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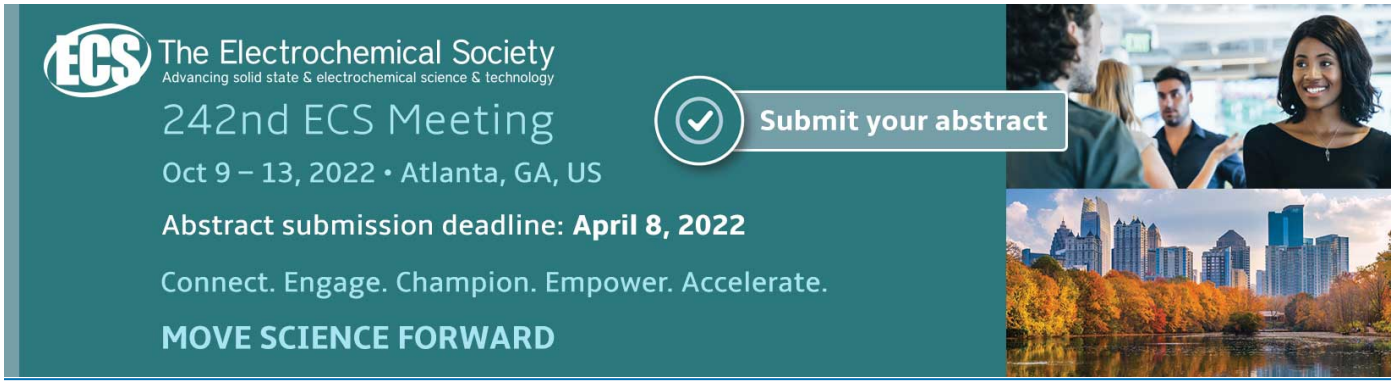

Interaction of parasitoids associated with fruit flies attacking star fruit *(Averrhoa carambolae)* in Denpasar City, Bali Province, Indonesia

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Abstract. Star fruit (Averrhoa carambola) is a fruit plant that has a high consumption rate, especially in the Central/South America and Asia-Pacific regions including Indonesia. The fruit fly, Bactrocera spp. become a major pest on star fruit commodities in Indonesia which can harm quantity and quality which in turn hampers export activities. The aims of this study was to identify the type of pest, the level of attack, and the type of parasitoid associated with star fruit flies in the Denpasar City area. Fruit samples were collected using a purposive sampling method, namely collecting symptomatic fruit planted in four sub-districts in Denpasar City. Identification was carried out on the types of fruit flies and parasitoids that emerged after the rearing period. The percentage of fruit damage and the degree of parasitization was also determined. The fruit flies identified were Bactrocera carambolae and B. dorsalis and two parasitoids, namely Fopius arisanus and Diachasmimorpha longicaudata. The percentage (%) of fruit damage was 83.10%. The interaction that occurs between the fruit fly population and the level of damage is also very close. In all observation sites in Denpasar City, the parasitization rate of F. arisanus was higher than that of D. longicaudata. Our findings indicate that fruit flies are one of the main causes of star fruit damage in Denpasar City and should be integrated into a more comprehensive Integrated Pest Management (IPM) program by the relevant authorities.

1. Introduction

The starfruit, Averrhoa carambola L., is one of the most significant fruit commodities found in Southeast Asia [1]. The nutritional composition of star fruit contains vitamin A, vitamin C, vitamin B1 & B2, citric acid, ketoglutaric acid, oxalic acid, tartaric acid, and carotene with mineral content in every 100 grams of fruit [1]. In Indonesia, starfruit plants are commonly planted in communal settlements and are utilized for different household requirements until they are sold to traditional markets. However, although

Indonesia is geographically located in a tropical climatic condition, several invasive insects and parasites that target star fruit have been claimed to have led to star fruit output declines and poor quality [2].

Fruit flies (Diptera: Tephritidae) are the most severe pests damaging fruit commodities in Indonesia, particularly during the rainy season. These pests affect star fruit (A. carambola L.), mango (Mangifera indica L.), and guava (Psidium guajava L.) commodities. The action of female fruit flies, for example, when laying eggs on fruit, can cause harm to fruit flesh. Furthermore, the eggs that are put in the flesh of the fruit that has developed into larvae will devour the fruit, therefore amplifying the amount of harm. Attack symptoms, such as black spots on the fruit, lead the fruit to fall before maturity. Secondary infection with fruit rot fungus and bacteria was also linked to qualitative damage. The incidence of crop failure causes quantitative harm in the form of a significant reduction in the number of harvests. According to some reports, fruit fly infestations can result in production losses of up to 50-75 %. Fruit fly infestations cause a 40-70 % reduction in fruit production in other nations, such as Bangladesh [3].

This is critical because each country must consider biosecurity problems such as the presence of invasive pests when exporting and importing fruit commodities. This practice is carried done to prevent pests from spreading to other nations via fruit flesh. In relation to this, agricultural product regulation in Indonesia is governed by Regulation of the Minister of Agriculture Number 61/PERMENTAN/OT.140/10/2010. The legislation explicitly specifies that it is required to develop and maintain technical plant quarantine policies, as well as to conduct plant biosafety surveillance against Invasive Alien Species (IAS), which has been the object of monitoring for agricultural commodities to date.

Farmers in the field, on the other hand, continue to employ chemical insecticides to control fruit fly infestations, and the application of these pesticides is massively utilized to mix various types of insecticides and spray them with a high frequency. Poor agronomic practices can lead to increased heavy metal pollution as well as other contaminants, such as the development of foodborne pathogens and pesticides that accumulate in fruit [4,5]. In terms of agroecology, pesticide application damages the variety of pollinating insects, predators, and parasitoids, leading to the establishment of new populations of resistant invading pests.

Fruit fly pests must be managed to enhance star fruit output. Integrated Pest Management (IPM) approaches include the employment of biological organisms like parasitoids, which are natural adversaries of fruit pests and can be employed as an alternative since they show promising possibilities. In nature, parasitoids can continue to develop indefinitely and do not require significant expenditures to use their services. Such control techniques are critical in the field to optimize the function of natural enemies of agricultural pests [6,7]. According to reports, the spontaneous administration of parasitoid agents can protect grapevines and is a low-cost method of controlling plant pests [8]. The parasitoids' mode of action is to parasitize the body of the host (insect) in order to weaken and harm it [9]. Fruit fly infestations have been extensively observed to be controlled by parasitoids from the Order Hymenoptera, Family Braconidae. Suputa et al. [10] report how the parasitoids F. arisanus, Agasnapis sp., and Asobara sp. successfully parasitize star fruit fly in Yogyakarta's Special Region (DIY). Putra et al. [11] reported an average of 11.12 % parasitoid parasitization on star fruit in Gianyar Regency, Bali.

There is currently no information available concerning fruit flies and the types of parasitoids found on star fruit in the Denpasar City region of Bali. This is significant since Denpasar City is the capital and largest urban region in Indonesia, with a population density of 10,798 people / km2. Fruit flies can be transmitted by population mobility activities that occur across cities/districts by transporting fruit commodities given to Traditional Markets (Badung Market) to supermarkets. The aim of the research is to species identification of fruit flies and their parasitoids mainly feed on star fruit in the Denpasar City region. These findings will be used to supplement prior data from a star fruit plantation in Gianyar, Bali [11]. This is, to the state of the art, the first survey of the impact of pest damage and parasitoids on star fruit in Denpasar.

2. Materials and methods

2.1. Study sites

The research was carried out between November 2020 - March 2021. In the Denpasar City region, field research is being conducted in residential areas with starfruit trees. The Integrated Pest Management Laboratory (IPMLab), Faculty of Agriculture, Udayana University, Bali, conducted laboratory-scale research.

2.2. Determination of location and samples

Purposive sampling was used to collect data in four districts of Denpasar City: Denpasar, West, South Denpasar, East Denpasar, and North Denpasar. At each location in the sub-district, 5 fruit trees were chosen, resulting in a total of 21 fruit trees as examples (see Figure 1). Up to ten-star fruits that exhibited symptoms of an assault were placed in a sterile plastic bag with a label on each tree. The sample period was repeated 5 times every 4 days.

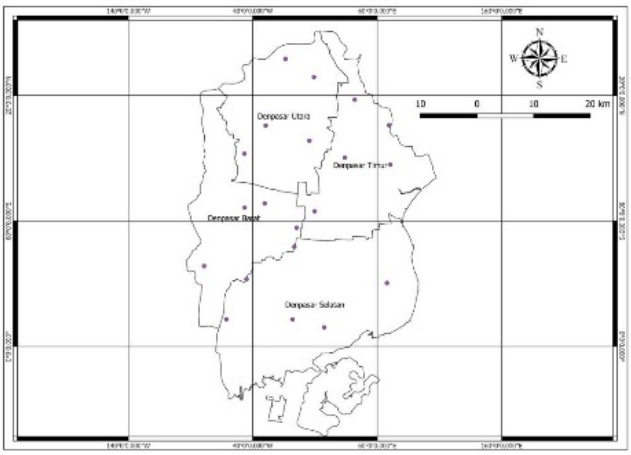


Figure 1. Study sites in Denpasar City, Bali Province

2.3. Maintenance method

The star fruit samples were placed in a clear plastic bottle that was used as a storage container. The bottle has a height of 23 cm and a diameter of 8.5 cm, and it has been filled to a height of 10 cm with sand. One symptomatic star fruit was placed in one bottle. Gauze was used to seal the bottle (Figure 2). Every day, observations on the appearance of parasitoids and fruit flies were made.

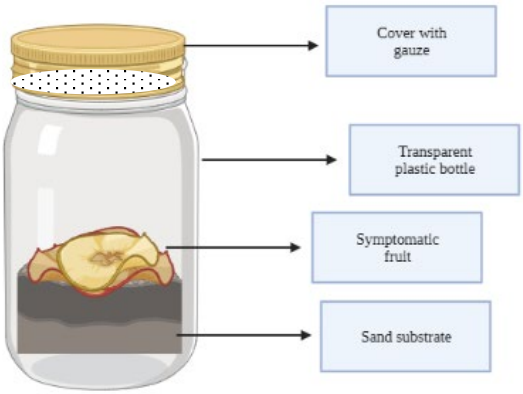


Figure 2. Fruit fly breeding container (Created with BioRender.com)

2.4. Research procedure

2.4.1. Identification of fruit flies and parasitoids

Adult flies in each rearing container were identified using a microscope based on the morphological characteristics of each species. Schutze et al. were cited as identification guidelines [12], International Center for the Management of Pest Fruit Flies (ICMPFF) & Ministry of Agriculture Republic of Indonesia (KEMENTAN) [13], and Suputa et al. [10]. As for the type of parasitoid identified referring to Sharkey and Wahl [14] and Carmichael et al. [15]. The findings of the identification are recorded and reported.

2.4.2. Relative abundance (%)

The relative abundance of fruit fly populations was determined using the equation of McCarthy and Magurran [16] namely:

$$Relative\ abundance = \frac{species\ number\ at\ x\ location}{total\ number\ of\ species\ at\ x\ location}\ x\ 100\% \quad (1)$$

2.4.3. Attack percentage (%)

The percentage of fruit fly attacks was determined by randomly selecting up to 50 fruits from each tree. The star fruit included in the assessment has a yellowish-green to totally yellowish color, including the fruit that has falling and those that are still on the tree. The following is the attack percentage equation:

$$Attack\ percentage = \frac{number\ of\ infected\ fruit}{total\ number\ of\ fruit}\ x\ 100\% \quad (2)$$

2.4.4. Parasitzation rate

The parasitization rate possessed by parasitoids was determined using the following equation:

$$Parasitization\ rate = \frac{\Sigma\ number\ of\ parasitoids}{\Sigma\ adult\ fruit\ fly + \Sigma\ adult\ parasitoid\ (a+b+c)}\ x\ 100\% \quad (3)$$

2.5. Data analysis

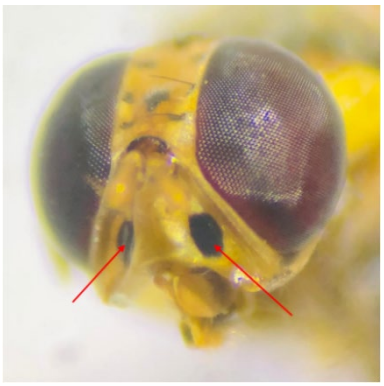
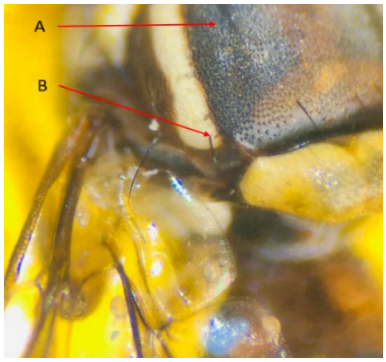
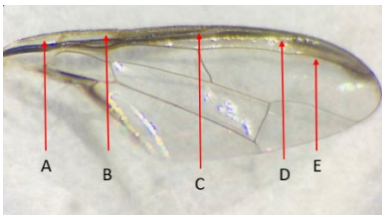
The collected data was examined descriptively, that is, by methodically, factually, and properly summarizing the facts and characteristics of the people in specific locations. Ms software was used to tabulate the data on relative abundance, attack percentage, and parasitization rate. Microsoft Excel 2019 (Microsoft, USA). Tables, graphs, and images are used to show information [17].

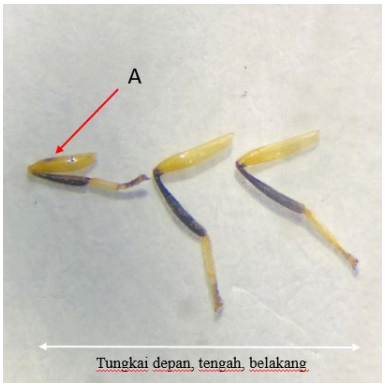
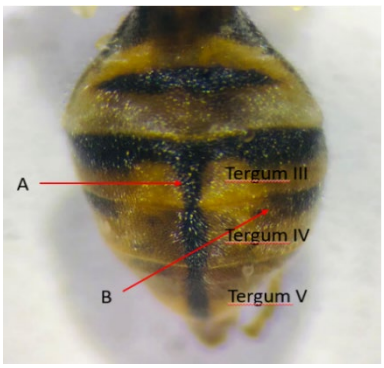
3. Results and discussion

3.1. Fruit flies

According to the identification findings, there are two species of fruit flies that attack star fruit in the Denpasar City area: *Bactrocera carambolae* and *Bactrocera dorsalis*. Table 1 shows the image of the identification result.

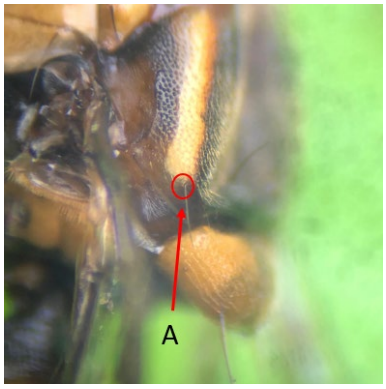
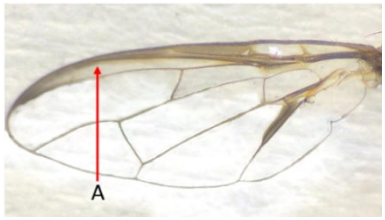
Table 1. Types of star fruit flies in the Denpasar City area

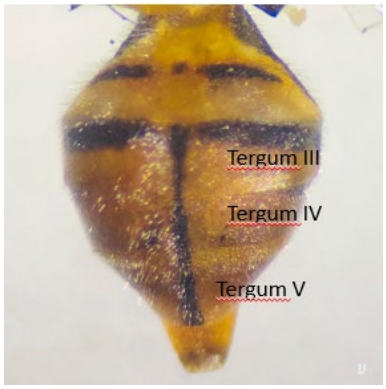
Bactrocera carambolae			
No	**Morphology**	**Figure**	**Description**
1	Whole body		• Body dark brown to black. • The caput is dark orange. • Legs light brown.
2	Head		The head is equipped with a pair of medium-sized black spots
3	Thorax		The dark color on the scutum (A), setae present before the tip of the yellow band on the lateral side (B).
4	Wings		Wings, Costal band 1 (A), Costal band 2 (B), R1 (C), R2+3 (D), R4+5 (E). The wing pattern at the end (apex) is shaped like a fishing rod and overlaps at R2+3

5	Insect limbs		The limbs of the front, middle and hind femurs are pale. dark front, middle, and back tibias. There is a dark spot on the apical femur (A).
6	Abdomen		The abdomen has a medial longitudinal line on tergum III-V (A), and there is a black pattern with a rectangular shape on terga IV (B).

Bactrocera dorsalis

No	Morphology	Figure	Description
1	Whole body		The whole body is brownish orange.

2	Head		On the head, there is a large black spot.
3	Thorax		The setae of the thorax are located at the tip and outside of the yellow band (A).
4	Wings		On the wing, the costal band is confluent with R2+3 (A).
5	Insect limbs		The color of the front, middle, and hind femurs are pale. The color of the front tibia is dark, middle dark, back dark to black.

6	Abdomen		Abdomen with well-defined segments, at tergum III –V orange-brown with T. pattern

3.2. Relative abundance

The proportional quantity of fruit flies that attack star fruit varies by observation region. The relative abundance of fruit fly population in East Denpasar District with *B. carambolae* species was determined to be 62.89 % (1,822 adults), followed by B. dorsalis species at 37.11 % (1,075 adults). The relative abundances of *B. carambolae* and *B. dorsalis* in South Denpasar District were 66.74 % (1,782 adults) and 33.26 % (888 adults) respectively. Furthermore, the relative abundance of *B. carambolae* fruit flies in the West and North Denpasar sub-districts was 63.48 % (1.884 adults) and 60.94 % (1.884 adults), respectively (1.743 adults, respectively). Meanwhile, *B. dorsalis* was identified in 36.52 % (1,084 adults) and 39.06 % (1,084 adults) of the last two sub-districts (1,117 adults). Figure 3 depicts the relative features of fruit flies.

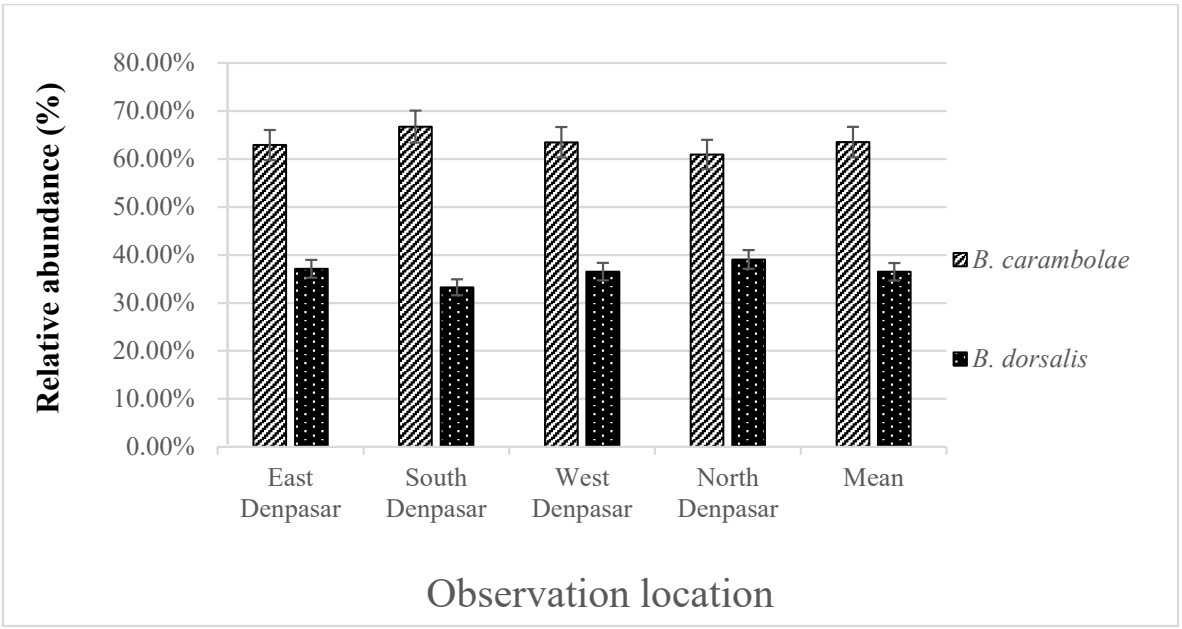


Figure 3. The relative abundance of fruit flies found on star fruit in the Denpasar City area

The variation in the number of adult flies in each sub-district can be attributed to a variety of factors, including the availability of fruit in the field, the level of fruit ripeness, and alternative hosts. The West Denpasar District has a disproportionately large amount of star fruit trees, making them simple to locate. When compared to other sub-districts, almost every house in the West Denpasar region has a starfruit tree with dense fruiting circumstances, and there are alternate hosts such as mango, guava, and water

guava that are adjacent to the starfruit tree. The presence of diverse varieties of fruit in a region provides a favorable environment for the growth of fruit fly pests [18]. Fruit maturity is dominated by yellowish-green to yellow in the West Denpasar District. Fruit flies choose these hues to deposit their eggs. This supports the results of Sahetapy et al. [19], who found that fruit flies prefer white and yellow over other colors. The golden color of ripe fruit has been identified as an appropriate host for female fruit flies to deposit eggs [20]. Susila and Supartha [21] have reported that the color and scent of the host fruit influence fruit fly activity in locating hosts.

3.3. Attack rate

In Denpasar City, the percentage of fruit fly attacks on star fruit varies from 83.10 percent to 83.10 %. According to our data, the West Denpasar area had the greatest percentage of attacks (85.20 %), while the South Denpasar area had the lowest (80.80 %). The outcome of the attack is depicted in Figure 4 below.

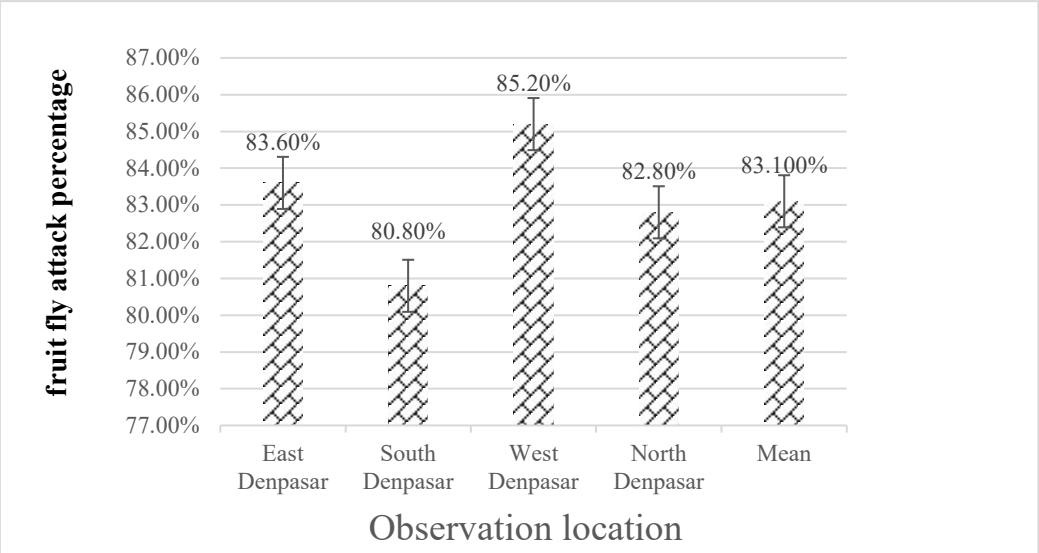


Figure 4. Percentage of fruit fly attacks on star fruit in Denpasar City

The proportion of attacks carried out is determined by the number of adult flies in the field; as the number of adults increases, so does the percentage of attacks. Furthermore, control measures like as trapping, cleanliness, and pesticide usage could all have an impact on the proportion of attacks [22].

3.4. Parasitism rate

Diachasmimorpha longicaudata and *Fopius arisanus* are two parasitoids that interact with fruit flies, according to our results. The interaction is in the form of parasitism that uses fruit flies as its host to continue its life development.The level of parasitoid parasitization in the four sub-districts in Denpasar City was ranging from 8.22 to 9.30 percent. The incidence found in East Denpasar sub-district, the parasitization level of *F. arisanus* was *(8.89%; 286* adults) and *D. longicaudata* (1.09%; 35 adults), while in South Denpasar sub-district, the parasitization level of *F. arisanus* was 8.22% with 241 adults and *D. longicaudata* was 1.09% with 35 adults). Parasitization rates of parasitoid *F. arisanus* were (9.30%; 308 adults) and (8.42%; 266 adults) in the Districts of West Denpasar and North Denpasar, while the parasitization rate of *D. longicaudata* was 1.06% with 35 adults and 1.04% with 33 adults) in West Denpasar (Figure 5).

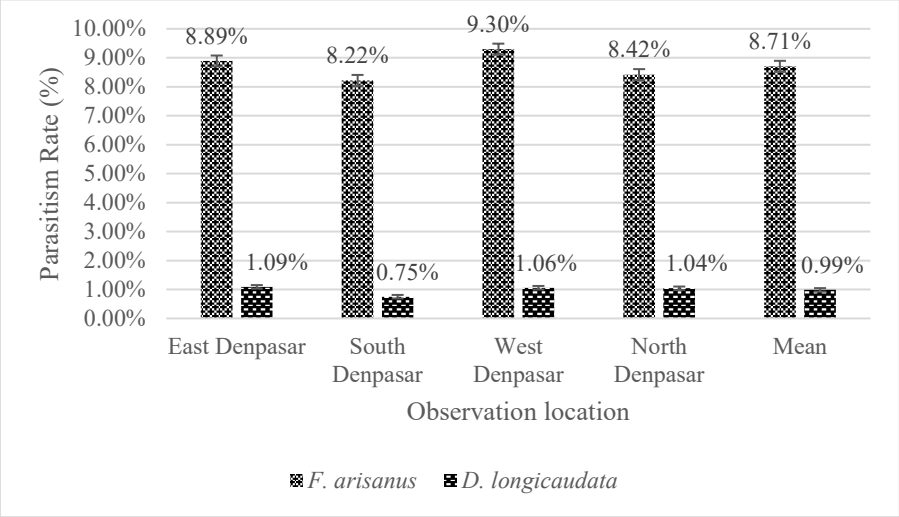


Figure 5. Parasitism rate of parasitoids against fruit flies on star fruit in Denpasar City area

The data revealed that the West Denpasar District has the greatest degree of parasitization. We believe this occurrence was caused by the sub-high district's quantity of fruit flies in comparison to other sub-districts in the Denpasar City region. According to Herlinda et al. [23] the parasitoid population can be influenced by the variety of the host plant and the host population (fruit fly). This proved that the rise in the number of parasitoids was exactly proportionate to the increase in the number of fruit flies in the field, and opposite. Several studies recommend attempts to improve parasitoids' efficacy as natural enemies, which may be accomplished by supplying increased food supplies such as sugar, which has a role in parasitoids' survival and reproduction [24,25]. Host quality, on the other hand, can influence the fitness and effectiveness of progeny parasites [26]. Different sizes of the same parasitoid affect various biological features, showing that larger parasitoids have longer life spans and are more competitive [27].

F. arisanus dominated the parasitization rate in all observation regions. *F. arisanus* is a single koinobiont parasitoid found in a variety of fruit species, particularly those of the genus Bactrocera. Researchers in Africa introduced *F. arisanus* for biological control of *Bactrocera dorsalis* in a variety of fruits and crops [28]. Similarly, prior research reported *F. arisanus* in *Silba adipata*, which attacked the white chili pepper *(Capsicum frutescens L.)* in Bali Province [29]. The findings also revealed that *D. longicaudata* had the highest parasitization rate in *S. adipata*, which attacked white chili peppers in Bali Province.

Based on these data, we hypothesized that the difference in parasitization rate of parasitoids was also highly impacted by the type and quantity of the host in the field. However, the parasitoid rate of parasitoids in star fruit flies in this study was high due to the high abundance of fruit flies in general, and the presence of star fruit cultivated in residential areas was not interfered with by the use of synthetic pesticides, so it became one of the indications that parasitoids still survive in plant hosts.

4. Conclusions

Parasitoids that interact with fruit flies on star fruit in Denpasar are *D. longicaudata* and *F. arisanus* with *B. carambolae* and *B. dorsalis*. The form of interaction is parasitism by utilizing fruit flies as a host for the survival of each parasitoid. The more dominant parasitoid parasitizing fruit flies was *F. arisanus* with parasitization levels ranging from 8.22 to 9.30 percent in the field. *B.carambolae* had a higher population abundance in all locations compared to *B. dorsalis* with an attack rate ranging from 80 - 85 percent in the field.

5. Acknowledgment
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