

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/365636140>

Association of Hymenoptera Parasitoid with Fruit Flies (*Bactrocera dorsalis* Complex) Attacking Guava Fruits (*Syzygium aqueum*) in Gianyar

Article · November 2022

CITATIONS

0

READS

49

6 authors, including:



I Wayan Susila

Udayana University

63 PUBLICATIONS 121 CITATIONS

[SEE PROFILE](#)



I Wayan Supartha

Udayana University

97 PUBLICATIONS 184 CITATIONS

[SEE PROFILE](#)



I Kadek Wisma Yudha

Udayana University

25 PUBLICATIONS 59 CITATIONS

[SEE PROFILE](#)



I Wayan Eka Karya Utama

Udayana University

16 PUBLICATIONS 19 CITATIONS

[SEE PROFILE](#)

Some of the authors of this publication are also working on these related projects:



Spatial Distribution Mapping and Farmer Responses to Invasive Pest Attacks Spodoptera Frugiperda J.E. Smith (Lepidoptera: Noctuidae) In Bali – Nusa Tenggara [View project](#)



New Record of *Silba adipata* McAlpine (Diptera: Lonchaeidae) as a Pest of White Chili Fruit in Bali of Indonesia [View project](#)

Association of Hymenoptera Parasitoid with Fruit flies (*Bactrocera dorsalis* Complex) attacking Guava fruits (*Syzygium aqueum*) in Gianyar, Bali Province, Indonesia

Susila, I. W.^{1*}, Sumiartha, I. K.¹, Supartha, I. W.¹, Yudha, I. K. W.²,
Utama, I. W. E. K.² and Wiradana, P. A.³

¹Laboratory of Integrated Pest and Management (IPMLab), Faculty of Agriculture, Udayana University, Bali Province, Indonesia; ²Doctoral Student of Agriculture Science, Faculty of Agriculture, Udayana University, Bali Province, Indonesia; ³Study Program of Biology, Faculty of Health, Science and Technology, Universitas Dhyana Pura, Bali Province, Indonesia.

Susila, I. W., Sumiartha, I. K., Supartha, I. W., Yudha, I. K. W., Utama, I. W. E. K and Wiradana, P. A. (2022). Association of Hymenoptera Parasitoid with Fruit Flies (*Bactrocera dorsalis* Complex) Attacking Guava Fruits (*Syzygium aqueum*) in Gianyar, Bali Province, Indonesia. International Journal of Agricultural Technology 18(6):2645-2662.

Abstract Fruit flies are considered a significant insect problem in Indonesia and worldwide as they prey on a wide variety of fruits and vegetables. The study found three types of fruit flies that attack water guava fruit in Gianyar Regency, namely *Bactrocera albistrigata*, *Bactrocera carambolae* and *Bactrocera dorsalis*. The highest percentage of attacks on water guava fruit was found in Gianyar District at 85.00%. The abundance of *B. albistrigata* species had the highest population with an average value of 353.4 individuals. Three species of parasitoid were found to be associated with fruit flies that attack water apple plants in Gianyar Regency, namely *Fopius arisanus*, *Diachasmimorpha longicaudata*, and *Opius* sp. Species *F. arisanus* was the highest parasitization rate of 14.28%, and is an effective natural enemy candidate in controlling fruit fly attacks on water apple. The study suggested that the different host plants of fruit fly species should be further evaluated as an effective control technique and early warning for farmers and policy makers.

Keywords: *Bactrocera dorsalis* complex, *Fopius arisanus*, Hymenoptera parasitoid, *Syzygium aqueum*

Introduction

Water guava (*Syzygium aqueum* Burm f. Alston) is a well-known fruit due to its nutrients such as vitamins A and C (Manaharan *et al.*, 2013). In the public health context, water guava is used as a traditional medicine to heal wounds on the mouth and tongue edges, increase immunity, prevent the aging process, relieve fatigue and lethargy, strengthen teeth, prevent and treat mouth sores, control blood pressure, and treat fever (Laily *et al.*, 2015). Furthermore,

* **Corresponding Author:** Susila, I. W.; **Email:** angga.wiradana@undhirabali.ac.id

the water guava production in Indonesia fluctuates from year to year. The report stated that the production in 2011 and 2012 totaled 103,156 tons and 104,392 tons, respectively. Water guava production decreased to 91,291 tons in 2013 and increased again in 2014 to 91,983 tons (BPS, 2015).

Fruit fly (Diptera: Tephritidae) is an important pest responsible for the decline in fruit production (Triplehorn *et al.*, 2005; Badii *et al.*, 2015; Aryuwandari *et al.*, 2020). Currently, fruit flies from the Tephritidae family are distributed almost throughout the Asia-Pacific region by attacking more than 26 types of host plants. This pest causes losses to the guava quantity and quality, such as low or rotten water guava production. Fruit flies generally attack unripe fruits, causing yield loss of about 90-100% depending on the fruit fly population, environment, variety, and season (Sarwar *et al.*, 2014). This pest is very difficult to control in many tropical countries including Indonesia (Clarke *et al.*, 2005; Susila and Supartha, 2020). Farmers also require significantly large funds to cope with fruit fly attacks. Therefore, several countries such as Japan and Australia implemented a strict system of importing fruit products to maintain product quality and prevent invasive pests from entering their countries (Dominiak and Ekman, 2013; Vargas *et al.*, 2015).

Fruit flies consist of two well-known genera, namely *Dacus* and *Bactrocera* (Prabhakar *et al.*, 2012). The adult fruit fly has important features on its head, chest, wings, and abdomen. They have a habit of laying eggs in water guava fruit tissue. The spawning grounds are marked with a small, fuzzy black dot (Dias *et al.*, 2017). This small spot is an ovipositor puncture which is then followed by a surrounding necrotic appearance. Meanwhile, the larvae that hatch from eggs will eat the flesh of the fruit, causing the appearance of small brown spots. The larvae also destroy the fruit pulp, causing the fruit to rot and fall before ripening. This fallen fruit must be collected and destroyed immediately to prevent larger fruit fly attacks (Wiratama *et al.*, 2017a).

Similar research conducted in Bali Province confirmed fruit fly pests on various fruit commodities. Research by Putra *et al.* (2019) showed that there were two fruit fly species attacking starfruit plants in the Gianyar Regency, namely *Batrocea carambolae* and *B. papayae* with an average attack percentage of 86.33%. Furthermore, Badriasih *et al.* (2019) stated that there were three species attacking mangoes in Buleleng Regency namely *B. papayae*, *B. carambolae*, and *B. occipitalis*. On citrus plants in Gianyar and Bangli Regencies, two fruit fly species were found, namely *B. crambolae* and *B. papayae* (Wiratama, 2017b).

Pest control is necessary to enhance guava plant productivity in the community. Biological control can be used to control fruit fly attacks (Garcia *et al.*, 2020; Supartha *et al.*, 2022a). According to Schöller *et al.* (1997),

biological control is a component of integrated pest control. Although the results of research by Ovruski *et al.* (2000) stated that there was a lack of success in the introduction of exotic fruit fly parasitoids in various Latin American countries. However, the study of natural biological control/conservation is the main area that is most studied; however, augmentative biological controls had a higher study success rate and potential for success, followed by classical biological controls (Dias *et al.*, 2022).

Parasitoids are insects in the pre-adult phase that act as parasites on the bodies of other insects (hosts). These parasitoids play a role in killing or weakening the host (Purnomo, 2010). Utilizing parasitoids provides many advantages because, in addition to being safe for the environment, they are also effective in suppressing the development of certain pest populations in the field (Hidayani *et al.*, 2011). A study showed that there are several parasitoid species from the *Hymenoptera* order of the *Braconidae* family having the potential to control fruit fly (Zamek *et al.*, 2012; Ndlela *et al.*, 2020). In Malaysia, the parasitoid potential from the *Braconidae* family reached 57% and in Italy reached 80-95% (Vijayasegaran and Osman, 1991). *Braconidae* is the dominant parasitoid family in mango, guava, and chili fruits in Benin at 97%, followed by *Eulophidae* (1.6%) and *Pteromalidae* (1.2%). Furthermore, Somta *et al.* (2010) observed that out of 1,105 parasitic pupae collected from Malabar yellow almonds in Thailand, four types of parasitoids were found, *Fopius arisanus*, *Psytalia* sp., *Diachasmimorpha longicaudatus* Ashmead, and *Spalangia* sp. The parasitization rate of *D. longicaudatus* on guava in Timor Leste was 28% (Oliviera, 2015). Putra *et al.* (2019) stated that there were three parasitoid species associated with fruit flies on star fruit in Gianyar Regency, Bali Province, namely *Diachasmimorpha* sp., *Opius* sp, and *Fopius arisanus*.

The study aimed to identify the types of fruit fly species associated with water guava fruit, calculate the percentage of fruit fly attacks, identified the types of parasitoid species associated with fruit flies, and the parasitization level of the parasitoid on fruit flies attacking water guava in Gianyar Regency.

Materials and methods

Study area

This study was conducted on a field and laboratory scale. The field-scale research was carried out in Gianyar Regency, Bali, while the laboratory research was carried out at the Laboratory of Integrated Pest and Plant Disease Control, Faculty of Agriculture, Udayana University. The study lasted for 6 months from March to August 2020.

Procedure

Determination of locations and sampling method

The locations were determined using the diagonal method (Figure 1) with the following results namely Sukawati, Gianyar, Ubud, Payangan, and Tampaksiring Districts. Each location had three bearing guava fruit trees (by purposive sampling) with a minimum distance of 3 km. In addition, each tree should have at least 10 fruits attacking by fruit fly. The sampling interval was carried out every 3 days with 6 replications. In all locations, 150 pieces were obtained, therefore the total fruit collected during the research was 900 pieces.

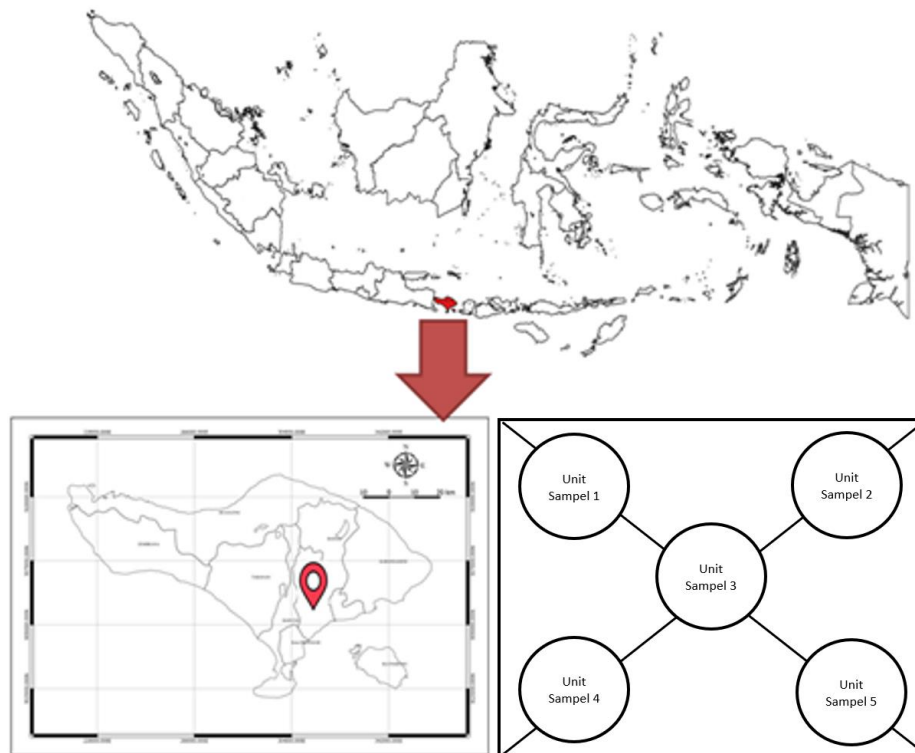


Figure 1. The sampling design in Gianyar Regency using diagonal method

Note: 1. = Payangan District (8°26'17"S, 115°16'0"E), 2. = Tampaksiring District (8°24'30"S, 115°19'18"E), 3. = Ubud District (8°32'0"S, 115°15'57"E), 4. = Sukawati District (8°34'33"S, 115°17'12"E) and 5. = Gianyar District (8°33'20"S, 115°20'12"E)

Maintenance of fruit flies

The water guava fruit showing symptoms were collected from the field and placed in a 23.5 cm high and 8.5 cm diameter transparent plastic container (Figure 2).

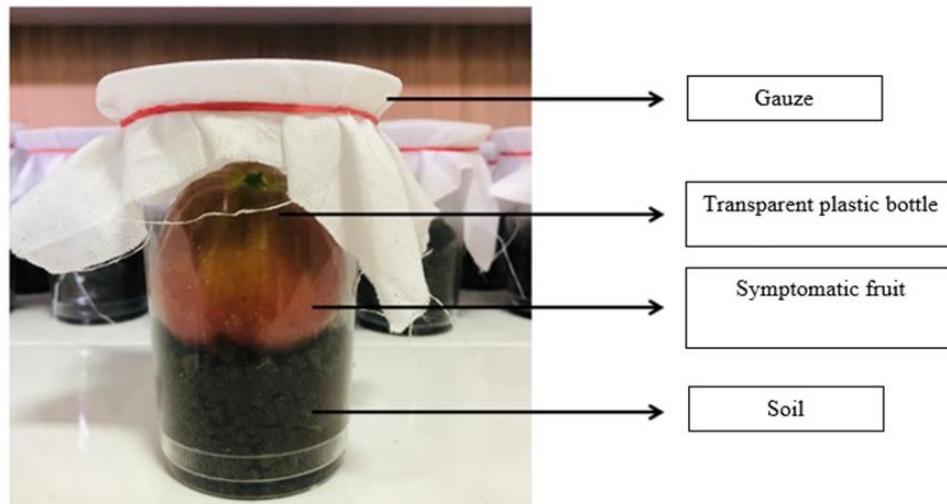


Figure 2. Fruit fly rearing container

As a medium for pupa formation, the container had soil media mixed with sand in a ratio of 1: 1 with 10 cm height, a cover, and air ventilation. The room temperature during the study was 23.00°C and 64% humidity. Furthermore, maintenance was carried out until the emergence of flies and adult parasitoids.

Fruit flies and parasitoids identification

The fruit flies and adult parasitoids that appeared in each rearing container were identified using a stereo-trinocular microscope (Olympus, Japan). Identification was carried out based on the morphological characteristics of adult fruit flies with standard protocol according to Schutze *et al.* (2018); International Center for the Management of Pest Fruit Flies (ICMPFF) & Ministry of Agriculture Republic of Indonesia (KEMENTAN) (2006); Suputa *et al.* (2006). Meanwhile, adult parasitoids were identified using the key of determination from Sharkey and Wahl (1992) and Carmichael *et al.* (2005). The identified adult fruit flies and parasitoids were recorded and documented.

Data analysis

The relative abundance index was calculated using the equation adopted from Krebs (1989). Meanwhile, the parasitization level was calculated using the formula from Buchori *et al.* (2008):

Population abundance

$$\text{Abundance (K)} = \frac{\text{Number of species found at location } x}{\text{Total number of species found at site } x} \times 100\%$$

Percentage of fruit fly attacks

$$\text{Attack percentage (I)} = \frac{\text{The number of fruit attacked}}{\text{The total number of fruits}} \times 100\%$$

Parasitization levels

$$\text{Levels of parasitization (P)} = \frac{\text{The number of adult parasitoids } A}{\text{Number of adult fruit flies} + \text{the number of parasitoids } A \text{ adult}} \times 100\%$$

Note: Parasitoid A = The number of adult parasitoids that appeared and
 Adult fruit flies = Total number of adult fruit flies from unparasitized pupae

Results

Identification of fruit fly species associated with water guava

Three species of *Bactrocera* spp. were identified, namely *Bactrocera albistrigata*, *Bactrocera carambolae* and *Bactrocera dorsalis*. The results of morphological identification showed that the three fruit fly species observed in this study.

1a There was no medial post sutural vittae in the scutum (Fig.3a)...**Genus *Bactrocera* 2**



(a)

Figure 3. The character of the medial post-sutural vittae of the *Bactrocera* spp. thorax

- 2a Face with a pair of medium-sized round dark spots (Fig.4a).....**3a**
- 2b Face with a pair of large oval black spots (Fig.4b).....**3b**

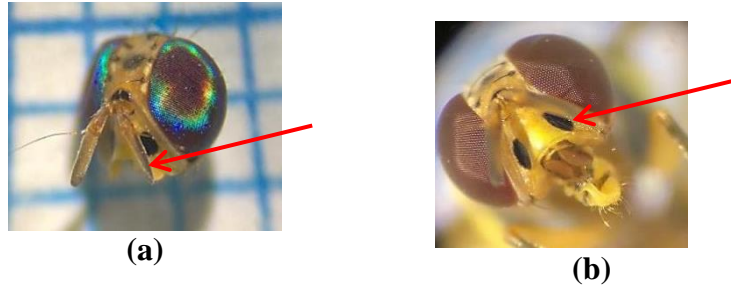


Figure 4. The spot shape at the top of the mouth (a) Round; (b) oval

- 3a The dark brown scutum (Fig.5a).....4a
- 3b The shiny black scutum (Fig.5b).....4b

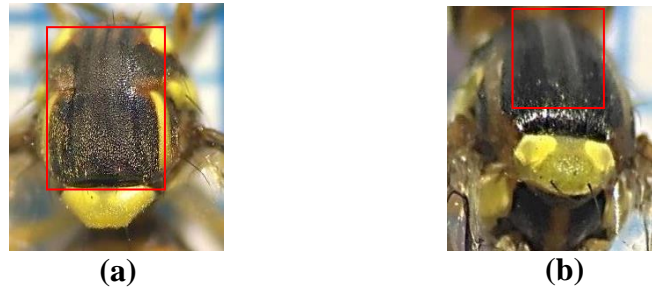
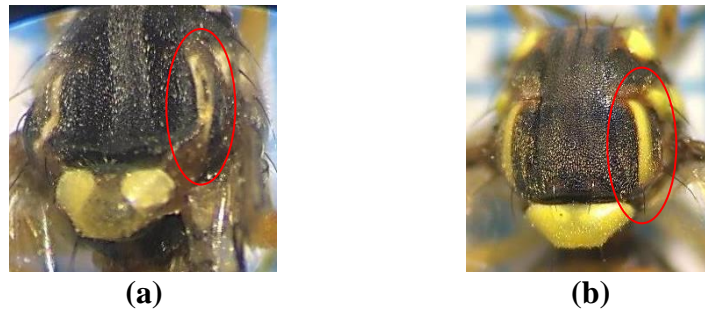


Figure 5. Scutum color. (a) Dark brown; (b) Black sparkle



- Figure 6.** The lateral width of the post sutural vittae. (a) Narrow; (b) Width
- 5a Black and narrowed T pattern of the III-V abdominal terga, rectangular pattern of terga III (Fig.7a).....6b
- 5b Black and widened T pattern of the III-V abdominal terga, triangular pattern of terga III (Fig.7b).....6a

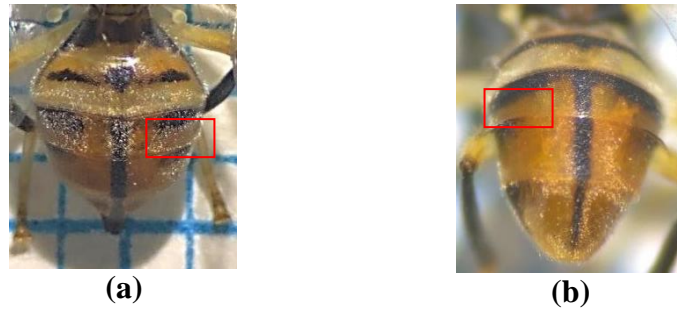
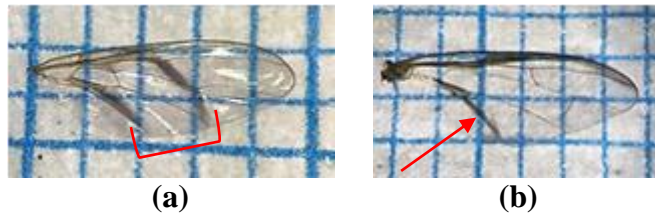


Figure 7. Abdominal pattern: (a) Quadrilateral (b) Triangle

- 6a 2 transverse bands from the costal boundary to the bottom
 (Fig. 8a).....*Bactrocera albistrigata*
 6b One transverse band on the anal part (under the wing)
 (Fig. 8b).....7



- Figure 8.** The number of bands across the flange (a) 2 bands (b) one band
 7a The costal band confluent to R_{2+3} and do not extend along the tips of the wings
 (Fig. 9a).....*Bactrocera dorsalis*
 7b The costal band overlaps with R_{2+3} with the same width until the ends of R_{2+3}
 (Fig.9b).....*Bactrocera carambolae*



Figure 9. The costal band (a) Confluent to R_{2+3} ; (b) Overlapping against R_{2+3}

Percentage of fruit fly attacks

The results showed that fruit fly attacks on water guava in Gianyar Regency had various percentages. These include Sukawati District (83.33%), Gianyar District (85.00%), Ubud District (84.44%), Payangan District

(83.89%), and Tampaksiring District (82.78%) with an average attack percentage in Gianyar Regency (83.89%) (Figure 10).

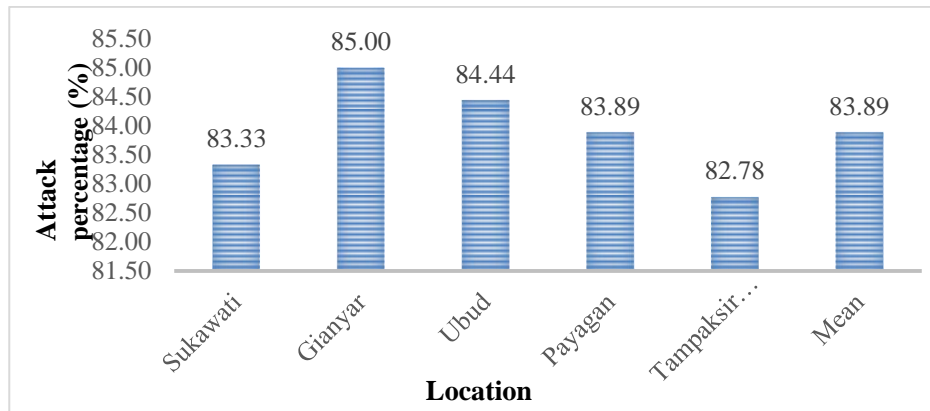


Figure 10. Percentage of Fruit Fly Attacks on Water Guava in Gianyar Regency

Abundance of fruit flies

The abundance of fruit flies attacking the guava plants showed different values in each district. The *B. albistrigata* had the highest population with an average value of 353.4 individuals. This was followed by *B. carambolae* with 349.8 individuals and *B. dorsalis* with 174.8 individuals. In Sukawati District, *B. albistrigata* constituted the dominant species with a population of 314 individuals, followed by *B. carambole* and *B. dorsalis* species with a population of 269 and 140 individuals. In contrast to Sukawati District, Gianyar District was more dominated by *B. carambole* species with a population of 394 individuals, followed by *B. albistrigata* (329 individuals) and *B. dorsalis* (171 individuals). Furthermore, the Ubud and Payangan districts were more dominated by *B. albistrigata* species with 381 and 405 individuals respectively, while the *B. carambolae* species attacking water guava totaled 343 and 388 individuals respectively. In Ubud and Payangan districts, *B. dorsalis* species had a total of 178 and 172 individuals respectively. Tampaksiring District was dominated by *B. carambolae* species of 355 individuals, followed by *B. albistrigata* (338 individuals) and *B. dorsalis* (213 individuals) (Figure 11).

Parasitoid species associated with fruit flies

There were 3 species of parasitoids associated with fruit flies attacking water guava plants in Gianyar Regency, namely *Diachasmimorpha longicaudata*, *Fopius arisanus*, and *Opius* sp. (Table 1).

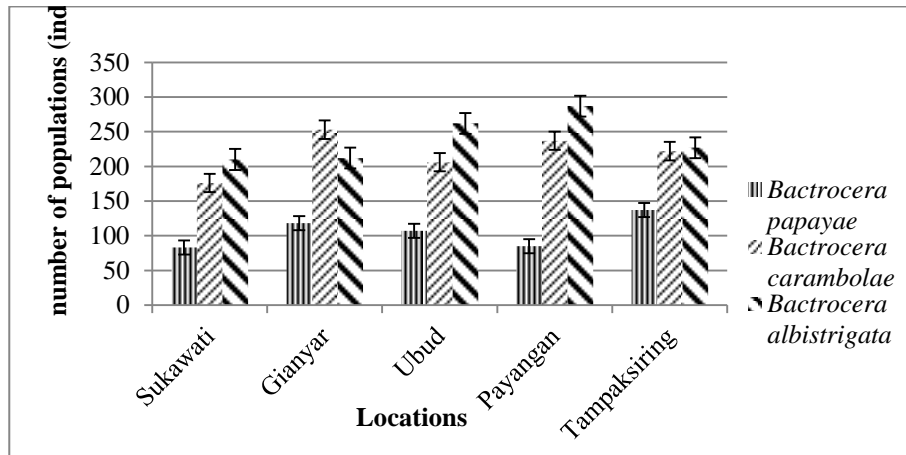











Figure 11. Abundance of Fruit Flies Attacking Water Guava in Gianyar Regency

Table 1. Types of fruit fly parasitoid species in water guava in Gianyar Regency

| <i>Fopius arisanus</i> | | | |
|------------------------|------------|---|---|
| No | Morphology | Figure | Identification |
| 1 | Whole body |  | <ul style="list-style-type: none"> • Body dark brown to black. • The caput is dark orange. • Legs light brown. |
| 2 | Thorax |  | <p>Thorax blackish brown. In the mesonotum, the notauli are clearly carved up to the midpit forming a "V"</p> |

| | | | |
|-------------------------------------|-------------------|---|--|
| 3 | Abdomen |  | <p>The belly is brownish in adult females. In tergum II there are tightly patterned lines.</p> |
| <i>Diachasmimorpha longicaudata</i> | | | |
| No | Morphology | Figure | Identification |
| 1 | Whole body |  | <p>The whole body is brownish orange.</p> |
| 2 | Thorax |  | <p>On the mesonotum, there are three lumps that are clearly visible. Notauli looks smooth and the midpit is clearly visible.</p> |
| 3 | Abdomen |  | <p>In targum II, there is an extensive pattern of longitudinal stripes</p> |

| <i>Opius</i> sp. | | | |
|------------------|------------|---|--|
| No | Morphology | Figure | Identification |
| 1 | Whole body |  | Body dark brown to black. |
| 2 | Thorax |  | The meoscutum consists of three lumps. |
| 3 | Abdomen |  | The abdomen is black. |

The results showed that the parasitoids associated with fruit flies on guava plants in the Gianyar Regency had different values for each species. *Fopius arisanus* had a very high parasitization level in all locations with an average value of 14.28%, while *Diachasmimorpha longicaudata* had a lower parasitization level and was found in Sukawati, Gianyar, Payangan, and Tampaksiring Districts with an average value of 0.23%. Furthermore, *Opius* sp. had the lowest parasitization level and was only found in Gianyar, Ubud, and Tampaksiring Districts with an average of 0.16% (Figure 12).

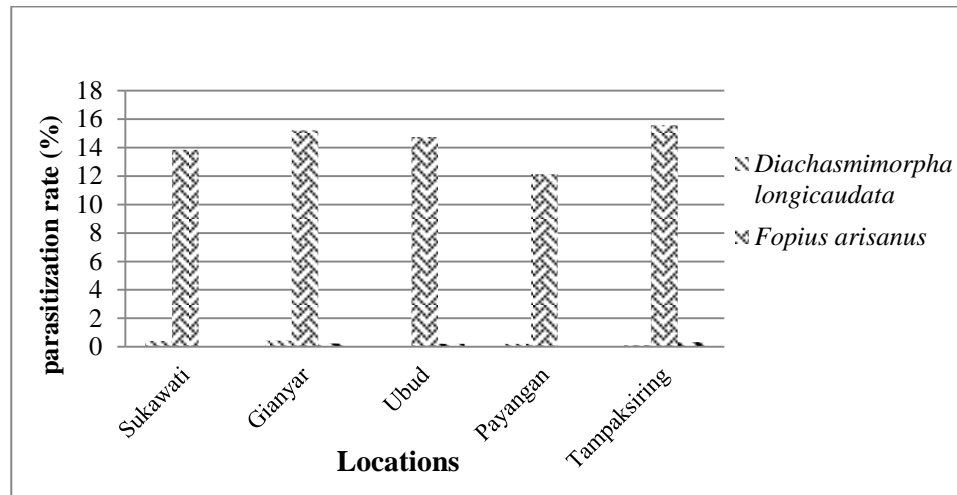


Figure 12. Parasitization Level of Fruit Flies Attacking Water Guava in Gianyar Regency

Discussion

A high percentage of fruit fly infestation has a positive correlation with a high abundance of fruit flies. The abundance of fruit flies attacking water guava plants occurred due to rarely intensive pest control treatment. In addition, the fruiting season also causes an increase in the fruit fly population due to the high number of hosts. This agrees with Radonjić *et al.* (2013) which stated that the abundance of fruit flies population is closely related to the abundance of host plants in the field. Studies also showed that fruit fly infestations also increase as the fruits ripen due to changes in skin texture and chlorophyll fluorescence when ripe (Grechi *et al.*, 2021). The percentage of attacks from fruit flies is also influenced by control techniques, namely traps, sanitation, and pesticides (Vargas *et al.*, 2015). The guava as a home plant is rarely cultivated widely and is only planted around the house yard. This causes low intensive pest control treatment when compared to other cultivated plants such as citrus, chili, and watermelon. In addition, the prevention of fruit fly infestations also involves adjusting the harvest time, especially by harvesting the fruit at the half-ripe stage (Grechi *et al.*, 2021).

The differences in the abundance of fruit flies that attack in each area in Gianyar Regency occurred due to several factors, namely biotic and abiotic (Choudhary *et al.*, 2021; Supartha *et al.*, 2022c). The biotic factors include life cycle, growth, development, survival, distribution, behavior and reproduction (Supartha *et al.*, 2020). However, the current study of insect ecology is focused on abiotic factors such as environmental temperature which impacts the rate of

development, geographic range, risk of invasive alien species and changes in insect survival (Fand *et al.*, 2014; Tonnang *et al.*, 2017). Changes in air temperature will have an impact on the abundance, range distribution and potential damage caused by fruit flies (Ahmed *et al.*, 2019). Changes in air temperature not only affect the life cycle of insects, but may also change the speed of feeding, growth, the chemical composition of the host plant, the activity of insect pest biocontrol agents, etc. (Dillon *et al.*, 2010; Kumar *et al.*, 2020).

The detection of parasitoid species is a strategic step for fruit fly control, especially for controlling the quality of its maintenance and evaluating the level of suppression of fruit flies after the mass release of parasitoids (Liang *et al.*, 2015). The results of the investigation by Liang *et al.* (2015) also support the hypothesis that *F. arisanus* and *D. longicaudata* emerged from pupae obtained from tropical almonds (*Terminalia catappa*) infested with *B. dorsalis*. Recent investigations have also shown that *F. arisanus* is found in African mangoes and has a more aggressive ability to repel other parasitoids such as *F. caudatus* (Karlsson *et al.*, 2018). *D. longicaudata* was shown to efficiently kill medfly (*Ceratitis capitata*) in peaches and oranges (Suárez *et al.*, 2019). Three wasps in the genus *Opius* spp. were shown to act as potential control agents against oriental fruit flies, namely *O. longicaudatus*, *O. vandenboschi*, and *O. ophilus* (Holt, 2017).

The parasitoid population is influenced by the host plant and host population (Cuny *et al.*, 2019; Supartha *et al.*, 2022b). In this study, the parasitization level of water guava plants were high, this may be due to the high abundance of fruit flies as parasitoid hosts. The parasitoids *F. arisanus* and *D. longicaudata* were able to coexist and attack different developmental stages of *B. dorsalis* in the same landscape (Yang *et al.*, 2018). Therefore, it is possible that interspecific competition related to “multiparasitism” occurred where these two parasitoids were able to coexist (Vargas *et al.*, 2013; Miranda *et al.*, 2015; Gao and Reitz, 2017). This provides an advantage for the parasitoids to carry out high parasitization. In addition, the absence of synthetic chemical pesticide intervention on host plants is also a factor that enables the parasitoids to survive better.

The fruit fly species associated with water guava in the Gianyar Regency were *Bactrocera albistrigata*, *Bactrocera carambolae*, and *Bactrocera dorsalis*. The highest percentage of fruit fly attacks on guava plantations was 85.00% in Gianyar District, while the lowest was in Tampaksiring District of 82.78%. The highest fruit flies population was dominated by *B. albistrigata* with an average value of 353.4, followed by *B. carambolae* with 349.8 individuals and *B. dorsalis* with 174.8 individuals. Three species of parasitoids associated with

fruit flies were observed, namely *Fopius arisanus*, *Diacasmimorpha longicaudata* and *Opius* sp. The parasitization level of *Fopius arisanus* species was very high in all locations with an average value of 14.28%. Further research is recommended for a broader fruit fly study, which is to be carried out throughout Bali Province. The expansion of sampling throughout Bali will reveal other species that have the potential to attack water guava fruit. Furthermore, unknown parasitoid species will then be identified by molecular biology using the DNA Barcoding approach.

Acknowledgements

The authors appreciate the Head Integrated Pest Management Laboratory (IPMLaB) Faculty of Agriculture, Udayana University, Bali, Indonesia which provided facilities and funding assistance. The authors are also grateful for the provided funding from the Hibah Unggulan Udayana of 2020 with Contract Number: B/1588-114/UN14.4.A/PT.01.03/2020.

References

- Ahmed, K., Sachindra, D. A., Shahid, S., Demirel, M. C. and Chung, E. S. (2019). Selection of multi-model ensemble of general circulation models for the simulation of precipitation and maximum and minimum temperature based on spatial assessment metrics. *Hydrology and Earth System Sciences*, 23:4803-4824.
- Aryuwandari, V. E. F., Trisyono, Y. A., Suputa, S., De Faveri, S. and Vijaysegaran, S. (2020). Survey of Fruit Flies (Diptera: Tephritidae) from 23 Species of Fruits Collected in Sleman, Yogyakarta. *Jurnal Perlindungan Tanaman Indonesia*, 24:122.
- Badan Pusat Statistik (BPS) (2015). *Produksi buah – buahan dan sayuran di Indonesia*. Jakarta, Indonesia. Retrieved from www.bps.go.id.
- Badii, K. B., Billah, M.K., Nuamah, K. A., Ofori, D. O. and G. Nyarko. (2015). Review of the pest status, economic impact and management of fruit-infesting flies (Diptera: Tephritidae) in Africa. *African Journal of Agricultural Research*, 10:1488-1498.
- Badriasih, K., Supartha, I. W. and Susila, I. W. (2019). Population Density and Distribution Patterns Fruit Flies (*Bactrocera* spp.) (Diptera: Tephritidae) that Attacking Mangoes (*Mangifera indica* L.) in Buleleng Regency. *Journal of Tropical Agroecotechnology*, 8:294-301.
- Buchori, D., Sahari, B. and Nurindah (2008). Conservation of Agroecosystem through Utilization of Parasitoid Diversity: Lesson for Promoting Sustainable Agriculture and Ecosystem Health. *HAYATI Journal of Biosciences*, 15:165-172.
- Carmichael, A. E., Wharton, R. A. and Clarke, A. R. (2005). Opiine parasitoids (Hymenoptera: Braconidae) of tropical fruit flies (Diptera: Tephritidae) of the Australian and South Pacific region. *Bulletin of Entomological Research*, 95:545-569.
- Choudhary, J. S., Mali, S. S., Naaz, N., Malik, S., Das, B., Singh, A. K., Srinivasa Rao, M. and Bhatt, B. P. (2021). Spatio and temporal variations in population abundance and distribution of peach fruit fly, *Bactrocera zonata* (Saunders) during future climate change scenarios based on temperature driven phenology model. *Climate Risk Management*, 32: 100277.
- Clarke, A. R., Armstrong, K. F., Carmichael, A. E., Milne, J. R., Raghu, S., Roderick, G. K. and Yeates, D. K. (2005). Invasive Phytophagous Pests Arising Through A Recent Tropical Evolutionary Radiation: The *Bactrocera dorsalis* Complex of Fruit Flies. *Annual Review of Entomology*, 50:293-319.

- Cuny, M. A. C., Traine, J., Bustos-Segura, C. and Benrey, B. (2019). Host density and parasitoid presence interact and shape the outcome of a tritrophic interaction on seeds of wild lima bean. *Scientific Reports*, 9:18591.
- Dias, N. P., Nava, D. E., Garcia, M. S., Silva, F. F. and Valgas, R. A. (2017). Oviposition of fruit flies (Diptera: Tephritidae) and its relation with the pericarp of citrus fruits. *Brazilian Journal of Biology*, 78:443-448.
- Dias, N. P., Montoya, P. and Nava, D. E. (2022). A 30-year systematic review reveals success in tephritid fruit fly biological control research. *Entomologia Experimentalis et Applicata*, 170:370-384. <https://doi.org/10.1111/eea.13157>
- Dillon, M. E., Wang, G. and Huey, R. B. (2010). Global metabolic impacts of recent climate warming. *Nature*, 467:704-706.
- Dominiak, B. C. and Ekman, J. H. (2013). The rise and demise of control options for fruit fly in Australia. *Crop Protection*, 51:57-67.
- Fand, B. B., Tonnang, H. E. Z., Kumar, M., Bal, S. K., Singh, N. P., Rao, D. V. K. N., Kamble, A. L., Nangare, D. D. and Minhas, P. S. (2014). Predicting the impact of climate change on regional and seasonal abundance of the mealybug *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) using temperature-driven phenology model linked to GIS. *Ecological Modelling*, 288:62-78.
- Gao, Y. and Reitz, S. R. (2017). Emerging Themes in Our Understanding of Species Displacements. *Annual Review of Entomology*, 62:165-183.
- Garcia, F. R. M., Ovruski, S. M., Suárez, L., Cancino, J. and Liburd, O. E. (2020). Biological control of tephritid fruit flies in the Americas and Hawaii: A review of the use of parasitoids and predators. *Insects*, 11:1-32.
- Grechi, I., Preterre, A.-L., Caillat, A., Chiroleu, F. and Ratnadass, A. (2021). Linking mango infestation by fruit flies to fruit maturity and fly pressure: A prerequisite to improve fruit fly damage management via harvest timing optimization. *Crop Protection*, 146:105663.
- Hidayani, H., Rusli, R. and Lubis, Y. S. (2014). Keanekaragaman Spesies Parasitoid Telur Hama Lepidoptera dan Parasitasinya pada Beberapa Tanaman di Kabupaten Solok, Sumatera Barat. *Jurnal Natur Indonesia*, 15:9.
- Holt, R. D. (2017). Species Coexistence ☆. In *Reference Module in Life Sciences*. Elsevier.
- International Centre for the Management of Pest Fruit Flies (ICMPFF), and Ministry of Agriculture Republic of Indonesia (KEMANTAN). (2006). *Training Workshop on Fruit Flies of Indonesia: Their Identification and Pest Status*. Griffith University and Ministry of Agriculture Republic of Indonesia. Darwin, Australia.
- Karlsson, M. F., de Souza, E. O., Ayelo, P. M., Zannou, J. A., Mègnigh èto, G. S. B. and Bokonon-Ganta, A. H. (2018). Interspecific competition between egg parasitoids: Native *Fopius caudatus* and exotic *Fopius arisanus*, in *Ceratitis cosyra*. *Biological Control*, 117:172-181.
- Krebs, C. J. (1989). *Ecological Methodology*. Harper and Row Publishers: New York, pp.654.
- Kumar, L., Sushilkumar, Choudhary, J. S. and Kumar, B. (2021). Host plant-mediated effects of elevated CO₂ and temperature on growth and developmental parameters of *Zygogramma bicolorata* (Coleoptera: Chrysomelidae). *Bulletin of Entomological Research*, 111:111-119.
- Laily, N., Kusumaningtyas, R.W., Sukarti, I. and Rini, M.R.D.K. (2015). The Potency of Guava *Psidium guajava* (L.) Leaves as a Functional Immunostimulatory Ingredient. *Procedia Chemistry*, 14:301-307.
- Liang, G. H., Jang, E. B., Heller, W. P., Chang, C. L., Chen, J. H., Zhang, F. P. and Geib, S. M. (2015). A qPCR-based method for detecting parasitism of *Fopius arisanus* (Sonan) in oriental fruit flies, *Bactrocera dorsalis* (Hendel). *Pest Management Science*, 71:1666-1674.
- Manaharan, T., Ming, C. H. and Palanisamy, U. D. (2013). *Syzygium aqueum* leaf extract and its bioactive compounds enhances pre-adipocyte differentiation and 2-NBDG uptake in 3T3-L1 cells. *Food Chemistry*, 136:354-363.

- Miranda, M., Sivinski, J., Rull, J., Cicero, L. and Aluja, M. (2015). Niche breadth and interspecific competition between *Doryctobracon crawfordi* and *Diachasmimorpha longicaudata* (Hymenoptera: Braconidae), native and introduced parasitoids of *Anastrepha* spp. fruit flies (Diptera: Tephritidae). *Biological Control*, 82:86-95.
- Ndlela, S., Mohamed, S. A., Azrag, A. G. A., Ndegwa, P. N., Ong'amo, G. O. and Ekesi, S. (2020). Interactions between two parasitoids of tephritidae: *Diachasmimorpha longicaudata* (ashmead) and *psytalia cosyrae* (wilkinson) (hymenoptera: Braconidae), under laboratory conditions. *Insects*, 11:1-16.
- Oliviera, N., Susila, I. W. and Supartha, I. W. (2016). Diversity of Fruit Flies and Parasitization Level of Parasitoid Associated with Plants Fruits in Lautem District, Timor Leste. *Journal of Tropical Agroecotechnology*, 5:(1).
- Ovruski, S., Aluja, M., Sivinski, J. and Wharton, R. (2000). Hymenopteran parasitoids on fruit infesting Tephritidae (Diptera) in Latin America and the southern United States: diversity, distribution, taxonomic status and their use in fruit fly biological control. *Integrated Pest Management Reviews*, 5:81-107.
- Prabhakar, C., Sood, P. and Mehta, P. (2012). Pictorial keys for predominant Bactrocera and Dacus fruit flies (Diptera: Tephritidae) of north western Himalaya. *Arthropods*, 1:101-111.
- Purnomo, H. (2010). *Pengantar Pengendalian Hayati*. Yogyakarta. Indonesia: Andi Publisher
- Putra, I. N. W., Susila, I. W. and Bagus, I. G. N. (2019). Abundance of Fruit Fly Species (Diptera: Tephritidae) and Its Parasitoid Associated on Star Fruit Plants (*Averrhoa carambola* L.) in Gianyar regency. *Agrotrop: Journal on Agriculture Science*, 9:1.
- Radonjić, S., Čizmović, M. and Pereira, R. (2013). Population Dynamics of the Mediterranean Fruit Fly in Montenegro. *International Journal of Insect Science*, 5:IJIS.S12964.
- Sarwar, M., Hamed, M., Yousaf, M. and Hussain, M. (2014). Surveillance on Population Dynamics and Fruits Infestation of Tephritid Fruit Flies (Diptera: Tephritidae) in Mango (*Mangifera indica* L.) Orchards of Faisalabad, Pakistan. *International Journal of Scientific Research in Environmental Sciences*, 2:113-119.
- Sch öller, M., Prozell, S., Al-Kirshi, A. G. and Reichmuth, C. (1997). Towards biological control as a major component of integrated pest management in stored product protection. *Journal of Stored Products Research*, 33:81-97.
- Schutze, M., McMahon, J., Krosch, M., Strutt, F., Royer, J., Bottrill, M., Woods, N., Cameron, S., Woods, B. and Blacket, M. (2018). *The Australian Handbook for the Identification of Fruit Flies (Version 3.1)*. Plant Health Australia.
- Sharkey, M. J. and Wahl, D. B. (1992). Cladistics of the Ichneumonoidea (Hymenoptera). *Journal of Hymenopteran Research*, 1:15-61.
- Somta, C., Winotai, A. and Ooi, P.A.C. (2010). Fruit flies reared from *Terminalia catappa* in Thailand. *Journal of Asia-Pacific Entomology*, 13:27-30.
- Su árez, L., Biancheri, M. J. B., Sánchez, G., Murúa, F., Funes, C. F., Kirschbaum, D. S., Molina, D., Lar á, O. and Ovruski, S. M. (2019). Effects of releasing two *Diachasmimorpha longicaudata* population lines for the control of *Ceratitis capitata* infesting three key host fruit species. *Biological Control*, 133:58-65.
- Supartha, I. W., Yudha, I. K. W., Wiradana, P. A. and Susila, I. W. (2020). Response of parasitoids to invasive pest *Phenacoccus manihoti* Matile-Ferrero (Hemiptera: Pseudococcidae) on cassava crop in Bali, Indonesia. *Biodiversitas Journal of Biological Diversity*, 21:(10).
- Supartha, I. W., Susila, I. W., Yohanes., Yudha, I. K. W. and Wiradana, P. A. (2022a). Potential of parasitoid *Gronotoma micromorpha* Perkin (Hymenoptera: Eucoilidae) as a biocontrol agent for pea leafminer fly, *Liriomyza huidobrensis* Blanchard (Diptera: Agromyzidae). *Acta Ecologica Sinica*, 42:90-94.
- Supartha, I. W., Widaningsih, D., Susila, I. W., Yudha, I. K. W., Utama, I. W. E. K. and Wiradana, P. A. (2022b). Range of host plants, spatial distribution, and insect predator of Phenacoccus

- manihoti (Hemiptera: Pseudococcidae) as an emerging pest of cassava plants in Bali, Indonesia. *Biodiversitas Journal of Biological Diversity*, 23(6).
- Supartha, I. W., Susila, I. W., Sulhan, W., Tulung, M., Laba, I. W., Yudha, I. K. W., Utama, I. W. E. K. and Wiradana, P. A. (2022c). Intraguild interaction, attack patterns, and community structure of maize caterpillar in Bali province. *International Journal of Agricultural Science and Technology*, 18:871-884.
- Suputa., Cahyani., Kustaryati, A., Railan, M. I., Susilaningtyas and Taufiq, A. (2006). A fly's guide to fruit viewing (Diptera: Tephritidae). Yogyakarta: UGM.
- Susila, I. W. and Supartha, I. W. (2020). The Role of parasitoid in controlling the population of fruit flies (*Bactrocera dorsalis* Complex.) (Diptera: Tephritidae) who attacked mangoes (*Mangifera indica* L) in Buleleng Regency. *Agrotrop: Journal on Agriculture Science*, 10:29-38.
- Tonnang, H. E. Z., Hervé B. D. B., Biber-Freudenberger, L., Salifu, D., Subramanian, S., Ngowi, V. B., Guimapi, R. Y. A., Anani, B., Kakmeni, F. M. M., Affognon, H., Niassy, S., Landmann, T., Ndjomatchoua, F. T., Pedro, S. A., Johansson, T., Tanga, C. M., Nana, P., Fiaboe, K. M., Mohamed, S. F. and Borgemeister, C. (2017). Advances in crop insect modelling methods—Towards a whole system approach. *Ecological Modelling*, 354:88-103.
- Triplehorn, C. A. and Johnson, N. F. (2005). Borror and Delong's Introduction to the Study of Insects. 7thed. United States (US): Thomson Brooks/Cole.
- Vargas, R. I., Piñero, J. C. and Leblanc, L. (2015). An overview of pest species of *Bactrocera* fruit flies (Diptera: Tephritidae) and the integration of biopesticides with other biological approaches for their management with a focus on the pacific region. *Insects*, 6:297-318.
- Vargas, R. I., Stark, J. D., Banks, J., Leblanc, L., Manoukis, N. C. and Peck, S. (2013). Spatial Dynamics of Two Oriental Fruit Fly (Diptera: Tephritidae) Parasitoids, *Fopius arisanus* and *Diachasmimorpha longicaudata* (Hymenoptera: Braconidae), in a Guava Orchard in Hawaii. *Environmental Entomology*, 42:888-901.
- Vijaysegaran, S. and Osman. M. S. (1991). Fruit Fly in Peninsular Malaysia, Their Economic Importance and Control Strategies. In Chua, T.H. and S.G. Khoo (Eds.). Problem and Management of Tropical Fruit Flies. Proceeding of the International Symposium the Biology and Control of Fruit Flies. Jointly Organized by the Food and Fertilizer of Technology Center the University of The Ryukyus. The Okinawa Prepectural Government, 137-140.
- Wiratama, M. D., Susila, I. W. and Supartha, I. W. (2017a). The Fruit Flies Species (*Bactrocera* spp.) attacking Citrus Orchard in Gianyar and Bangli Regency of Bali. *Agroekoteknologi Tropika*, 6:405-413.
- Wiratama, M., Susila, I. W. and Supartha, I. W. (2017b). Population Abundance of Fruit Flies (*Bactrocera* spp.) And Parasitoid Parasitization Levels at the Provincial Citrus Plantation Center. *Jurnal Agroekoteknologi Tropika*, 6:(4).
- Yang, J., Cai, P., Chen, J., Zhang, H., Wang, C., Xiang, H., Wu, J., Yang, Y., Chen, J., Ji, Q. and Song, D. (2018). Interspecific competition between *Fopius arisanus* and *Psytalia incisi* (Hymenoptera: Braconidae), parasitoids of *Bactrocera dorsalis* (Diptera: Tephritidae). *Biological Control*, 121:183-189.
- Zamek, A. L., Spinner, J. E., Micallef, J. L., Gurr, G. M. and Reynolds, O. L. (2012). Parasitoids of Queensland Fruit Fly *Bactrocera tryoni* in Australia and Prospects for Improved Biological Control. *Insects*, 3:1056-1083.

(Received: 13 May 2022, accepted: 30 October 2022)