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THE DIVERSITY OF INSECT VISITORS ON INDONESIAN SALACCA (*SALACCA* SPP.) IN MEKARSARI FRUITS GARDEN, BOGOR, INDONESIA

Tri Atmowidi[1], Sih Kahono[2], Dorly[1], Suci Dwi Rahmawati[1], Delbert Reinaldo[1], Eris Safiril Ummah[1]

[1] Department of Biology, Faculty of Mathematics and Natural Science, Bogor Agricultural University (IPB University), Bogor, Indonesia 16680

[2] Laboratory of Entomology, Zoology Division, Research Center for Biology, Indonesian Institute of Sciences (LIPI), Cibinong, Indonesia 16911

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Abstract

Salacca (*Salacca* spp.) is a dioecious plant with male and female flowers existing on a different plant, therefore requires agents of pollination. More than thirty cultivars of salacca are found in Indonesia. This research aimed to study the diversity of visiting insects on the three varieties of salacca, i.e., Pondoh, Mawar and Kalimantan in Indonesia, as well measuring the pollen load on the pollinators. The visiting insects were observed on the male flowers using the fix sample method in ten minutes for fifteen days. Results showed that nine insect species visited the flowers and three species were potential pollinators, i.e., *Nodocnemis* sp., *Apis cerana* and *Tetragonula laeviceps*. The highest diversity of visiting insects was found in Kalimantan salacca (H' = 1.31, E = 0.74) followed by Pondoh salacca (H' = 0.72, E = 0.23) and Mawar salacca (H' = 0.51, E = 0.19). There was no dominant species found in Kalimantan salacca. The high similarity of visiting insects was found in Pondoh-Mawar salacca (SN = 0.59). Furthermore, the pollen load on *Nodocnemis* sp., *A. cerana* and *T. laeviceps* were about 127, 7893, and 4228 pollen grains, respectively.

Keywords: *Nodocnemis*, pollinator, pollen load, salacca

INTRODUCTION

Salacca, *Salacca zalacca* (Gaert.) Voss is an Indonesian native plant with high economic value. Nineteen species of *Salacca* have been identified (Mogea, 1978) and distributed in southern Yunnan, Burma, Thailand, Malaysia, Sumatra, Java, Borneo, and Philippines (Mogea, 1980). Borneo has the largest number of species (10 species), followed by the Malay Peninsula (7 species) and Sumatra (7 species). The two main species cultivated in Indonesia are *S. sumatrana* and *S. zalacca* (Mogea, 1978) and about thirty cultivars are found in Indonesia (Sudaryono and Purnomo, 1993). Two varieties of salacca, i.e., *S. zalacca* var. *zalacca* (Pondoh and Mawar salacca) are commonly found in Java and Madura and *S. zalacca* var. *amboinensis* (Becc.) Mogea (Bali salacca) are common in Bali (Mogea, 1982). Fruit's texture, color, size, aroma, taste, and habitus are the main characteristics of each variety.

Pondoh salacca is a superior variety compared to others, in that its fruit is sweet, white flesh and crispy in taste (Ashari, 2002). Mawar salacca is

a breed between Sidempon and Bali salacca and this variety is commonly used as a donor of pollens during manual pollination since it produces a lot of pollens that mature in 2–3 days. Kalimantan salacca, *S. affinis* (Mogea) distributed in Sumatra, Borneo and Malaysia. It grows in solitary or in small groups (2–3 plants) with male and female flowers of about 3–6 cm and 5–8 cm in length, respectively (Gari, 2005). In general, salacca plants are dioecious with male and female inflorescences are found on different plants. However, the Bali salacca are monoecious with male and female flowers are found on the same plant (Schuiling, 1991) and are arranged in the inflorescences (Suskendriyati *et al*., 2000).

Because the plants are generally dioecious, the pollination is mainly assisted by wind, insects and humans. A previous study showed that the curculionid beetle is a major pollinator of salacca. Other insects that visited the salacca flowers are stingless bees (Apidae: Hymenoptera) and beetle, *Rhynchophora palmarum* L. (Coleoptera). The latest beetle species was reported as a pest that damages the flowers (Mogea, 1978). Curculionid beetle, *Nodocnemis* sp. (Coleoptera: Curculionidae) is the main pollinator of Pondoh salacca in Sleman, Yogyakarta (Wagiman *et al*., 2014). The beetle species also was reported as the main pollinator of Sumatra salacca (*S. sumatrana* Becc.) (Tanjung *et al*., 2019). Before this time, the publications on pollinating insects of salacca were limited. This research aimed to study the diversity of visiting insects on the three varieties of salacca, i.e., Pondoh, Mawar and Kalimantan found in Indonesia, as well as measuring the pollen load on the pollinators.

MATERIALS AND METHODS

Study Site

This study was conducted in Mekarsari Fruit Garden (MFG), Bogor, Indonesia as a center for the preservation of tropical fruits as well as vegetables and flowers and ornamental plants as a source of germplasm in Indonesia. This garden also functions as a recreation park. MFG collected six species of salacca, i.e., *Salacca zalacca*, *S. sumatrana*, *S. wallichiana*, *S. affinis*, *S. magnifica*, and *S. glabrescens*. In this study, we used *S. zalacca* (var. pondoh and mawar) and S. *affinis* (var. kalimantan) to study the diversity of flower-visiting insects.

Observation of Visiting Insect Diversity

The diversity of the visiting insects were observed in male flowers of Pondoh, Mawar, and Kalimantan salacca (Fig. 1) in Mekarsari Fruits Garden from February to March 2015. Visiting insects diversity was observed by using the fixed sample method (Dafni, 1992) in 10 minutes from 9.00–11.00 am and 1.00–3.00 pm on sunny days for fifteen days (6 days in two weeks in February and 9 days in three weeks in March). The abundance and species composition of floral insect visitors were measured. Some individuals of each insect species were captured using an insect net and then put inside a jar containing ethyl acetate. The specimens were preserved through the drying method (Borror *et al*., 1989). During the observation of the insect diversity, the air temperature and humidity of the study site also were measured.

Identification of Insect Specimens

The insect specimens were identified based on McAlpine *et al*. (1981; 1992), Borror *et al*. (1989), Sakagami and Ohgushi (1990), Lawrence (1991), and Subyanto (1997). The pollinating curculionid species was identified based on Wagiman *et al*. (2014). The insect specimens were verified at the Entomology Laboratory, Zoology Division, Indonesian Institute of Sciences (LIPI) at Cibinong, West Java, Indonesia.

Pollen Load Measurements

The pollen load of the three pollinating insects (curculionid beetle, honey bee and stingless bee) were measured. The number of species measured

1a 1b 1c

1: *Flowers of salacca: 1a Pondoh salacca; 1b Mawar salacca; and 1c Kalimantan salacca*

were 25, 20, and 20 individuals, respectively. Each insect was placed in a microtube containing 0.5 ml of 70% ethanol: glycerol at 4 : 1. The microtubes were rotated for 24 hours, after which the individual of the insect was removed and the solution centrifuged at 2000 rpm for 10 minutes (Dafni, 1992). The supernatant was removed and 0.1 ml of the remaining solution was shaken till it was homogeneous. This homogeneous solution was dropped onto a Neubauer Improved type hemocytometer and the number of pollens was counted under the light microscope. The number of pollens in one individual insect was calculated by the following formula:

$$V1/N1 = V2/N2;$$

where
V1 ... volume of four quadrants in a hemocytometer,
V2 ... total volume of solution,
N1 ... number of pollens counted in four quadrants, and
N2 ... total of pollens load.

Data Analysis

Data of the visiting insects on the salacca flowers were analyzed using Shannon diversity index (H‘) and evenness (E) in the Paleontological Statistics (PAST) software version 4.4 (Hammer *et al.*, 2001). The similarity of insect composition among salacca varieties was analyzed using Sorensen quantitative index (Magurran, 2004).

RESULTS

During observation of insect diversity, the air temperature at the study site ranged from 26.6–35.8 °C with humidity between 65–92%. The visiting insects observed on the Pondoh and Mawar salacca male flowers were 9 species belonging to 6 families and 3 orders. However, the Kalimantan salacca was visited by 5 species belonging to 4 families and 3 orders (Tab. I). The curculionid beetle, *Nodocnemis* sp. was the main pollinator of Pondoh and Mawar salacca with a visit percentage of 83% and 88.83%, respectively. Other visiting species consist of *A. cerana* (6.97% and 4.85%), *Tetragonula laeviceps* (Apidae: Hymenoptera) (Fig. 2) (0.81% and 0.29%), *Colocasiomyia* cf. *xanthogaster* (Drosophilidae: Diptera) (5.64% and 3.78%), *Nerius* sp. (Neriidae: Diptera) (0.63% and 0.25%), *Scaptodrosophila* sp. (Drosophilidae: Diptera) (0.3% and 0.17%), and *Salpingogaster* sp. (Syrphidae: Diptera) (0.6% and 1.12%), respectively. However, the *Nodocnemis* sp. did not visit the male flowers of Kalimantan salacca. The potential species as pollinators on Kalimantan salacca were *A. cerana*, *T. laeviceps*, and *Salpingogaster* sp. (50.6%, 6.8%, and 11.9%, respectively). The male of *Nodocnemis* sp. has a smaller body-size (about 2.68 mm in length) compared with a female (2.77 mm). Other species of curculionid beetle (*Rhabdocnemis maculate*) belong to the group of pest insect which damages the flowers, while *Vespa affinis* (Vespidae: Hymenoptera) belong to predatory insects.

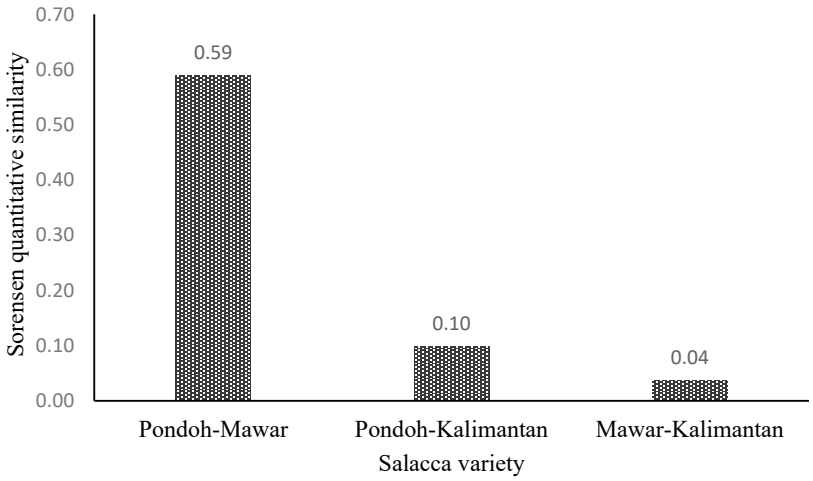
The diversity and evenness of visiting insects on Pondoh and Mawar salacca were low (H‘ = 0.72, E = 0.23 and H‘ = 0.51, E = 0.19). These low diversity and evenness were caused by the dominance of *Nodocnemis* sp. in both varieties of salacca, i.e., 83.02% and 88.83%, respectively. In Kalimantan salacca, the Shannon index was highest (H‘ = 1.31).

I: *Diversity of visiting insects on pondoh, mawar, and kalimantan salacca male flowers in Mekarsari Fruit Park, Indonesia*

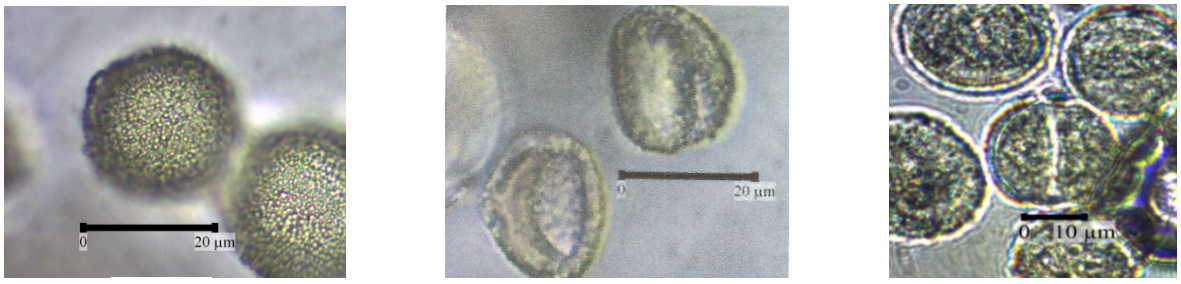
Order	Family	Species	Number of individuals			Percentage (%)		
			Pondoh	Mawar	Kalimantan	Pondoh	Mawar	Kalimantan
Coleoptera	Curculionidae	*Nodocnemis* sp.	2752	7246	-	83.02	88.83	-
		Rhabdocnemis maculate	37	11	41	1.12	0.13	23.3
Hymenoptera	Apidae	*Apis cerana*	231	396	89	6.97	4.85	50.6
		Tetragonula laeviceps	27	24	12	0.81	0.29	6.8
	Vespidae	*Vespa affinis*	30	47	13	0.9	0.58	7.4
Diptera	Syrphidae	*Salpingogaster* sp.	20	91	21	0.6	1.12	11.9
	Neriidae	*Nerius* sp.	21	20	-	0.63	0.25	-
	Drosophilidae	*Scaptodrosophila* sp.	10	14	-	0.3	0.17	-
		Colocasiomyia cf *xanthogaster*	187	308	-	5.64	3.78	-
Number of individuals (N)			3315	8157	176	-	-	-
Number of species (S)			9	9	5	-	-	-
Shannon diversity index (H’)			0.72	0.51	1.31	-	-	-
Evenness index (E)			0.23	0.19	0.74	-	-	-

2a 2b 2c

2: *Three dominant insect species as pollinators of salacca: 2a Nodocnemis sp.; 2b Apis cerana; and 2c Tetragonula laeviceps*



3: *Sorensen quantitative similarity of visiting insect species between Pondoh-Mawar, Pondoh-Kalimantan, and Mawar-Kalimantan salacca*



4a 4b 4c

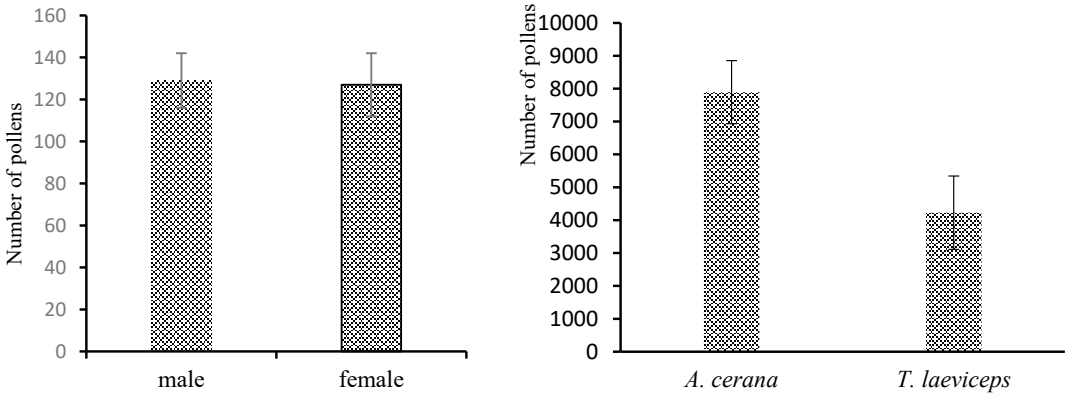
4: *Pollens of salacca: 4a Pondoh salacca; 4b Mawar salacca, and 4c Kalimantan salacca*

The individual number of each species showed highly even (E = 0.74) and no dominant species was found. The similarity of species composition was highest in Pondoh-Mawar salacca (SN = 0.59) compared to Pondoh-Kalimantan (SN = 0.10), and Mawar-Kalimantan (SN = 0.04) (Fig. 3).

The pollen of salacca is around 20 µm in diameter (Fig. 4). The average pollen load on *Nodocnemis* sp. were about 129 pollen grains (male) and 127 pollen grains (female). However, the pollen load on *A. cerana*, and *T. laeviceps* were 7893 and 4228 pollen grains, respectively (Fig. 5).

DISCUSSION

The male inflorescence of salacca is in the range of 10–15 cm in length. Male flowers are usually reddish and arranged as tile-like and suitable for foraging of pollinating insects which allow for pollination. The dominant insects found on the male flowers of pondoh and mawar salacca were *Nodocnemis* sp., *A. cerana* and *C.* cf *xanthogaster*, respectively. However, in Kalimantan salacca the dominant visiting insects were Hymenoptera, Coleoptera and Diptera, and bees (*A. cerana* and *T. laeviceps*) were as potential pollinators. *Nodocnemis* sp. visited the Pondoh and Mawar



5: *The average of pollen load of salacca on: 5a Nodocnemis sp.; 5b Apis cerana and Tetragonula laeviceps. Standart error is shown in each bar*

salacca during the day. The beetle species was also reported as the dominant pollinator of Pondoh salacca at Sleman, Yogyakarta (Mogea, 1978). In this study, we didn't found *Nodocnemis* sp. on Kalimantan salacca flowers. Similarly, the beetle species was absent on Bali salacca (*Salacca zalacca* var. *amboinensis*) (Darmadi *et al*., 2002). This could be due to the chemical composition in Kalimantan and Bali varieties which might be repellent to the beetle.

The results also showed that honey bee, *A. cerana* foraged on the three varieties of salacca (Pondoh, Mawar and Kalimantan). Bees are potential pollinating insects on most crops related to their foraging activity (Michener, 2000). Environmental parameters affect the foraging activity of *A. cerana* (Faheem *et al*., 2004). The foraging activities of honey bees are high in a temperature range of 26–34 °C (Amano *et al*., 2000). *Apis cerana* is a social insect with hundreds to thousands of individuals in the colony. Worker bees actively looking for pollen and nectar for their colony needed. During foraging, the pollens are loaded in the corbicula of the hind legs. Moreover, previous studies reported that the honey bees as the main pollinators in the agricultural landscape (Kremen *et al*., 2002), such as in chili (Raw, 2000), jatropha (Atmowidi *et al*., 2008), sunflower (Greenleaf *et al*., 2006), and strawberry (Chang *et al*., 2001). Stingless bees (*T. laeviceps*) with small body-size (4–6 cm in length) (Faheem *et al*., 2004) foraged on salacca flowers. The species also was reported as a pollinator of salacca (Mogea, 1978). Nagamitsu and Inoue (2002) reported in Sarawak, Malaysia, the peak activity of stingless bees was in the morning. Additionally, a previous study showed that *T. laeviceps* was the main pollinator of plants with small flowers (Michener and Boongird, 2004). This species was also reported as pollinators of *Jatropha* (Greenleaf *et al*., 2006), cucumber (Solange *et al*., 2008), and nutmeg (Dennis, 1994). The wasp, *V. affinis* on the other hand was found to be a predatory insect that hunts for prey on salacca flowers. Matsuura (1988) reported the honey bees were prey to *Vespa*. Koeniger *et al*., (1994) reported *Vespa* foraged on flowers and other locations where honey bees are commonly found.

Syrphid fly, *Salpingogaster* sp. is another important pollinator of plants (Apituley *et al*., 2012). This study showed that the species also foraged on Pondoh, Mawar and Kalimantan salacca. This fly was also reported visited flowers of *Psilochilus modestus* (Orchidaceae) in North America (Pansarin *et al*., 2008). Another species of fly foraged on salacca flowers was *Colocasiomyia* cf. *xanthogaster* (Drosophilidae: Diptera). Similarly, the activities of *Colocasiomyia* were found on the flowers of Arecaceae, Araceae and Magnoliaceae (Takano *et al*., 2011). This species was also reported as the pollinator of taro (Okada and Yafuso, 1989; Takano *et al*., 2012). The bloom of taro flowers produces a strong aroma which attracts *Colocasiomyia* to lay eggs in the pistil and staminodia. *Scaptodrosophila* sp. (Diptera) was also visited the flowers of Pondoh and Mawar salacca. This species also visited the flowers of *Hibiscus raukensis* in Australia (McEvey and Baker, 2001).

The diversity of visiting insects in Pondoh and Mawar salacca was lower than that in Kalimantan salacca. It was caused by one dominant species (*Nodocnemis* sp.) in Pondoh and Mawar salacca and the similarity of species composition in these varieties was high. Contrary, no dominant species was found in Kalimantan salacca caused a high diversity index. The diversity and abundance of visiting insects were also influenced by environmental parameters, such as temperature, light intensity and humidity. In apple plants, compositions of visiting insects was positively correlated with temperature, but negatively correlated with humidity (Pansarin and Amaral, 2008).

The visiting insects on salacca flowers are also determined by the available pollens as a source of proteins. Pollens also contain vitamins, carbohydrates and fats (Appanah, 1995). Based

on the aperture, salacca pollens are grouped as monocolpate (Huang, 1972) with about 20 µm in diameter. Moreover, pollen load on *Nodocnemis* sp. was low (127 pollen grains), compared to *A. cerana* (7,893 pollen grains) and *T. laeviceps* (4,228 pollen grains). The previous study showed that the pollen load on the three species of stingless bees, i.e., *Heterotrigona itama*, *Lepidotrigona terminata* and *T. laeviceps* were 31392, 23017 and 8015 pollen grains, respectively and the number of pollens attached on the body positively correlated with body weight (Pangestika *et al*., 2017).

CONCLUSION

Salacca is a dioecious plant that needs agents of pollination. At least, nine species of insect visit the salacca flowers and three dominant species were *Nodocnemis* sp., *A. cerana* and *Tetragonula laeviceps* as agents of pollination. The salacca pollen load on *Nodocnemis* sp., *A. cerana* and *T. laeviceps* were at least 127, 7,893 and 4,228 pollen grains, respectively.

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Contact information

Tri Atmowidi: atmowidi@apps.ipb.ac.id