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Diversity and abundance of insect pollinators on avocado (*Persea Americana* Mill.) and rambutan (*Nephelium lappaceum* L.) and their contribution to fruit set

B. R. JAYANTHIMALA* and P.V. RAMI REDDY

Division of Crop Protection, ICAR-Indian Institute of Horticultural Research, Hesaraghatta Lake P.O., Bengaluru-560089, India

***E-mail:** entjaya@gmail.com

ABSTRACT: Diversity of pollinator fauna in two fruit crops *viz.,* avocado and rambutan was assessed. Peak foraging hours of pollinators were recorded in order to decide the plant protection practices without affecting the pollinators. The peak foraging hours in avocado were between 9.00 AM and 4.30 PM and in rambutan from 9.00 AM to 12.00 noon. The major pollinators observed foraging on avocado were honey bees (*Apis cerana* Fab*., Apis florea* Fab.) and dipteran flies (Syrphids).However, in rambutan, *Apis florea* was observed as the predominant pollinator. Pollinator diversity, peak foraging hours, role of pollinators in fruit set are discussed in detail.

Keywords: Pollinators, *Apis cerana, Apis florea,* avocado, rambutan

INTRODUCTION

Pollination is an important key process in any of the ecosystems and is directly correlated with the abundance of the pollinators. Under humid tropics, several fruits are being cultivated *viz.,* avocado, litchi, rambutan, kokum, garcinia etc. More than 73% of the crops are pollinated by bees (Zych and Jakubiec, 2006) followed by other group of insects like flies, wasps, butterflies, thrips etc. Most of these fruit crops are highly cross pollinated and need to decide the time of plant protection measures to conserve pollinators. An attempt was made in this study to understand the pollinator diversity, abundance and their peak foraging hours on avocado and rambutan, two crops gaining popularity in the recent past.

Avocado (*Persea americana*) belongs to the family Lauraceae, and is mainly dependent on insect pollination (Ish-Am and Lahav, 2011). One of the reasons for low fruit set is inadequate pollination. Avocado has perfect flowers but exhibits protogynous diurnally synchronous dichogamy (PDSD). It produces two types of flowers *viz.,* A type and B type. Female phase opens early in both types. In A type, the female phase opens in the morning and the male phase will open in the next day afternoon while in B type, the female phase opens in the afternoon and the male phase opens in the next day morning (Gazit, 1976). Sequential development of reproductive function observed in avocado flowers (Ish-Am and Lahav, 2011). The flower opens two times, on first day stigma is receptive and the second day only stamens open and pollen dehiscence occur. Thus, the self-pollination is almost ruled out and cross pollination through insects is of crucial importance in avocado fruit set. Rambutan (*Nephelium lappaceum* L.) of family Sapindaceae too is an entomophilous fruit crop. Also called the "hairy" lychee, it is a native of Malaysia and Indonesia and is widely grown in Southeast Asia. (Lim, 1992; Zee, 1993; Zee *et al*. 1998). Under humid tropic conditions rambutan flowers during the months of March-April (CHES, Chettalli).The inflorescence of rambutan is erect, widely branched, bearing many flowers, and are produced mainly on shoot tips although pseudo terminal panicles also occur. The flowers are either male or hermaphrodite (Tindall, 1994).The female flowers produce two-three times more nectar than male flowers, therefore, rambutan is an important nectar source for bees. The absence of free pollen on the anthers of the hermaphrodite flowers suggests either the need for pollen transfers from the male tree for fertilization of that the hermaphrodite trees capable of apomictic fruit formation (Van Welzen *et al*, 1998). Considering the importance of insect pollinators in both these crops, studies were conducted to document pollinator diversity and their foraging ecology on avocado

MATERIALS AND METHODS

Field experiments were conducted at Central Horticultural Experiment Station (CHES) Chettalli, Kodagu (12.38^{o}N; 75.64^{o}E), Karnataka, India during 2013-14 to document pollinator diversity and foraging behavior on avocado and rambutan. Observations were recorded during flowering periods of avocado (September-October,2013 and 2014) and rambutan (March-April 2013 and 2014). In addition to natural

pollinator fauna, both the orchards were within reach of honey bees (*Apis cerana indica* F.) from the apiary of CHES farm. Open pollinated rambutan and avocado plants were planted at 6 x 6 m spacing. Observations were recorded during peak flowering period from 10 randomly selected trees @ 10 panicles per tree. Each plant was considered as one replication. Data were recorded on number and kind of insect visitors were recorded at hourly interval from 6.00 AM to 6.00 PM. Observations were continued for seven days. In another experiment to assess the impact of pollinators on fruit set, 50 panicles (@ 5 panicles each from10 trees) each in avocado and rambutan were bagged with a nylon mesh before flower opening. Fruit set was compared with panicles exposed to open pollination (Shivaramu, *et al*., 2012). The data were subjected to ANOVA to understand the diversity and significant difference among the pollinator abundance in each crop and T test was performed using Graph pad Prism version 7.0 software.

RESULTS AND DISCUSSION

Pollinator diversity on avocado

The observations were recorded during September-October. The insect pollinators visiting avocado flowers mainly consisted of orders *viz.,* Hymenoptera, Diptera and Coleoptera. Major species from Hymenoptera recorded were *Apis cerana*, *Apis florea* and *Tetragonula iridipennis*. Besides these honey bee species, others included an unidentified wasp and ant was observed. From Diptera, two species of syrphid flies, three species of calliphorids and one species of *Musca* were recorded and from Coleoptera, three unidentified beetle species were observed visiting avocado flowers. Among all the visitor groups, Hymenopterans constituted the major chunk of pollinators (52.66%) followed by dipterans (39.57%) and coleopterans (7.62%) (Fig.1).

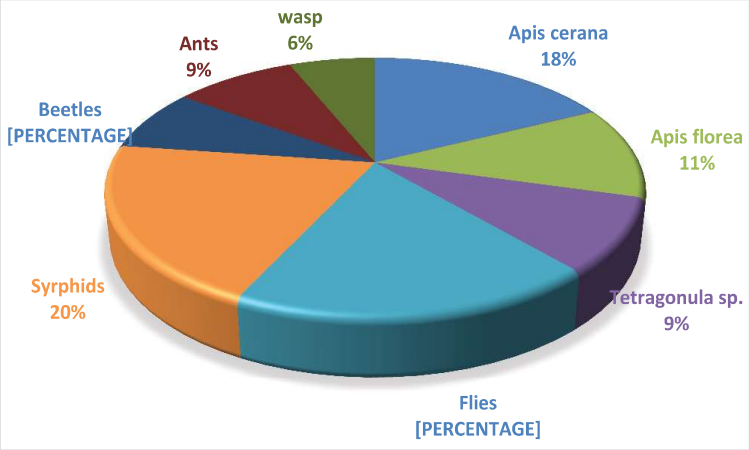


Fig. 1. *Apis* and non-*Apis* spp of pollinators abundance in avocado

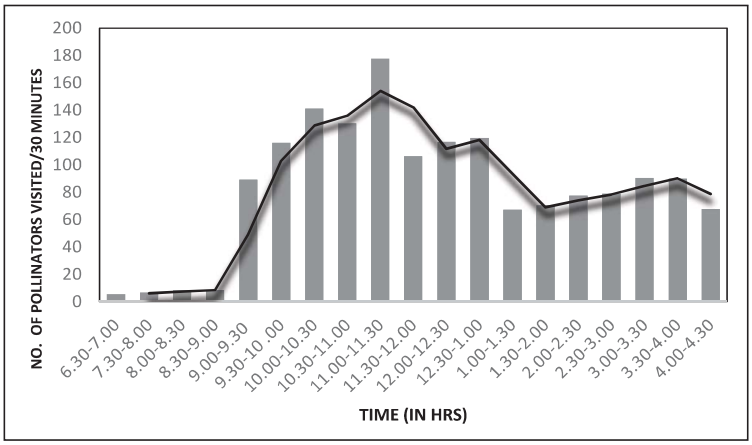


Fig. 2. Diurnal variations in the foraging activity of pollinators on avocado

In the group of Hymenopterans, *A. cerena* was observed as the dominant pollinator with (17.56%) followed by *A. florea* (11.3%) and *Tetragonula iridipennis* (8.82%) whereas ants and wasps comprised 6.16% of total hymenopterans. *Apis dorsata* was not found visiting avocado flowers (Fig.1). *A. cerena* starts foraging from 6.00hrs. in the morning and continues till 12.00 hrs. However, it was observed that the peak foraging period for *A. florea, Tetragonula* sp. was from 9.00-12.00hrs. in avocado. Pollinators belong to *Apis* spp. were appeared to be foraging avocado flowers till 12.30 in the noon. From the order Diptera, syrphids constituted highest proportion (20.51%) while other fly species were to the tune of 19.06 per cent. Of total bee population, *A. cerena* had the maximum number of visits (7.87 visits/panicle/30min) followed by *A. florea* (5.06visits/panicle/30min), and *Tetragonula iridipennis* and ant species (3.96 visits/panicle/30min) each. Among the dipterans, syrphids had a mean number of 9.19 visits/panicle/30min followed by *Musca* sp. with 8.53 visits/30min. The peak foraging hours of pollinators in avocado was observed throughout the day from 9.00 AM to 4.30 PM (Fig.2). Since avocado exhibits synchronous dichogamy flowering phase, the pollinator abundance was observed throughout the day. In the recent studies of Read *et al*, (2017) also honey bees were reported as the predominant visitors of avocado orchards representing 92.9% of all the insects recorded in New Zealand. Some of the studies also reveal that avocado flowers are visited by several insects including bees, flies, wasps, beetles and thrips (Vithanage, 1990). In Central America the avocado is pollinated by stingless bees (Meliponinae) and wasps (Vespidae) (Ish-Am and Eisikowitch, 1993), while in Colombia ants, bees (*A. mellifera* and *Trigona* sp.), flies and wasps are the most frequent floral visitors (Vasquez *et al*., 2011).

It was observed that the *Apis* spp. foraged on avocado flowers till 12.30 PM and thereafter activity started declining (Fig. 3). However non-*Apis* pollinators like dipterans continued to be active beyond noon hours. The peak activity of non-*Apis* pollinators during the afternoon hours of the day indicates their importance to pollination as the avocado flowers exhibit protogynous diurnally synchronous dichogamy. In correspondence to the flower development the pollinator attendance throughout the day is very crucial.

Impact of pollinators on avocado fruit set

There was significant difference in the fruit set per panicle in bagged and open flower bunch (*P=<0.0001; t=5.21; df=49*). In case of open pollination, observed higher number of fruit set (mean of 0.6 fruits/ bunch of flowers) compared to bagged panicles (0.1 fruits/ bunch) (Table 2). This indicates that there was 84.66% reduction in fruit set when flowers were excluded from insects which emphasizes the role of insect pollinators in avocado fruit set. Positive correlation between honey bee visitation and avocado yield was earlier reported by Eisikowitch and Melamud (1982), Ish-Am (1994), Ish-Am and Eisikowitch(1998) and Vithanage (1990).

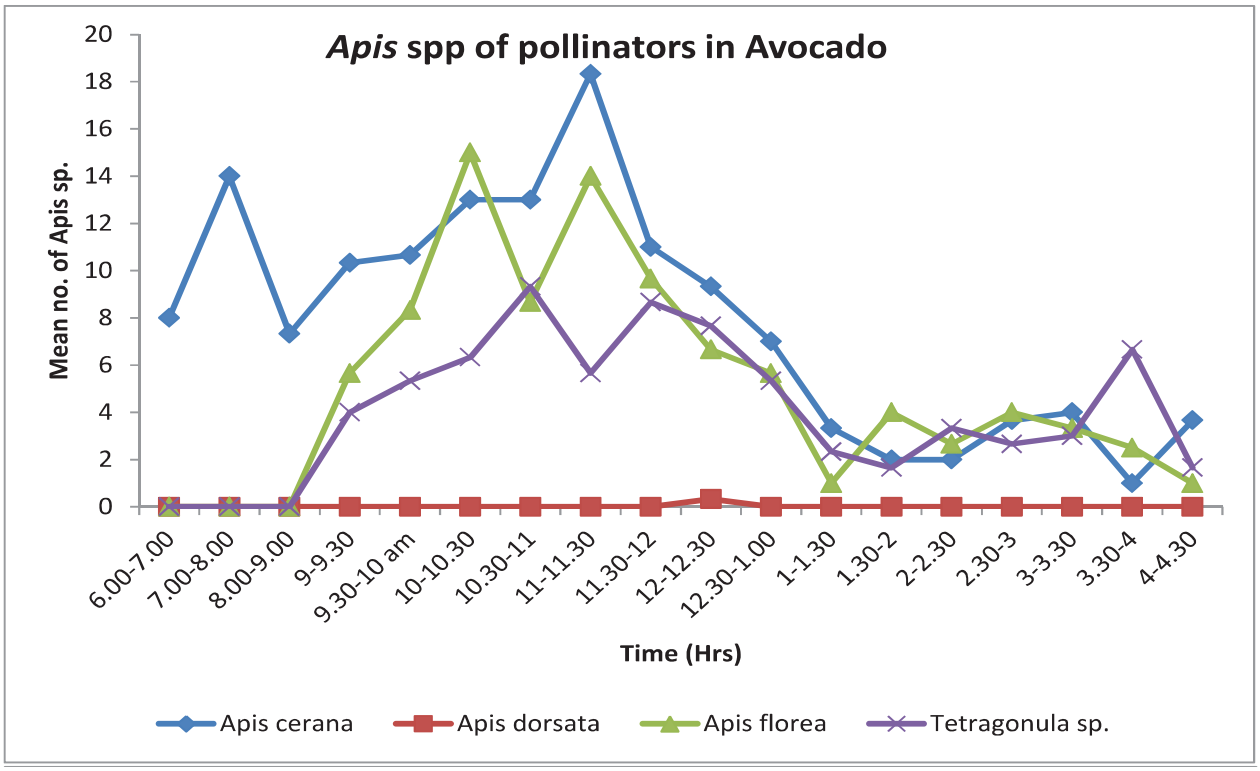
Pollinator diversity in rambutan

The major insect pollinators visiting rambutan belonged to the insect orders Hymneoptera and Diptera. Among the insect pollinator groups, hymenopterans were the dominant group constituting 90% of the total pollinators. Among hymenopterans, *Apis* spp. constituted about 71% and non-*Apis* spp. to the tune of 19% of the total hymenopterans. In *Apis* spp. group, *A. cerana, A. florea, Tetragonula* sp whereas under no-apis spp. one species each of unidentified wasp and ant was recorded on avocado flowers. In the dipteran order we observed two species of syrphids and one *Musca* sp. The proportion of pollinators from the order Diptera was significantly low (9%)

Among bee species, *A. florea* was found to be the predominant among all the visitors and peak period foraging time was 9.00 to 11.00 AM (Fig.5). The total number of *A. florea* was 47.88 per panicle per 30 minutes which is about 59 % of the total visitors. The total number of *A. cerena* was 4.33 per panicle per 30 minutes and the peak foraging activity was between 6.00 and 8.00 AM. (Fig.6) and it was to the tune of 5.79% of the total visitors. The unidentified ants comprised 16 % of total visitors. Peak activity of ants was observed during 9.00 -11.00 hrs. The purpose of ants visiting the rambutan flowers is not known. The total number of *Tetragonula* sp. was 6.13 per panicle per 30 minutes was observed. The peak foraging hours were 9.00 AM to 12.00 noon. The unidentified butterflies and wasps were also observed in rambutan to the tune of 1% and 3% respectively (Fig.4 and Table.1). From Diptera, syrphid flies constituted 5% and *Musca* sp. 4 per cent. Similar studies conducted by Shivaramu *et al.,* (2012), revealed that *Tetragonula irridipennis* was the most dominant forager followed by *A. cerena.* But in the present studies, *A. florea* was observed to be in abundance (47.88 /panicle /day) followed by *Tetragonula* sp. *Api. dorsata* and unidentified butterflies were present in negligible numbers.

Impact of pollinators on rambutan fruit set

The study on the effect of pollinators on fruit set in rambutan had clearly proved the essentiality of insect pollinators to fruit set in rambutan. There was



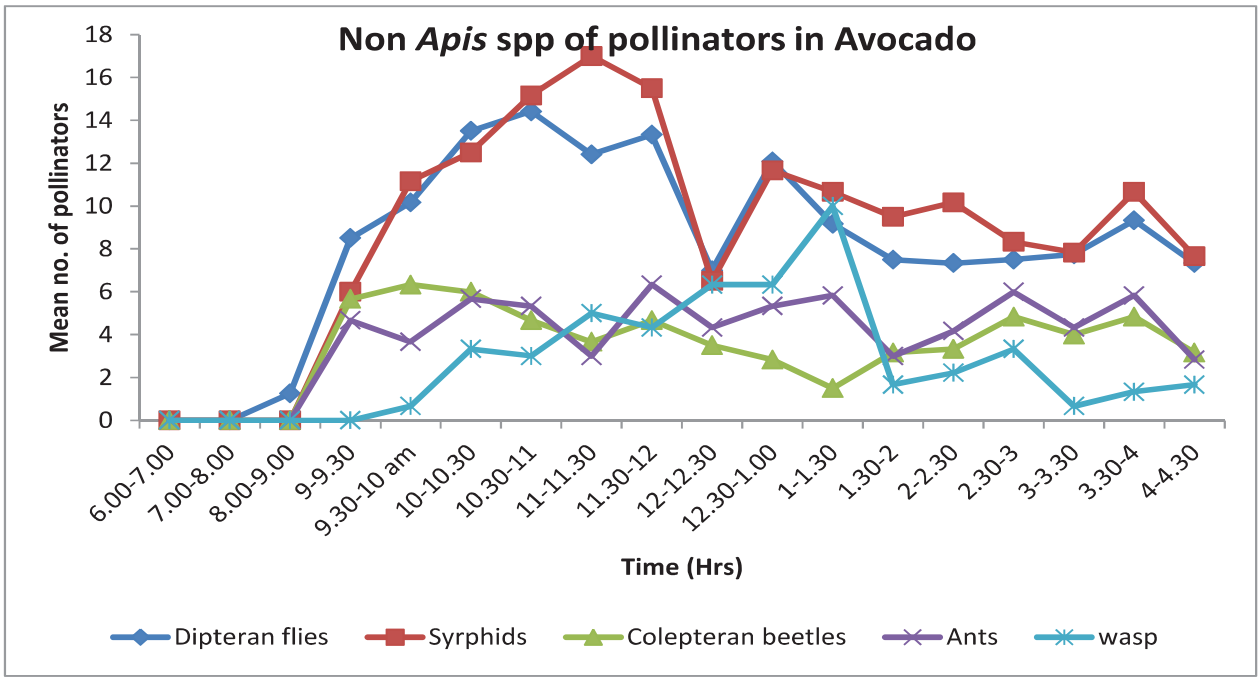


Fig. 3. Peak foraging hours of *Apis* and non-*Apis* pollinators in avocado

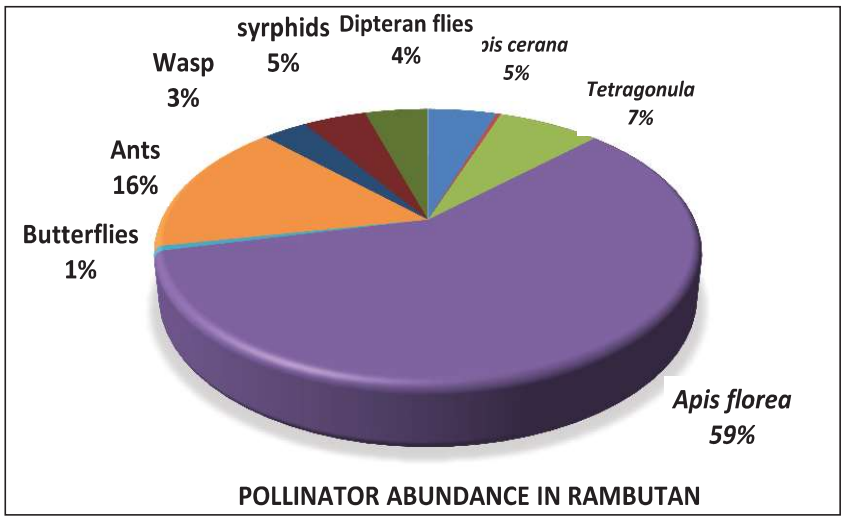


Fig 4. *Apis* and non-*Apis* spp. of pollinators abundance in Rambutan

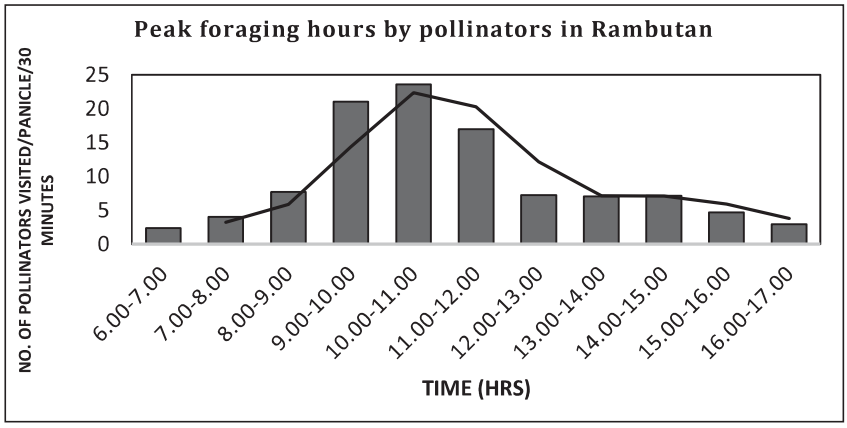


Fig 5. Peak foraging hours of pollinators in rambutan during the day

Table 1. Species abundance of pollinators on hermaphroditic rambutan

Pollinator	Total number of visitors / panicle/ 30 minutes
Apis cerana	4.33 (2.31)
Apis dorsata	0.25 (1.12)
Tetragonula sp.	6.13 (2.67)
Apis florea	47.88 (6.99)
Butterflies	0.42 (1.19)
Ants	13.09 (3.75)
Wasp	2.79 (1.95)
SEm±	0.12
CD (P=0.05)	0.34

Table 2: Impact of pollinators on fruit set of avocado and rambutan

	Mean no. of fruit set	
	Avocado	**Rambutan**
Bagged	0.1	1.38
Open	0.6	13.08
t	5.21	7.14
df	49	49
P	<0.0001	<0.0001

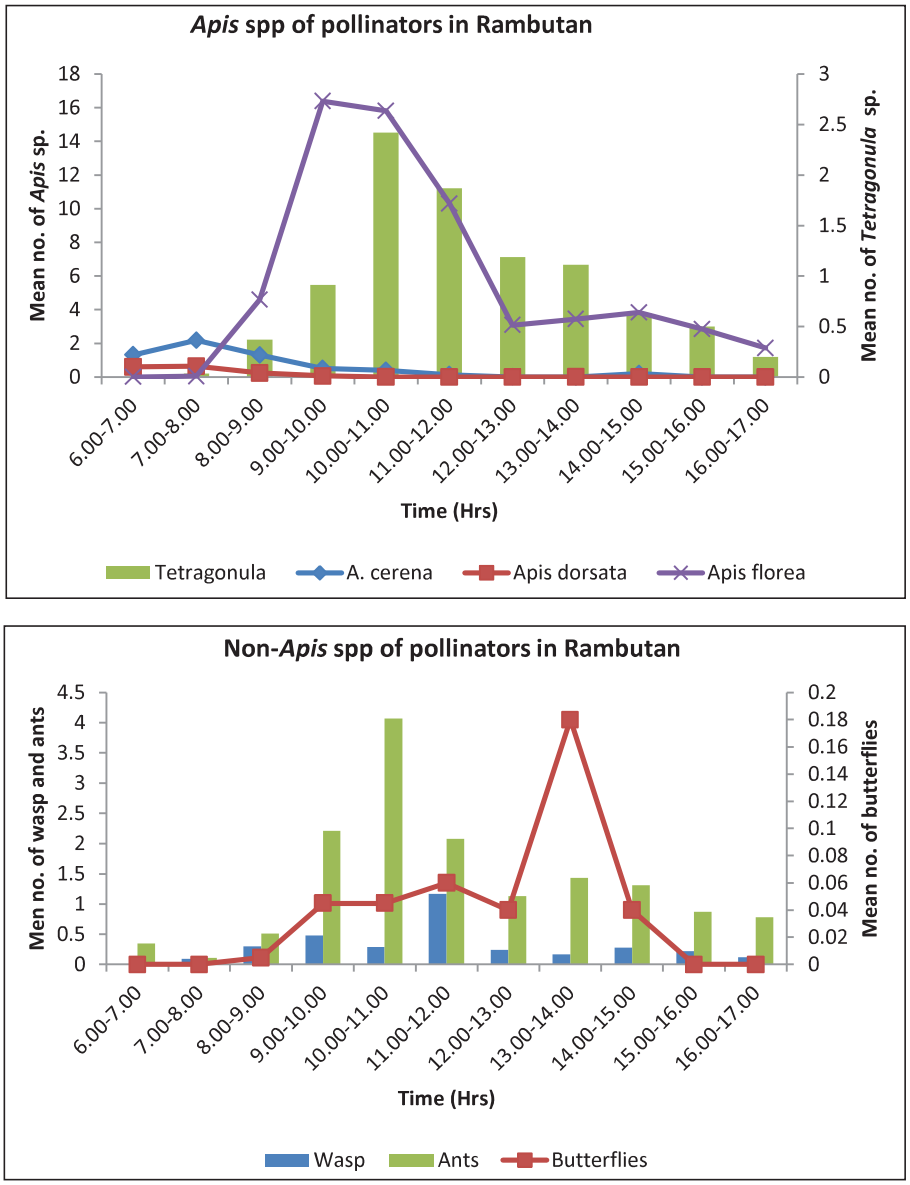


Fig 6. Peak foraging hours of *Apis* and non- *Apis* spp. of pollinators in Rambutan

negligible (1.38/panicle) fruit set in bagged flowers compared to 13.08 in open pollinated flowers indicating the dependency of rambutan on insects for pollination (*P=<0.0001; t=7.14;df=49*) (Table-2).

In the present study it was found that two wild species of bees viz., *A. florea* and *Tetragonula iridipennis* were the predominant insect foragers on rambutan. Efforts should be made to conserve these two native pollinators. It is to conclude that the pollinators need to be conserved and augmented for the better fruit set in rambutan. This study helps us in deciding the time of plant protection measures to augment pollinators. Honey bees play an important role in pollen transfer which is necessary for pollination and subsequent fruit set in avocado and rambutan.

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