# Diversity of Pollinators in Drumstick, *Moringa oleifera* Lam. Ecosystem

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**A study was conducted to assess the diversity of pollinators indrumstick, *Moringa oleifera* Lam. orchardat Oddanchatram, Dindigul district of Tamil Nadu. A total of 27 species of pollinators were recorded including 13 species of Hymenopterans, 7 species of Dipterans and Lepidopterans each. *Apis cerana indica* F. was the dominant pollinator followed by *Amegillazonata* L. and *Apisdorsata* F. Among the Dipterans, *Episyrphus* sp. was dominant followed by *Sarcophaga* sp. and *Lucilia* sp. Among the Lepidopterans, *Oriensgoloides* M. was found to be the maximum followed by *Papiliopolytes* L. and *Danaus chrysippus* L. Simpson's D was the highest at 14.00 to 15.00 h. Simpson's E ranged from 0.3 to 0.7 with maximum evenness at 06.00 to 07.00 h. Pollination Efficiency Index was found to be the highest in case of *Xylocopa* sp. followed by *A.cerana indica* F. and *A. dorsata* F. results indicated that *A.cerena.indica* F. was the most abundant pollinator but *Xylocopa* sp. was the most efficient pollinator in drumstick ecosystem.**

**Key words:** Pollinators, Hymenopterans, Dipterans, Drumstick, Species diversity

*Moringa oleifera* Lam.is nativeto India. The tree is not only grown in India but also widely grown in different countries (Fahey, 2005). In India, drumstick trees grown in about 40,000 ha (India Agristat, 2018). Major cultivation occurs in Tamil Nadu, Karnataka, Kerala, and Andhra Pradesh. In Tamil Nadu, it is grown in 7,500 ha in Dindigul, Thoothukudi, Karur and Erode districts. It is a drought-tolerant, fast-growing, multi-purpose and one of the most useful trees due to medicinal and nutritional properties hence called as'miracle tree' (Fuglie, 2005; Rashid *et. al.,* 2008).

Drumstick is a crop that flowers for about six months in a year and hence serves as pasturage for different types of pollinators and flower visitors from various insect orders. It is highly cross pollinated and entomophilous,bees were major pollinators. Besides *Xylocopa sp.* different types of thrips, *Apis* sp., *Amegilla* and some members of Lepidoptera visit flowers to nourish them. The carpenter bees (*Xylocopa latipes D.*) and (*Xylocopa pubescens* L.) have been found the most reliable pollinator (Pushpalatha and Hariprasad, 2015). Sunbirds have also been observed as active pollinators.With this background information, a field survey was conducted in a farmer's holding to find out the diversity of insect pollinators in drumstick ecosystem in Tamil Nadu, India.

## Material and Methods

A drumstick orchard with Kappalpatti local variety in Oddanchatram(10°50'N and 77°83'S), Dindigul district of Tamil Nadu was selected for studying the diversity of pollinators during February 2018.In the orchard, five randomly selected trees were marked. In

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each tree, five inflorescences (total 25 inflorescences in 5 trees) were selected (FAO, 2008). Population of insect visitors were recorded by visual observation for a period of 10 days during peak flowering (after 20% of flowering).Insects were collected using aerial net and preserved it in 100% ethyl alcohol. Collected insect specimens were photographed in stereo-zoom microscope (LEICA M205A).

### Diversity indices

#### (a) Shannon's diversity index (H)

The proportion of species *i* relative to the total number of species (p*i*) was calculated and was summed across species and multiplied by -1(Davilla *et al.,* 2012).

$$H = - \sum_{i=0}^{S} pi \ln pi$$

The total number of species in the community known as species richness (S) was found out. Shanon's equality ($E_H$) was calculated by dividing H by $H_{max}$ (here $H_{max}$ = lnS). Equality assumes a value between 0 and 1 being complete evenness.

$$EH = \frac{H}{H\,max} = \frac{H}{\ln(S)}$$

#### (b) Simpson's diversity index

The proportion of species I relative to the number of species (*pi*) was calculated and squared. The squared proportions for all the species were summed and the reciprocal was taken.

$$D = \frac{1}{\sum_{i=1}^{S} pi2}$$

Equitability (ED) was calculated by taking Simpson's index (D) and it as a proportion of maximum value D could assume if individuals in the

community were completely evenly distributed ($D_{max}$) which equals S.

$$ED = \frac{D}{D\ max}$$

### Pollination Efficiency Index (PEI)

Pollination efficiency index for each visitor species was calculated using procedures developed by Sihag(1986). This is usually the product of performance score of LP (Loose pollen adhering to the body of the insect) and performance score (PS) of mean number of insect visitor (PA) during peak flowering hours.

Pollination Efficiency Index = PS of LP X PS of PA X 100

$$\text{Where PS of LP} = \frac{LPi}{\sum_{i=1}^{n} LPi}$$

$$\text{PS of PA} = \frac{PAi}{\sum_{i=1}^{n} PAi}$$

## Results and Discussion

A total of 27 species of pollinators were observed in Drumstick ecosystem at Oddanchatram, Dindigul district during 2018 which were identified by the taxonomist at the Biosystematics unit of Department of Agricultural Entomology, TNAU, Coimbatore.

**Table 1. List of floral visitors in drumstick eco system**

| Pollinators* | Systematic position (Order : Family) | Role (N/P/N+P) |
|---|---|---|
| *Apisceranaindica* | Hymenoptera : Apidae | N+P |
| A. dorsata | Hymenoptera : Apidae | N+P |
| A.florea | Hymenoptera : Apidae | N+P |
| *Amegillazonata* | Hymenoptera : Apidae | N+P |
| *Amegillaquadrifasciata* | Hymenoptera : Apidae | N+P |
| *Xylocopa* sp. | Hymenoptera : Apidae | N+P |
| *Polistes* sp. | Hymenoptera : Vespidae | N |
| *Vespa orientalis* | Hymenoptera : Vespidae | N |
| *Scolia*sp. | Hymenoptera : Scoliidae | N |
| *Sphex* sp. | Hymenoptera : Sphecidae | N |
| *Megachile* sp. | Hymenoptera : Megachilidae | N+P |
| *Pepsis* sp. | Hymenoptera : Pompilidae | N |
| *Halictus* sp. | Hymenoptera : Halictidae | N+P |
| *Episyrphus* sp. | Diptera : Syrphidae | N |
| *Sarcophaga* sp. | Diptera : Sarcophigidae | N |
| *Luciliapapuensis* | Diptera : Calliphoridae | N |
| Eristalinusarvorum | Diptera : Syrphidae | N |
| *Condylostyus* sp. | Diptera : Dolichopodidae | N |
| *C. occidentalis* | Diptera : Dolichopodidae | N |
| *Muscadomestica* | Diptera : Muscidae | N |
| *Papiliopolytes* | Lepidoptera : Papilionidae | N |
| Pierisrapae | Lepidoptera : Pieridae | N |
| *Tirumalalimniace* | Lepidoptera : Nymphalidae | N |
| *Hypolimnasbolina* | Lepidoptera : Nymphalidae | N |
| *Oriensgoloides* | Lepidoptera : Hesperidae | N |
| *Danauschrysippus* | Lepidoptera : Nymphalidae | N |
| *Sphinx* sp. | Lepidoptera : Sphingidae | N |

N- Collects nectar only P-Pollen only N+P-Nectar and Pollen

* The number of floral visitor were observed per 25 inflorescences per 5 min. Insects were collected using aerial net (except *Sphinx* sp.) and preserved in 100% ethyl alcohol. Collected insect specimens were photographed in stereo-zoom microscope (LEICA M205A).

Among them 13 belonged to Hymenoptera, seven each to Diptera and Lepidoptera. In Hymenoptera, Apidae was the dominant family followed by Vespidae, Scolidae, Sphecidae ,Megachillidae, Halictidae, and Pompilidae. Among Dipterans 7 insects belongs to Syrphidae, Dolichopodidae,Sarcophigidae, Calliphoridae and Muscidae . Among Lepidopterans 7 insects belongs to Nymphalidae, Papilionidae, Pieridae, Hesperidae andSphingidae (Table 1). The pollinators were categorised into four groups such as *Apis* Hymenopterans, Non *Apis*Hymenopterans, Dipterans and Lepidopterans. Among them Apis Hymenopterans werehigh, followed by Non *Apis* Hymenopterans, Dipterans and Lepidopterans (Fig. 1.).

### Species composition and relative abundance of flower visitors

Among the hymenopterans, *Apis* genus included three insect species and Non *Apis* genera included ten insect species. In *Apis* Hymenopterans, *A. ceranaindica* F. was the major pollinator followed by *A. dorsata* F. and *A. florea* F. The mean population of *A. cerana indica* F. was maximum at 08.00 to 09.00 h ( 4.8/ 25 inflorescences/ 5 min) followed by 10.00 to 11.00 h (4.7/ 25 inflorescences/ 5 min) and 11.00 to 12.00 h ( 4.5/ 25 inflorescences/ 5 min). At 10.00 to 11.00h and 15.00 to 16.00 h the total population of *Apis* Hymenopteran that visited drumstick was 7.6 and 4.8/ 25 inflorescences/ 5 min respectively (Table 2).

In non *Apis* Hymenopterans, the major pollinator was *Amegillazonata* L.followed by *Polistes*sp., *Vespa orientalis* L., *Scolia* sp., *Xylocopa* sp*., Halictus*sp*.,Amegilla quadrifasciata*V., *Sphex* sp., *Pepsis* sp. and *Megachile* sp. The mean population of *Amegilla zonata* L. was found to be maximum (2.1/ 25 inflorescences/ 5 min) at 12.00 to 13.00 h and 09.00 to 10.00 h followed by 11.00 to 12.00 h and 08.00 to 09.00 h (1.9 /25 inflorescences/ 5 min). At 14.00 to 15.00 h and 12.00 to 13.00 h the total population of Non-*Apis* hymenopteran were4.5 and 4.3/ 25 inflorescences/ 5 min respectively.

Among Dipterans, *Episyrphus*sp. wasthe major flower visitor followed by *Luciliapapuensis* R. and *Sarcophaga* sp*., Eristalius arvorum* R*., Condylostylus* sp*., C. Occidentalis* B.and *Musca domestica* L. The population of *Episyrphus* sp. visiting drumstick inflorescence was maximum at 16.00 to 17.00 h (1.1/ 25 inflorescences/ 5 min). At 17.00 to 18.00 hand 09.00 to 10.00 h the total population of Dipteran visitors were3.0 and 2.4/ 25 inflorescences/ 5 min respectively.

In Lepidopterans, the major pollinator was *O.Goloides* M.followed by *P.polytes* L.and *D. Chrysippus* L., *Pierisrapae* L*., Hypolimnasbolina* L*., Tirumalalimniace* C. and *Sphinx* sp. The mean population of *O.goloides* M.was maximum at 15.00 to 16.00 h (0.4/ 25 inflorescences/ 5 min) followed by 12.00 to 01.00 h (0.3/ 25 inflorescences/ 5 min) (Table 2).At 09.00 to 10.00 h, 12.00 to 01.00 h and

**Table 2. Diversity of pollinators at different hours of the day on drumstick inflorescence**

| Species / time of day | Pollinators population /25 inflorescences/5min* | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 06.00-07.00 | 07.00-08.00 | 08.00-09.00 | 09.00-10.00 | 10.00-11.00 | 11.00-12.00 | 12.00-13.00 | 13.00-14.00 | 14.00-15.00 | 15.00-16.00 | 16.00-17.00 | 17.00-18.00 | Mean |
| *Apisceranaindica* | 0.4 | 1.9 | 4.8 | 4 | 4.7 | 4.5 | 3.8 | 3.3 | 3.2 | 3.6 | 4 | 2.1 | 3.36 |
| *A.dorsata* | 0 | 0.2 | 1.9 | 2.3 | 2.8 | 2.4 | 1.8 | 1.6 | 1.3 | 1.1 | 1.7 | 1 | 1.51 |
| *A.florea* | 0 | 0 | 0.2 | 0.3 | 0.1 | 0 | 0 | 0.1 | 0.1 | 0.1 | 0 | 0.1 | 0.08 |
| *Apis* Hymenopterans | 0.4 | 2.1 | 6.9 | 6.6 | 7.6 | 6.9 | 5.6 | 5.0 | 4.6 | 4.8 | 5.7 | 3.2 | 4.95 |
| *Amegillazonata* | 0.9 | 0.7 | 1.8 | 1.9 | 1.6 | 1.9 | 2.1 | 1.8 | 1.5 | 1.5 | 1 | 1.6 | 1.53 |
| *A. quadrifasciata* | 0 | 0.1 | 0.1 | 0.1 | 0.2 | 0 | 0.3 | 0.1 | 0.3 | 0.1 | 0.3 | 0 | 0.13 |
| *Polistes* sp. | 0.2 | 0.1 | 0.4 | 1 | 1.1 | 1.2 | 0.9 | 0.8 | 1.1 | 1 | 0.7 | 1 | 0.79 |
| *Vespa orientalis* | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.1 | 0.2 | 0 | 0 | 0 | 0 | 0.03 |
| *Xylocopa* sp. | 0 | 0 | 0 | 0.4 | 0.3 | 0.6 | 0.5 | 0 | 0.6 | 0.3 | 0 | 0 | 0.23 |
| *Scolia* sp. | 0 | 0.1 | 0.3 | 0.1 | 0.4 | 0.2 | 0.4 | 0.2 | 0.7 | 0.4 | 0.2 | 0.1 | 0.26 |
| *Sphex* sp. | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0.4 | 0.2 | 0.2 | 0 | 0 | 0.08 |
| *Megachile* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0.1 | 0.1 | 0 | 0 | 0.03 |
| *Pepsis* sp. | 0 | 0 | 0 | 0.2 | 0.1 | 0.1 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0.04 |
| *Halictus* sp. | 0 | 0 | 0 | 0.3 | 0.4 | 0.3 | 0.4 | 0.3 | 0.6 | 0.1 | 0.3 | 0 | 0.23 |
| *Non Apis Hymenopterans* | 1.1 | 1.0 | 2.6 | 3.7 | 3.9 | 4.1 | 4.3 | 3.8 | 4.5 | 3.6 | 2.2 | 2.7 | 3.12 |
| *Episyrphus* sp. | 0 | 0.9 | 0.7 | 0.7 | 0 | 0 | 0 | 0 | 0.1 | 0.5 | 1.1 | 0.4 | 0.37 |
| *Sarcophaga* sp. | 0 | 0.4 | 0.4 | 0.2 | 0.3 | 0.3 | 0.4 | 0.3 | 0.2 | 0.2 | 0.5 | 0.3 | 0.29 |
| *Luciliapapuensis* | 0 | 0.2 | 0.4 | 0.5 | 0.3 | 0.3 | 0.1 | 0.3 | 0.3 | 0.5 | 0.7 | 0.4 | 0.33 |
| *Eristalinusarvorum* | 0 | 0.2 | 0.2 | 0.4 | 0.2 | 0 | 0 | 0.3 | 0.3 | 0.1 | 0.4 | 0.4 | 0.21 |
| *Condylostyus* sp. | 0 | 0.1 | 0.3 | 0.2 | 0.2 | 0 | 0.3 | 0.3 | 0.1 | 0.4 | 0.1 | 0.1 | 0.18 |
| *C. Occidentalis* | 0 | 0 | 0 | 0.3 | 0.3 | 0.2 | 0.2 | 0.3 | 0 | 0.2 | 0.1 | 0.1 | 0.14 |
| *Muscadomestica* | 0.2 | 0.3 | 0.2 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0.08 |
| *Dipterans* | 0.2 | 2.1 | 2.2 | 2.4 | 1.3 | 0.8 | 1.0 | 1.5 | 1.0 | 1.9 | 3.0 | 1.7 | 1.59 |
| *Papiliopolytes* | 0 | 0 | 0.2 | 0.3 | 0.2 | 0.1 | 0.3 | 0.3 | 0.1 | 0.1 | 0 | 0 | 0.13 |
| *Pierisrapae* | 0 | 0 | 0 | 0.2 | 0 | 0.2 | 0 | 0.2 | 0.2 | 0 | 0.1 | 0 | 0.08 |
| *Tirumalalimniace* | 0 | 0.1 | 0 | 0 | 0 | 0.2 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0.03 |
| *Hypolimnasbolina* | 0 | 0 | 0 | 0 | 0.3 | 0.1 | 0 | 0 | 0.2 | 0 | 0.1 | 0 | 0.06 |
| *Oriensgoloides* | 0 | 0 | 0 | 0.2 | 0.1 | 0.1 | 0.3 | 0.2 | 0.2 | 0.4 | 0.1 | 0.2 | 0.15 |
| *Danauschrysippus* | 0 | 0.1 | 0 | 0.2 | 0 | 0.1 | 0.2 | 0.2 | 0 | 0 | 0.4 | 0 | 0.10 |
| *Sphinx* sp. | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 |
| Lepidopterans | 0.2 | 0.2 | 0.2 | 0.9 | 0.6 | 0.8 | 0.9 | 0.9 | 0.7 | 0.5 | 0.7 | 0.2 | 0.56 |
| Diversity indices | | | | | | | | | | | | | |
| Species richness | | | | | | | | | | | | | |
| | 5.0 | 14 | 14.0 | 21.0 | 19.0 | 18.0 | 17.0 | 21.0 | 20.0 | 19.0 | 18 | 13.0 | |
| Simpson's D | 3.3 | 5.5 | 4.5 | 7.0 | 5.5 | 5.2 | 6.2 | 7.2 | 7.6 | 6.4 | 6.2 | 6.3 | |
| Simpson's E | 0.7 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.4 | 0.3 | 0.3 | 0.5 | |
| Shannon's H | 1.4 | 2.1 | 2.0 | 2.4 | 2.2 | 2.1 | 2.2 | 2.4 | 2.4 | 2.3 | 2.3 | 2.1 | |
| Shannon's E | 0.9 | 0.8 | 0.7 | 0.8 | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | |

*Mean of ten observations. The population of pollinators were observed per 25 inflorescences per 5 min.

13.00 to14.00 h the total population of Lepidopteran visitors was 0.9/ 25 inflorescences/ 5 min followed by 0.8/ 25 inflorescences/ 5 min at 11.00 to 12.00 h. The values were highly variable during the day.

Species richness (S) was maximum at 09.00-10.00 and 13.00-14.00 h with 21 species. 'S' value was minimum (5.0) at 06.00-07.00 h. The

**Table 3. Pollination Efficiency Index (PEI) of different floral visitors of drumstick**

| Insect species | Loose pollen adhering to the body | | Pollinator abundance | | Pollinator efficiency index LP pi x PA pi x 100 | Pollinator rank |
|---|---|---|---|---|---|---|
| | Number of (LP) * in thousands | Performance score (LP pi) | No. of insects (PA)** | Performance score (PA pi) | | |
| *Apisceranaindica* | 65.1 | 0.172 | 7.52 | 0.345 | 5.9 | 2 |
| A. *dorsata* | 92.7 | 0.244 | 5.11 | 0.235 | 5.7 | 3 |
| *Amegillazonata* | 82.2 | 0.217 | 4.60ns | 0.211 | 4.6 | 4 |
| *Xylocopa* sp. | 139.6 | 0.368 | 4.56ns | 0.209 | 7.7 | 1 |
| CD at 5% | 5.9 | | 0.41 | | | |

LP- Loose Pollen, PA – Pollinator abundance
*Mean of five observations under stereo zoom microscope. In a column, mean are significantly differ at p=0.05.
**Number of pollinators for 5 min / 25 inflorescences (Mean of ten observations). In a column, mean are significantly differ at p=0.05

highest values of diversity indices Simpson's D and Shannon's H were recorded at 14.00-15.00 h and the lowest at 06.00-07.00 h (Table 2). The evenness calculated namely Simpson's E and Shannon's E were not much variable during the day. In general the *Apis*Hymenopterans were more during the forenoon while non-*Apis*Hymenopterans and dipterans were slightly higher during afternoon.

In the current research work, it was found that 27 insect species viz., bees, wasps, true flies, butterflies and skipper were visited the inflorescence in the drumstick orchard.  Similar results were obtained in West Africa where totally 26 insect species with bees, wasps, ants, butterflies, bugs and sunbirds were observed (Krieg *et al*., 2015). *A. cerana indica*F. was the most dominant pollinator species followed by *Amegilla zonata*L. and *A.dorsata*F. among the 27 species recorded in the present study.
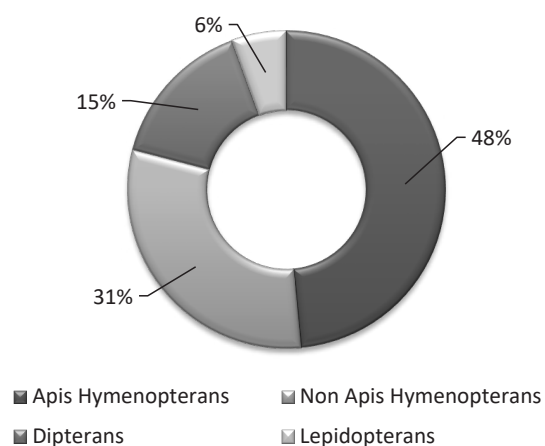


**Fig. 1. Population of pollinator groups visiting drumstick inflorescence**

Results of our studies are different from that of (Krieg *et al*., 2015) who reported that carpenter bees, stingless bees, sunbirds, wasps and moths were the most common visitors of drumstick inflorescence.

It was also interesting and intriguing to note that stingless bees did not visit drumstick inflorescence during the period of study even though stingless bees were available in plenty in the vicinity in other crops.Palanichamy *et al*.(1995) studied the insect pollination of the drumstick. The pollen collection from anthers of the drumstick flowers by *A. florea* was more at about 1000 h and less at about 1600 h.Our observations are in concurrence with Chukunda, (2016) who also concluded that Xylocopa, *Pierisrapae*and*Danauschrysippus*are the important pollinators in drumstick.

Studies in other fruits and vegetable crops revealed similar results of current study in drumstick. The major pollinators in mango inflorescence included honeybees (*A. cerana* and *A. mellifera* L.) and an allodapine bee (*Braunsapishewitti C.*) of the Apidae and sweat bees (*Halictus*sp. and *Lassioglossum*sp.) of the Halictidae among the Hymenoptera and

*Chrysomyamegacephala* F., *Chrysomyapinguis*W. and *Muscadomestica* L.of the Diptera, which were the dominant species due to their frequent appearance (Sung *et al*., 2006).Another study in mango revealed a total of 17 species of pollinators in mango inflorescence at various mango growing areas of Tamil Nadu during 2016-17 (Vasanthakumar *et al.,* 2018). Among them, six belonged to Hymenoptera, seven to Diptera, three to Lepidoptera and one to Coleoptera. *A.florea*was the predominant visitor with a mean of 18.4/5 inflorescence/10 min. Among the pollinators, *A.cerana indica* F. (6.4) and *Tetragonulairidipennis* S.(6.7) were the prominent visitors. The honey bees, hover flies and native bees were recorded as the pollinators of avocado crop (Vithanage, 1990).

***Pollination efficiency index (PEI)***

The pollination efficiency indices were worked out for four insect species. It was worked out based on loose pollen adhering to the insect body and abundance of pollinators. The number of loose pollen grains (in thousands) sticking to the body per insect of *Xylocopa* sp. was the highest (139.6) followed by *A.dorsata*(92.7), *Amegilla zonata*(82.2) and *A. cerana indica*(65.1) (Table 3). This may be attributed to the size as well as the hairiness of the insect species that helps in increased surface area and increased number of loose pollen grains sticking to the body. The abundance of pollinators was maximum in *A. c. indica*(7.52 / 5 inflorescence/ 5 min) followed by *A.dorsata*(5.11), *Amegilla zonata*(4.60) and *Xylocopa* sp. (4.56). PEI calculated by multiplying proportion of loose pollen (LP pi) and proportion of pollinator abundance (PA pi) was the highest for *Xylocopa* sp. (7.7), followed by *A. c. indica*(5.9), *Amegillazonata*(4.6) and *A.dorsata*(5.9).

In a similar study in mango in Australia, *Tetragonula* sp. was the most efficient pollinators (Anderson *et al.*, 1982). However, similar studies in drumstick are lacking and the current study is the first of its kind in this crop.

**Conclusion**

Hymenopterans were the most common and abundant pollinators and *A. cerana indica* F. being the most abundant species that visit the drumstick crop. *Xylocopa* sp. was found to be the most efficient insect pollinator. Since rearing methodologies are not available for *Xylocopa* sp. the next efficient pollinator, *A.cerana indica* F. can be effectively used for pollination in drumstick by keeping honey bee boxes in field during flowering.

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