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Biodiversity and Pollination Activity of Stingless Bees (*Meliponini*) in Agro Forest Zone

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ABSTRACT: This study was conducted to evaluate biodiversity and pollination activity of stingless bees in the University of Ilorin agro forest. Stingless bees, their nests, trees hosting the bees and trees and crops visited by the bees were identified. The species of bees foraging on flowers of trees were observed and counted in 1m by 1m quadrat area of the flowers. The results showed that *Melliponula ferruginae* was found more in the cavities of *Gmelina arborea*, *Dactylurina staudingeri* constructed aerial nests on *Daniella oliveri* while *Hypotrigona ruspolli* was more in windows, doors and walls of old buildings. Seventeen plants/ crops were identified to be visited by *Melliponula ferruginae, Dactylurina staudingeriHypotrigona ruspolli* and *Apis melliffera* out of which eight were fruit crops, two were oil crops and seven were the other trees of economic importance in the area. Pollination activity of the bees showed that *Meliponula ferruginae* was found on 11.2% of the plants, *D. staudingeri* on 41.2%, *H. ruspolii* on 94.1% and *Apis mellifera* (common honey bees) on 82.4%. All the flowering plants identified were pollen producers (100%) while 64.7% were nectar producers. *Dactylurina staudingeri* was found in great numbers on fruit crops (*A. occidentale*, *M. indica* and *P. guajava*), oil crop (*J. curcas*) and trees. *Hypotrigona ruspolii* was found in great number mostly on fruit crops especially Citrus species, two oil crops and the economic important trees. *Meliponula ferruginae* was only found on two plants, a fruit crop and a tree. *Apis mellifera* was found on the fruit crops, one oil crop and the trees. Higher numbers of *D. staudingeri* visited many of the plants compared to *A. mellifera*. Based on the descriptive analysis employed, stingless bees found in the agro forest were responsible for the pollination of the commercial crops and economic important trees in the forest.

Keywords: *Melliponula ferruginae, Dactylurina staudingeri, Hypotrigona ruspolli, Apis melliffera*, pollination activities, fruit crops, oil crops, economic important trees.

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Introduction

It is no more a myth that bees (Apoidea) pollinate many wild and cultivated plant species (1, 2). Pollination is an important service to agriculture (3). Bees are the predominant and most economically important group of pollinators in most geographical regions. Pollination services are provided by both wild and commercially managed bee species.

It has been found that out of some 100 crop species that provide 90% of food worldwide, 71 of these are bee pollinated (4). Klein *et al*. (5) reported that yields of certain fruit, seed and nut crops decreased by more than 90% without bee pollination. At La Selva in Malaysia, more than 50% of canopy trees and 36% of sub canopy trees were pollinated by bees (6). Therefore a change in the pollinators' community will impact tree composition (7) and the whole food chain.

Bees have special needs with regards to suitable nesting and floral sources but habitat loss has been a threat to their continued survival (8). Honey bees biodiversity in agricultural areas is threatened by increasing intensification of agricultural practices through extensive monoculture as well as loss of natural and semi natural habitats (9, 10). Anthropogenic changes, such as deforestation and pollution, have contributed to the extinction of many native and managed bee populations, with severe negative consequences for both natural and agricultural ecosystems (11, 8). Developed countries are working with pollinators' shortage although only a small number of them are successfully bred for agricultural use (12).

Although the importance of pollinators in agriculture is well known, until now their use is not remarkable in underdeveloped countries (13). The situation is changing because of new initiatives concerning pollinators' use in crops and the successful crops resulting from the pollinators' use in green houses that are competing in the world market (13).

A new scenario opens focusing stingless bees use as crop pollinators (14-16). They are known to be important pollinators in tropical rain forest (17) and also good for pollination in agricultural ecosystems (18, 19).

Stingless honey bees are a large group of bees in the family Apidae and tribe Meliponini, and closely related to the common honey bees. Keeping of these bees is known as Meliponiculture. About 700 species have been recorded worldwide and they are mostly found in tropical countries (19). They are variable in their body size, ranging from 2 to 4 mm. Currently, 32 species of them were identified (20, 21, Osawa and Tsubaki, 2003).

Stingless bees are active all year round and they do not sting but will defend by biting if their nest is disturbed. They usually nest in hollow trunks, tree branches, underground cavities, or rock crevices but they have also been encountered in wall cavities, old rubbish bins, water meters, and storage drums. Stingless bees are true generalists, collecting nectar and pollen from a vast array of plants (22, 23). Stingless bees are known to be important pollinator in tropical rainforest (17) and also good candidates for providing pollination services in agricultural ecosystem (18, 19).

The majority of stingless bee species nest in preformed cavities in live trees (24, 21, 25). Others can live in dead trees (such as *Ptilotrigona lurida mocsaryi* and *Trigona fulviventris* in Brazilian Amazon (26); *T. melanocephala* and *T. rufibasalis* in Sarawak, Malaysia (7).

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This study explores the relationship between prevailing plants and stingless bees in the University of Ilorin Agro forest. It is noteworthy that the species of stingless bees and the species of trees that host them in the University of Ilorin Agro forest need to be documented. Data on trees that host stingless bees are very sparse in literature, therefore, there is a need to document the species of trees that host them and the trees they forage on in the University of Ilorin Agro forest.

Materials and Methods

Study Area

The study site was the University of Ilorin Agro Forest located in the Guinea Savanna region of Nigeria which is predominantly rich in trees and shrubs with evergreen plants that produce pollen in the wet and dry seasons. It lies between 8^{o} 29` 10`` N and $4^{o}$ 40` 38`` E with the elevation of 408 m. The climate of Ilorin is characterized by wet and dry seasons, with annual mean rainfall of about 1150 mm (27). There was, generally, a wide range of variation in climatic elements in the study area, the wet season usually commences around March and ends in October while the dry season is normally from November till February. Mean monthly temperature varies from 25 ^{o}C to 29 ^{o}C, and the relative humidity varies from 70% in the dry months to 80% in the wet months (28-30).

The University Agro Forest was partly clear felled and planted with Jatropha *(Jatropha curcas*) (about 44.5 hectare), Citrus species (about 10 hectares), Teak (*Tectona grandis*) (about 500 hectares), Date palm (*Phoenix dactylifera*) (about 28 hectares), Moringa (*Moringa oleifera)* (about 2 hectares) and Cashew (*Anacardium occidentale*) (about 20 hectares) plantations and these plantations form the dominant vegetation type in the area. The study was carried out between January, 2012 and June, 2012.

In spite of the disturbance in the vicinity of the study area, a good number of wild animals were present and these include monkeys, hares, grass cutters, giant rats, squirrels, snakes and birds.

Sampling Methods

The sampling methods used in the field for the regular sampling of bees include the use of putter (plate 1a) and quadrat (plate 1b). Apart from these, other methods employed in the field include visual estimation of the bees.

Plate 1 a. Putter **b. Quadrat**

Identification of stingless bees

Stingless bee species were collected for identification using Eardley descriptions and identification keys to African stingless bees (31).Plant species and other substrates e.g. doors and windows old buildings that host stingless bees were identified and recorded. Nests of stingless bees were searched and found in about 20 hectares of the agro forest based on the description by Kwapong *et al.*, (32). The behaviour of bees was determined based on aggressiveness, defence mechanism, abscondness after the first visit to the nests. Visual observation of the stingless bees in and around the nests was ensured to record their behaviour.

The vegetation, trees and crops visited by stingless bees were identified and the number and species of honey bees on their flowers were observed and counted for about 10 minutes per 1 m x 1 m quadrat area of the flowers for three consecutive days. The identification of the trees and crops was done in the Department of Forest Resources Management and Plant Biology, University of Ilorin. The behavior of bees on the flowers was observed and then classified into landing on the flower petals, staying on the centre of flower without foraging pollen, and pollen foraging. The pollen source plants were detected by observing the bees collecting pollen loads on their hind legs.

Table 1: Diversity of stingless bees, honey production and pollen harvested in the University of Ilorin Agro Forest

species	N. N	F (%)	C. B. H	N.N. B. H	A. H.	A. P
Dactylurina staudingeri	4	11.77	Mango tree Balsam tree	*Mangifera indica* 1 *Daniella oliveri* 3	-	214g
Meliponula ferruginae	3	8.82	- Gmelina	Dead tree cavity 1 *Gmelina Arborea* 2	1.5 litres	322g
Hypotrigona ruspolii	27	79.41	-	Window 1 Doors 3 Walls 23	-	-

Note:
N. N.: Number of nests of individual species identified in the forest
F: Frequency of the nests found.
C. B. H: Common names of bee hosts (where the nests were found)
N. N. B. H: Names and number of bee hosts (names and number of where nests were found)
A. H: Average honey harvested from the nests
A. P: Average pollen harvested from the nests

Table 2: Number of Identified stingless bees visiting nectar and pollen source trees in the University of Ilorin Agro Forest.

Plants	Common names	*D. staudingeri*	*H. ruspolii*	*M. ferruginae*	*A. melliffera*	Pollination Rewards		Month(s) / Year
						Pollen	Nectar	
Anacardium occidentale	Cashew	60	-	-	40	+	+	January, 2012
Mangifera indica	Mango	25	60	-	20	+	+	Jan/Feb, 2012
Psidium guajava	Guava	45	25	-	30	+	+	March, 2012
Citrus tangelo	Tangelo	-	110	-	6	+	+	April, 2012
Citrus sinensis	Sweet Orange	-	80	-	6	+	+	April, 2012
Citrus nobilis (*deliciosa)*	Tangarine	-	90	-	4	+	+	April, 2012
Citrus paradisi	Grapes	-	42	-	-	+	-	Mar/April, 2012
Citrus reticulata	Cleopatra mandarin	-	58	10	6	+	+	Mar/April, 2012
Thevetia peruviana	Thevetia	-	14	-	-	+	-	April/May, 2012
Jatropha curcas	Jatropha	20	8	-	12	+	+	April/May, 2012
Eucalyptus camaldulensis	Eucalyptus	8	20	-	8	+	+	April/May, 2012
Gmelina arborea	Gmelina	-	88	-	8	+	-	April/May, 2012
Albizia spp.	Albizia	-	12	-	6	+	-	April/May, 2012
Delonix regia	Flame of the forest	16	22	20	10	+	+	May/June, 2012
Terminalia catappa	Almond	-	12	-	2	+	+	April/ May, 2012
Hura creptans	Sand box tree	-	6	-	-	+	-	April, 2012
Crossopteryx febrifuga	African bark	20	22	-	9	+	-	April/May, 2012
		7 (41.2%)[a]	16 (94.1%)[b]	2 (11.8%)[c]	14 (82.4%)[d]	17 (100%)[e]	11 (64.7%)[f]	

+ = present and - = absent

a. Number and percentage of trees visited by D. Staundingeri
b. Number and percentage of trees visited by H. ruspollii
c. Number and percentage of trees visited by M. ferruginae
d. Number and percentage of trees visited by A. Melliffera
e. Number and percentage of trees that produce pollen
f. Number and percentage of trees that produce nectar

a b c

Plate 2: (a.) Nest of *D. staudingeri*. before opening (b.) brood section after opening (c.) pollen store (pollen cups) and brood section after opening.

Plate 3: Pollen harvested from *D. staudingeri*.

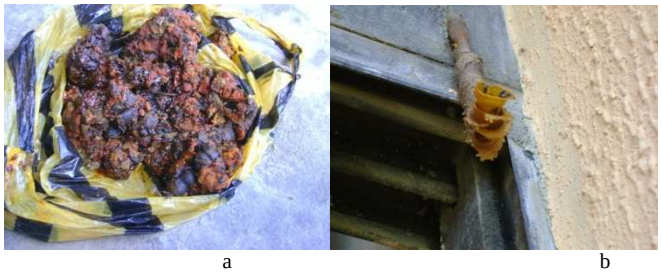
a b c

Plate 4: (a.) Nest of *M. ferruginae* before disturbance (b.) and (c.) the nest after opening.

Plate 5: Brood section and nursing bees

a b c

Plate 6: (a.) Two capped queen cups of *M. ferruginae* (b.) Raw honey and (c.) filtered honey harvested from the nest.



a b

Plate 7: (a.) pollen grains harvested from the *M. ferruginae* nests (b.) Nest of *H. ruspolii* in a window.

Results

Diversity, nests and behaviour of stingless bees

Table 1 shows three species of stingless bees encountered in the study area namely *Dactylurina staudingeri*,*Meliponula ferruginae*and *Hypotrigonal ruspolii*. The species were associated with four (4), three (3) and twenty seven (27) nests respectively.

One nest of *D. staudingeri* (Plate 2a) was found on a mango tree, *Mangifera indica* while the remaining three were located on Balsam tree, *Daniella oliveri*. This represents 11.77% of the total number of nests identified in the study area. *D. staudingeri* constructs aerial nest using wax, resin, plant materials and soil particles in making batumen.

Attempts to collect *Dactylurina staudingeri* from the opening of the nest stimulated the watching guards (workers) to attack by biting and possibly secreting an alarm pheromone. A sticky substance was left on the cloth of the observer after the attack which looks like pollen found in the nest of the bees. After the opening of the nest, the bees remained in the nest for a week before absconding due to the disturbance by pests like ants and *Apis mellifera* stealing the little honey and pollen left in the store.

The broods section was in rows, coil and laid vertical (Plate 2b). Large quantities of pollen bread were found in the pollen pots of the bees (Plate 2c) and this could be due to the large number of broods found in the nest. Honey could not be harvested from the nests because of the time of the year when the nest was opened but honey pots were found. About 214g of pollen bread (Plate 3) was harvested from the nest.

Three nests of *Meliponula ferruginae* (Plate 4a) were found, one in a cavity of a dead tree and two in cavities of Gmelina arborea. The cavity was lined with batumen (Plate 4b). This represents 8.82% of the total number of the nests identified in the study area. The cavity was divided into honey store (Plate 4c), pollen store and brood section (Plate 5).
The guards of *Meliponula ferruginae* withdrew and the bees were only hovering in the air when the nest was disturbed. *Meliponula ferruginae* did not show any sign of aggressiveness. The brood section was in layers laid horizontally (Plate 5c). Two queen cells were found in the nest (Plate 6a). Average of 1.5 litres (Plate 6b and 6c) of honey was harvested from the nest during the nectar dearth period (wet season). About 322g (Plate 7a) of pollen was harvested from the nest.
Twenty seven (27) nests of *Hypotrigona ruspolii* were identified in the study area. They were found in windows (Plate 7b), doors, and walls of old buildings. This represents 79.41% of the total number of the nests identified in the study area. The nests were not opened because they were found in windows and doors.

Pollination Activity
Table 2 shows that a total of seventeen plants/crops were visited by stingless bees out of which eight were fruit crops (*Anacardium occidentale, Mangifera indica, Psidium guajava, Citrus sinensis, Citrus tangelo, Citrus nobilis, Citrus paradisi, Citrus reticulata*), two were oil crops (*Jatropha curcas* and *Thevetia peruviana*) and seven were trees of economic importance (*Gmelina arborea, Delonix regia, Eucalyptus camaldulensis, Albizia spp., Terminalia catappa, Hura creptans and Crossopteryx febrifuga*) in the study area. *Dactylurina staudingeri* was found on 41.2% of the plants, *H. ruspolii* on 94.1%, *M. ferruginae* on 11.2% and *Apis mellifera* (common honey bees) on 82.4%. All the flowering plants identified were pollen producers (100%) while 64.7% were nectar producers. The data collected indicated that these plant species provided a food source for the bees in the form of pollen and nectar.
Table 2 further shows that *D. staudingeri* was found in great numbers on fruit crops (*A. occidentale, M. indica* and *P. guajava*), oil crop (*J. curcas*) and trees. It was found mostly on *A. occidentale* followed by *P. guajava. Hypotrigona ruspolii* was found in great number mostly on fruit crops especially Citrus species except *A. occidentale*. It was also present on the two oil crops and trees with the highest number occurring on *G. arborea.Meliponula ferruginae* was only found on two plants , a fruit crop (*C. reticulata)* and a tree (*D. regia). Apis mellifera* was found in all the fruit crops except *Citrus paradisi* and it was more on *A. occidentale, M. indica* and *P. guajava* than Citrus species. It was also found on *J. curcas* but not on *T. peruviana*. It was found in all the trees except *H. creptans. Hypotrigona ruspolii* visited all the plants except *A. occidentale* and it was more on most of the plants than other honey bees. Higher numbers of *D. staudingeri* visited many of the plants compared to *A. mellifera*.

Discussion

Diversity, Nests and Behaviour of Stingless Bees
Three species of stingless bees namely *Dactylurina staudingeri, Meliponula ferruginae* and *Hypotrigonal ruspolii* have been identified in the University of Ilorin agro forest. The findings showed that *D. staudingeri* construct aerial nest while *M. ferruginae* and *H. ruspolii* are cavity nesters. *D. staudingeri* found on tops of *D. oliveri* and *M. indica* could be a defence mechanism adopted by the species. *D. staudingeri* nests were found more on *Daniella oliveri* and this might be due to the tallness of the tree which was about 15m in height. The behaviour of the bees showed that they were not as aggressive as *Apis mellifera.* The alert pheromone secreted by *D. staudingeri* when biting was not as strong as that of *Apis mellifera*. *Dactylurina staudingeri* and *Meliponula ferruginae* can survive in the study area considering the large quantities of pollen and the number of broods associated with their nests. Elton *et al.,* (33) showed strong positive correlation between brood and pollen collection. This further demonstrated that they were aggressive pollen collectors indicating that they are efficient pollinators. Delaplane and Daniel (34) reported that pollen collectors are efficient pollinators.
Meliponula ferruginae did not show any sign of aggressiveness during honey harvest. Within a month after disturbance the bees rebuilt the nest. This is a good behavior of bees that can be cultured for honeybee products and pollination in the study area.
Finding the nests of *Hypotrigona ruspolii* in windows, doors and walls is an indication of deforestation indicating indiscriminate felling of trees as species of trees hosting the bees might have been cut. The species richness of honey bees and where they are found can serve as a bio indicator of the state of the environment (Kevan, 1999).

Pollination Activity
The plants visited by the bees in the study area were pollen producers which stand the better chance of being pollinated by the bees because the bees visited many flowers of the same species. Delaplane and Daniel (34) observed that honey bees exclusively visited many flowers of the same species during a single trip and the pollen has a greater chance of coming in contact with stigma, the pollination efficiency of the plants might be improved. In another investigation, Free*et al.,* (35) observed that pollen foragers provide better pollination than nectar foragers.
This research demonstrated that most of the fruit crops in the study area were pollinated by stingless bees considering the large number of *H. ruspolii* found on *Citrus sinensis, Citrus paradisi, Citrus nobilis, Citrus reticulata, Citrus tangelo* and *Mangifera indica* as well as large number of *D. staudingeri* on *Anacardium occidentale, Psidium guajava* and *Mangifera indica.* Slaa *et al., (*19) demonstrated that starfruits, mango, durian, watermelon, guava and coconut could be pollinated by stingless bees. This was further buttressed by Klein *et al*., (5) who showed that yields of certain fruit, seed and nut crops will decrease by 90% without stingless bees. Two oil crops (biodiesel crops), *Jatropha curcas* and *Thevetia peruviana* were pollinated by stingless bees as only H. ruspolii was found on *Thevetia peruviana* and *D. staudingeri* and *H. ruspolii* were found collecting pollen and nectar on *Jatropha curcas*. This was also demonstrated by Klein *et al.,* (5) who showed that yields of certain fruit, seed and nut crops will decrease without honey bees which are efficient pollinators. This was further proved by Gallai *et al*., (36) who showed that the leading pollinator-dependent crops are vegetables and fruits followed by oil crops, stimulants (coffee, cocoa etc.), nuts and spices.
Stingless bees identified in the area were responsible for the pollination of trees of economic importance like *Gmelina arborea, Eucalyptus camaldulensis, Terminalia catappa* and *Delonix regia*.
The high foraging density of *H. ruspolii on Citrus sinensis, Citrus paradisi, Citrus nobilis, Citrus reticulata, Citrus tangelo, Mangifera indica* and *Gmelina aborea* might be because they produce large quantities of nectar and pollen and have conspicuous flowers. Similar observation was made by Southwick *et a*l., (37) that bee visitation rates increased in flowers patches with increasing number of nectar bearing flowers, nectar volume and sugar concentration.

Meliponula ferruginae found on very few plants showed that the bees are selective and exhibit flower constancy and bees that exhibit high flower constancy are efficient pollinators. Heinrich (38) and Wells and Wells (39) had earlier demonstrated that honey bees showed flower constancy by restricting their foraging activity to one or few flowering species.

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