Importance of stingless bees as alternative pollinators in crop pollination

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For fruit and seed set, most of the crop plants depend on pollination and insect pollination of crops is a critical ecosystem service. More than 75 % of the 115 major crop species directly depend upon animal pollination, whereas only about 28 % crop species depend on wind and self-pollination worldwide (Klein et al., 2007). It is well reported that one third of the total human food supply relies on insect for pollination (Jivan, 2013; Said et al., 2015). The insect pollination value for agricultural production in worldwide is estimated to be € 153 billion, representing 9.5% value of the world agricultural production used for human food in 2005 (Gallai et al., 2009). As far as India is concerned, the total value of Indian agriculture is 1291369.63 crores at 2012-13 prices or USD 258.27 billion and the proportion of animal pollinated crops is 422827.52 crores ($ 84.57 billion), representing 32.74%. Whereas, the direct contribution of insect pollination to Indian agriculture is staggering 112615.73 crores (USD 22.52 billion) annually, representing 8.72% (Chaudhary and Chand, 2017). Co-evolution between flowering plants and their pollinators started about 225 million years ago (Price, 1975). Insects from the orders of Hymenoptera, Lepidoptera, Diptera, Coleoptera, Thysanoptera, Hemiptera and Neuroptera reported as major pollinators of different crops (Mitra et al., 2008). Among different insect group, bees are the most important and constitute more than 80% of the total. Effective pollination results in increased crop production, quality improvement, and more seed production. Many of fruits, vegetables, edible oil and nuts are highly dependent on bee pollination (Irshad and Stephen, 2014).

Stingless bees

Stingless bees are the smallest honey producing bees belong to the family Apidae, subfamily Apinae and tribe Meliponini. Rearing or beekeeping with stingless bees is called meliponiculture. They are eusocial like true honey bees and live in perennial colonies, consisting of hundreds or thousands of workers (Wille, 1983). They are widely known as dammar bees in India, since dammar is a kind of resin collected from dipterocarp trees for construction of their nest along with wax produced from their body (Rasmussen, 2013). They differ from *Apis* species in terms of biology and nesting characteristics. In stingless bee the larval feeding process is termed as mass provisioning, whereas in *Apis* spp., progressive feeding with royal jelly and bee bread during growth and development of the larvae can be seen (Heard, 1999). On the contrary, in nest architecture, numerous elliptical/spherical pots can be seen to store honey and pollen, made by “cerumen”, a mixture of wax secreted from wax gland and resins collected from plants (Quezada-Euán, 2018). They prefer to make their nests in dark places like empty logs, cavities in tree trunks, cracks and crevices in old walls etc.,

where the nest entrance mostly projects as an external tube (Wille, 1983). In India, Danaraddi (2007) reported that the *T. iridipennis* was found to be nesting in tree cavity and wall cavity at Dharwad. Roopa (2002) and Gajanan et al. (2005) found the similar nesting behaviour of *T. iridipennis* in Bangalore and Muthuraman (2006) in Tamil Nadu. Also in a recent study, Kunal et al., (2020) reported nesting of *T. bengalensis* in tree-cavities, concrete wall, mud wall, iron pipe and wash basin from West Bengal, India. The name stingless bee implies due to having no or vestigial form of sting. Hence, they protect their nest from intruders very effectively by biting with their stout mandibles and also get into the hairs, ear and nose of the intruders (Muthuraman et al., 2013).

Diversity and distribution

Stingless bees evolved around 80 million years, before - longer than *Apis* bees and assumed to be emerged first in African continent and later spread across the rest of the world (Crane, 1992; Wilie, 1983). The inefficiency of controlling nest temperature, especially when the temperature is low, limited their distribution to tropical and subtropical areas and they are found in Australia, Asia, Central and South America (Muthuraman et al., 2013). Meliponinae includes 8 genera with 15 subgenera and having more than 500 species worldwide (Wille, 1983). Similarly three genera viz., *Tetragonula, Lepidotrigona* and *Lisotrigona* with eight named species of stingless bees are found to be distributed throughout the Indian subcontinent (Rasmussen, 2013) and among the different species, *Trigona* (*Tetragonula*) *iridipennis* most commonly seen in India (Raakhee and Devanesan, 2000).

Why alternative pollinators?

Though the group bee is widely diversified (wild and managed bees), the managed bees of *Apis* spp. (*Apis mellifera* and *Apis cerana*) appear as major crop pollinators across worldwide due to its manageable property. But threats include habitat destruction or alteration, overuse of pesticides, parasites and diseases, and the introduction of alien species resulting rapid declining of both managed and wild bees' population, causing global concern for pollination services (Buchmann and Nabhan, 1996).

Additionally, honeybees are not always the most suitable pollinators due to various factors, e.g. a miss-match in body size and flower size, low in nectar production and specialized pollen release mechanisms in some plants, including those with poricidal anthers (ex. solanacceous plants) (Kearns and Inouye, 1997). Hence, diversification of crop pollinators would help to achieve pollination services when the commonly used pollinator (specifically honeybees for most crops nowadays) is not available in sufficient numbers.

Stingless bee as an alternative pollinator

Sometimes the wild or non-Apis bees effectively complement honey bee pollination in many crops, including the solitary bees Nomia and Osmia (for orchard crops), bumble bees (for Solanaceae crops e.g. tomatoes), Megachile bees (for alfalfa) and more recently, stingless bees (Free, 1993; Heard, 1999). But most of these non-Apis bees have limitations, such as solitary bees have limited life span of annul cycle, bumble bees only found in higher altitudes etc. and in this context diverse group of stingless bees (Meliponini) can be appeared

as future potential pollinators (Heard, 1999). Though distribution throughout the tropical and subtropical parts of the world with significant variation in colony size (from a few dozen to tens of thousands of individuals), body size (from 2 to 14 mm; compare to 12 mm for honeybees), and foraging strategy (some species recruit nest mates to high quality food sources, like honeybees, whereas others forage mainly individually like bumble bees) give adaptive advantages to stingless bees as alternative pollinators over non-Apis bees (Roubik, 1992; Michener, 2000). In addition, colonies are naturally long-lived and perennial; don't die after reproducing, unlike *Bombus* (Slaa, 2006), thus can forage year-round. Similarly, like true honey bees, they are domesticated and can be manipulated in relatively small hives. Their small size allows them to co-exist peacefully with other commercial bees as they can access many kind of flowers, whose openings are too narrow to permit penetration for other bees (Abrol, 2012). Being true generalists and perennial, they can collect nectar and pollen from a vast array of plants throughout the year (Roubik, 1989; Biesmeijer et al., 2005).

Lacking of functional sting and having smaller foraging range than that of the honey bees, they can be efficiently used as pollinators in confined spaces such as cages and greenhouses (Katayama, 1987; Kakutani et al., 1993). In contrast to the honey bee (*Apis* spp.), stingless bee colonies are typically long-lived (Roubik, 2006; Quezada-Euán, 2018) and have low absconding behaviour. Unlike honey bees, they are not affected by the various diseases (bacterial, viral or fungal) and parasites (mites), however, they have their own natural enemies but neither shared with honey bees nor very serious (Abrol, 2012). More importantly, certain larger species of the genus *Melipona* are capable of buzz pollination, where pollen is released through vibration or sonication i.e. buzzing from poricidal anthers of solanaceae plants (e.g. tomato and eggplant) (Buchmann, 1983).

Crops pollinated by stingless bees

Stingless bees can act as pollinators of a wide range of plants including vegetables, pulses, oilseeds, fruit trees, plantations etc. throughout the tropical and subtropical parts of the world, few list of plants presented in table 1. Apart from these (tropical and subtropical crops), there are certain plants that are visited by stingless bees but pollination occurs occasionally or partially, examples are fruits like Peach, Pear, Plum etc.; although there are many crops for which stingless bee pollination has not been thoroughly investigated (Heard, 1999).

Limitations of stingless bees

The major disadvantage of stingless bees as pollinator use is their distribution. They are limited to the tropical and subtropical regions due to their inefficiency of controlling nest temperature, especially when the temperature is low. Although attempt has been made to maintain colonies indoors in colder climates, using temperature-controlled rooms and/or hives (Amano, 2004). Apart from this, study also showed that stingless bee, *Trigona fulviventris* affect the pollination of plants by damaging the flowers, where they cut anthers to access pollens and often styles, during their lengthy visits on *Eriocnema fulva*, a threatened Melastomataceae of the Atlantic Forest, Brazil (Rego et al., 2018).

Conclusion

The characteristics like eusociality, colony perenniality, floral constancy, polylecty, harmlessness etc. enhance the importance of stingless bees as effective crop pollinators for both cultivated and wild floral diversity. But the lack of proper knowledge about meliponiculture as well as insufficient study of pollination effect of stingless bees on different crops should be considered for better improvement in future aspect.

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Table 1. List of plants pollinated by stingless bees

Sl. No.	Plant group	Plants
1.	Pulses	Pigeon pea
2.	Vegetables	Cucumber, Water melon, Squash, Bitter gourd, Sweet pepper, Eggplant, Onion, Ash gourd (Chauhan et al., 2019)
3.	Oil seeds	Sun flower, Castor, Niger
4.	Spices	Cardamom, Coriander
5.	Fruits	Peach (Cortopassi-Laurino et al., 1991), Plum & Pear (Boonithee et al., 1991), Guava, Citrus, Litchi, Strawberry, Jack fruit, Bread fruit
6.	Trees	Indian jujube, Subabul, Soap nut, Kapok, Tamarind, Sago palm, Rubber, Eucalyptus

Source: Abrol, 2012