464 kg of fruit per plant, 92.8 tonnes per ha of yield, and no fruit in the netting treatment.

***Key words**:* Insect diversity; Pollination; Yield; Elephant apple.

INTRODUCTION

Elephant apple (*Dillenia indica*), from the Dilleniaceae family, is a large, knobby fruit with an acidic taste that grows in tropical forests in the western peninsula, Bihar, sub-Himalayan tracts, Assam, Bengal, and central and southern India from Sylhet to Sri Lanka. Thailand, Malaysia, Indonesia, India, eastern China (Yunnan), and Vietnam are home of *Dillenia indica* (Lim 2012). *Dillenia indica* and *Dillenia pentagyna* are found in a wide range of Asian countries. Bhutan, India, Indonesia, Laos, Malaysia, Myanmar, Nepal, Bangladesh, the Philippines, Sri Lanka, Thailand, and Vietnam have *Dillenia indica* in their valleys and streamside areas.

Fruit is rounded with a few odd bumps, a little bit like an elephant's toe, and it also served as the main food source for the wild elephants. Thus, it is popularly called elephant apple. This plant is widely used as a herb by the various tribes of the entire North East, along with Assam (Sandipan *et al.* 2009). Greenish yellow fruits have thick leathery husk. Unripe fruits are pickled and eaten uncooked. Indian curries, jams, and jellies use the bitter-sour pulp. Chutneys are made using coconut and spices. *Dillenia indica* and *D. pentagyna* fruits are consumed raw (Sharma and Pegu 2011, Dubey *et al*. 2009, Pradhan and Badola 2008). *D. indica* has several common names (Khanum *et al*. 2007, Khare 2007, Rastogi *et al*. 2001).

Elephant apple plants have a wide range of pollinators. Bees, honey bees, solitary bees, bumble bees, pollen wasps, ants, flies, including bee flies, hoverflies, and mosquitoes, lepidopterans, butterflies and moths, and flower beetles (Lever *et al*. 2014) pollinate fruit plants. Insects and bees pollinate approximately 80%. They are the best pollinators (Robinson *et al.* 1989). Presence of few pollinators

reduces fruit and seed yields (Pradhan and Badola 2008). Insecticides and vigorous mechanical control are used for pest management, notwithstanding the benefits of pollinating insects on fruits. Slowly declining pollinators and other useful insects may threaten our ecosystem and food productivity. Accordingly, the present study sought to identify elephant apple flower-visiting insects and assess pollinator impact on elephant apple yield.

MATERIAL AND METHODS

The experiment was conducted at the Sher-e-Bangla Agricultural University (SAU) campus, Sher-e-Bangla Nagar, Dhaka, Bangladesh situated at 23°74'N latitude and 90°35'E longitude. The experiment was carried out during the bare period of the elephant apple in the months from June to November 2021. The experiment was laid out in a paired plot technique with 15 replications. Two treatments were applied. They are T_1=without netting and T_2=netting. Three elephant apple plants in each treatment. For T_2, the flowers of each plant were netted before opening to keep the pollinators away. Because the trees ranged in height from 30 to 35 feet, netting was done in the lower branches only. Visual observation was done for flower-visiting insects. The foraging insects and pollinators were observed from 6.30 am to 5.30 pm. Data were collected from the morning hours of 6.30 am to 5.30 pm during the flowering period of the month of June. At harvest, the single fruit weight and total fruit numbers were recorded for both T_1 and T_2. The data were statistically analyzed for the analysis of variance (ANOVA) and F tests using the STATA-10 program.

RESULTS AND DISCUSSION

Diversity of insect pollinators

The insect pollinators visiting the elephant apple flowers were collected and their taxonomic classification was made by using the available literature (Table 1). In total, six different species (*Apis cerana*, *Apis dorsata*, *Xylocopa* sp., *Vespa* sp., *Camponotus copressus* and *Syrphus* sp.) from five different families of insects, namely Apidae, Vespidae, Anthophoridae, Formicidae, and Syrphidae under two orders, Hymenoptera and Diptera, were found as flower-visiting insects of the elephant apple plants which were similar to the observation of Raju (1988). Beetles were missing in the present observation, but flies and bees were found as flower visitors, which are partially supported by the works of Steinbach and Gottsberger (1994).

Table 1. List of different pollinators visited the elephant apple plants.

Name	Taxonomic profile		
	Scientific name	**Family**	**Order**
Indian Bee	*Apis cerana*	Apidae	Hymenoptera
Giant Honey bee	*Apis dorsata*		
Carpenter bee	*Xylocopa* sp.	Anthophoridae	
Wasp	*Vespa* sp.	Vespidae	
Ant	*Camponotus copressus*	Formicidae	
Syrphid fly	*Syrphid* sp.	Syrphidae	Diptera

Relative abundance

The relative abundance of pollinators was recorded on elephant apple flowers at seven day intervals during June 2021, during the peak blooming of the flowers. The number of pollinators recorded per

sweep per flower of the elephant apple is presented in Table 2. Among the different insect pollinators, *A. dorsata* was the predominant species visiting the elephant apple flowers during the entire flowering period. The average population of *A. dorsata* was recorded at 5.00 per flower, which represented 47.62% of the population of total insect pollinators visiting elephant apple flowers. *A. cerana* was the second dominant insect visitor, with an average of 1.75 insects per flower, constituting 16.67% of the total insect population. Other than *Xylocopa* sp., bees were also found visiting the flowers throughout the flowering period, with an average of 1.5 insects per flower, which ranked third with 14.29% abundance. *Camponotus* sp. of ants was on average 1.0 per flower, with 9.52% abundance of total insects and ranked fourth. The lowest (0.5) number of insects per flower were found in *Vespa* sp. with an abundance of 4.76%. *Syrphus* sp. of fly was the 5th position with an abundance of 7.14% and ranked 5th as visitors to elephant apples.

Table 2. Observations for the relative abundance of different pollinators on elephant apple flowers (percentage of insect/branch/sweeps).

Pollinator	Taxonomic profile	Date				Total	Mean	Mean population (%)
		7.6.21	13.6.21	20.6.21	27.6.21			
Indian bee	*Apis cerana indica*	1.0	2.0	2.0	2.0	7.0	1.75	16.67
Honey bee	*Apis dorsata*	4.0	5.0	6.0	5.0	20	5.0	47.62
Syrphid fly	*Syrphus* sp.	1.0	1.0	0.0	1.0	3.0	0.75	7.14
Carpenter bee	*Xylocopa* sp.	1.0	2.0	1.0	2.0	6.0	1.5	14.20
Ant	*Camponotus copressus*	2.0	1.0	1.00	0.00	4.0	1.0	9.52
Wasp	*Vespa* sp.	1.0	0.0	0.0	1.0	2.0	0.5	4.76
Total		**10.0**	**12.0**	**10.0**	**10.0**	**42**	**10.0**	**100**

Diversity and abundance of pollinators on elephant apple flowers in open field

A total of five genera of pollinators were identified. The numbers of insect pollinators from Apidae were 2, Vespidae 1, Formicidae 1, Syrphidae 1 and Anthoporidae 1. As flower visitors, the number of insect species in these groups was as follows: Apidae 33.33%, Vespidae 16.67%, Formicidae 16.67%, Syrphidae 16.67%, and Anthoporidae 16.67%.

Table 3. Biodiversity index assessment (genus).

Family	Genus	Pi	log_2pi	$pilog_2pi$
Apidae	1	0.2	-1.61	-0.322
Vespidae	1	0.2	-1.61	-0.322
Formicidae	1	0.2	-1.61	-0.322
Syrphidae	1	0.2	-1.61	-0.322
Anthophoridae	1	0.2	-1.61	-0.322
Total	5		8.05	-1.61
Speices Richness (SR)			6	
H or H$'$			1.61	
H_{max}			1.61	
Evenness			1	

Diversity Index: The Shannon-Wiener diversity index for elephant apple flower species was 1.562 with 6 species richness, whereas the evenness was 0.87. A total of five families and six species were

identified. The diversity of insect pollinators was observed, and among others, the presence of *A. dorsata* and *A. cerana* was observed as the most frequently visited pollinators. The Shannon-Weaver diversity index in elephant apple plants for six observed species was 1.562, with 45% community dominance (Tables 3 and 4).

Table 4. Biodiversity index assessment (species).

Family	Species	Pi	log_2pi	$pilog_2pi$
Apidae	2	0.333	-1.099	-0.366
Vespidae	1	0.167	-1.789	-0.299
Formicidae	1	0.167	-1.789	-0.299
Syrphidae	1	0.167	-1.789	-0.299
Anthophoridae	1	0.167	-1.789	-0.299
Total	6		8.26	-1.562
Speices Richness (SR)		6		
H or H'		1.562		
H_{max}		1.789		
Evenness		0.87		

Foraging behaviour of pollinators

The foraging behaviour of different species of honey bees, *viz. A. cerana* and *A. dorsata* was observed. To study the foraging behaviour, observations regarding foraging rate (number of flowers visited per forager per minute) and foraging speed (time spent by each species on an elephant apple flower) were recorded. All the observations on the abundance (percentage of insect fauna per flower per 5 min) of different insect pollinators visiting elephant apple flowers were made during the flowering period from 6.00 am to 7.00 pm once a week at the following intervals: 7.00-9.00 am, 9.00-11.00 am, 11.00-1.00 pm, 1.00-3.00 pm, and 3.00 pm-5.00 pm (Table 5).

Table 5. Temporal budget (in minutes) for six different species (pollinators) stating from 7 am-5 pm in field condition.

Pollinator	7.00 am-9.00 am (min)	9.00 am-11.00 am (min)	11.00 am-1.00 pm (min)	1.00 pm-3.00 pm (min)	3.00 pm-5.00 pm (min)	Total (min)	Mean (min)
A. cerana	1.00	0.50	0.50	0.00	1.00	3.00	0.6
A. dorsata	0.00	2.00	1.50	1.50	2.00	7.00	1.4
Camponotus copressus	3.00	0.00	0.00	0.00	3.00	6.00	1.2
Xylocopa sp.	0.25	0.25	0.25	0.00	0.25	1.00	0.2
Vespa sp.	1.00	1.00	0.00	0.00	0.00	2.00	0.4
Syrphid sp.	0.25	0.25	0.50	0.00	0.50	1.00	0.2

Foraging speed of pollinators

The foraging speed of various pollinators in terms of time spent by each species on an elephant apple flower is presented in Table 5. Foraging started nearly at 7.00 am and the highest foraging duration recorded for *A. dorsata* was1.4 minutes per flower. *A. dorsata* started their visit around 7.00 am and continued up to 5.00 pm. The shortest (0.2 min) foraging time was spent by *Syrphid* sp. Their visit started from early morning (7.00 am) to late afternoon (5.00 pm). Similar time spent was also observed in *Xylocopa* sp.

Foraging rate of pollinators

The foraging rate of different pollinators in terms of the number of flowers visited per forager per 5 minutes is presented in Table 6. Among the two honey bees, *A. dorsata* had the highest mean foraging rate (3.2), which was sequentially followed by *A. cerana* (2.0) on an elephant apple flower. The lowest flower visitor was *Vespa* sp. (0.4 flowers per 5 minutes), which was similar to the results of Shebl and Farag (2015) with the exception of *A. florea.*

Table 6. Foraging rates (number of pollinator visited per flower per 5 minutes) of seven pollinators.

Pollinator	7.00 am-9.00 am	9.00 am-11.00 am	11.00 am-1.00 pm	1.00 pm-3.00 pm	3.00 pm-5.00 pm	Total	Mean
A. cerana	2.00	1.00	3.00	2.00	2.00	10.00	2.00
A. dorsata	0.00	4.00	5.00	4.00	3.00	16.00	3.2
Camponotus copressus	1.00	1.00	1.00	0.00	1.00	4.00	0.8
Xylocopa sp.	1.00	1.00	2.00	2.00	1.00	7.00	1.40
Vespa sp.	1.00	1.00	0.00	0.00	0.00	2.00	0.40
Syrphid sp.	1.00	1.00	1.00	0.00	1.00	4.00	0.80

Effect of netting on elephant apple plant

Flower/plant: Without netting and netting condition, the average number of flowers per plant of elephant apple was 187.33 and 152.50, respectively. The pollinating agent did not affect the blooming of elephant apple flowers (Table 7).

Fruit girth and fruit length: Without netting and netting condition, the average girth of fruit of elephant apple was 5.00 inch and 0.00 inch, respectively; the average length of fruit of elephant apple was 4.06 inch and 0.00 inch, respectively. The pollinating agent did not affect the fruit setting as there was no fruit setting in wetting condition., without netting and with netting (Table 7 and Fig. 1).

Table 7. Yield contributing characters influenced by netting on elephant apple plant.

Yield contributing Characters	Treatment			
	Without netting	Netting	Lsd (0.05)	CV
Flower /plant	187.00a	152.50a	30.50	8.14
Fruit girth (inch)	5.00a	0.00b	0.64	5.33
Fruit length (inch)	4.06a	0.00b	0.52	5.09
No. of fruit set/branch	7.50a	0.00b	2.50	11.91
No. of fruit harvested /branch	7.33a	0.00b	2.98	5.95
Single fruit weight (g)	807.13a	0.00b	131.02	14.30
Yield/plant (kg)	464.00a	0.00b	128.39	10.66
Yield (t/ha)	92.8a	0.00b	32.51	7.51

Yield and yield contributing characters influenced by netting on elephant apple plant

No. of fruit set/branch: The average number of fruit set in the elephant apple plant was 7.50/branch and 0.00/branch without netting and with netting, respectively. The pollinators had a great effect on the fruit setting.

No. of fruit harvested/branch: Considering without netting and netting condition, the average number of fruit harvested per branch of elephant apple plant were 7.33 and zero, respectively. The pollinating agents had a direct influence on fruit setting.

Fig. 1. Pictorial presentation of elephant apple flower and fruits: **a**. *Apis dorsata* visiting elephant apple flower (semi exposed); **b**. *Apis dorsata* visiting elephant apple flower (fully exposed); **c**. Elephant apple fruit setting in the open flower condition; and **d**. Elephant apple flower in netting condition.

Single fruit weight (g): The average single fruit weight of the elephant apple plant was 807.13g without netting. No fruit developed in the netting condition.

Fruit yield: The total weight of the fruit of elephant apple was 464.00 kg/plant equivalent to 92.8 t/ha without netting. With netting no fruits were developed.

From the above study it may be concluded that hymenopteran insects are the main flower visitors of elephant apple. Among the hymenopteran insect, *A. dorsata* is the frequent visitor of flowers and play a vital role in elephant apple pollination. Elephant apple yield is fully dependent on insect pollinators and fruiting of elephant apple plant is not possible in absence of insect pollinators.

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