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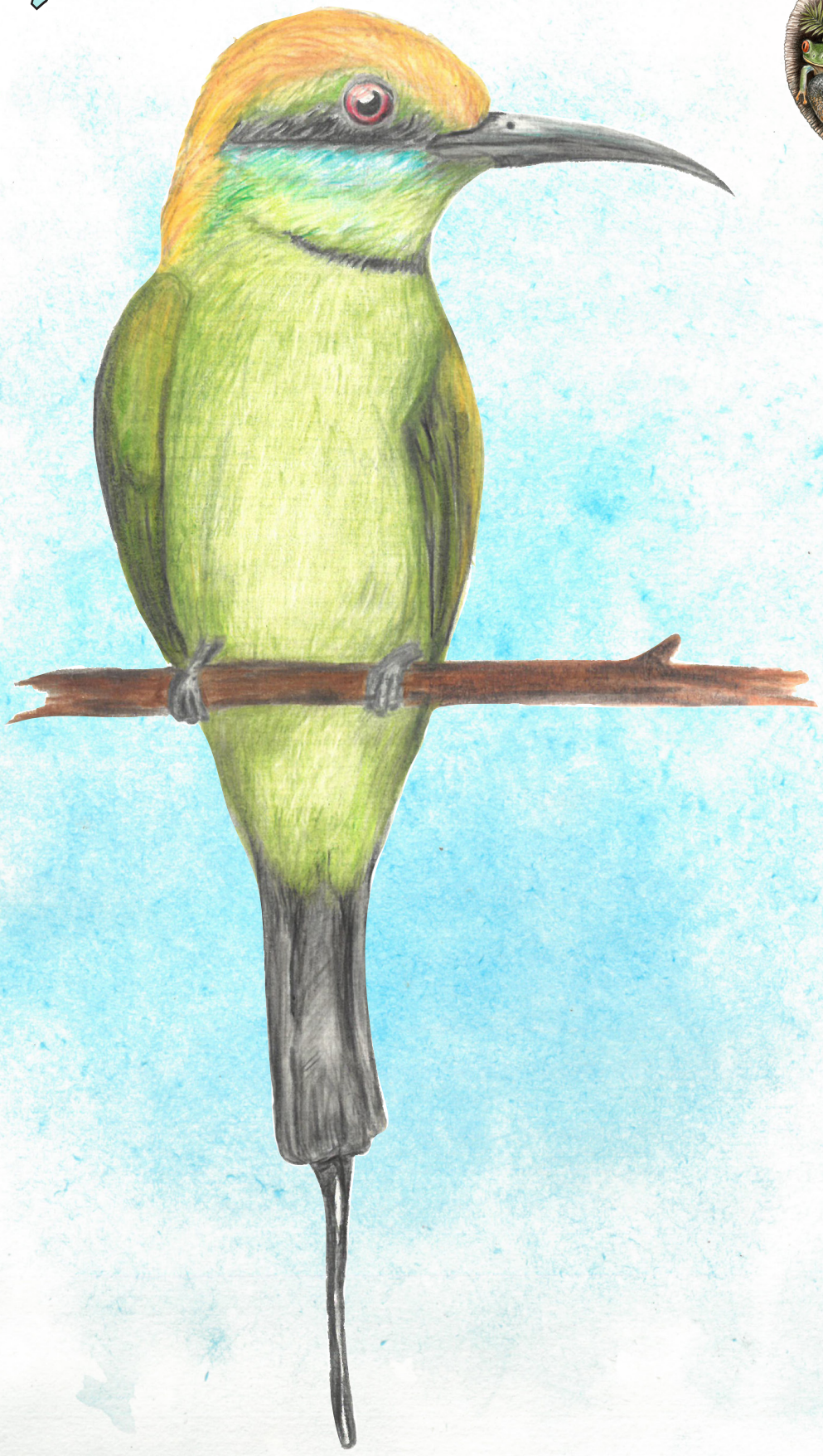

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Cover: Green Bee-eater with colour pencils and watercolor wash by Elakshi Mahika Molur.

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SHORT COMMUNICATION

Diversity of bees in two crops in an agroforestry ecosystem in Kangsabati South Forest Division, Purulia, West Bengal, India

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Abstract: The investigation study assesses the diversity of bees in Brinjal *Solanum melongena* L. and Ridge Gourd *Luffa acutangula* L. crop field from agroforestry ecosystem in South Kangsabati Forest Division, India. The study was carried out in May 2021 to May 2022 that based on transect, focal observation and pan trap samplings. A total of 1,085 individuals were identified during the field work, belonging to three family seven genera (*Apis*, *Tetragonula*, *Xylocopa*, *Ceratina*, *Amegelia*, *Nomia*, and *Megachile*) and seventeen species, the non *Apis* bees (63.78%) were most abundant than *Apis* bees (36.22%). In brinjal, Shannon diversity index of bees is 2.12 and Shannon evenness index is 0.35, whereas, Shannon diversity index in ridge gourd was 1.94 and Shannon evenness index is 0.3. The observations signify greater diversity and population of wild bees. The natural habitat close to agricultural land helps to sustain the diversity and population of wild bees, which enhance the crop quality and yield.

Keywords: Agro forestry, *Apis* bees, eggplant, non *Apis* bees, pollinator, Ridge Gourd, *Tetragonula*, *Xylocopa*.

Now-a-days, agroforestry is an important ecosystem especially in a tropical country and it is an intensive land management system. It consists of agriculture systems and have potential biodiversity conservation sites. The agroforestry ecosystem provide rural livelihood alongside biodiversity conservation in a sustainable land use system. This system is a transitional process from conventional agricultural practices to agro-ecological agricultural practices (Souza et al. 2014). Combination of crops and diverse plants species in forest provide a rich insect diversity due to increased niche diversity than any agro-ecosystems (Stamps & Linit 1998). Heterogeneous agroforestry ecosystem provides floral resources for pollinators (Sinu & Shivanna 2007). Habitat loss and intensification of agricultural practices threaten wild as well as domestic pollinators. Agroforestry ecosystem provides them suitable nesting sites and floral resources, enhancing their pollination services to crops at a landscape level (Sutter 2017; Kay et al. 2019). Bees are the primary pollinators and roughly cover 90% of world plant population (Winfree 2010).

In agriculture land bees are the essential pollinators for pollination as well as crop production. Non *Apis* species are effective pollinators than honey bees (Javorek 2002; Kreman et al. 2002), but they both can together enhance crop production (Greenleaf & Kreman 2006). Brinjal *Solanum melongena* L. and Ridge Gourd *Luffa acutangula* L. are important and widely cultivated crops across the studied area and also bee-attracting vegetable crops. Buzz pollinators are effective pollinators for solanaceous (Brinjal) and cucurbitaceous (ridge gourd) crops. Brinjal flowers have abundance of pollen but to expel the pollen requires vibration by insects called 'buzz pollination'. Wild bees are efficient in buzz pollination than honey bees (Buchmann 1983; Herren & Ochieng 2008). Natural forest is a suitable habitat for wild bees but due to extensive deforestation they are

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in threat. This investigation was carried out to generate information about the diversity of bees in pollination dependent crops in an agroforestry ecosystem.

Study Area

The study was conducted in an agroforestry ecosystem in western part of West Bengal, India. The studied area is in Kangsabati South Forest Division in Purulia. The forest division is situated between 23.166–22.833 N & 86.666–87.000 E, covering 310.27 km^2 areas, which are continuations of the Chotanagpur Plateau (Figure 1). Mixed cropping system is practiced dominantly in the studied area. Fourteen plots were selected randomly throughout the South Kangsabati Forest Division on the basis of easy accessibility and densely blooming flowering plots. These fourteen plots were equally divided into seven plots for each crop. The experimental study was conducted in various farm lands from May 2021 to May 2022 in the eggplant and ridge gourd crops fields.

Methods

All bee surveys were conducting from 0830 h to 1630 h, split in three time hours: 0830–0930 h, 1130–1230 h, & 1530–1630 h. Bees are active in warm, sunny days so rainy and cloudy days were avoided for the unbiased data. Three methods—transect, focal observation (15 mins), and pan traps (yellow, white, blue colored pan traps)—were followed throughout one year of survey. The transect length was 100 m with 2-m breadth on each side (Sutherland 1996). In focal observation (Gibson et al. 2011), a 1 m^2 flowering plot was selected randomly and bees were observed for 15 mins. Pan traps of three different color sets were used for passive sampling (Westphal et al. 2008). Yellow, white, blue pan traps were used which were painted with UV-bright colors. Five clusters of pan traps were installed where each cluster was separated from another by a distance of 15 m. Each cluster contained three sets of pan traps filled with 400 ml soapy water. The species not identified in the field were collected through sweep net, killed by ethyl acetate, and preserved in 70% ethanol for future

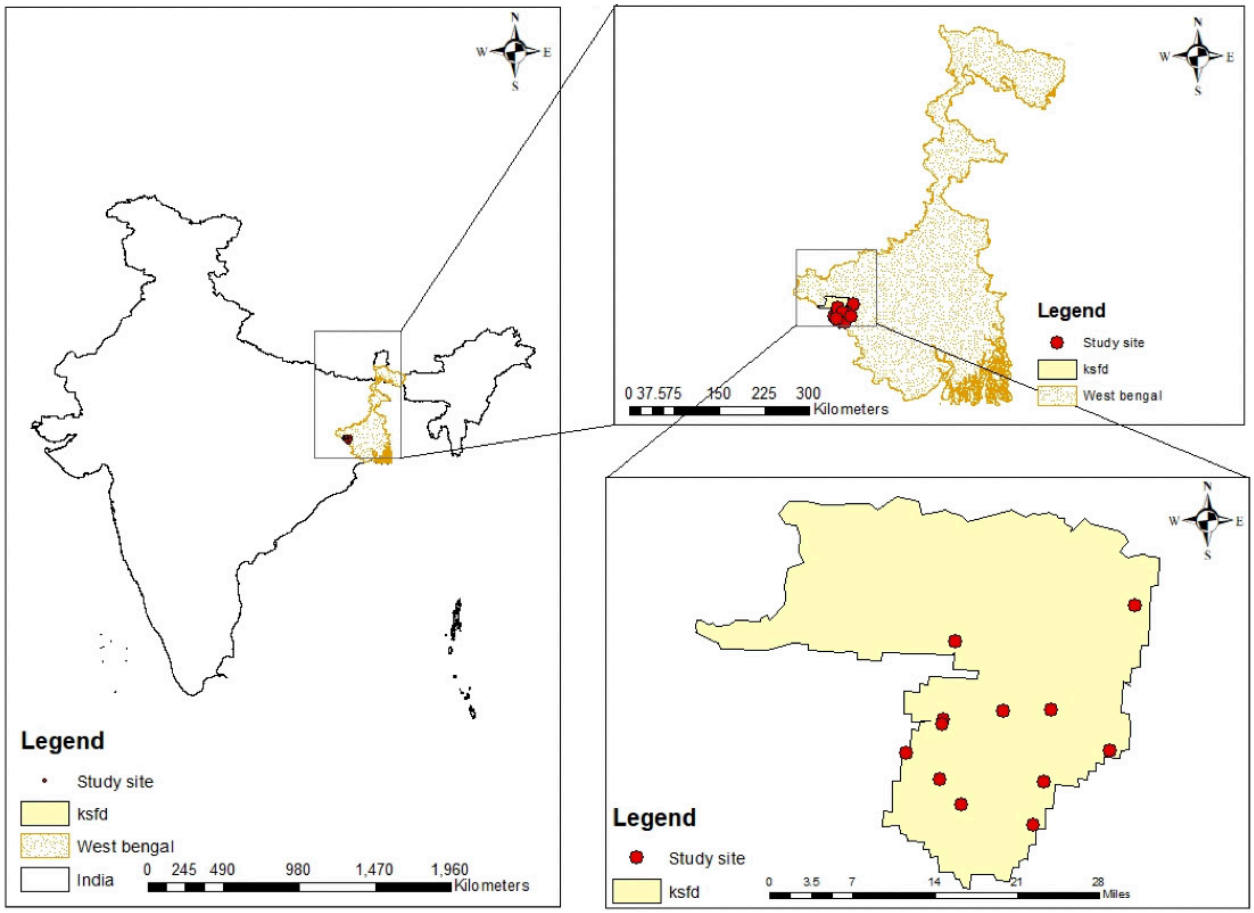

Figure 1. The study site Kangsabati South Forest Division (KSFD), Purulia, West Bengal, India.

reference. We followed Bingham (1897) and Michener (1974, 1994, 2007) for bee identification.

We observed diversity and abundance of bees by observing bees visiting Brinjal and Ridge Gourd flowers. These data were used for analyzing bee diversity by Shannon diversity index (H') and Shannon evenness index (J'). The number of bees data (sampled via transect, focal observation & pan trap) were pooled in each crop independently for analysis of richness and abundance. The data were analyzed using Past Software 3.4.

Shannon Diversity Index (H') = $-\Sigma p_i * ln(p_i)$

Shannon evenness index (J) = H/lnS

Relative Abundance= $(N_i/N)*100$

Where, S is the total number of species and p_i is the proportion of the entire community made up of species i. N_i is the abundance of species i and N is the total of all species encountered.

Results and Discussion

A total of 1,085 bee individuals were encountered belonging to three families (Apidae, Halictidae, Megachilidae), seven genera and 17 species during the survey. *Tetragonula iridipennis* was most dominant species with 262 individuals followed by *Apis florea* (182 individuals) and *Nomia elliotii* (169 individuals). Most of the bee species belonging to the family Apidae were observed during the study. During the survey time, non *Apis* bees (63.78%) were dominant in abundance than *Apis* bees (36.22%).

Among these two vegetable crops, Brinjal had most diverse and abundant number of bee visitors. Shannon diversity index of bees in eggplant crop is 2.12 and Shannon evenness index is 0.35; the most abundant bee species was *Tetragonula iridipennis* (33.97%) followed by *Megachile lanata* (14.83%), *Nomia elliotii* (14.59%), *Xylocopa fenestrate* (9.09%). Some rare bees like *Megachile hera* (0.7%), *Nomia westwoodii* (1.7%), and *Ceratina hieroglyphica* (1.2%) were also encountered. The pollinator fauna of Brinjal consist of two species from Megachilidae, three species from Halictidae, and six wild bee species from Apidae family.

In the Ridge Gourd, the Shannon diversity index was 1.94 and Shannon evenness index was 0.3, *Apis florea* was the most abundant species with 23.48%, followed by *Apis dorsata* (21.25%) and *Tetragonula iridipennis* (17.83%). *Amegilla zonata* (0.74%) and *Megachile lanata* (0.3%) were rare visitors of ridge gourd flower. *Apis* bees were the most dominant visitors of ridge gourd flower followed by *Nomia elliotii* of Halictidae family, bees from subfamily Xylocopinae (*Xylocopa* & *Ceratina* bees) were frequently observed from Apidae family. Among wild bees, *Xylocopa fenestrata* and *Nomia elliotii* were dominant throughout the survey in both the crops.

Patricio et al. (2012) recorded the role of bees as

Table 1. List and abundance of the bee species individuals encountered during the survey of Brinjal and Ridge Gourd fields.

Order	Family	Species	Brinjal	Ridge Gourd	Total
Hymenoptera	Apidae	*Apis dorsata* Fabricius, 1793	8	143	152
		Apis cerena Fabricius, 1793	10	49	59
		Apis florea Fabricius, 1787	24	158	182
		Tetragonula iridipennis Smith, 1854	142	120	262
		Xylocopa fenestrate Fabricius, 1798	38	25	63
		Xylocopa aestuans Linnaeus, 1758	7	16	23
		Xylocopa magnifica Cockerell, 1929	0	8	8
		Xylocopa sp.	3	0	3
		Ceratina smaragdula Fabricius, 1787	0	39	39
		Ceratina hieroglyphica Smith, 1854	5	0	5
		Amegilla zonata Linnaeus, 1758	16	5	11
		Amegilla calceifera Cockerell, 1911	13	0	13
	Halictidae	*Nomia elliotii* Smith, 1875	61	108	169
		Nomia crassipes Fabricius, 1798	22	0	22
		Nomia westwoodi Gribodo, 1894	7	0	7
	Megachilidae	*Megachile lanata* Fabricius, 1775	62	2	64
		Megachile hera Bingham, 1897	3	0	3

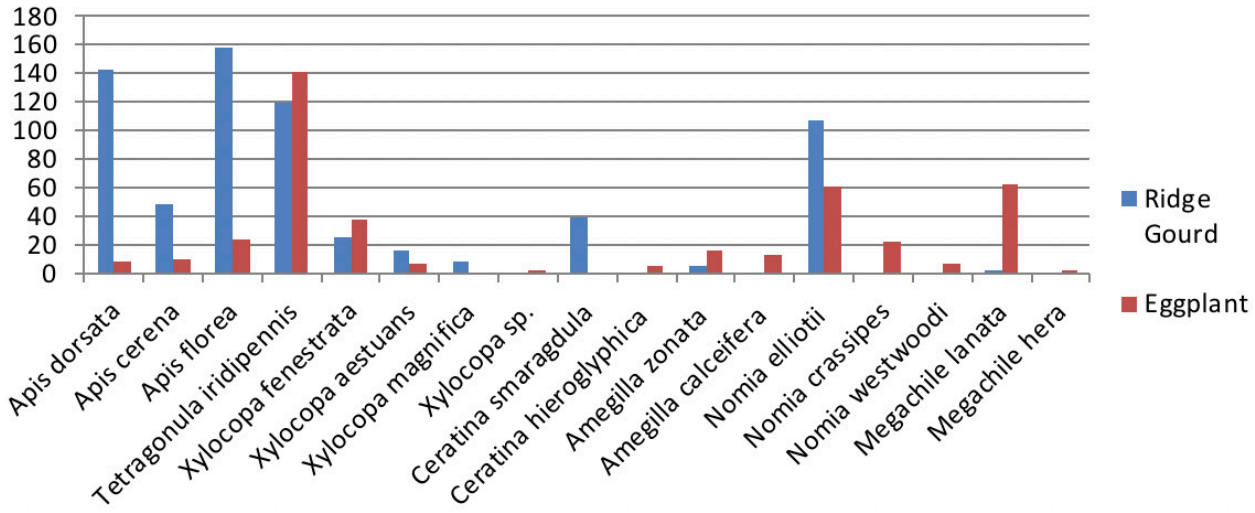

Figure 2. Relative abundance of bees in Ridge Gourd and Brinjal crop fields, where Y axis indicates individual number of bee species & X axis indicates bee species.

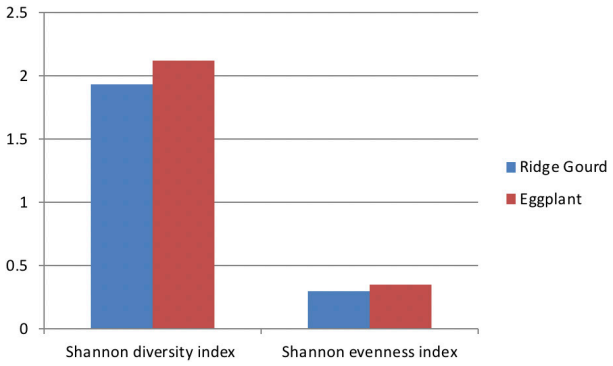

Figure 3. Shannon diversity index & Shannon evenness index of bee species in the Ridge Gourd & Brinjal crop fields.

very significant in promoting good yields in Brinjal. Our results exhibit that stingless bees *Tetragonula iridipennis* are effective pollinators for both the crops in fields and similar results observed in greenhouses by Silva et al. (2013). In an earlier study, Herren & Ochieng (2008) observed that *Xylocopa caffra* was an effective pollinator of Brinjal crop and its visitation rates significantly reduces with the distance from wild habitat. Land management is one of the factors which determines the efficiency of pollination in agriculture (Patricio et al. 2012) as flowers of wild plants was important foraging source for bees. Agro-ecosystem, close to high proportion of natural habitat is benefited by bee diversity, foraging movement, and their mutualistic behavior (Hagen & Kraemer 2010; Balachandran et al. 2017). Agroforestry not only provides niche diversity, it also reduces pest problems (Stamps & Linit 1998).

Conclusion

The experimental study proves that there is a great diversity and abundance of non *Apis* bee species along with *Apis* bee species present in Brinjal and Ridge Gourd fields, as surrounding natural habitat provide them alternative habitat and floral resources which enhance the diversity and population of wild bees.

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