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Population Dynamic of Fruit Fly Pests *Bactrocera* spp. in Salacca Orchard in Relation to Host Plants and Climate Factors

Yuliani Dwi Putri[1)], Rachmad Gunadi[2)], Deni Pranowo[3)], Affandi[4)], and Suputa[1*)]

[1)] Departement of Plant Protection, Faculty of Agriculture, Universitas Gadjah Mada, Sleman 55281, Yogyakarta, Indonesia
[2)] Departement of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada, Sleman 55281, Yogyakarta, Indonesia
[3)] Departement of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Gadjah Mada, Sleman 55281, Yogyakarta, Indonesia
[4)] National Research and Innovation Agency, Indonesia

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*) Corresponding author:
E-mail: puta@ugm.ac.id

ABSTRACT

Fruit flies are an economic important of pest on horticultural crops. One of the commodities that are affected much due to fruit fly attack is salacca var. pondoh. The number of fruit flies attacking salacca increased from 2018 to 2021. The aims of the research was to study the population dynamics in salacca orchards in relation to climate factors and host plants. The research was conducted from July 2022 to May 2023 in salacca orchards that are members of the Salacca Farmers Association Mitra Turindo in Wonokerto, Turi, Sleman, Yogyakarta, Indonesia. The methods were counting the number of fruit flies trapped in three observation groups with different levels of sanitation and host plants around salacca orchards. Descriptive and arithmetic methods were used to determine the pattern of population oscillation among the three observation groups and differences in sanitation levels and host plants around the salacca orchards. The result showed that population fluctuations of *Bactrocera* spp. in salacca orchards were correlated with rainfall and relative humidity and less correlated with temperature and wind speed. Fruit fly abundance was lower in salacca orchards with better sanitation and fewer host plants around the salacca orchard.

INTRODUCTION

One of the most damaging major pests of horticultural crops worldwide, including Indonesia, is the fruit fly (Stephens et al., 2007). Vargas et al. (2015) and Doorenweerd et al. (2018) reported that there are 932 species of fruit flies belonging to Dacinae. These include the genus of *Bactrocera*, with 9 species which are reported to be highly destructive. Invasive fruit fly species attack many commercial fruits, making this pest as a threat. *Bactrocera dorsalis* species complex is a complex species consisting of 70 species of fruit flies including *B. dorsalis* and *B. carambolae* which are important pests due to their wide host range (Drew & Romig, 2013). *Bactrocera dorsalis* species complex is a fruit fly with an almost uniform distribution in several countries of the world, with a wide host range (polyphagous) and a high morphological similarity and compatibility (Schutze et al., 2012; Schutze et al., 2013). Based on Schutze et al. (2015), *B. papayae*, *B. philipinensis*, and *B. invadens* are classified as one species with *B. dorsalis* because they share many similarities in morphological, molecular genetic, cytogenetic, sexual compatibility, and chemoecological characters. Allwood et al. (1999) and Suputa et al. (2010) reported that there are different types of fruit fly larval host plants in

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Indonesia. Female fruit flies use ovipositor to lay eggs in the fruit, causing puncture wounds. These wounds facilitate microbes to enter the fruit and the rotting process occurs more quickly thus reducing the economic value of the fruit. According to Putra & Suputa (2013), *B. dorsalis* species complex are the fruit fly species causing the most yield defection to many agricultural plants in Indonesia. Aryuwandari et al. (2020) and Fitrah et al. (2020) reported that *B. dorsalis* and *B. carambolae* are known to attack salacca fruit in Yogyakarta.

The plants that grow around the orchard are strongly related to the presence and population of pests in the orchard (Affandi et al., 2019). Especially plants that can be the main and alternative hosts of fruit flies (Mwatawala et al., 2006; Kamala Jayanthi & Verghese, 2011). Population dynamics of fruit fly pests can be influenced by several factors, including main and alternate host plants in an agroecosystem, agroclimatic conditions and natural enemies (Aluja & Rull, 2009; Ahmad, 2020; Bana et al., 2017; Susanto et al., 2022; Yin et al., 2018).

Fruit orchards are typically infested with fruit fly pests due to the wide range of fruit fly host preferences and plant species around the orchards as the fruit flies's hosts. Area-wide integrated pest management (AW-IPM) is an appropriate method to achieve low pest prevalence. AW-IPM programs aim to suppress specific pest populations in and around agricultural areas until they reach a state of low pest prevalence (Area of Low Pest Prevalence (ALPP)) (FAO/IPPC, 2016). Based on FAO/IPPC (2017; 2018) as one of the export requirements, ALPP is designated as a buffer area to achieve PFA in areas that are not geographically isolated. The export value of salacca fruit in 2021 increase by more than 30% (Direktorat Jenderal Hortikultura (Ditjenhorti), 2022). Good agricultural practices (GAP) are the first step for farmers trying to export their agricultural products. One of the requirements for fruit exports is that the fruit must be yielded from those that have implemented Standard Operational Procedures (SOP), GAP, and IPM as stated in the Protocol of Phytosanitary Requirements for the Export of Salacca Fruit from Indonesia to China in 2019. NNC reports related to the detection of fruit fly larvae in salacca fruit from Indonesia were also reported by the Netherlands in 2019, 2020 and 2021 (EPPO, 2019; 2020; 2021).

Sleman Regency has a large agricultural area. Nearly 70% of the district is agricultural land (orchards and paddy fields) and forests. The agricultural commodities cultivated are food crops, horticulture and plantations (BPS, 2022). One of the leading horticultural products of Sleman Regency is salacca. According to BPS (2022), the production of salacca in Yogyakarta increased throughout 2019–2021, and Sleman Regency is the highest salacca producer in Yogyakarta. One of the production centers in Sleman Regency is Wonokerto, Turi, Sleman. Wonokerto has a salacca orchards that have implemented GAP and the farms are registered. This supports the research on the population dynamics of *Bactrocera* spp. Management strategies for *Bactrocera* spp. can be successful with basic information on population dynamic and abundance. Therefore, all factors that affect the abundance and dynamic of the population must be recorded. Climate, especially rainfall, is an important factor in determining the growth and developmental stages of *Bactrocera* spp. in salacca orchards. The aim of this study was to describe the population dynamics of *Bactrocera* spp. on salacca and to correlate it with climate and salacca development.

MATERIALS AND METHODS

Experimental Time and Site

The research was conducted in salacca orchard with the area of 2.1 ha. The orchards belong to Mitra Turindo Salacca Farmer Group Association, Wonokerto, Turi, Sleman, DI Yogyakarta. The research was also conducted in the Laboratory of Basic Entomology, Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Gadjah Mada (UGM). The site was divided into three groups, and each group covered the area of 0.7 ha. The distance between plants within a row is 1.5 – 2 m and the distance between rows is 2–2.5 m. The trees are 15–20 years old. The Group 1 site was treated with sanitation. The condition represented less leaf litter due to pruning of the fronds and low availability of alternate hosts. Group 2 was treated with sanitation similar Group 1, yet with high availability of alternate hosts. In Group 3, huge leaf litter from fronds pruning was allowed surrounding the plants with high availability of alternate hosts. The site was located at altitude of 487-604 m asl. Detail of the sampling sites was presented in Fig. 1 and Table 1. Daily data of rainfall, relative humidity, temperature, and wind speed were obtained from Climate Station (BMKG), Yogyakarta. Details of the distance between Climate Station Yogyakarta and experimental site were presented in Table 2. The study was conducted from July 2022 to May 2023.

Trapping and Identification

The Steiner traps was made following the procedure developed by FAO and IAEA

(International Atomic Energy Agency (IAEA), 2003) with modifications. Five traps were set in each group with an average distance between traps was 205 meters (Fig. 1). The trap was made from a cylindrical plastic container with a diameter of 9.5 cm and 4.5 cm high. The base and lid had Ø 3 cm holes for fruit flies to enter (Fig. 2). The inside of the jar was given an iron wire to hook the dental cotton and the wire was given fly- proof glue to avoid ants and other insects. The jar was installed horizontally.

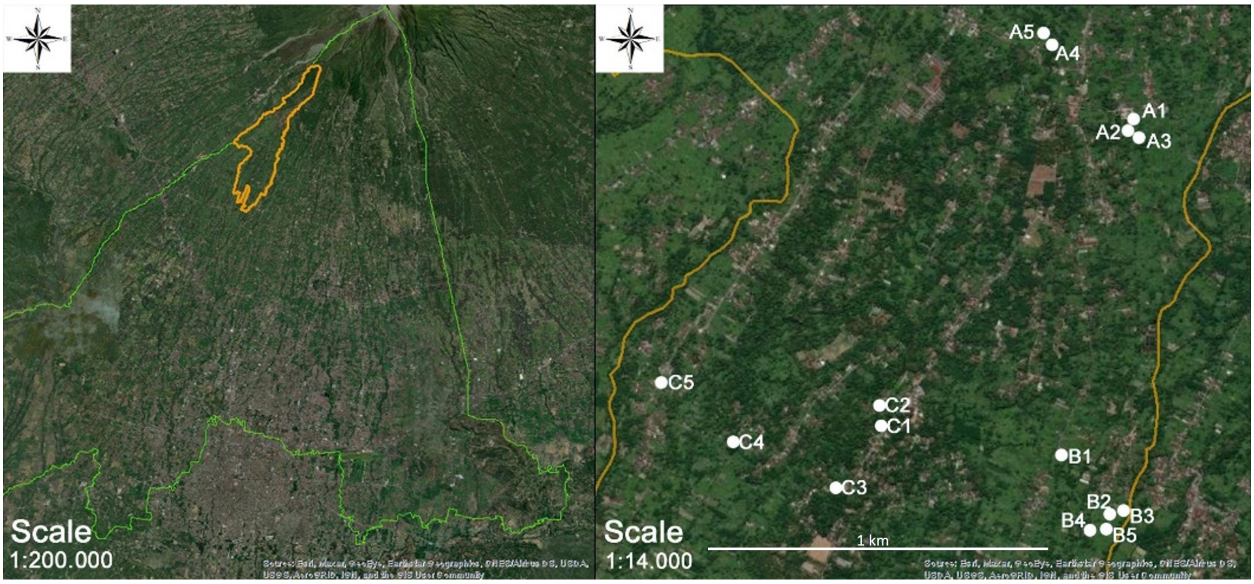

Fig. 1. Experimental site in Wonokerto, Turi, Sleman

Table 1. Detail characteristics of observation site

Location		GPS coordinate	Category	
Group	Trap number		Sanitation	Host Plant
1	A1	7°37’17.30”S 110°23’05.80”E	++	- -
	A2	7°37’18.10”S 110°23’05.60”E	++	- -
	A3	7°37’18.60”S 110°23’06.10”E	++	- -
	B4	7°38’10.60”S 110°23’00.50”E	++	- -
	B5	7°38’10.50”S 110°23’01.70”E	++	- -
2	B1	7°38’00.90”S 110°22’56.70”E	++	-
	B2	7°38’08.50”S 110°23’03.00”E	++	-
	B3	7°38’08.40”S 110°23’04.20”E	++	-
	A4	7°37’06.60”S 110°22’54.90”E	++	-
	A5	7°37’05.70”S 110°22’54.40”E	++	-
3	C1	7°37’56.90”S 110°22’32.90”E	+	-
	C2	7°37’54.33”S 110°22’33.26”E	+	-
	C3	7°38’05.00”S 110°22’27.00”E	+	-
	C4	7°37’59.10”S 110°22’13.60”E	+	-
	C5	7°37’51.40”S 110°22’04.10”E	+	-

Remarks: Sanitation in The Orchard Category: **++** The salacca orchard less leaf litter. The results of cutting the fronds through gathering them between the salacca plants, **+** The salacca orchard huge leaf litter from the leaves of the shade trees and the results of cutting the fronds by cutting them into small pieces and spreading them on the soil surface; Host Plants around The Orchard Category: **- -** There are few alternate host plants of *B. dorsalis* and *B. carambolae* around the orchard; **-** There are many alternater host plants of *B. dorsalis* and *B. carambolae* around the orchard

The jar was mounted on a 150 cm high iron pole as shown in Fig. 3. Transparant sheet was placed on the top of the steiner trap to protect the trap from rain. The mix attractant methyl eugenol (ME) in the amount of 2 ml and 0.5 ml insecticide (lambda-cyhalothrin 25 g/l) were injected into dental cotton. The trapped fruit flies were collected weekly from July to December 2022, then brought to the laboratory for preservation and identification. Identification of fruit flies was carried out following the book of Drew & Romig (2013) and Larasati et al. (2016).

Bactrocera dorsalis has a medium-sized circular facial spot with black coloration. The thorax has a scutum color that varies from reddish brown to black and sometimes has a dark lanceolate pattern in the middle, medium-sized mesopleural stripe. Medial postsutural vittae are absent. Scutellum, postpronotal lobes and notopleura are yellow, there is a pair of broad lateral postsutural vittae of parallel or subparallel type whose length reaches the intra alar seta. The femurs are pale yellow and the tibiae are brownish yellow to blackish brown. Cells bc and c are transparent with microtrichia only on the outer corner of cell c. There is a narrow blackish-brown costal band. Costal band is right at the R2+3 (sometimes slightly beyond the R2+3) and extends to the wing apex (sometimes slightly beyond the R4+5). The pale brown anal streak is narrow. The abdomen is orange-brown and varies in pattern but basically has a black "T" pattern on tergum III-V. The "T" pattern is formed by narrow transverse stripes along tergum III and narrow longitudinal stripes on the medial part of tergum III-V. The anterolateral corners of tergum IV and V are blackish brown, sometimes triangular in shape, especially on tergum IV. A pair of orange-brown or pale yellowish oval-shaped ceromata on tergum V.

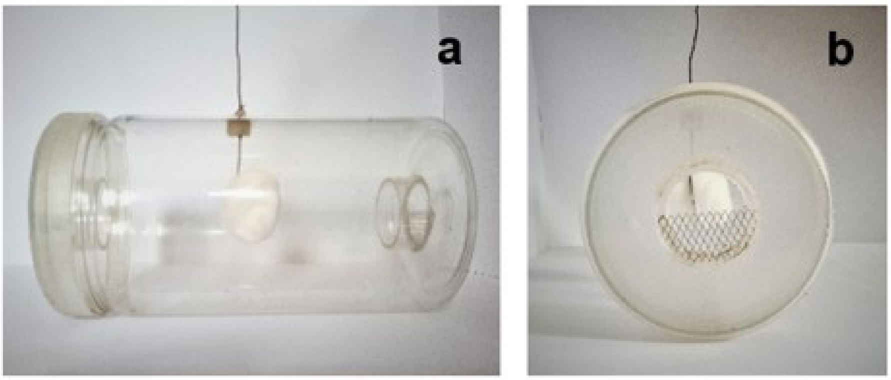

Fig. 2. Modified Steiner Trap side view (a) and front view (b)

Table 2. The distance of Climate Station Yogyakarta from experimental site (meters)

Trap Number	Climate Station Yogyakarta	
	Main office 7°43'52.31"S 110°21'16.94"E	Ledoknongko Rainfall Observation Post 7°39'52.80"S 110°21'27.40"E
A1	12.640	5.650
A2	12.612	5.626
A3	12.598	5.620
B4	11.018	4.243
B5	11.033	4.271
B1	11.272	4.392
B2	11.104	4.343
B3	11.114	4.370
A4	12.871	5.767
A5	12.895	5.785
C1	11.212	4.084
C2	11.292	4.164
C3	10.934	3.787
C4	11.034	3.767
C5	11.225	3.894

Meanwhile, *B. carambolae* has a medium-sized oval-shaped facial spot in black. The thorax has a black scutum with brown coloration on the posterior lateral postsutural vittae, medium-sized mesopleural stripe. Lacks medial postsutural vittae. Scutellum, postpronotal lobes and notopleura are yellow, there is a pair of wide lateral postsutural vittae of parallel or subparallel type whose length reaches the intra alar seta. The femurs are pale yellow. The tibiae are blackish brown and pale apically. Cells bc and c are transparent with microtrichia only at the outer corners of cell c. There are costal bands and narrow anal streaks of blackish brown color. The costal band is slightly past the R2+3 venation and extends past the end of the R2+3 venation and the R4+5 venation, sometimes forming a hook-like shape at the end. Abdomen is orange brown, tergum III-V has a black "T" pattern. The "T" pattern is formed by a narrow transverse line along tergum III that widens laterally and a medium-sized longitudinal line on the medial part of tergum III-V. On the anterolateral corners of tergum IV, there is a blackish-brown pattern with a rectangular shape, blackish-brown anterolateral corners of tergum V, and a pair of orange-brown oval-shaped ceromata on tergum V. Further, the identification was also supported by digital microscope, carried out up to the species level. The identified fruit flies species were then verified by fruit fly taxonomic expert.

Data Analysis

Log10 transformed raw data to satisfy parametric normality assumption. The population data was used to observe the population dynamics of fruit flies in salacca orchards in Wonokerto, Turi, Sleman. Flies per trap per day (FTD) were counted from each trap at different locations. Data of trapped fruit flies, climate factors (rainfall, relative humidity, temperature and wind speed) were analyzed using parametric statistics to determine the correlation. Data of trapped fruit flies by sanitation category and alternate host plant category were analyzed with Independent Sampe T-test. Data on the presence of flowers and fruits in the orchards, fruit fly population data in Group 1, Group 2, and Group 3 were analyzed using One-Way ANOVA with Tukey post-hoc test (α = 0.05).

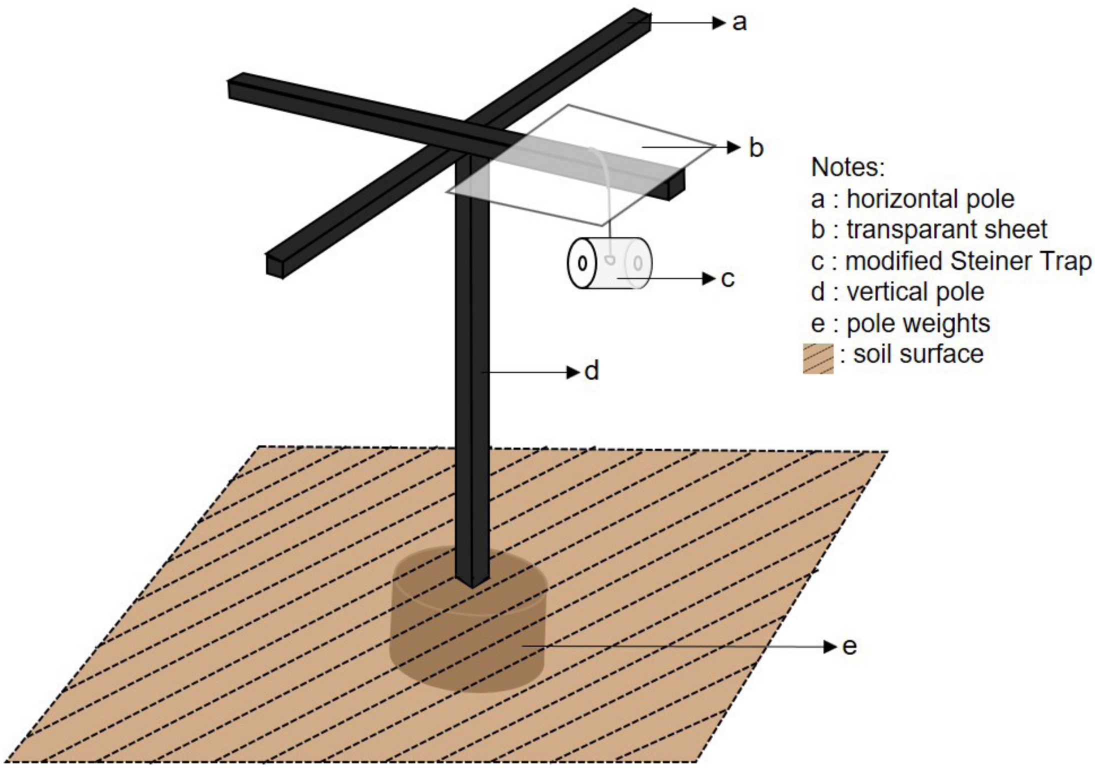

Fig. 3. Modified Steiner Trap Pole

RESULTS AND DISCUSSION

Fruit Fly Species

During the trapping period, 2 fruit fly species were found. The identification of fruit fly indicated that two species were discovered associate in salacca orchard i.e. *B. dorsalis* and *B. carambolae* (Fig. 4 and Fig. 5). In this research, *B. dorsalis* and *B. carambolae* were trapped in salacca orchard. Similar research survey of fruit flies associated with fruits in Sleman indicated that *B.* dorsalis and *B. carambolae* were associated with salacca cv. Pondoh (Aryuwandari et al., 2020; Fitrah et al., 2020). The most distinction characteristics between *B. dorsalis* and *B. carambolae* could be seen on the costal band and tergum.

The life cycles of *B. dorsalis* and *B. carambolae* are generally similar. Danjuma et al. (2014) found that *B. carambolae* and *B. papayae* have an optimal temperature for mating at 25-27°C. Michel A. et al. (2021) reported the life cycle of *B. dorsalis* in the temperature range of 20-33°C, eggs take an average of 1-2 days to hatch, larvae become pupae in an average of 7-11 days, pupae becomes imago in an average of 7-14 days. The life cycle of *B. carambolae* in the temperature range of 20-30°C, eggs take an average of 1-2 days to hatch, larvae becomes pupae in an average of 7-13 days, and pupae becomes imago in an average of 7-14 days (Danjuma et al., 2014).

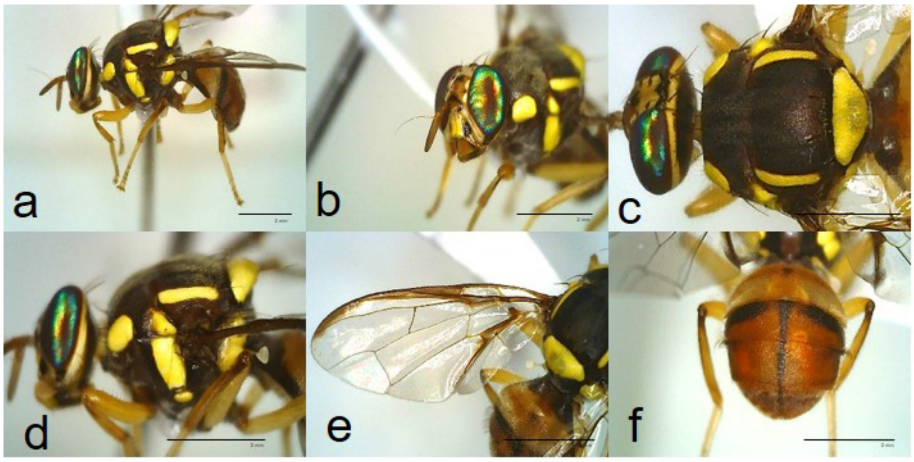

Fig. 4. Morphology of male *Bactrocera dorsalis* lateral view (a), head (b), dorsal thorax (c), lateral thorax (d), wings (e), and dorsal abdomen (f)

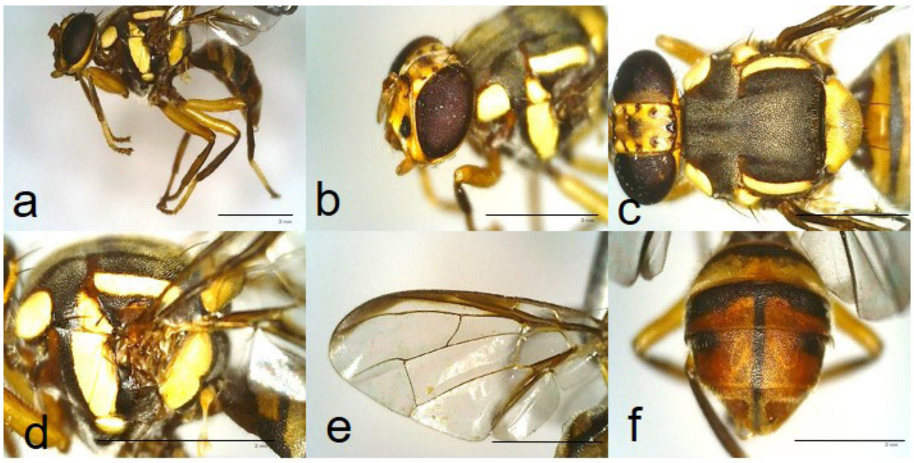

Fig. 5. Morphology of male *Bactrocera carmbolae* lateral view (a), head (b), dorsal thorax (c), lateral thorax (d), wings (e), and dorsal abdomen (f)

A fluctuate population dynamic of fruit fly was gained from the three groups. In early observation the population was relatively high (July–August 2022) and reached the peak of population (September 2022), then decline and gained the lowest flat population during December to January 2022. Further, escalation fruit fly population was happened step by step from February to May. Seem likely the available of mature salacca as source of egg laying trigger the existence of male fruit fly to interact for female (Fig. 6). Abiotic factor especially rainfall and relative humidity correlated to the fluctuation population of fruit fly in the research area (Table 3). The population dynamics of fruit flies in the homogenous orchard was mostly correlated with biotic and abiotic factors. Biotic factors include the numbers and availability of alternate hosts. Abiotic factors involved the climatic factors such as rainfall, humidity, temperature, and wind speed (Tan & Serit, 1994; Danjuma et al., 2014).

The population mean of fruit fly in Group 1 was significantly different from Group 2 and 3, however, Group 2 was not significantly different with Group 3 (Table 4). Apparently, sanitation plays a significant role in determine population fluctuation of fruit flies. According to Niassy et al. (2022), Klungness et al. (2005), Jang et al. (2007), Hasyim et al. (2008), orchard sanitation is strongly correlated with fruit fly population abundance.

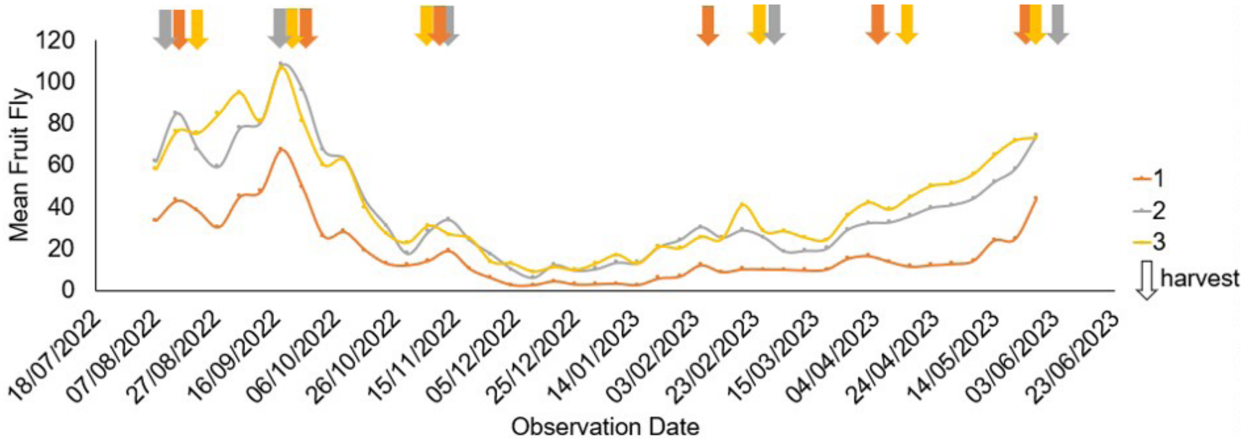

Fig. 6. Population dynamics of *Bactrocera* spp. in three observation Group

Table 3. Relationship beetwen climate factors and fruit fly population

	Rainfall	Relative Humidity	Temperature	Wind Speed
N	**42**	**42**	**42**	**42**
Sig. (2-tailed)	0.000*	0.006*	0.662	0.119
Correlation coefficient (Spearman)	-0.731	-0.416	0.078	-0.202

Remarks: Values marked (*) indicate a correlation α < 0.05

Table 4. One-way ANOVA of mean fruit fly population, number of fruit flies, number of flowers, and number of fruits in Group 1, Group 2, and Group 3

	Group	N	Fruit flies	Flowers	Fruit
Average	1	43	1.11[a]	1.10[a]	9.28[a]
	2	43	1.50[b]	1.11[a]	9.08[a]
	3	43	1.53[b]	1.08[a]	9.28[a]
F			21.25	0.26	0.36
Sig.			0.00*	0.77	0.70

Remarks: Number followed by different letters in a column the same shows there is significant difference based on the test Tukey HSD α = 0.05; Values marked (*) indicate the is a significant difference in α = 0.05

The salacca fruits can be harvested throughout the year, since the the flowers emerged periodically even, the pollination process requires human assistance. The availability of host plants is one of the factors that influence the presence of fruit flies. The availability of fruit fly hosts guarantees the availability of breeding grounds for fruit fly larvae. The availability of salacca fruit in each observation groups is not the only factor that causes the abundance of *B. dorsalis* and *B. carambolae*. Based on one-way ANOVA analysis, there is no significant difference in flowers and fruits in Group 1, Group 2 and Group 3 as shown in Table 4. The average number of flowers and fruits in each Groups are not significantly different.

However, based on Table 5 and Fig. 7 the presence of *B. dorsalis* and *B. carambolae* in the alternate host plants around salacca orchard, indiated that the closer the salacca orchard to the alternate host plants, the fruit flies population wound be higher. These alternate host plants can increase the breeding source of *B. dorsalis* and *B. carambolae* almost throughout the year (Kamala Jayanthi & Verghese, 2011).

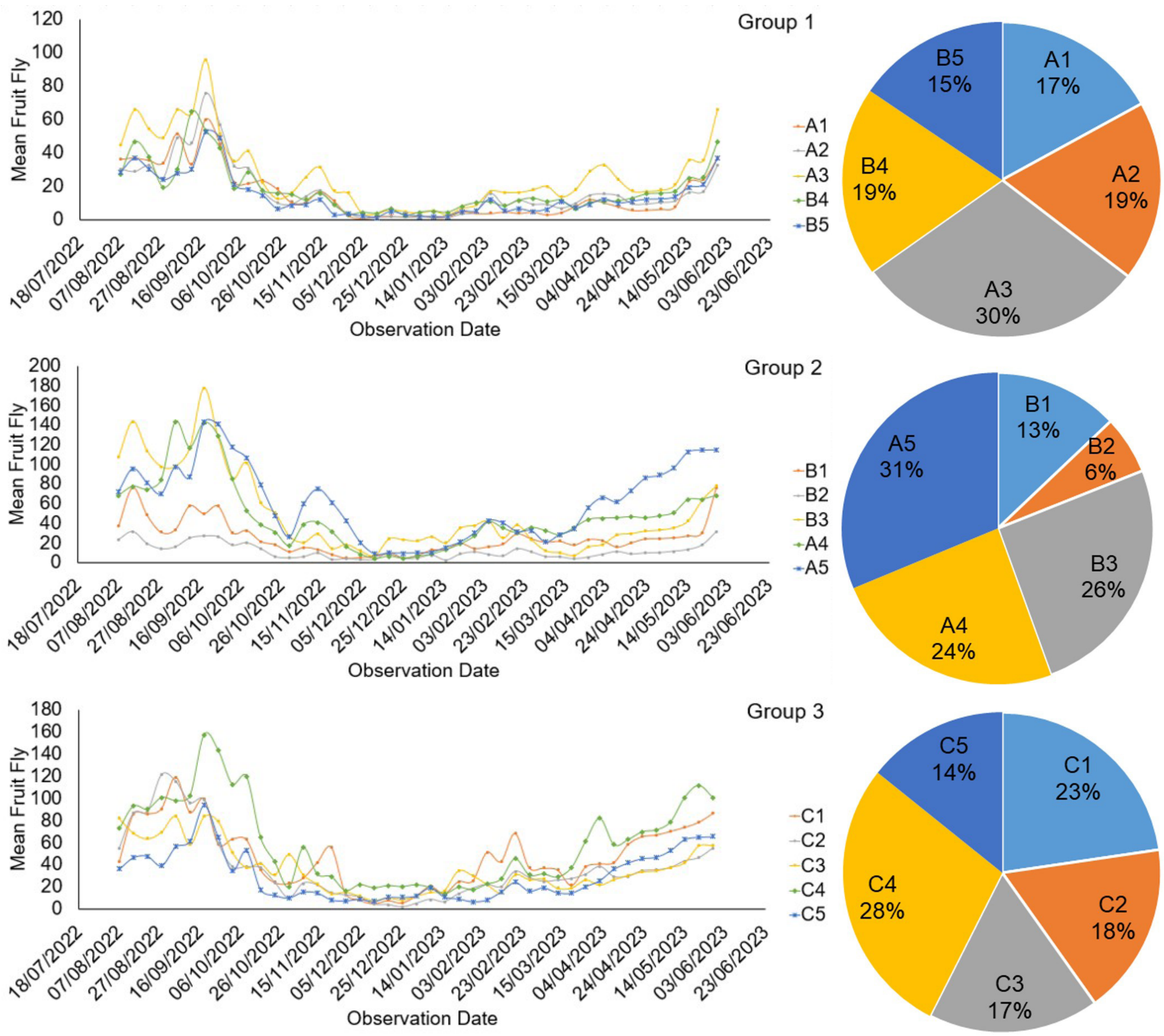

Fig. 7. Population dynamics (left) and population abudance composition (right) of *Bactrocera* spp. at each trap in Group 1, Group 2, and Group 3

Salacca orchard in Sleman Regency is included in the homogeneous land category. Homogeneous land is land where only one type of plant dominates. Salacca plants are plants that need shade, so there are shade trees in the land that are taller than Salacca trees. The shade trees found in the middle of the salacca orchard are large woody trees such as Banyan and Water Guava. Other plants that can harbor fruit flies around the salacca orchard can also affect the abundance of fruit flies.

Table 5. Independent Sampe T-test analysis of fruit fly population mean

Category	N	df	Sig. (2-tailed)	t
Cleanliness	43	84	0.00*	4.70*
Host Plant	43	84	0.00*	5.70*

Remarks: The value marked (*) in the Sig. (2-tailed) indicated the is significant difference at α = 0.05; The value marked (*) in the t column indicates significantly difference; The t value N with df 84 = 2.00. In the Category of Cleanliness and Host Plants has a $t_{value} > t_{table}$ indicates significantly difference

The presence of *B. dorsalis* and *B. carambolae* host plants in each Groups are shown in Fig. 8. Fig. 8 shows that there are fewer host plants of *B. dorsalis* and *B. carambolae* in Group 1 compared to Group 2 and Group 3. Group 1 has fewer alternative hosts including jackfruit, papaya and water guava. Group 2 has more alternative hosts like bitter gourd, chili, cucumber, guava, malay apple, orange, papaya and water apple. In Group 3 there are also many alternative hosts such as bitter gourd, chili, breadfruit, guava, cucumber, jackfruit, tomato and water apple. According to Allwood et al. (1999) and Suputa et al. (2010) the alternate hosts have been recorded in Fig. 8 are *B. dorsalis* and *B. carambolae* hosts.

Indonesia is known to be an equatorial country with a tropical climate. Countries with tropical climate tend to have warm temperatures and humid air throughout the year. Indonesia has two seasons, the rainy and dry seasons. The rainy season started from October to March and the dry season is usually from April to September. Tan & Serit (1994) and Clarke (2019) explained that in areas where fruit flies are endemic (especially the genus *Bactrocera*), and temperature and humidity tend to be stable, the factor that affects the abundance and population dynamics is the presence of hosts. As shown in Fig. 9, the increase in the fruit fly population from July to September 2022 coincided with the low rainfall during that month. The decrease in fruit fly population that occurred from October 2022 to January 2023 also coincided with the high rainfall that occurred during that month. After that, the rainfall intensity decreased again until the end of the observation in May 2023. It appears that 100–160 mm per week of rainfall could significantly reduce fruit fly populations. In accordance with the opinion of Khan et al. (2021), rainfall was found have a negative correlation with fruit fly abundance. Based on Fig. 9, Fig. 10 and Table 3, rainfall and relative humidity are correlated with fruit fly population, while temperature and wind speed are not correlated with fruit fly population. The Spearman correlation coefficient values of rainfall and relative humidity are 0.731 and -0.416, which means that the level of correlation between rainfall and fruit fly population is strong, and the level of correlation between relative humidity and fruit fly population is at a moderate degree. The negative sign on the correlation coefficient value means that the higher the rainfall and relative humidity, the lower the fruit fly population. The research of Vayssieres et al. (2009; 2015) on the population of *Bactrocera* invadens in mango orchards in Africa showed that rainfall has a strong positive correlation with the role of increasing fruit fly populations. These results are slightly different from Bana et al. (2017), found that wind speed was the most influential factor on *B. dorsalis* abundance in mango orchards in India, with rainfall having little effect on abundance.

Rainfall has a strong influence on relative humidity. Rainfall also affects the amount of soil moisture in the orchards. The feeding larvae inside the fruit cause the fruit to soften and eventually fall to the ground. The prepupal larvae then jump out of the fruit onto the ground to pupate. Fruit fly pupae require soil to develop into imago. When the rain occurs almost every day with high intensity, the soil in the orchards will be wet. Research on *B. dorsalis*, *B. latifrons*, *B cucurbitae*, and *Ceratitis capitata* has shown that fruit flies are more suitable for pupation in moist media than in dry media and prefer larger media particles (Aloykhin et al,. 2001; Jackson et al., 1998). The relative humidity of fruit fly pupation media has been shown to affect the success rate of fruit flies in becoming imago. In media with higher relative humidity, the success rate of *B. oleae* and *B. dorsalis* to become imago is lower (Dimou et al., 2003; Hou et al., 2006).

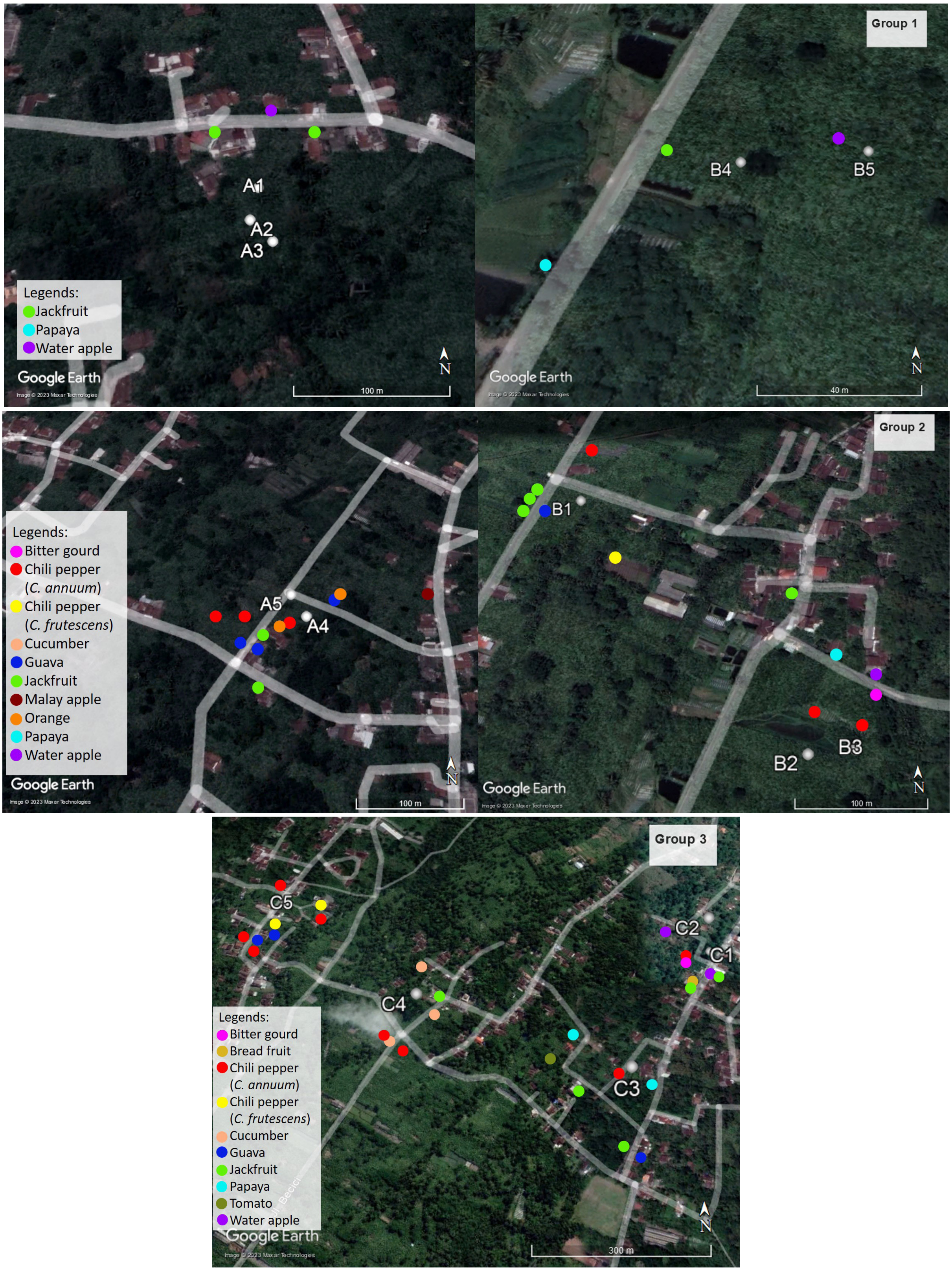

Fig. 8. Alternate host plants of *B. dorsalis* and *B. carambolae* around salacca orchard Group 1, Group 2 and Group 3

Research by Amaral et al. (2021) on the effect of soil type (loamy soil, sandy loam, and sandy soil) and moisture level (0%, 30%, 60%, and 90%) on pupation depth and viability of *B. carambolae* pupae found something slightly different. Strong interactions between soil type and soil moisture affect pupal viability. The emergence of *B. carambolae* pupae increased at high soil moisture levels in loamy and sandy loam soils. Similar findings were reported by Hulthen & Clarke (2006) for *B. tryoni*. In the research of El-Gendy & AbdAllah (2019), it was revealed that the age of *B. zonata* pupae affects the success of becoming imago in the treatment of different soil types and different soil moisture levels. Four-day-old pupae were more resistant to the treatment and produced more imago than 0-day-old and 7-day-old pupae.

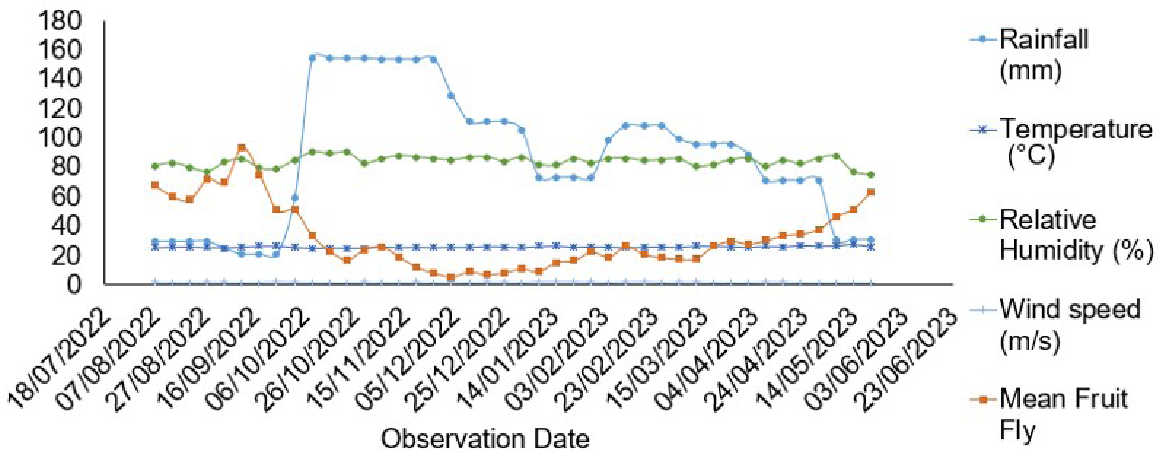

Fig. 9. Comparison of rainfall, temperature, relative humidity, wind speed, and fruit fly population

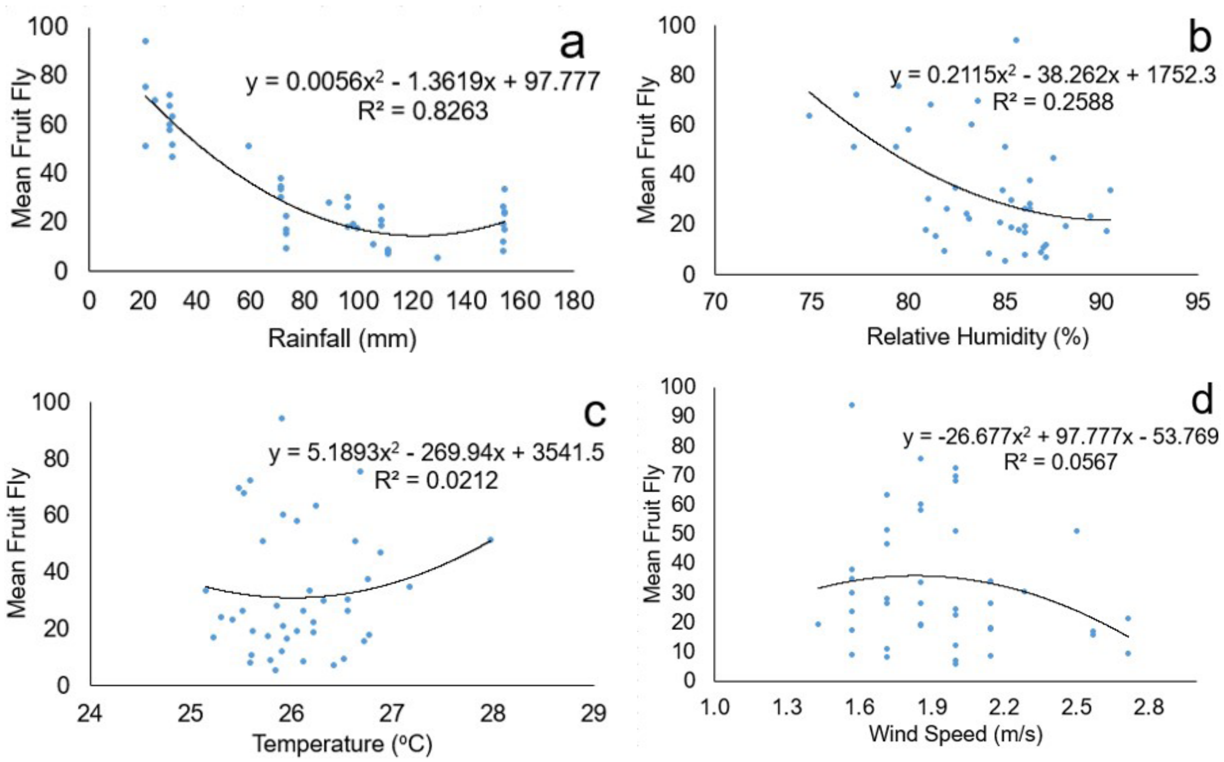

Fig. 10. Correlation of climate factors (rainfall (a), relative humidity (b), temperature (c), wind speed (d)) to fruit fly population

CONCLUSION

The population of *Bactrocera* spp. in salacca orchards were fluctuated and formed a seasonal pattern. Population dynamics of *Bactrocera* spp. in salacca orchards were correlated with rainfall and relative humidity. Population dynamics were not correlated with temperature and wind speed. The Salacca orchard with cleaner conditions and few alternate host plant have fewer *Bactrocera* spp. populations compared to others.

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