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Insect Diversity and Visitation Patterns on *Nephelium ramboutan-ake* in Mekarsari, Bogor

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Abstract. *Information on flower-visiting insects, especially pollinators of the pulasan plant (Nephelium ramboutan-ake), a species that tends to cross-pollinate, is essential for increasing fruit production. Unfortunately, there is minimal information on flower-visiting insects associated with pulasan. This research aimed to study the diversity and abundance of visiting insects on pulasan in the Mekarsari Fruit Garden, Bogor. Observations of insects were conducted using the fixed sample method, with samples taken every 20 minutes through direct observation from 06:00 am to 02:00 pm during the flowering period. Results showed that 24 insect species, belonging to 24 genera across six orders, visited the pulasan, with the order Diptera being the most dominant among the visiting insects. The potential insect species as pollinators of pulasan were Lathyrophthalmus* sp. *and Amata huebneri. Knowledge about flower-visiting insects plays an important role in the conservation of insects—especially pollinators—as well as the pulasan plant, a local species.*

Keywords: *bees, pollen, pollinator, syrphid fly*

Citation
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INTRODUCTION

Pollination is a prerequisite for the growth of fruits and seeds (Shivannaa, 2003). This process is influenced by both internal factors, such as the number of flowers, fertility, and pollen viability, and external factors, including the environment and pollination agents. Insects are common agents involved in the pollination process. Approximately two-thirds of all flowering plant species rely on pollinating insects as part of the mechanism for producing optimal seeds (Klein et al., 2002). In rambutan (*Nephelium lappaceum* L.), the presence of two stingless bee species, *Scaptotrigona mexicana* (Apidae, Meliponini) and social halictid bees (*Halictus hesperus*), was able to increase the fruit production nearly 10-fold (Rincón-Rabanales et al., 2015). In other crops, pollinators not only increased fruit production but also improved fruit quality in strawberries (Abrol, 2017) and influenced the size, shape, and market classification of specific apple cultivars (Garratt et al., 2014). Moreover, in the absence of pollinating insects, some plants are unable to produce fruits (Delaplane and Mayer, 2000). In addition, other factors also affect the success of pollination, including pollen viability, pistil receptivity, genetic interactions, or post-zygotic miscarriage (Dafni, 1992).

The diversity of insect pollinators in an area is related to the condition of the habitat. Agricultural land condition influences the diversity and abundance of insect pollinators, as it relates to the availability of natural habitats and changes in their functions (Klein et al., 2002). Syarifuddin et al. (2018) reported differences in the species composition of insect visitors to rambutan (*Nephelium lappaceum*) that grows in two different ecotones: the oil palm garden forest (dominated by bees) and the oil palm plantation (dominated by *Calliphorid flies*). Rambutan trees at the Central Horticultural Experiment Station in Karnataka, India, were frequently visited by *Trigona iridipennis* and *Apis cerana* (Shivaramu et al., 2012). Like rambutan, Pulasan (*Nephelium ramboutan-ake*) is an outcrossing plant that insects pollinate, as it has male and hermaphrodite flowers on different trees; however, the anthers of its hermaphrodite flowers never open (Djuita et al., 2016).

Pulasan has significant potential for development as a fruit-producing crop. However, it remains less popular than its close relative, rambutan. One reason is the limited information available about this species, including its pollinators. Information on insects that play a role in cross-pollination in pulasan is minimal, although it is important as supporting data for the success of pulasan fruit sets. Therefore, this study aimed to investigate the diversity and abundance of insect visitors to pulasan flowers during their blooming period at the Mekarsari Fruit Garden in Bogor, West Java.

MATERIALS AND METHODS

Observations of Flower-Visiting Insects

Observations of visiting insect species on pulasan flowers were conducted using the fixed sample method (Dafni, 1992) over four days, coinciding with the flowering period. Observations of the visiting insects were conducted every 20 minutes, followed by a 10-minute break, and so on, from 06:00 am to 02:00 pm, which is considered an active foraging time for insects, with a total of 16 observation cycles per day. The number of plants observed is four trees. The insects were then caught using an insect net and placed in a plastic container, and subsequently transferred into a bottle containing 96% ethanol to observe the presence of pollen. Several environmental factors were measured during the insect observation, including temperature, humidity, light intensity, and wind speed.

Observations of Pollens on Insects

Each species sample was placed in a separate container. Then, one individual insect from each species was taken to observe whether it carried pollen or not, resulting in a total of 24 individuals observed across all species. A total of 1.5 ml of 96% ethanol of the sediments of each insect was put into the eppendorf tube, and was centrifuged at 5000 rpm. The sediment was then dropped onto a glass slide with 2% aceto-orcein dye, and the pollen grains were observed with a compound microscope. Furthermore, from the 24 samples of insects, four samples were selected to be observed using a scanning electron microscope (SEM), i.e., *Lathyrophthalmus* sp. (Diptera) and *Vespa affinis* (Hymenoptera), *Amata huebneri* (Lepidoptera), and *Glycyphana quadricolor* (Coleoptera). The four samples were selected based on the high number of individual visits (*Lathyrophthalmus* sp. and *V. affinis*) and represented the orders Lepidoptera (*A. huebneri*) and Coleoptera (*G. quadricolor*).

Preservation and Identification of Insects

The large insects were preserved using the dry method, while the relatively small insects were preserved in 96% ethanol. Furthermore, the insects were dried in an oven at 35°C for three days (Borror et al., 1996). The insect specimens were identified using the keys of Borror et al. (1996) and Subyanto and Sulthoni (1997).

Data Analysis

The total number of visiting insects on pulasan plants, the average number, and the percentage of each species in the total observations were calculated. The diversity index was calculated using the Shannon diversity index (H') and the Evenness index (E). Data on the number of individuals were correlated with environmental parameters using Pearson correlation analysis using IBM SPSS software version 16 (Magurran, 2004). Correlation is significant if *p*-value < 0.05.

Shannon-Wiener Index: $H' = -\sum pi * \ln(pi)$

Evenness Index: $E = H'/\ln S$

where *H'*= Shannon-Wiener index, *pi*= proportion of ith species in the community, *E*= Evenness index, *S*= number of species, and *i*= i^{th} species).

RESULTS AND DISCUSSION

Based on the observations, there were 24 species of the visiting insects of pulasan which classified into six orders including Diptera (66.99%, 272 individuals), Hymenoptera (19.95%, 81 individuals), Lepidoptera (9.6%, 39 individuals), Coleoptera (2.7%, 11 individuals), Orthoptera (0.5%, two individuals), and Hemiptera (0.25%, one individual) (Table 1; Figure 1). The dominant visiting species on Pulasan were *Lathyrophthalmus* sp. (54.93%, 223 individuals), *V. affinis* (7.17%, 29 individuals), and *Chrysomya* sp. (5.67%, 23 individuals). The diversity and evenness indices of insects were 1.8575 and 0.5844, respectively. Based on observations of deposits from the 96% ethanol solution, we found pulasan pollens on *Lathyrophthalmus* sp. After comparing the pollen of male and hermaphrodite flowers of pulasan (collected by NRD), it was found that the pollen of the insect species was similar (Figure 2). However, pollens were not found in the other species of insects. The SEM observations on the bodies of four insect samples indicated the presence of pulasan pollens on *A. huebneri* (order Lepidoptera). The pollen was located between the two compound eyes (Figure 3). No pollens were found on *V. affinis*, *Lathyrophthalmus* sp., and *G. quadricolor*. The absence of pollen detection in *Lathyrophthalmus* sp. in SEM observation, but was detected in alcohol solution, because the ethanol washing process may be more effective in releasing pollen from the insect body than visual observation under SEM. Ethanol can release pollen attached to the insect's body, allowing it to be detected through further analysis. The presence of pollen on *A. huebneri* observed under SEM indicates that this insect has the potential to be a pollinator of kapulasan; however, further research is still needed.

Figure 1. Some insect visitors of pulasan: (a) *Lathyrophthalmus* sp., (b) *Atherigona* sp., (c) *Chrysomya* sp., (d) *Salpingogaster* sp., (e) *Stilbomyia fuscipennis*, (f) *Limnophora* sp. (Diptera) (g) *Amata huebneri*, (h) *Ypthima philomela*, (i) *Neptis hyla* (Lepidoptera), (j) *Xantophimpla* sp., (k) *Lasioglossum* sp., (l) *Vespa affinis* (Hymenoptera),(m) *Metacorna fulvipes*, (n) *Monolepta* sp. (o) *Glycyphana quadricolor* (Coleoptera).

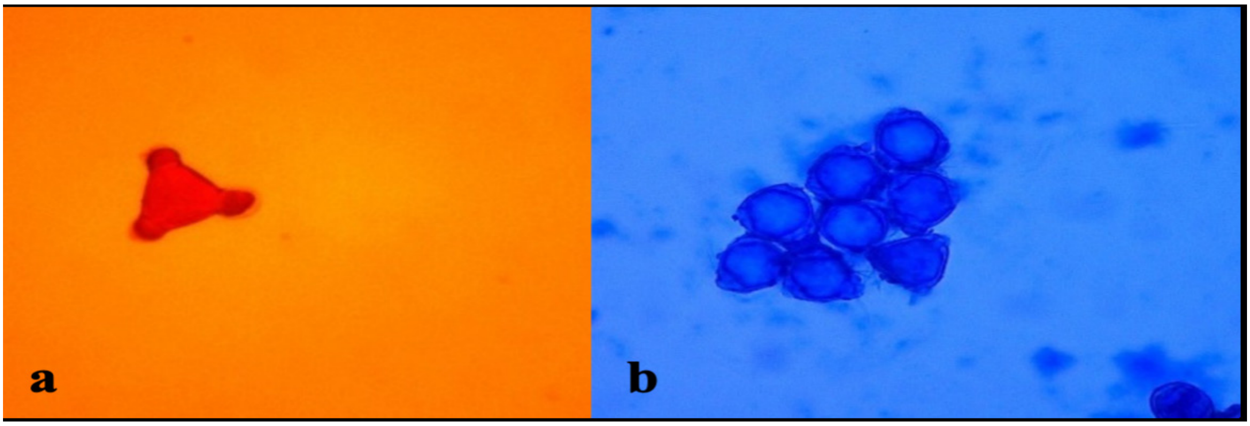

Figure 2. The pollens of pulasan taken from the compound microscope: (a) the pollen of a male flower with the aceto orcein dye, (b) the pollens of a hermaphrodite flower with aniline blue dye. (Collection of NRD).

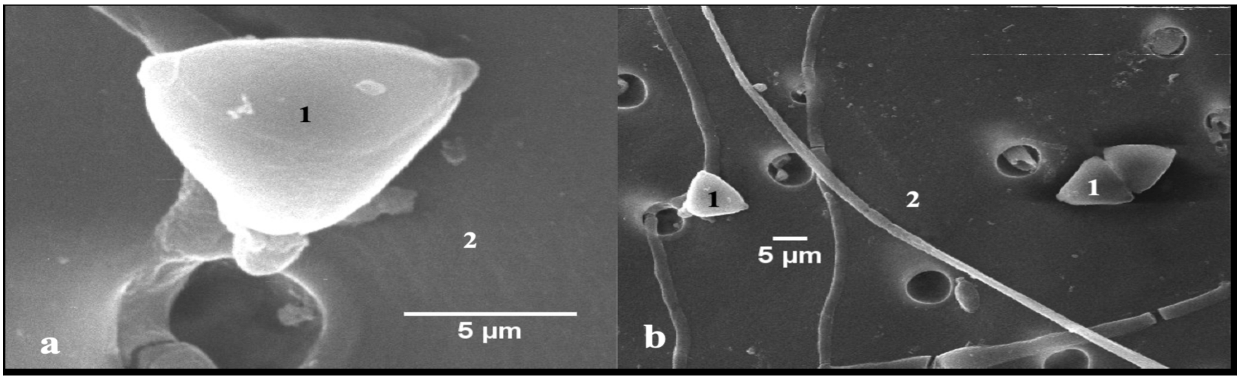

Figure 3. Pollen of pulasan on SEM image: (a) and (b) pollens of hermaphrodite flower on *A. huebneri*. 1. pollen, 2. compound eye

The average environmental parameters measured during the four-day sampling period indicated that the air temperature ranged from 26.1°C to 38.8°C, light intensity ranged from 221 lux to 1958 lux, relative humidity ranged from 15.6% to 63.9%, and wind speed ranged from 0 m/s to 12.8 m/s. The wind speed in the morning and midday was 0 m/s, while the highest wind speed occurred at 09.00 am (12.8 m/s (Table 2). The visiting insects tend to visit pulasan in the morning (Table 3). The highest number of insects observed during the study (14 species, 98 individuals) occurred between 07:00 and 08:00 a.m., with an average temperature of 27.01°C, light intensity of 536.3 lux, and relative humidity of 56.8%.

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Table 1. The number of individuals of flower-visiting insects on Pulasan

Order (Family)	Species	Number of individuals	Percentage (%)
Coleoptera			
Cetoniidae	*Glycyphana quadricolor*	2	0.50
Chrysomelidae	*Metacoryna fulvipes*	2	0.50
	Monolepta sp.	7	1.72
Diptera			
Calliphoridae	*Chrysomya* sp.	23	5.67
	*Stilbomyia fuscipenni*s	1	0.25
Muscidae	*Limnophora* sp.	2	0.50
	Atherigona sp.	21	5.17
Stratomidae	*Salpingogaster* sp.	2	0.50
Syrphidae	*Lathyrophthalmus* sp.	223	54.93
Hemiptera			
Tessaratomidae	*Tessaratoma javanica*	1	0.25
Hymenoptera			
Apidae	*Lassioglossum* sp.	3	0.73
Formicidae	*Camphonotus* sp.	1	0.25
Halictidae	*Pseudapis* sp.	21	5.17
	Lasioglossum sp.	16	3.94
Crabronidae	*Pison* sp.	3	0.73
Ichneumonidae	*Xantophimpla* sp.	7	1.72
Vespidae	*Vespa affinis*	29	7.14
	Delta campaniforme	1	0.25
Lepidoptera			
Amatidae	*Amata huebneri*	19	4.68
Lycaenidae	*Marmesses* sp.	3	0.73
	Rapala sp.	3	0.73
Nymphalidae	*Ypthima philomela*	1	0.24
	Neptis hylas	13	3.20
Orthoptera			
Blatidae	*Batella germanica*	2	0.50
The total number of individuals (N)		406	100
Average of Individuals/day		101.5	
The total number of species (S)		24	
Shannon diversity index (H')		1.8575	
Evenness index (E)		0.5844	

Table 2. The average environmental parameters measured during the observation period

Time	Temperature (°C)			Light intensity (x100 lux)			Wind speed (m/s)			Relative humidity (%)		
	a	b	c	a	b	c	a	b	c	a	b	c
06.00	27.4	29.0	28.0	344	786	536.3	0	0	0	54.5	61.2	56.8
07.00	26.1	28.0	27.1	462	1704	1200.0	0	0	0	15.6	38.5	26.2
08.00	29.2	32.8	31.3	710	1958	1369.0	0	3.7	1.2	36.2	63.9	56.3
09.00	32.8	35.6	34.0	1047	1837	1564.0	0.6	12.8	5.0	39.9	58.8	51.8
10.00	30.4	38.8	34.8	991	1636	1180.0	3.5	10.0	7.3	46.7	58.7	50.6
11.00	34.7	36.7	35.7	221	1707	1137.0	4.5	12.1	8.5	44.7	53.0	48.7
12.00	31.1	36.8	34.9	276	1058	667.3	0	9.5	5.8	41.9	53.1	48.2
13.00	35.3	36.8	36.1	320	1478	643.3	0	6.2	2.8	42.4	52.2	46.3
14.00	34.8	36.5	35.6	377	1643	820.0	0	7.2	2.8	45.7	56.0	50.3

Note: (a=minimum, b=maximum, dan c=average)

Table 3. The environmental parameters, number of species (S) and individuals (N), Shannon and evenness index (H', E) of flower-visiting insects on Pulasan

Time	S	N	H'	E	A (°C)	B (x100 lux)	C (m/s)	D (%)
06.00-07.00	10	68	0.2993	0.1299	28.0	536.3	0	56.8
07.00-08.00	14	98	0.3431	0.1300	27.1	1199.8	0	26.3
08.00-09.00	15	76	0.3137	0.1158	31.3	1368.8	1.2	56.3
09.00.10.00	12	55	0.2708	0.1090	34.0	1563.8	5.0	51.8
10.00-11.00	11	36	0.2148	0.0895	34.8	1179.5	7.3	50.7
11.00-12.00	5	26	0.1760	0.1093	35.7	1137.3	8.5	48.8
12.00-13.00	10	22	0.1580	0.6866	34.9	667.3	5.8	48.2
13.00-14.00	8	25	0.1716	0.0815	36.1	643.3	2.8	46.4
Total	24	406	1.9473	1.4546				
Average	10.6	50.8	0.2434	0.1818	32.7	1037.0	3.8	48.2

Note: (S: the number of species, N: number of individuals, H': Shannon diversity index, E: Evenness index, A: air temperature, B: intensity of light, C: wind speed, and D: relative humidity)

Temperature and wind speed have a significant negative correlation with the number of insect individuals. The optimal temperature for insects varies among species; however, temperatures outside this range can generally reduce their activity. Strong winds may physically obstruct insect flight, thereby reducing their ability to reach target locations. In insects such as bees, various environmental factors—including wind, rainfall, and extreme temperatures—can inhibit flight. Bee foraging activity tends to decline when wind speeds exceed 6–6.7 m/s (Vincze et al., 2025). At high temperatures, bees may experience stress, resulting in decreased foraging activity (Kamboj, 2024). In contrast, the number of individuals was positively correlated with the number of species ($p<0.05$). Relative humidity and light intensity do not correlate with the number of individuals ($p>0.05$) (Table 4).

The insect pollinators belong to the orders Hymenoptera, Lepidoptera, and Diptera (Banjo et al., 2006). Some species of visiting insects have the potential to be pollinators of pulasan. The syrphid fly *Lathyrophthalmus* sp. was found with Pulasan pollen on its body, indicating its potential as a pollinator of this plant. However, further study is needed to observe whether the insect visits the pistil of pulasan flowers. The wasp, *Vespa affinis*, was observed in high abundance in Pulasan. This species in the environment is a predator of other small insects (Richter, 2000). Their body has fewer hairs and fewer pollen attached. As a predator, *Vespa affinis* likely visits the pulasan plant due to its interactions with other insect species present on the plant, such as pollinators or potential prey. The species belong to the order Lepidoptera with the highest abundance, such as *A. huebneri* and *N. hylas*. Moths are generally active at night; however, *A. huebneri* is an exception, as it is active during the day. The results of a study by Mamangkay et al. (2022), which observed pollinating insects on tomato plants from morning to evening, showed that *A. huebneri* was active during this period. *Amata huebneri* was also found to be active between 14:00 and 17:00 WIB during insect observations in vegetable fields in Ogan Ilir Village (Keshya et al., 2022). Based on the SEM image, some pollen are attached to *A. huebneri*'s body. However, the role of the species as a pollinator of pulasan remains uncertain.

Tripelhorn and Johnson (2005) reported that Lepidopteran (butterfly and moth) help pollination through the pollens attached to the proboscis, scales on the body, and legs, which move from one flower to another. Species belonging to the orders Orthoptera, Coleoptera, and Hemiptera visited the Pulasan in low abundance, and most of the species are potentially plant pests. The species *T. javanica* (Hemiptera: Tessaratomidae) has been reported as a pest of lychee (*Litchi chinensis*) in India (Kumar and Singh, 2007). Most species belong to Orthoptera and Coleoptera and are herbivorous. Most of them are pests on crops (Triplehorn and Johnson, 2005).

The closest relatives of pulasan, e.g., rambutan (*Nephelium lappaceum*), have many visitor insects. In Chiapas, Mexico, rambutan was visited by two of the highest pollinators: *Halictus hesperus* (Halictidae) and *Scaptotrigona mexicana* (Apidae), with the latter serving as the primary pollinator (Rincón-Rabanales et al., 2015). Meanwhile, in Leuser National Park, North Sumatra, rambutan was visited by Hymenoptera, Diptera, and Lepidoptera, and the most common visitors were *Apis cerana*, *Chrysomya megacephala*, and *Trigona* sp.

(Syarifuddin et al., 2018). Pham (2012) reported that in longan, *Dimocarpus longan* (Sapindaceae), more diverse orders were found, consisting of the order Blattodea, Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, Neuroptera, and Thysanoptera, and the most significant number of visitors was *Apis cerana* at 09.00-11.00 am. Honey bee, *A. cerana* is a generalist insect that visits many species of plants, such as rambutan (Syarifuddin et al., 2018), longan (Pham, 2012), castor (Atmowidi et al., 2008), and mango (Deuri et al., 2018).

Pollinator insects are generally attracted to plants because they contain visual attractants, such as attractive petals, brightly colored stamens, bunched flowers, or fragrances and floral odors. Although pulasan flowers are small (<5 mm), they are arranged in compound flowers that attract insects. Volatile compounds in flowers also affect insect visits. For example, *Apis mellifera* bees prefer rambutan in Herradero gardens that produce limonene and pinene compounds over those in Metapa gardens, Mexico (Aceves-Chong, 2017). After visiting a flower, insects receive a reward (pollen or nectar) (Kevan & Baker, 1983). Pulasan produces pollens (Hasan et al., 2018) as an attractant for insects. Stingless bees, *Tetragonula* sp. in Sekayu and Borneo, favor pollen from pulasan (Hasan et al., 2018). Insects need pollen as a source of protein (Minarti, 2009).

Table 4. The Pearson correlation between the number of individuals and number of species to the environmental parameters

Pearson Correlation	Total number of individual	Number of species	Temperature	Relative humidity	Light intensity	Wind speed
Total number of individuals	1	0.77	-0.913	-0.357	0.351	-0.779
Number of species	0.770	1	-0.594	-0.169	0.450	-0.591
Temperature	-0.913	-0.594	1	0.327	0.011	0.818
Relative humidity	-0.357	-0.169	0.327	1	-0.086	0.212
Light intensity	0.351	0.45	0.011	-0.086	1	0.192
Wind speed	-0.779	-0.591	0.818	0.212	0.192	1
Sig. (2-tailed)						
Number of individual	-	0.025*	0.002*	0.385	0.394	0.023*
Number of species	0.025*	-	0.121	0.688	0.263	0.123
Temperature	0	0.121	-	0.429	0.979	0.013*
Relative humidity	0.385	0.688	0.979	-	0.840	0.614
Light intensity	0.394	0.263	0.979	0.84	-	0.649
Wind speed	0.023*	0.123	0.013*	0.614	0.649	-

Correlation significan if p-value < 0,05
*Correlation: significant

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The most commonly visited insects of Pulasan (14 species) occurred in the morning (7:00 to 8:00 am). The morning is the most effective time for pollination because it coincides with the anthesis period of flowers and the foraging time of insects. The anthesis peak time of *Nephelium* flowers is between 06:00 and 08:00 (Shivaramu et al., 2012). However, a different result was found in *N. lappaceum* in Serdang, Malaysia, where the most insect visits occur at the time of anthesis, between 09:00 and 11:00 am (Lan, 1984).

Based on Spearman correlation, humidity and light intensity do not correlate with the number of individuals. Temperature and wind speed negatively correlate with the number of individuals visiting the insects of Pulasan. Rising air temperatures and wind speeds in the environment will cause a decrease in the number of individuals visiting Pulasan. Insects are most active in the morning, and their activity decreases as the day progresses, along with the rising temperature. Insects are poikilothermic organisms, meaning their body temperature is primarily influenced by environmental temperature. Generally, the effective temperature ranges of insects encompass a minimum temperature of 15°C, an optimum temperature of 25°C, and a maximum temperature of 45°C (Jumar, 2000). The temperature observed in this study ranged from 26.1°C to 38.8°C, which is still within the normal range for insects to be able to carry out their activities.

CONCLUSION

The flower-visiting insects of Pulasan in Mekarsari Fruit Park comprise 24 species belonging to six orders: Diptera, Hymenoptera, Hemiptera, Coleoptera, Lepidoptera, and Orthoptera. The highest number of individuals was the *Lathyrophthalmus* sp. Some species of visiting insects have the potential to be pollinators of pulasan, such as *Lathyrophthalmus* sp. and *A. huebneri*. The presence of pollinating insects can enhance the success of cross-pollination in pulasan, which is expected to increase both the yield and quality of the fruit.

AUTHOR CONTRIBUTION

The contributions of all authors in this research: **M.J.** carried out the collection examination and wrote the first draft of the manuscript. All authors revised, improved, and approved the final manuscript.

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CONFLICT OF INTEREST

All co-authors have reviewed and agreed to the manuscript's contents, and there is no financial interest to report.

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