Research Article

BOWL TRAP SAMPLING TO STUDY POLLINATOR DIVERSITY IN MORINGA ECOSYSTEM

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ABSTRACT

Honey bees are important pollinator of agricultural and horticultural crops. Moringa, *Moringa oleifera* Lam. commonly known as drumstick is a vegetable native to India. Due to medicinal and nutritional properties it is also called as 'miracle tree'. It is highly cross pollinated and entomophilous, bees were major pollinators. Flowers can be a source of nectar and pollen for the pollinators. The objective was to describe the pollinator community in moringa fields, to determine the trap colour that is most appropriate for characterizing their abundance and diversity. Bowl trap is a common method of sampling bees. Totally, bowl traps of three different colours *viz*., fluorescent yellow, blue and white were used to capture the insect pollinators. Bowl trap catches were recorded for 10 days during peak flowering at 08.00 to 18.00 h. When all trap type captures were combined, we collected 601 individuals and at least 21 species. From the 21 insect species collected, fourteen were belonged to Hymenoptera and seven belongs to Diptera. The most abundant species collected was *Condylostylus* sp. (Diptera: Dolichopodidae) followed by *Halictus* sp. (Hymenoptera: Halictidae) and *Sarcophaga* sp. (Diptera: Sarcophagidae). Most pollinators were captured in fluorescent yellow bowls (353 individuals, 21 species), blue bowls (137 individuals, 18 species) and white bowls (111 individuals, 16 species). In fluorescent yellow trap, *Apis cerana indica* was collected more followed by *Polistes* sp., *Amegilla zonata* and *Xylocopa* sp. Our data suggest a diverse community of pollinators composed of mostly native flies and solitary bees visit moringa fields and forage on their flowers.

INTRODUCTION

Moringa, *Moringa oleifera* Lam. commonly known as drumstick is a vegetable nativeto India. The cultivation of drumstick in India occurs mainly in the southern states of Tamil Nadu, Karnataka, Kerala, and Andhra Pradesh. Globally the drumstick market is estimated at more than Rs. 27,000 crores, which is expected to cross Rs. 47,000 crores by 2020, growing at a rate of 9% per year. In India, as per recent figures, drumstick trees are grown in about 40,000 ha (IndiaAgristat,2018). In Tamil Nadu, it is grown in about 7500 ha in Dindigul, Thoothukudi, Karur and Erode districts of Tamil Nadu. Drumstick flowers twice a year, once during February-May and later during September-November.

Moringa flowers are highly cross-pollinated due to heteromorphism. Flowers can be a source of nectar and pollen for the pollinators. Wild insects, native bees and flower-visiting flies, also visit crop flowers and contribute to crop pollination. Despite these relationships, descriptions of flower visiting insect communities and their interactions with crops are lacking for many major productions systems. However, the relationship between pollinators and floral resources available in moringa is not well defined. In a more general context, understanding pollinator communities can inform conservation and management decisions by providing baseline data for assessing pollinator response to landscape changes and pest management practices. Establishing sampling methods to effectively survey pollinators in moringa fields is vital for obtaining data that accurately characterizes the diversity and abundance of pollinators in this cropping system.

Sweep netting is widely used for sampling insect communities in many different row crops and is capable of capturing high amounts of foliar dwelling insects per sample unit with minimal damage to plants (Kogan and Pitre, 1980). Traps left in the field in the absence of human disturbance and remain in the field over time may be a more efficient way to collect species with different foraging patterns. Schmidt *et al.* (2008) observed more syrphids

collected on yellow sticky traps than sweep nets when both were used in moringa fields. Drawbacks associated with yellow sticky traps include difficulty in identifying insects, as defining characters can be damaged. Other traps have been optimized for attracting and capturing bees, including a method analogous to sampling with pan traps (hereafter referred to as "bee bowls"). This method has been used in bee surveys across a wide range of geographical regions and different plant communities (Grundel *et al.,* 2010). Bee bowls painted in fluorescent colors mimic flower colors with wavelengths attractive to bees (Kevan and Baker, 1983).

Because bee bowls are customized for trapping bees, the attractiveness of bee bowls to other flower visitors, such as fly pollinators, is unclear. In contrast to the benefits of bee bowls, some negative aspects have been reported. Bee bowls may preferentially attract small-bodied bees and may not effectively monitor larger bees such as *A. mellifera.* Tuell and Isaacs (2009) noted that *A. mellifera* was captured when traps were places at canopy height as opposed to directly on the ground. Therefore, pollinator diversity, abundance, and floral relationships may be poorly represented in bee bowls. However, additional evidence, like the presence of pollen from collected specimens can help confirm that foraging took place and bees were not just moving through a habitat in which bee bowls were deployed. The need to standardize sampling methods for monitoring pollinators to effectively conduct large-scale inventories, compare pollinator communities in different habitats, and determine pollinator relationships to flowering crop species is mentioned among many studies (LeBuhn *et al.*, 2012).

Lastly, we hypothesize pollinators captured in the moringa fields are visiting moringa flowers and the greatest abundance of pollinators will be observed during moringa reproductive stages in which flowers are blooming. Pushpalatha and Hariprasad (2015) mentioned that the maximum potential number of seed (yield) is fixed at fertilization. It offers nectar and pollen as food source for the pollinators. The effective nototribic pollination in drumstick was recorded in *Xylocopa* and *Amegilla* which carry pollen on the head and/or thorax act as efficient foragers. Our objectives were to describe the pollinator community in moringa fields, determine which coloured trap is most appropriate for characterizing their abundance and diversity.

MATERIALS AND METHODS

Survey and monitoring of pollinator diversity on drumstick inflorescence was conducted in Oddanchatram (10º50'N and 77º83'S) of Dindigul district where drumstick is grown in large scale. Five year old trees of drumstick (local variety: Kappalpatti) cultivated in Oddanchatram, Dindigul district was selected for the study. It is situated at an altitude of 302 m above MSL and lies at 10º 30'24.4" N latitude and 77º50'18.7" E longitude. The area receives good rainfall during north-east monsoon (October to December). The minimum temperature ranges from 18ºC to 21º C and maximum 30º C to 33º C with a relative humidity of 70 to 85 per cent.

Fig. 1. Indian bee colonies placed in a moringa orchrd at Oddanchatram, Dindigul District

In the orchard, five randomly selected trees were marked and bowl traps were placed (Figure 1). In each randomly kept bowl trap, the regular reading of flower visitors data was recorded for studying the pollinator's diversity (Figure 2). The natural flower visitation per day was observed in each of the bowl traps and final data expressed as flower visitor count/ day/ trap. This data was recorded from 6 am to 6 pm. Population of insect visitors were recorded for a period of 10 days during peak flowering (after 20 % of flowering) during February 2018 with each day's data serving as a replication, thus totally ten replications were recorded. Pollinators were recorded by keeping all traps after opening of flowers to a stage when petals changed to light yellow or started to wither.

Fig 2. Bowl traps placed in moringa orchard nearby moringa flowers

Fig. 3. Bowl traps in different colours (Fluorescent yellow, blue and white)

Pan traps / bowl traps are a common method of sampling bees. Bowl traps are small plastic cups which are smeared with white, fluorescent blue or fluorescent yellow colours (usual colours for bowl trap) (Figure 3). These traps/ bowls were filled with water with small amount of detergent (3%) and kept at ground / elevated place (Figure 4) (Geroff *et al.*, 2014). Each bowl has a capacity of 350 ml and is 7 cm tall with a bottom diameter of 8.5 cm and 12 cm top diameter. The bowls were kept in such a way as to transect the field. Each of the three coloured bowls were replicated eight times and daily bowl trap catches were recorded for 10 days during flowering. Finally the bowl trap catches were expressed as number of insects trapped/ trap/ day.

Fig 4. Preparation of bowl traps

The insects are attracted to the bright coloured bowls and get trapped in the water kept in bowls and drown. Here soap diminishes/ reduces the surfacetension, the fallen insect sink instead of floating. Traps were operated on clear, warm, calm days from Feb 1 to 19, on alternate days and 10 days observations were taken. On each day of operation, traps were set at 0800 and collected at 1800 h.

Collected insect specimen were photographed in image analyser microscope (LEICA M205A) and preserved for further identification was done in surveys (Figure 5). Collected bees were pinned, labelled and the identification narrowed down using Discover Life online identification key (www.discoverlife.org). The specimens were identified to the level of species/genus/family with the help of taxonomists at the Insect Biosystematics Laboratory, TNAU.

Fig 5. Insects preserved with 100 per cent ethanol

a. *Tetragonulairidipennis* c. *Apisceranaindica*
b. *Apisflorea* d. *Apisdorsata*

Fig 6. Different bees collected from bowl traps

Fig 7. Fluorescent yellow trap with more number of Indian bees

RESULTS AND DISCUSSION

Bowl trap collection to study pollinator diversity

Survey and monitoring of pollinators population was conducted in Oddanchatram of Dindigul district where drumstick was grown in large scale. A total of 21 species of pollinators were observed in drumstick ecosystem at Oddanchatram, Dindigul district during 2018. Bee abundance and species richness varied significantly by color of bee bowl. From the 21 insect species were collected, out of which fourteen were belonged to Hymenoptera and seven belongs Diptera. We observed major bees *viz*, *Apis cerana indica*, *Apis dorsata*, *Apis florae* and *Tetragonula iridipennis* in the bowl traps (Figure 6).

Among the identified pollinators, ten belonged to Hymenoptera, Dipteraeach and one to Lepidoptera. Among hymenopterans *Apis* group includes three species *viz*., *A. cerana indica* (Figure 14a), *A. dorsata* (Figure 14b), *A. florae* and non *Apis* group included seven species that belonged to Apidae, Vespidae, Scoliidae, Sphecidae, Megachilidae, Halictidae and Pompilidae. Among the Dipterans, ten species that belonged to Syrphidae, Sarcophigidae, Calliphoridae, Dolichopodidae and Muscidae were recorded. Among Lepidopterans, one species belonging to Hesperidae were documented (Table 1).

Table 1. Evaluating different coloured bowl traps for trapping different pollinators at Oddanchatram, Dindigul on 2018

Species	Number of insects/day/trap*			
	Fluorescent yellow	**Blue**	**White**	**Mean ± SEd**
Apisceranaindica	0.400±0.48	0.088±0.14	0.050±0.05	0.179±0.20
A. dorsata	0.013±0.04	0.000±0.00	0.000±0.00	0.004±0.01
A.florea	0.050±0.05	0.025±0.05	0.013±0.04	0.029±0.03
Tetragonulairridipennis	0.025±0.05	0.000±0.00	0.000±0.00	0.008±0.02
Amegillazonata	0.163±0.18	0.150±0.11	0.088±0.8	0.133±0.04
*Polistes*sp.	0.200±0.09	0.050±0.05	0.088±0.06	0.113±0.04
*Dolichovespula*sp.	0.125±0.17	0.088±0.08	0.013±0.04	0.075±0.06
*Xylocopa*sp.	0.038±0.05	0.075±0.09	0.025±0.05	0.046±0.04
*Sphex*sp.	0.075±0.07	0.025±0.07	0.000±0.00	0.033±0.03
*Megachile*sp.	0.025±0.05	0.050±0.08	0.000±0.00	0.025±0.03
*Lasioglossum*sp.	0.363±0.20	0.163±0.18	0.050±0.05	0.192±0.10
*Osmia*sp.	0.150±0.11	0.000±0.00	0.050±0.08	0.067±0.05
Pepsis sp.	0.300±0.24	0.063±0.07	0.075±0.09	0.146±0.09
*Halictus*sp.	0.413±0.16	0.213±0.15	0.288±0.14	0.304±0.06
*Episyrpus*sp.	0.213±0.20	0.063±0.07	0.075±0.12	0.117±0.08
*Sarcophaga*sp.	0.488±0.25	0.138±0.20	0.175±0.10	0.262±0.13
Luciliapapuensis	0.138±0.09	0.075±0.07	0.038±0.07	0.083±0.04
*Condylostyus*sp.	0.763±0.35	0.200±0.17	0.138±0.13	0.367±0.08
C. occidentalis	0.113±0.11	0.100±0.15	0.138±0.14	0.117±0.07
Muscadomestica	0.125±0.12	0.063±0.07	0.088±0.08	0.092±0.05
Oriensgoloides	0.238±0.14	0.088±0.08	0.000±0.00	0.108±0.04
Mean ± SEd	0.201±0.05	0.078±0.01	0.063±0.02	

*Mean ± SEd of 80 observations (8 replications x 10 days)

Among the flower visitors *A. cerana indica*, *A. dorsata*, *A.florea*, *Tetragonula irridipennis*, *Amegilla zonata*, *Polistes* sp., *Dolichovespula* sp., *Xylocopa* sp., *Megachile* sp. And *Halictus* sp. were both nectar and pollen foragers. Then *Sphex* sp., *Lasioglossum* sp., *Osmia* sp., *Pepsis* sp., *Episyrpus* sp., *Sarcophaga* sp., *Luciliapapuensis*, *Condylostyus* sp., *C.occidentalis*, *Musca domestica* and *Oriens goloides* were only nectar foragers (Table 2).

The most abundant species collected was *Condylostylus* sp. (Diptera: Dolichopodidae) followed by *Halictus* sp. (Hymenoptera: Halictidae) and *Sarcophaga* sp. (Diptera: Sarcophagidae). Among, the most pollinators were captured in fluorescent yellow bowls (353 individuals, 21 species), blue bowls (137 individuals, 18 species) and white bowls (111 individuals, 16 species). In fluorescent yellow trap, *Apis cerana indica* was collected more followed by *Polistes*

sp., *Amegilla zonata* and *Xylocopa* sp. *Andrena* and *Halictus*bees were highly attracted towards the bluish and yellowish bowls while *Apis, Lasioglossum, Megachila, Osmia* bees and wasps *Polistes* and *Campso meriella* were not. Bees were highly attracted towards yellowish and bluish bowls than wasps. Yellowish bowls were highly efficient in collection of hymenopteran bee pollinators than bluish bowls (Khan *et al.*, 2016). Our data suggest a diverse community of pollinators composed of mostly native flies and solitary bees visit moringa fields and forage on their flowers.

We hypothesized the abundance and diversity of pollinators in moringa fields would vary across different colours of bowl traps. Aerial netting method was used for collection of different insect species Arora (1990). Bowl traps were also used for the insect collection. Bees were highly attracted towards yellowish and bluish bowls than wasps. *Andrena, Nomia* and *Halictus* bees were highly attracted towards the bluish and yellowish bowls while *Apis, Lasioglossum, Megachila, Osmia* bees and wasps *Polistes* and *Campsomeriella* were not. Yellowish bowls were highly efficient in collection of hymenopteran bee pollinators than bluish bowls (Khan *et al.*, 2016).

Totally bowl traps of three different colours viz., fluorescent yellow, blue and white were used to capture the insect pollinators. From the traps, 21 insect species were collected, out of which ten were belonged to Hymenoptera, Diptera belongs each and one from lepidoptera. The species-wise trap count details in bowl trap are given in Table 1. The bowl trap collection is classified according to groups and provided in Table 2.

Table 2. Evaluating different coloured bowl traps for collecting major insect pollinators at moringa ecosystem at Oddanchatram, Dindigul on 2018

Species	Number of insects / day / trap*			
	Fluorescent yellow	**Blue**	**White**	**Mean ± SEd**
Apisceranaindica	0.40 ± 0.48	0.08 ± 0.13	0.05 ± 0.05	0.179 ± 0.20
Amegillacingulata	0.13 ± 0.18	0.15 ± 0.10	0.08 ± 0.08	0.133 ± 0.04
*Polistes*sp.	0.20 ± 0.09	0.05 ± 0.05	0.08 ± 0.06	0.113 ± 0.04
*Xylocopa*sp.	0.03 ± 0.05	0.07 ± 0.08	0.02 ± 0.04	0.046 ± 0.04
Other hymenopterans	1.23 ± 0.66	0.50 ± 0.22	0.39 ± 0.23	0.700 ± 0.45
Dipterans	2.10 ± 2.13	0.72 ± 0.50	0.74 ± 0.49	1.190 ± 0.78
Mean±SEd	0.68 ± 0.81	0.26 ± 0.28	0.23 ± 0.28	

*Mean of ten days observation

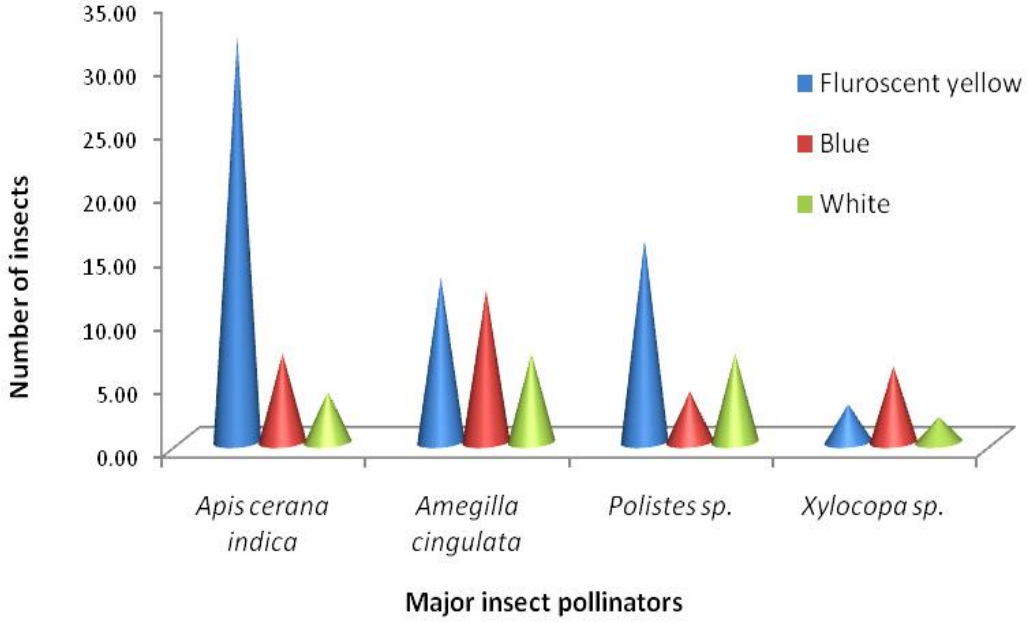

Fig. 8. Evaluating of different coloured bowl traps for major pollinators at Oddanchatram, Dindigul on 2018

A. cerana indica (0.17) was collected in highest mean population followed by *Polistes* sp. (0.11), *Amegilla zonata* (0.13) and *Xylocopa* sp. (0.04) (Fig. 8). Among the traps more population was recorded in fluorescent yellow (0.201) followed by blue (0.78) and white (0.63). In fluorescent yellow trap, *A. cerana indica* (0.40) was collected more followed by *Polistes* sp. (0.20), *Amegilla zonata* (0.13) and *Xylocopa*sp. (0.03) (Table 1).

These data suggest that bee bowls can provide an estimate of the pollinator community in moringa fields, both in terms of abundance and diversity. The biodiversity of insects within moringa fields is influenced by the surrounding landscape, as species richness of some insect taxa increases when a field is surrounded by a greater diversity of land-use types. Two evidences suggest that the bees captured were likely using these fields for forage. First, this diversity was not limited to field edges as abundance and diversity was not limited to bee bowls located near field edges. Second, bees were screened for moringa pollen to confirm that they had visited moringa flowers, and were not just present in moringa fields because of the attractive nature of the traps. Compared to Dipterans, Hymenopterans found more in all 3 traps (Fig. 9).

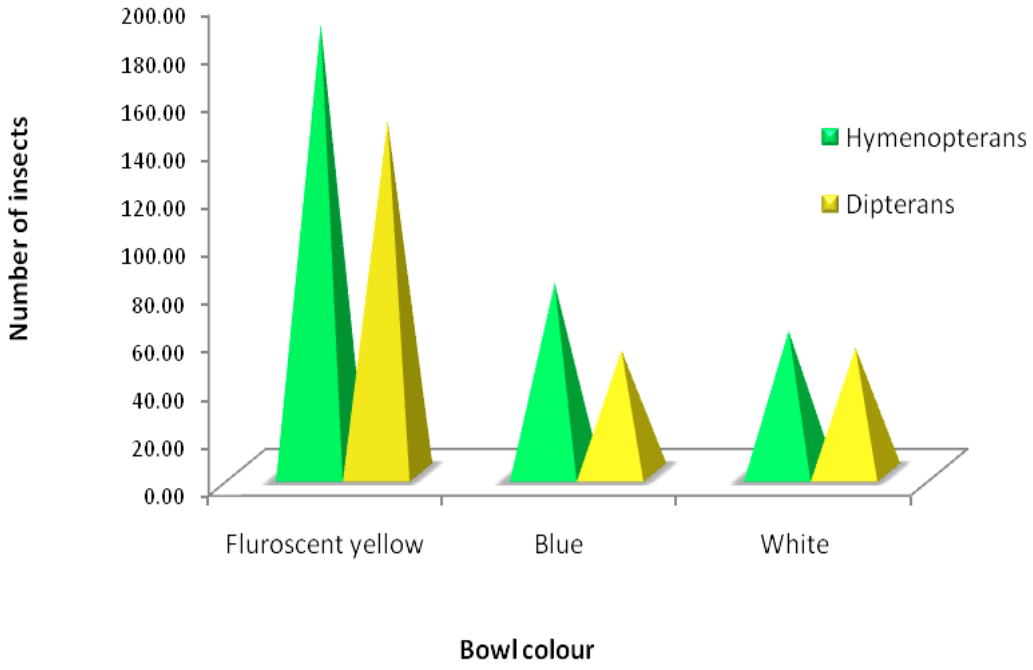

Fig. 9. Evaluating of different coloured bowl traps for Hymenopterans and Dipterans at Oddanchatram, Dindigul on 2018

Though bee bowls captured a diverse community of bees, with some species especially abundant (e.g. *Condylostylus* sp. and *Halictus* sp.), other important bee species were rarely captured. Although there is evidence that *A. cerana indica* visit moringa flowers (Erickson *et al.* 1978), moringa flowers were thought to attract few bees. But in our studies we found more number of Indian bees attracted to moringa flowers (Figure 7). Rust *et al.* (1980) also reported 29 species of native bees from soybean fields in USA, but did not report the occurrence of dipteran pollinators. But in case of moringa ecosystem we did not recorded any coleopterans found in bowl trap. We recommend that future studies of pollinator communities in moringa uses a standard methodology that rely on bee bowls being used within this study. Additional studies are required, however, to determine if pollen is transferred to these plants, as the type or amount of pollen carried on a bees' body is not always a reliable proxy for determining pollinator efficacy.

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