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Pollinator's diversity and abundance on *Strychnos nux-vomica* L.: A valuable medicinal plant of tropical dry deciduous forest

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Abstract
Studies were conducted to document pollinator diversity and foraging behaviour of major insect pollinators on *Strychnos nux-vomica* L. (Loganiaceae) during 2017 at Silvicultural Research Station, Ghatikia, Bhubaneswar, Odisha. Ten species of insects belonging to nine genera, six families and four orders were recorded. Among the insects species *Apis dorsata* (Apidae: Hymenoptera) *and Episyrphus balteatus* (Syrphidae: Diptera) were the most dominating foragers. Hymenopterans constituted 53.01% to the total insect pollinators. The mean number of pollinators foraging nux-vomica flower was 22.13 insects/m^2 branch/10 min. Peak activity of all foragers was between 9.00-12.00hours. They were rewarded with nectar and pollen. *Vespa spp.* visited maximum number of inflorescences per minute and spent least time in a flower.

Keywords: pollinator diversity**,** hymenoptera, diptera, *Strychnos nux-vomica*, shannon-wiener

Introduction
Strychnos nux-vomica L. (family: Loganiaceae, common name: Strychnine tree) is an important non-timber forest product (NTFP) yielding tree species in tropical dry deciduous forests of central and South India. Seeds are extensively collected and traded for poisonous alkaloids strychnine and brucine. Detoxified seed is official in many systems of medicine viz. Unani, Ayurveda, Tibetan, Chinese, Homeopathy as well as modern treatise. Seeds are acrid and after proper detoxification used as aphrodisiac, appetizer, anti-periodic, digestive, purgative, and stimulant (Victor *et al.*, 2016 and Bhati *et al.*, 2012) [1, 2]. Leaves, barks and seeds are also used as insecticide, nematicide, rodenticide, avicide and Piscicide (Behera *et al.*, 2017) [3]. Most of the seed required by pharmaceutical industries in India and exported raw drug (seed) are collected from forest. It is cultivated commercially in United States, European Union, Fujian, Guangdong, Guangxi, Hainan, North Australia, Taiwan, and throughout tropical Asia (Patel *et al.*, 2012) [4]. It is a potential crop for cultivation in semi arid and arid regions of central and South India. Low fruiting and seeding is a major problem in nux-vomica and poor pollination is a major reason for this (Atluri *et al.*, 2008) [5].

Pollination is a fundamental ecological process desired for the maintenance of viability and diversity in flowering plants. Different forces in nature viz. wind, water, animals, birds and insects assists pollination process but it is the insects contribute maximum. About 67% of flowering plants depend on insects for pollination (Kearns and Inouye 1997) [6]. For these kinds of plants, the pollinator-plant mutual relation is vital as light and water. Entomophilic flowers of nux-vomica possess mixed mating system indicating importance of pollinators in reproduction success (Atluri *et al.*, 2008) [5]. Hence it is imperative to identify and document insect vectors assisting pollination in nux-vomica. Perusal of literature reveals that, no detailed information is available in this regard. Hence the present study was undertaken to identify and document insects visiting nux-vomica flower, their diversity, abundance and foraging behaviour in a lieu to assist pollination management for higher fruit and seed yield.

Materials and Methods
The current study was undertaken at Silvicultural Research Station (SRS), Ghatikia, Bhubaneswar (latitude $20^0$27' 0" N, E longitude 85^0 78' 0"E and altitude 25.9m amsl) during the year 2017 (Mar-May) to ascertain the diversity of insect pollinators, their occurrence and

abundance on *Strychnos nux-vomica*. The climate of experimental site is sub-humid sub-tropical, with an annual rainfall of 1273.9 mm. The maximum temperature ranged from 29.4 - 38.0 ^{0}C; while the minimum temperature varied from 15.4 - 26.6 ^{0}C. Relative humidity of SRS during study period ranged from 70-80%. Ten good bearing tree having height ≥ 10m, girth over bark (GBH) ≥ 60 cm and crown diameter ≥ 5.0m were selected randomly. Five branches of one meter length (possessing 10-12 inflorescences) per tree at approachable distance were tagged prior to anthesis.

Observations of floral visitors and pollinators were made for ten minutes at hourly interval between 7.00-17.00hr for seven consecutive days during peak flowering periods (starting from 1st day of anthesis up to 90% flowering was over). All insect visits to each inflorescence, flower handling behaviour were recorded manually using binoculars & digital camera. The visiting insects were caught by a trapping net, preserved and identified by comparing with maintained reference collection at Department of entomology, College of Agriculture, OUAT, Bhubaneswar. The diversity indices were calculated as per Magurran (2004) [7].

1. Margalef's Species richness d = (S-1)/Log (N) – measure of number of pollinator species attaining flowers of nux-vomica.
2. Pielou's evenness J = H$'$/ln(S) – measure of how evenly individuals are distributed among the different pollinator species.
3. Shannon-wiener Index $H' = -\sum_{i=1}^{n} P_i\ (ln P_i)$ – measure of both pollinator species richness and equitability components

Where,

N_i= the number of individuals of species i in the sample,

N = total number of pollinators in the sample ($\Sigma\ n_i = N$).

P_i= n_i/N (proportion of individuals of species "i" in the sample)

S = total number of pollinator species

The replicated data were statistically analyzed using SPSS software version 20 for windows and ANOVA done to determine the significance of the treatments at p= 0.05.

Results and Discussion

Diversity of pollinators

Nux-vomica flowers attracted a wide variety of insects belonging to 4 orders, 6 families, 9 genera and 10 species (Table 1). Among them four belonging to order Hymenoptera, four to Lepidoptera, one to Coleoptera and one to Diptera. The hymenopterans were the major floral visitors comprising from two families, viz. Apidae (*Apis dorsata*, *A. melifera* and *Trigona Spp.*) and Vespidae (*Vespa spp.*). They were followed in order of diversity by lepidopterans from two families, viz. Nymphalidae (*Danaus chrysippus, Euploea core, Junonia iphita*) and Pieridae (*Catopsilia pyranthe*). Among the total number of insect species visiting nux-vomica flower *Apis dorsata* constitute 21.21% and *Episyrphus balteatus* 20.84% respectively (Table 1). The Shannon-Wiener Index (H$'$) of diversity & Pielou's evenness (J) index was computed 10.183 and 9.436 respectively. Margalef's Species richness index was 4.798. This indicates that Silvicultural Research Station have high degree of diversity of pollinators.

Floral features like color, odour, shape, reward etc. are associated to pollination syndromes (Martins and Batalha 2006) [8]. These syndromes generally common or specific to plant species adapted to a certain type of pollinator. Pollination syndromes play a critical role in determining the likeliest group of pollinators for a particular species in a given habitat (Faegri and Van Der 1966) [9]. The pollination syndrome of nux-vomica flowers includes colour (greenish-white corolla), odour (mild sweet) and reward (pollen & nectar). The flowers are not large and colourful to attract attention of insect visitors but synchronized blooming and their arrangement in inflorescence rachis makes them showy. Simple & generalist blossom features like tubular corolla with rim curvature at mouth, greenish-whitish colour and mild scent attract a group of insects towards nux-vomica flower. The hymenopterans and lepidopterans visited regularly between 700-1600h (Fig.1) and constitute 53.01% and 22.49% to total insect visitors to nux-vomica flowers (Table-1). They were rewarded with nectar, pollen or both. Flower visiting insects might have signalled by odour and once they become closer to the tree, the colour combination (greenish-white corolla and shiny green leaf) attracts them towards flower. Tubular corolla allows bees and butter flies to land on the top of the flower. The bees probed the flowers in an upright position where the stigma head get easily contacted by virtue of its position and thus transfer of pollen load. At the time of flower opening the stigmatic surface was at par with anthers and with passage of time protrudes out of corolla cavity due to increased stylar growth. Early withering of stamens and enhanced position of stigma above corolla brim creates a small gap and provides sufficient space to the flower visitors to collect nectar. Small length of corolla tube (7.424±0.646 mm) assists flower visitor in getting relatively copious amounts of nectar. Pollination syndrome apart from attracting a number of flower visitors to forage flower but also insures their visiting rate sufficient for adequate pollination (Fig2).

Abundance of pollinators

Abundance of major insect pollinators on nux-vomica flowers at different hours showed a significant difference. Highest mean abundance (38.67 insects/m^2 branch/10min) was recorded in *Apis dorsata* and *E. balteatus* (38.00 insects/m^2 branch/10 min). Lowest abundance was recorded in *J. Iphita* (6.67 insects/m^2 branch/10 min) and *Coccinella spp.* (6.67 insects/m^2 branch/10 min). From the present study, it was evident that *hymenopteran* insects were more abundant pollinators on nux-vomica flower (Table 2 and Fig.2). The interaction of insect species and hours of day shows significant difference and 21.13 insects/m^2 branch/10 min was recorded.

Foraging behaviour of different pollinators in relation to different hours of the day

Hourly observations of insect visiting nux-vomica flowers revealed that maximum population of Hymenopterans was observed between 0900 to 1200 hour of the day (Fig.1). Significant difference in number of pollinating insects at different hours of day time was observed (Table-2). Maximum mean number of insects (25.00 insects/m^2 branch/10 min) was recorded between 0700-1000 hours. In case of *A. dorsata* the maximum activity was recorded during 0900-1200 hours of the day while as in *E.* balteatus it was during 0800-1000hours (fig.1). This might be due to variation in microclimate (temperature and humidity) from morning to noon. Similar types of results were reported by Dashad (1989) [10] who reported that foraging activity of dipterans and

hymenopterans are significantly and positively correlated with humidity. The abundance of lepidopterans was low during early morning and their number increased towards noon (fig.1). This observation was in accordance with earlier reporting by Altaf *et al*., (2017) [11] regarding foraging behaviour of butterflies. The time spent by a foraging insect on a flower determines the pollination success rate. It was observed that *Vespa spp.* visited maximum number of inflorescences per minute but spent minimum time. Butterfly species *J. iphita* spent maximum time on a inflorescence (Fig.3).

Table 1: Diversity of various insect pollinators/visitors on *S. nux-vomica* flowers at SRS, Ghatikia during 2017

Order	Family	Scientific name	Rewards	% age of total visitor	
Hymenoptera	Apidae	*Apis dorsata*	N, P	21.21	53.01
		Apis melifera	N, P	14.99	
		Trigona Spp	N, P	12.61	
	Vespidae	*Vespa Spp.*	N	4.20	
Diptera	Syrphidae	*Episyrphus balteatus*	N	20.84	
Lepidoptera	Pieridae	*Catopsilia pyranthe*	N	7.13	22.49
	Nymphalidae	*Danaus chrysippus*	N	6.58	
		Euploea core	N	5.12	
		Junonia iphita	N	3.66	
Coleoptera	Coccinellidae	*Coccinella spp*	N	3.66	
Species richness (d)		4.798			
Pielou's evenness (J)		9.436			
Shannon-Wiener Index (H')		10.183			

N-Nectar, P- Pollen

Table 2: Relative abundance of insect pollinators on *S. nux-vomica* at different hours of the day during flowering period at SRS, Ghatikia during 2017

Time	Insect pollinators (insects/m² branch/10 min)*										Mean
	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	
7-10h	73.0	45.0	17.0	27.0	2.0	6.0	19.0	11.0	11.0	8.0	25.00
10-13h	26.0	23.0	33.0	78.0	17.0	6.0	3.0	5.0	2.0	5.0	23.88
14-17h	17.0	14.0	19.0	9.0	4.0	27.0	14.0	12.0	7.0	7.0	14.50
Mean	38.67	27.33	23.00	38.00	7.67	13.00	12.00	9.33	6.67	6.67	21.13

Factors	SEm (±)	CD (P=0.05)
Species	1.35	3.80
Hour	0.74	2.08
Species × Hour	2.33	6.59

* Insect pollinators A- Apis dorsata, B- Apis melifera, C- Trigona Spp, D-Episyrphus balteatus, E-Vespa Spp., F-Catopsilia pyranthe, G-Danaus chrysippus, H-Euploea core, I-Junonia iphita, J-Coccinella spp.

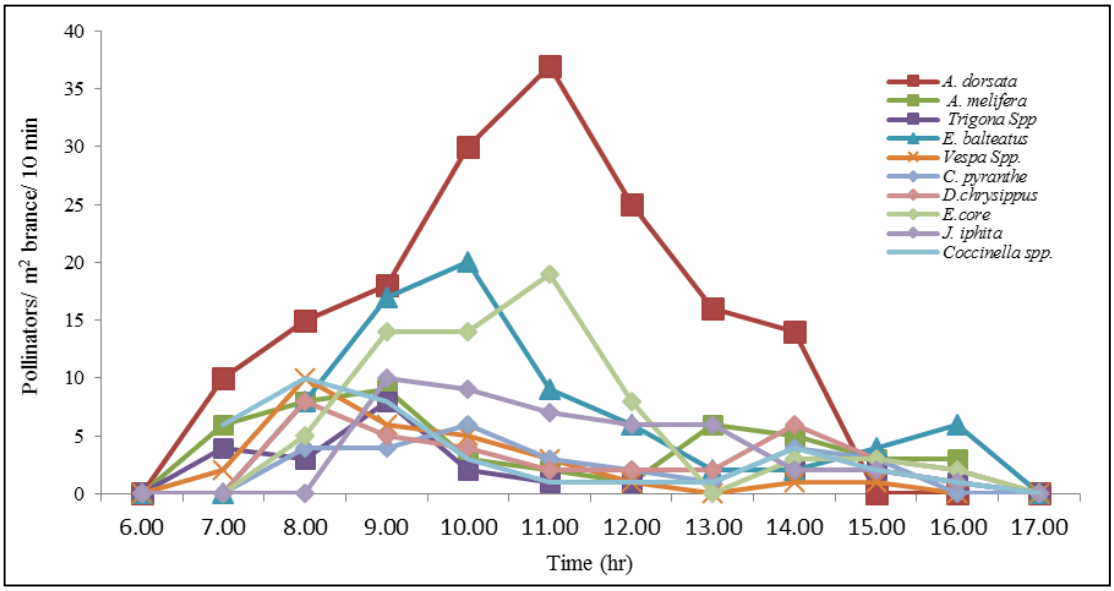

Fig 1: Foraging behaviour of pollinating insects at different hours of day

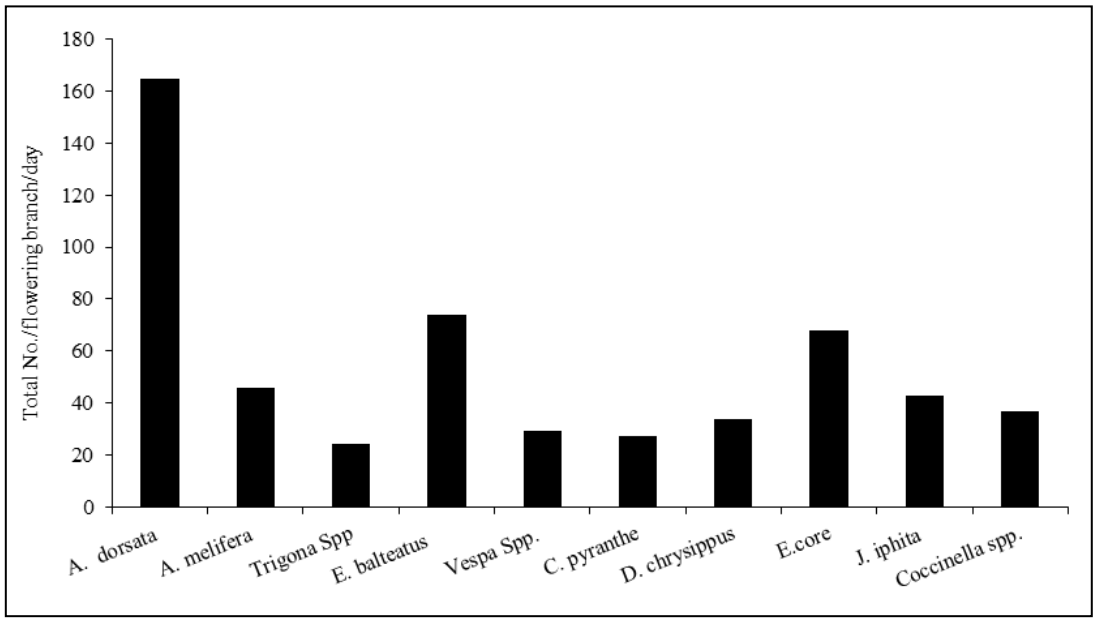

Fig 2: Species abundance of pollinators on *S. nux-vomica*

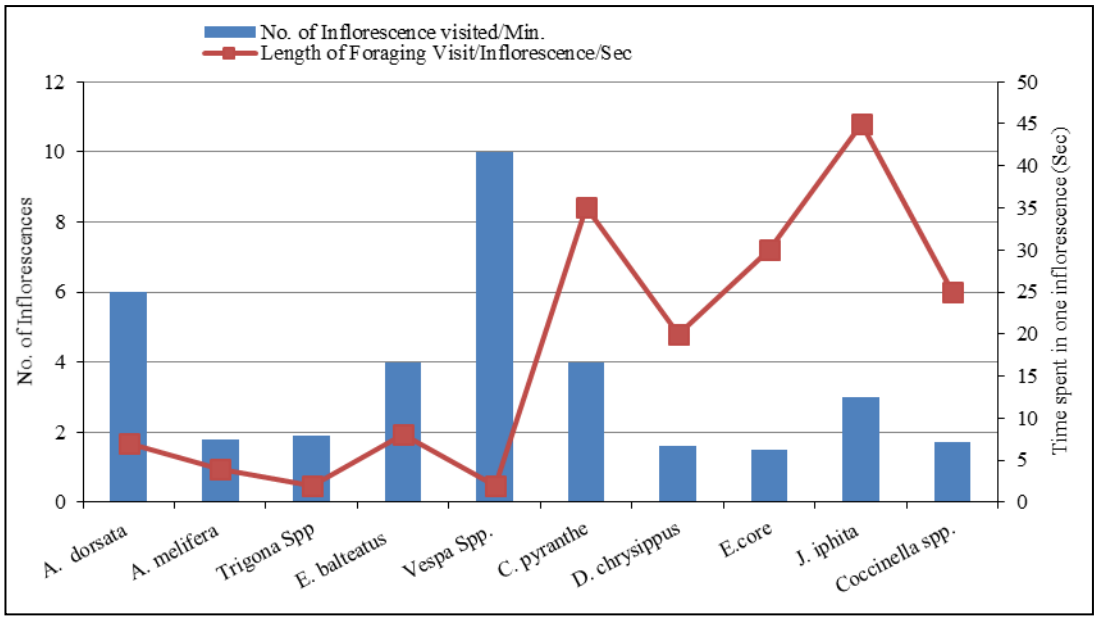

Fig 3: Activity of pollinating insects on *S. nux-vomica inflorescence*

Conclusion

During the course of observation at Silvicultural research Station, Ghatikia, Bhubaneswar on the occurrence and pollinating activities of insects on *S. nux-vomica*, various species representing different orders and family were collected. Most abundant insects foraging nux-vomica flowers was *A. dorsata* (Hymenoptera) and *E. balteatus* (Diptera).

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