BIODIVERSITAS
Volume 24, Number 4, April 2023
Pages: 2447-2457

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d240460

Short Communication: Dacini tribe's fruit fly species in Depok (Indonesia) with special reference to the abundance of orchard fly, *Bactrocera dorsalis*, for fruit pest controlling

QORY HERRAHMAWATI[1], RATNA YUNIATI[1,2], YASMAN[1,2,♥]

[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Indonesia. C Building, Kampus UI Depok 16424, West Java, Indonesia. Tel/Fax.: +62-21-7270163, ♥email: yasman.si@sci.ui.ac.id

[2]Research Group of Metabolomics and Chemical Ecology, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Indonesia. Depok 16424, West Java, Indonesia

Manuscript received: 1 March 2023. Revision accepted: 29 April 2023.

Abstract. *Herrahmawati Q, Yuniati R, Yasman. 2023. Short Communication: Dacini tribe's fruit fly species in Depok (Indonesia) with special reference to the abundance of orchard fly,* Bactrocera dorsalis*, for fruit pest controlling. Biodiversitas 24: 2447-2457.* Knowledge of diversity and regularly monitoring pest insects in fields is crucial in crop protection and is key to effective pest control management. Our research group aims to map the species diversity of the Dacini tribe's fruit flies in Depok (Indonesia) using lure fruit fly traps and rearing fruit fly larvae from infected fruits. This preliminary study result is important for our next study to control fruit flies using tropical fruit extract as a natural lure. Four fruit flies were obtained from infected fruit purchased from a traditional fruit seller: *Bactrocera dorsalis* (Hendel 1912) and *Bactrocera albistrigata* (Meijere 1911) from *Syzygium aqueum* (Burm.fil.) Alston fruit and *Bactrocera fuscitibia* (Drew & Hancock 1994) and *Bactrocera carambolae* (Drew & Hancock 1994) from *arum manis* (*Mangifera indica* L.) fruit. Meanwhile, three fruit fly species were caught in lure traps using methyl eugenol: *B. dorsalis, Bactrocera umbrosa* (Fabricius 1805), and *Bactrocera musae* (Tryon 1927). Detailed morphological descriptions were provided for each species obtained. *B. dorsalis* was the most abundant, while *B. musae* were the least abundant. This study's total number of individuals was 6,329 for *B. dorsalis*, 485 for *B. umbrosa*, and 34 for *B. musae*. *B. dorsalis* is widely distributed in many tropical areas of Asia-Pacific and is considered an invasive species in Africa. Moreover, it is well known as one of the most important pest species within the Tephritidae family. While the remaining obtained fruit fly species have also been reported as pests, it is interesting to note that *B. fuscitibia* was reported as a non-pest species but was obtained from an infected mango fruit in this preliminary study. *B. musae* was also reported for the first time in Depok, West Java Province, Indonesia.

Keywords: *Bactrocera* spp., Dacini tribe, Depok, fruit flies, pest controlling

INTRODUCTION

The two fly families referred to as fruit flies are Tephritidae and Drosophilidae. Tephritidae species are known as true fruit flies, while Drosophilidae species are referred to as common fruit flies. Both families belong to the order Diptera and class Insecta (Christenson and Foote 1960). Tephritidae contains 500 genera and approximately 4,000 species. Although only a small percentage of these species, less than 10%, are pests, they are of ecological and economic importance as pollinators. Of the thousands of species worldwide, only about 350 are of economic importance as fruit or flower pests (Plant Health Australia 2018). In the Asia-Pacific region, there are 730 species of the Dacini tribe's fruit flies reported, but only 72 of these species are important pests (Doorenweerd et al. 2018). In the western part of Indonesia, there are 90 species of the Dacini tribe's fruit flies, but only eight are important pests. Despite this, this number constitutes the largest among the economically important insects of the order Diptera (Siwi and Hidayat 2006). Both environmental and biotic conditions influence the population of fruit flies. Environmental factors include the speed and direction of wind, humidity, temperature, and rainfall. On the other hand, biotic factors include the diversity of host plants and the presence of natural enemies like predators and parasitoids (Tan and Nishida 2012; Haryono et al. 2016; Sari et al. 2020).

Based on the external morphology, the Dacini tribe of fruit flies (Subfamily Dacinae) is divided into four genera: *Bactrocera*, *Zeugodacus*, *Dacus*, and *Monacrostichus* (Doorenweerd et al. 2018). Among these, *Bactrocera* is the most diverse and one of the most important pests of insects (Doorenweerd et al. 2018; Jaleel et al. 2019, 2021; Jayanthi et al. 2021). This native tropical species is found in the Asia-Pacific region, where 53 of its 451 known species are pests of fruits and flowers (Doorenweerd et al. 2018). In Indonesia, 62 *Bactrocera* species have been found, 26 of which are on Java Island (Haryono et al. 2016). *Bactrocera* spp. have been reported to cause significant damage to horticultural products, especially commercial fruit crops (Zheng et al. 2012; Plant Health Australia 2018; Jaleel et al. 2021; Jayanthi et al. 2021; Ono et al. 2021). In Australia, for instance, this has major implications for the sustainability and market access of the multi-billion-dollar horticultural industry (Plant Health Australia 2018). According to Vayssieres et al. (2008), the invasion of fruit flies is causing significant yield losses in mango production in the Sudanian zone of Benin. Furthermore, the *Bactrocera dorsalis* (Hendel 1912) fruit fly is responsible for yield losses of up to 100% in mango production across Sub-Saharan Africa (SSA) (Ocitti et al. 2021).

Fruit flies use visual and chemical cues, such as color, size, volatile chemical compounds, and nutrient content of the host plant, to locate a suitable host (Park et al. 2020; Jaleel et al. 2021). Female fruit flies use their ovipositor to insert their eggs into the fruit during oviposition, causing damage to the fruit. The larval phase is the most critical stage for the host plant, as fruit fly larvae consume the fruit pulp, leading to premature fruit fall (Siwi 2005; Scolari et al. 2021). An effective and eco-friendly way to control fruit flies is using an attractant trap that doesn't leave any residue, such as methyl eugenol, which has been proven to work (Zheng et al. 2012; Park et al. 2020; Tan 2020; Jayanthi et al. 2021). Besides, regular monitoring of pest populations is crucial in pest control management since understanding the diversity of pest insects is a critical factor (Faria et al. 2014; Vargas et al. 2015; Douglas 2018; Dara 2019).

Our research group aims to map the diversity of *Bactrocera* in Depok using fruit fly trap methods and by rearing the fruit fly larvae from infected fruits, following the methods previously established by other researchers (Siwi and Hidayat 2006; Wee and Shelly 2013; Hee et al. 2015; Cunningham et al. 2016; Haryono et al. 2016; Aryuwandari et al. 2020; Park et al. 2020). Understanding the diversity of pest insects is a critical factor in pest control management (Faria et al. 2014; Douglas 2018). Therefore, regularly monitoring pest populations is essential for protecting crops (Dara 2019). The current study seeks to gather information on the diversity of fruit flies *Bactrocera* in Depok, specifically on the campus of FMIPA UI, which will serve as a preliminary study for our ongoing research on controlling pests using tropical fruit extracts as attractants. Our group hopes to contribute positively to integrated pest management practices, particularly in Indonesia.

MATERIALS AND METHODS

Sampling area

We collected *Bactrocera* spp. fruit flies from potential host plants located in the Faculty of Mathematics and Natural Sciences (FMIPA) at the Universitas Indonesia (UI) campus in Depok, West Java Province, Indonesia (Figure 1). To rear the fruit fly larvae, we purchased infected fruit from traditional fruit sellers around the UI campus. The sampling of specimens was conducted from March to April 2022.

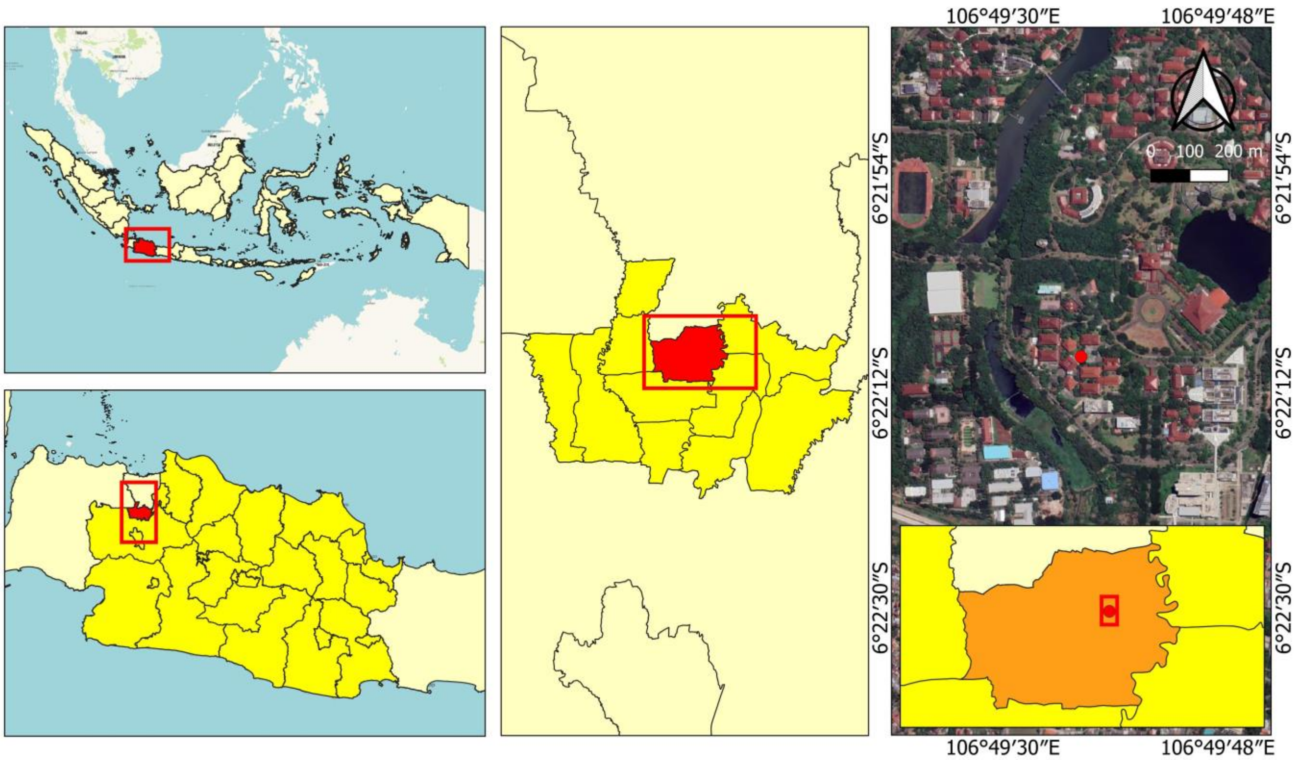

Figure 1. The location of fruit fly sampling was at the FMIPA campus of Universitas Indonesia, Depok, West Java Province, Indonesia

Procedures

Specimens sampling

The collection of fruit fly (*Bactrocera* spp.) samples in the FMIPA area of the Universitas Indonesia was done using a modified Steiner trap with 1.5 mL of methyl eugenol (Petrogenol) as bait. The traps were placed using a purposive sampling method on branches of trees 1-2 meters above the ground. The traps were placed and removed in the morning every two days within a week. The experiment was conducted with three replications for one month. The placement of fruit fly traps was done on plant species such as guava (*Psidium guajava* L.), papaya (*Carica papaya* L.), mango (*Mangifera indica* L.), durian (*Durio zibethinus* Murray), water apple (*Syzygium aqueum* (Burm.fil.) Alston), starfruit (*Averrhoa carambola* L.), bilimbi (*Averrhoa bilimbi* L.), gnetum (*Gnetum gnemon* L.), and jackfruit (*Artocarpus heterophyllus* Lam.). The population count of fruit flies trapped in the Steiner trap was also recorded for each trap. Additionally, we reared fruit fly larvae from infected fruit purchased from traditional fruit sellers around the UI campus.

Steiner traps

Furthermore, a fruit fly trap was made using a modified Steiner trap with a 600 mL mineral water bottle. A third of the head was cut horizontally, and the cap was removed. The mouth of the bottle was attached as a funnel to serve as the trap's entry point for fruit flies. The wire was attached to both bottle ends to facilitate hanging. Then, a hole was created in the middle of the bottle using a syringe to administer cotton with methyl eugenol, which was tied to the device using wire. Next, a small hole was created in the bottle to release the aroma from the Methyl Eugenol (ME). Detergent water was filled to a quarter of the bottle's height, serving as a trap for fruit flies that had entered so they could not escape. Trapped fruit flies were soaked in water for approximately one minute, and the dripping water was filtered using gauze. Collected fruit flies were finally placed in a collection bottle, and methyl eugenol was refilled to a predetermined volume each time an adult fruit fly was collected.

Morphology identification

The identification of fruit flies was carried out using a determination key based on morphological characteristics of the thorax, wings, legs, and abdomen, referring to Siwi and Hidayat (2006) and the Australian Handbook for the Identification of Fruit Flies, Version 3.1 (Plant Health Australia 2018). The morphological characteristics were observed using a stereo microscope and recorded using a smartphone camera.

Structure community

The diversity index of the fruit flies in the FMIPA area of Universitas Indonesia was analyzed using the Shannon Index of Diversity. The diversity index is represented by H', where "S" represents the number of species, "N" represents the total number of individuals of all species, and "pi" represents the ratio of the number of individuals of each species to the total number of individuals. Therefore, the diversity index can be evaluated based on the value of H': a value of H' less than 1 is considered low, values between 1 and 3 are considered moderate, and values greater than 3 are considered high (Omayio and Mzungu 2019).

$$H' = -\sum_{i=1}^{S} pi.\ln.pi \quad \text{where} \quad Pi = \frac{ni}{N}$$

The domination index of fruit flies was analyzed by comparing the dominance values obtained with the frequency. The frequency, denoted by F, is calculated as the number of individuals of species i (ni) divided by the total number of individuals found (N). The dominance (D) of a species is determined by comparing the value of F with the value of 1/S, where S represents the number of species found in the study area. If the value of F is greater than the value of 1/S, the species is considered dominant (d); otherwise, it is considered non-dominant (n) (Sa et al. 2012).

$$F = \frac{ni}{N}$$

The Morisita index (Id) is used to evaluate the distribution pattern of fruit flies, and the formula is as follows: "n" *represents* the number of plots, "x" represents the number of individuals per plot, and "N" represents the total number of individuals. The Id value can be used to determine the distribution pattern of fruit flies: 1 represents a random distribution, values less than 1 indicate a uniform distribution, and values greater than 1 indicate a clustered distribution (Golay et al. 2017).

$$\mathrm{Id} = \mathrm{n}\,\frac{\sum X2 - N}{N(N-1)}$$

Data analysis

The data analysis regarding the species diversity index, dominance index, and distribution pattern of fruit flies was performed using the formulas specified in the section on structure community above. Then, the species of fruit flies found at the FMIPA campus of Universitas Indonesia were described in detail. Finally, to determine the relationship between methyl eugenol and the type of fruit flies, linear regression and correlation coefficients (R) were analyzed.

RESULTS AND DISCUSSION

Community structure of fruit flies in FMIPA UI Campus

A study conducted in the Faculty of Mathematics and Natural Sciences at the Universitas Indonesia examined nine potential host plant species: gnetum, *belimbing wuluh*, durian, papaya, star fruit, guava, water guava, jackfruit, and mango. The three host plants from which the most samples were trapped were jackfruit, water guava, and guava. During the study, a total of 6,848 fruit flies were trapped, with the highest number of flies being caught on jackfruit (1,240 individuals), followed by guava (1,076 individuals) and water guava (1,068 individuals) (Table 1).

Table 1. The potential host plants (families and species) were found to harbor varying numbers of trapped *Bactrocera* spp.

Family	Species	Number of trapped *Bactrocera* spp.
Gnetaceae	Gnetum (*Gnetum gnemon*)	349
Oxalidaceae	*Belimbing wuluh* (*Averrhoa bilimbi*)	624
Malvaceae	Durian *(Durio zibethinus)*	622
Caricaceae	Papaya (*Carica papaya*)	445
Oxalidaceae	Star fruit (*Averrhoa carambola*)	499
Myrtaceae	Guava (*Psidium guajava*)	1,068
Myrtaceae	Water guava (*Syzygium aqueum*)	1,076
Moraceae	Jackfruit (*Artocarpus heterophyllus*)	1,240
Anacardiaceae	Mango (*Mangifera indica*)	925

Three fruit flies were trapped using methyl eugenol (ME) lure: *Bactrocera umbrosa* (Fabricius 1805), *B. dorsalis*, and *Bactrocera musae* (Tryon 1927), consisting of 6,329 *B. dorsalis*, 485 *B. umbrosa*, and 34 *B. musae* (Table 2). *B. dorsalis* was the most common species, accounting for 92% of the total, while *B. umbrosa* made up 7% and *B. musae* made up only 1%. The study found that the diversity index in the research location was low (Table 2), with *B. dorsalis* being the dominant species (Table 3). The distribution pattern of *Bactrocera* spp. was clustered with an Id value of 2.578 based on the Morisita index (Id).

The fruit collection at the Faculty of Mathematics and Natural Sciences, University of Indonesia, comprises diverse fruit species. In the study, 6,848 fruit flies were trapped (see Table 2), which is higher than the number reported by Sari et al. (2020), who found 1,121 individuals on Campus C, Universitas Airlangga. Fruit flies have been observed attacking fruits at all stages of ripeness in the study area, from unripe to ripe. Although they prefer ripe fruits for laying eggs, studies have shown that they can also infest unripe ones. *B. dorsalis*, in particular, has been observed to lay eggs in fruit still in the hard green stage (Rattanapun et al. 2009; Doorenweerd et al. 2018; Plant Health Australia 2018). Therefore, fruit flies use olfactory senses to locate fruits, as Biasazin et al. (2014) reported. In addition, fruit contains volatile compounds such as ethyl acetate, propionate, and butyrate. Which could attract fruit flies from an early stage, as reported by Kardinan et al. (2009), Cunningham et al. (2016), and Liu and Zhou (2016). Fruit flies can continue to infest the fruit until it becomes rotten due to bacterial contamination, destroying the fruit. Therefore, fruit growers must control fruit fly infestations throughout the growth and ripening stages to avoid economic losses.

The diversity index at the research location is relatively low due to the dominance of one particular fruit fly species. However, the dominance value of this species is close to one, indicating competition and species dominance. *B. dorsalis* is the dominant species found in traps, with the highest abundance among fruit fly species due to its wide distribution across many host plants. The species was successfully trapped in various types of fruits, including guava (*P. guajava*), papaya (*C. papaya*), mango (*M. indica*), durian (*D. zibethinus*), guava (*S. aqueum*), starfruit (*A. carambola*), *starfruit* (*A. bilimbi*), melinjo (*G. gnemon*), and jackfruit (*A. heterophyllus)*. Mutamiswa et al. (2021) reported that *B. dorsalis* is the primary fruit pest and that mango and guava are among the most commonly attacked fruits, which is consistent with the findings of this study. Hudiwaku et al. (2021) also found that the availability of host plants such as fruits increases the number of individual *B. dorsalis* species becoming dominant. Additionally, Supratiwi et al. (2020) concluded that *B. dorsalis* is the most commonly found fruit fly species. Also, Jaleel et al. (2018) reported that it is a polyphagous pest that can attack various host plant species, particularly fruits such as mangoes, guavas, papayas, bananas, and citrus fruits.

Table 2. Diversity index of the fruit fly at FMIPA Universitas Indonesia Campus, Indonesia

Species	Number of individuals	Pi	ln (Pi)	(Pi.ln Pi)
Bactrocera dorsalis Hendel 1912	6,329	0.924	-0.079	-0.073
Bactrocera umbrosa Fabricius 1805	485	0.071	-2.648	-0.188
Bactrocera musae Tryon 1927	34	0.005	-5.305	-0.026
Total of Individuals (N)	6,848			
Total of Species (S)	3			
Diversity Index (H')	0.287			
Category	Low			

Table 3. Dominance index of a fruit fly at FMIPA Universitas Indonesia Campus, Indonesia

Species	Number of individuals	F	d/nd
Bactrocera dorsalis Hendel 1912	6,329	0.924	d
Bactrocera umbrosa Fabricius 1805	485	0.071	nd
Bactrocera musae Tryon 1927	34	0.005	nd
Total individuals (N)	6,848		
Total Species (S)	3		
1/S	0.333		

Notes: F: Frequency, d: Dominant, nd: Non-dominant

Plants and insects use volatile compounds and pheromones to communicate with each other (Blande 2021). For example, fruit flies rely on visual and chemical cues to locate suitable fruit for oviposition. Therefore physical and chemical requirements play a crucial role in their oviposition behavior. The color influences their oviposition preferences, and they prefer to lay their eggs on the soft fruit skin (Jaleel et al. 2021). After they insert their eggs into the fruit using their ovipositors, the larvae develop inside the fruit, consuming its contents until they mature and leave the fruit to pupate (Huan et al. 2019; Saeed et al. 2022). Understanding the physical and chemical cues that fruit flies use to locate host plants and lay their eggs can manage to develop effective methods to control their populations and protect crops.

Moreover, fruit fly larvae eat the inside of the fruit, causing it to rot, and fruit rot is caused by microorganisms that damage fruit tissue (Rattanapun et al. 2009). The nutritional content of the fruit can affect the development and survival of fruit flies, and the number of imago fruit flies can affect pest attacks. The signs of fruit fly infestation include small holes in the fruit that cause the soft fruit skin to turn brown and black. The damage caused by fruit flies include fruit tissue being pierced during oviposition, known as black spots, and changes in fruit skin color (Huan et al. 2019; Mutamiswa et al. 2021). Fruit flies are preferred in finding their hosts through visual and chemical cues. Visual requirements include shape, color, and size, but chemical signals play a more significant role in host selection (Saeed et al. 2022). Fruit flies prefer soft fruit to support the life and development of *Bactrocera* (Rattanapun et al. 2009; Jaleel et al. 2018).

Bactrocera umbrosa and *B. musae* are oligophagous pests with a limited range of host plants and lower dominance. *B. umbrosa* primarily infests plants belonging to the Moraceae family, such as jackfruit, breadfruit, and figs, which are also commonly found in the FMIPA area of Universitas Indonesia (Linda et al. 2018). However, it has infested various other fruits, such as melinjo, starfruit, durian, papaya, guava, and mango (Putra 1997; Haryono et al. 2016; Pujiastuti et al. 2020). This wide range of host plants may make it difficult to control this pest.

Bactrocera umbrosa is an endemic species originating from Asia and the Pacific, and it is the primary pest of *Artocarpus*, especially *Artocarpus integer* (Thunb.) Merr., *A. heterophyllous*, and *Artocarpus altilis* (Parkinson) Fosberg (Krosch et al. 2018). According to Tan (2020), *B. umbrosa* is highly attracted to methyl eugenol, which has also been effective in catching this pest in Steiner traps (Royer and Mayer 2018). In addition, Song et al. (2022) reported that methyl eugenol could attract *B. umbrosa* male fruit flies. Therefore, methyl eugenol may be useful for controlling *B. umbrosa* populations.

Bactrocera musae, a type of fruit fly, can be found in star fruit, durian, papaya, guava, jackfruit, and mango. Methyl eugenol can trap *B. musae* by placing the trap near a banana tree, which is the host plant of this species. Rubber forests and various plants to the north surround the Faculty of Mathematics and Natural Sciences at the University of Indonesia. In contrast, a lake and natural vegetation surround the south, and many of the plants in the area are not just horticultural plants but also forest plants that serve as alternative host plants. The availability of alternative host plants increases the adaptability of fruit flies. Kardinan et al. (2009) reported that the radius of the aroma of the attractant produced by methyl eugenol ranges from around 20 to 100 m and can reach up to 3 km with wind assistance. This explains why Royer and Mayer (2018) found that methyl eugenol traps could catch *B. dorsalis* male fruit flies as far as 20 m away. Fruit flies in the Faculty of Mathematics and Natural Sciences area are clustered due to their availability of host plants in certain areas, leading to a clustering pattern for *Bactrocera*. In addition, fruit flies use pheromone trails as direction indicators, which means they can follow the trails of previous fruit flies that led to the trap.

Host plants were found to be the main influence on the presence and diversity of fruit flies, with a positive correlation between methyl eugenol lure and fruit flies being observed (Figures 2, 3, and 4). Methyl eugenol positively affects *B. dorsalis*, as evidenced by a regression analysis showing that a 1-unit increase in methyl eugenol led to a 29.51 increase in *B. dorsalis*. The constant term of 86.852 indicates that in the absence of methyl eugenol, *B. dorsalis* would be present at a level of 86.852. The t-test probability value or p-value of .000 <0.05 indicates that methyl eugenol significantly affects the number of *B. dorsalis*. That shows methyl eugenol is an attractant compound that can attract fruit flies. The coefficient of determination, R-squared value, was 0.4314, indicating that 43.14% of the variation in *B. dorsalis* can be explained by the presence of methyl eugenol. While methyl eugenol is the most effective attractant for *B. dorsalis*, methyl eugenol has been shown to have a similar aroma to the sex pheromones produced by female fruit flies for copulation, which attracts male fruit flies to the trap. Research by Haq et al. (2018) found that administering methyl eugenol increased the mating success of male *B. dorsalis*. *B. dorsalis* has a wide distribution, high cruising ability, is polyphagous, and has strong reproductive power, according to Vargas et al. (2007).

The impact of methyl eugenol on *B. umbrosa* was positive, indicating that a one-unit increase in methyl eugenol leads to a 1.85 increase in *B. umbrosa*. The constant of 8.68 indicates that *B. umbrosa* is 8.68 when the methyl eugenol variable is 0. The results of the t-test probability /p-value are 0.001 <0.05; there is a significant effect of methyl eugenol on the number of *B. umbrosa*. The R-squared value of 0.3519 indicates that methyl eugenol can affect *B. umbrosa* by 35.19%. These results are consistent with Linda et al. (2018) findings, which discovered that *B. dorsalis* and *B. umbrosa* were trapped in methyl eugenol.

Similarly, the effect of methyl eugenol on *B. musae* was positive, with a one-unit increase in methyl eugenol resulting in a 0.20 increase in *B. musae*. The constant of 0.23 indicates that *B. musae* is 0.23 when the methyl eugenol variable is 0. The t-test probability value/p-value of 0.047 <0.05 indicates a significant effect of methyl eugenol on the number of *B. musae*. The R-squared value of 0.1486 indicates that methyl eugenol can affect *B. musae* by 14.86%. Sastono et al. (2017) research revealed that methyl eugenol could attract male fruit flies, and the attractant's volatility allows it to cover a considerable radius, depending on the wind direction. Furthermore, Kardinan et al. (2009) discovered that methyl eugenol includes semiochemicals as an aromatic attractant for fruit flies and can evaporate.

Methyl eugenol is an effective and environmentally friendly attractant that can suppress fly populations, particularly *Bactrocera* spp. Its scent is similar to that of female fruit flies, making it an attractive lure for male fruit flies. Consequently, it is widely used to detect, monitor, and manage *B. dorsalis* populations and is a crucial component of the male extermination technique. As a phenylpropanoid compound, methyl eugenol enhances the attractiveness of pheromones in plants, making it a potent lure for male fruit flies. Tan and Nashida (2012) and Chieng et al. (2018) noted its effectiveness in attracting male fruit flies due to its volatile nature. The use of methyl eugenol offers a safe and effective alternative to traditional pest control methods, protecting fruit plants from damage. Additionally, the volatile compounds in methyl eugenol act as: chemical messengers, assisting herbivorous insects in locating host plants for feeding, copulation and oviposition, and helping parasitoids and predators find prey species. Since it evaporates quickly, it emits a fragrant aroma that can attract male fruit flies. Moreover, methyl eugenol has the same scent as female fruit flies, leading male fruit flies to locate females emitting this scent. Nebapure and Sagar (2015) found that methyl eugenol is a secondary metabolite that traps *Bactrocera* spp., particularly male fruit flies. The use of methyl eugenol as a male attractant to control *B. dorsalis* has been reported by Gu et al. (2018) and Fan et al. (2022). Wee et al. (2018) also discovered that methyl eugenol could attract most males of many *B. umbrosa* species, enhancing the pheromone signal by attracting more male *B. umbrosa*. Notably, males' attraction to methyl eugenol is greater than females'. Overall, using methyl eugenol as part of an environmentally friendly control strategy, such as the male extermination technique, helps protect fruit plants while providing a safe alternative to traditional pest control methods.

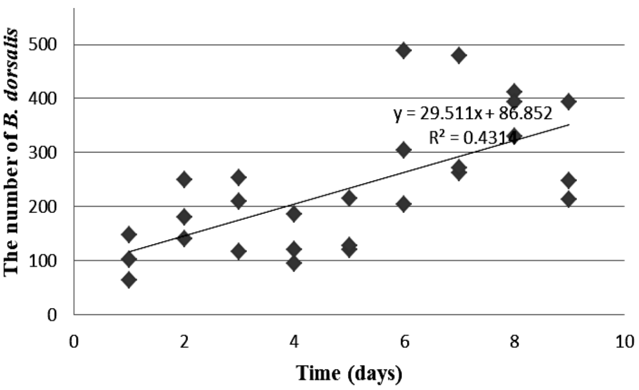

Figure 2. Linear regression between time (days) and *B. dorsalis*

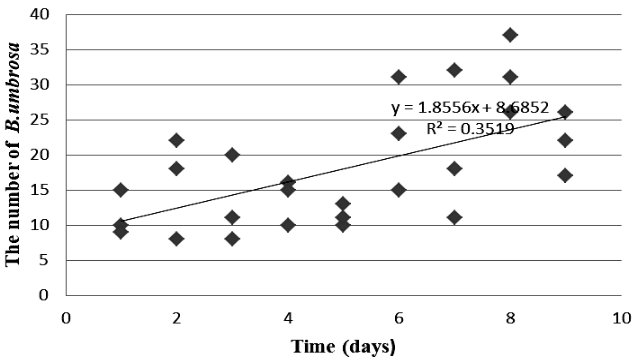

Figure 3. Linear regression between time (days) and *B. umbrosa*

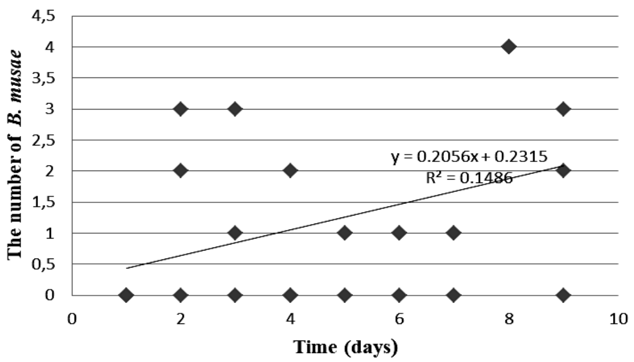

Figure 4. Linear regression between time (days) and *B. musae*

Description of fruit fly species and relevant information

This study used methyl eugenol lure traps to capture three fruit flies, as previously presented above. At the same time, two species were obtained from hatched larvae in fruits infected with fruit fly larvae purchased from local fruit traders around the UI campus.

Bactrocera dorsalis

The detailed description of the morphological characteristics of *B. dorsalis* (Figure 5) is as follows: it has a black scutum on its thorax with a lateral yellow stripe, a yellow post pronotal lobe, and scutellum. The wings are transparent with a narrow costal band that dips in at the end of R_{2+3} and a very narrow anal streak. The abdomen has terga III-V with a wraparound "T" pattern in brick red color with a black band in the middle of the terga, which may be minimal or have dark anterolateral corners of terga IV and V. The "T" pattern on the abdomen of *B. dorsalis* is characterized by a thin or narrow black line on tergum IV, distinguishable from the "T" pattern of *Bactrocera carambolae* (Drew & Hancock 1994), as also reported by Ilyafad et al. (2022). Each of its yellow-brown legs consists of four tarsi, with the front femur being brown and the tibia black.

Bactrocera dorsalis is a highly destructive and invasive pest that causes significant damage to fruit crops. This species is attracted to methyl eugenol, a pheromone compound commonly used in insects to attract mates. *B. dorsalis* is known to feed on more than 300 hosts, with a preference for edible fruits such as mango, papaya, guava, avocado, banana, and orange. This species has also been observed to lay eggs in some fruits during the hard green stage, leading to significant damage and losses. In Indonesia, numerous reports have documented the impact of *B. dorsalis* on economically important fruits, with studies published by various authors such as Haryono et al. (2016), Manwan and Nurjanani (2017), Aryuwandari et al. (2020), Pujiastuti et al. (2020), Sari et al. (2020), Yudistira et al. (2020), Saputra and Afriyansyah (2021), Ilyafad et al. (2022), and Susanto et al. (2022). These reports highlight this pest's significant impact on fruit production and the importance of effective control measures to minimize losses.

Bactrocera carambolae

Bactrocera carambolae observed in this study (1 individual) was isolated from infected mango fruit. It has a long body, and wings feature black bands on the costal and anal lines. The wings have a thin black costal band that runs slightly overlapping R_{2+3} and expands around the apex of R_{4+5}, taking on a fish-hook-like appearance. The thorax of *B. carambolae* has postpronotal lobes and yellow notopleura. The scutum has fine hairs or intra-allar and is black with two yellow lateral bands of the post-sutural vittae. The scutellum is also yellow. The abdomen of *B. carambolae* is oval, orange on terga III-V, and has a clear "T" pattern with a thick black line transverse from tergum III that widens to cover the sides, distinguishable from the "T" pattern of *B. dorsalis*, as also reported by Ilyafad et al. (2022). On tergum IV, the color is reddish black to black, and the black pattern on the lateral side is more prominent, forming a rectangle (Figure 6).

Bactrocera carambolae has been recorded infesting 75 host species from 26 families, including major commercial hosts such as: carambola (Oxalidaceae), mango (Anacardiaceae), sapodilla (Sapotaceae), jackfruit (Moraceae), guava (Myrtaceae), as well as other plant species from 21 families (Doorenweerd et al. 2018; Plant Health Australia 2018; Soares et al. 2023). Alongside *B. dorsalis*, *B. carambolae* is one of the most economically significant pests worldwide (Doorenweerd et al. 2018). In Indonesia, multiple reports have documented the infection of this species, published by various authors, including Haryono et al. (2016), Aryuwandari et al. (2020), Pujiastuti et al. (2020), Sari et al. (2020), Saputra and Afriyansyah (2021), Ilyafad et al. (2022), and Susanto et al. (2022).

Bactrocera musae

Bactrocera musae is a species with a medium-sized body and a dominant orange color. It has a yellow post-pronotal lobe, two lateral post-sutural vittae, a yellow lateral stripe on the scutum, and a yellow scutellum; the wings are transparent, with black bands only along the ribs and anal line. The abdomen is orange, with a longitudinal band dividing tergite III-IV. The legs have brown femurs and tibias, and each yellow-brown leg is composed of four tarsi. This species closely resembles *B. dorsalis*; however, it can be differentiated by the lack of dark anterolateral corners on terga IV and V and the presence of microtrichia in a slightly wider anal streak, as depicted in Figure 7.

The primary economic host for *B. musae* is banana (Musaceae), although papaya (Caricaceae) and guava (Myrtaceae) have also been reported as occasional hosts. While there are 13 other reported hosts, these are mostly single records or specimens of dubious classification (Plant Health Australia 2018). Initially reported only in Papua, Indonesia (Plant Health Australia 2018), this species has since been found in other regions, including Halmahera Utara (Sunarno and Popoko 2013) and Surabaya (Sari et al. 2020), suggesting that its distribution may be more extensive than previously thought.

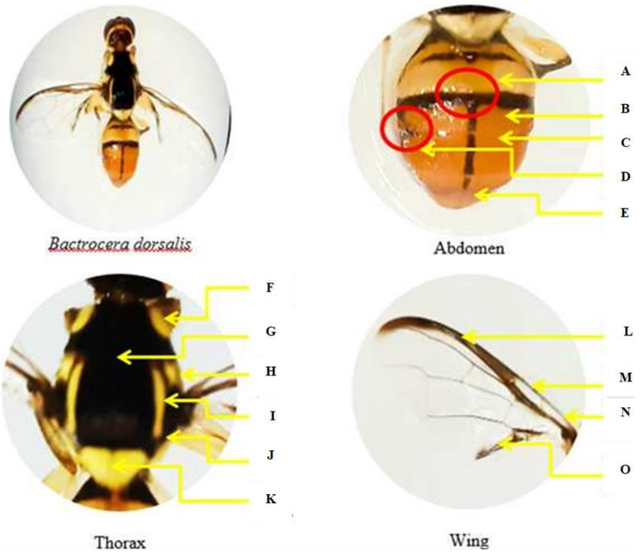

Figure 5. Morphological characteristics of *Bactrocera dorsalis*. A. Oval abdomen having a T shape, B. Tergum III, C. Tergum IV, D. Triangular form of the anterolateral corner, E. Tergum V, F. Postprontal lobe, G. Scutum, H. Notopleuron, I. Lateral post sutural vittae, J. Ia. Setae, K. Scutellum, L. Basal costal cell, M. Costal cell, N. R_{2+3}; O. Anal streak

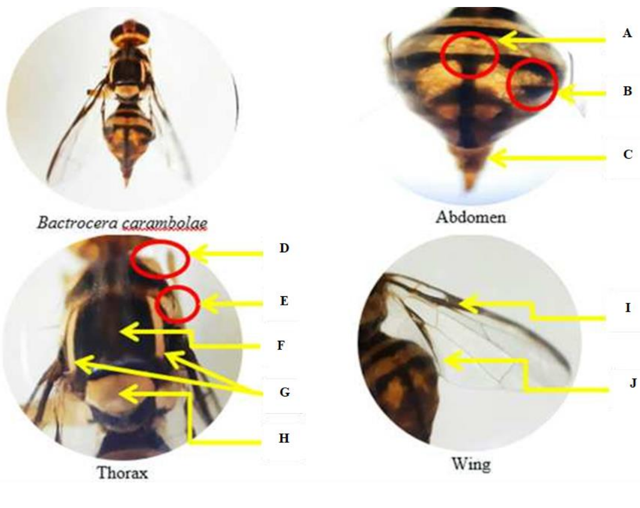

Figure 6. Morphological characteristics of *B. carambolae*. A. Oval abdomen with T pattern, B. Quadrilateral margin, C. Ovipositor, D. Postpronotal lobe, E. Notopleura, F. Scutum, G. Lateral post-sutural vittae, H. Scutellum, I. Costal band, J. Anal streak

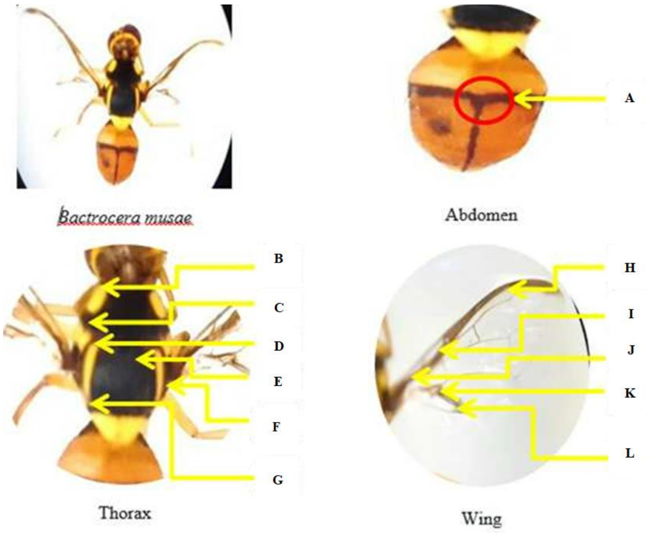

Figure 7. Morphological characteristics of *B. musae.* A. Abdomen having T pattern, B. Postprontal lobe, C. Mesopleural stripe, D. Notopleural calli, E. Scutum, F. Lateral post sutural vittae, G. Intra-alar setae, H. Basal costal cell, I. Costal cell, J. R_{2+3}, K. Anal streak, L. Microtrichia

Bactrocera fuscitibia

Two specimens of *Bactrocera fuscitibia* (Drew & Hancock 1994) were observed in this study, isolated from infected mango fruit. The observed fruit flies have a long body shape and supra-alar hair on the thorax. The scutum is black with two yellow lateral post-sutural vittae, and the scutellum and post-pronotal lobe are also yellow. The abdomen is brown and oval, with a black lateral margin on tergum III, and the black stripe pattern on the abdomen does not form a T-shape. The wings are transparent, with overlapping costal bands at R_{2+3}. The front legs have a brown femur and black tibia, and the hind legs have four tarsi. An ovipositor is present on the abdomen (Figure 8).

Saputra and Afriyansyah (2021) reported that this species had been attracted to cue lure traps on Bangka Island, but there are no reports of its infection in local economically important fruits. However, Pujiastuti et al. (2020) reported that *B. fuscitibia* was obtained from six different infected fruits, including banana, guava, water guava, papaya, pineapple, and mango. Consistent with these findings, our study also isolated *B. fuscitibia* from an infected mango fruit, which is noteworthy because *B. fuscitibia* was previously classified as a non-pest species (Doorenweerd et al. 2018).

Bactrocera umbrosa

Bactrocera umbrosa is a species with a medium-sized body. The thorax is black and features a yellow band on the lateral side of the scutum, which is black with a yellow line on either side. The scutum also contains the lateral post-sutural vittae. These species' wings are easily distinguishable due to the presence of three additional yellow bands, making them morphologically distinct from other species. The fuscous costal band and anal streak on the wing are wide, while the three yellow fuscous costal bands have a baseline that merges with the anal line. The abdomen is oval in shape, and it has an orange color with black lines on terga IV and V that fade to orange-brown, as well as two wide longitudinal black bands above terga III-V. The femur and tibia of the legs are brown, and each leg consists of four yellow-brown tarsi (Figure 9).

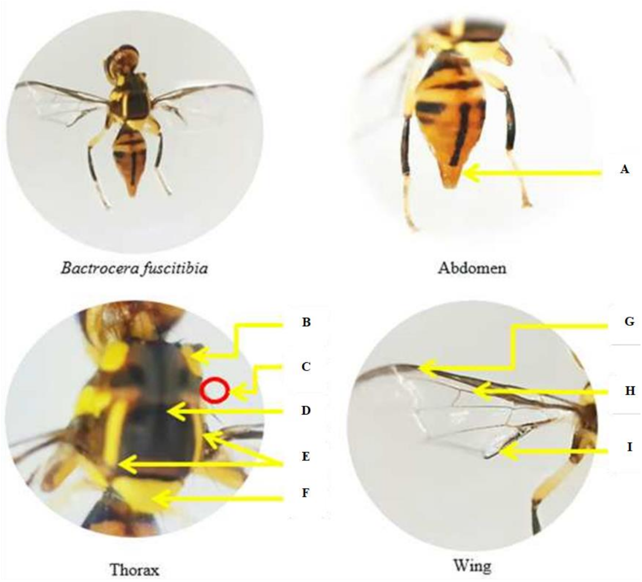

Figure 8. Morphological characteristics of *B. fuscitibia.* A. Ovipositor, B. Pospronotal lobe, C. Supra alar setae, D. Scutum, E. Lateral post-sutural vittae, F. Scutellum, G. R_{2+3}, H. Costal band, I. Anal streak

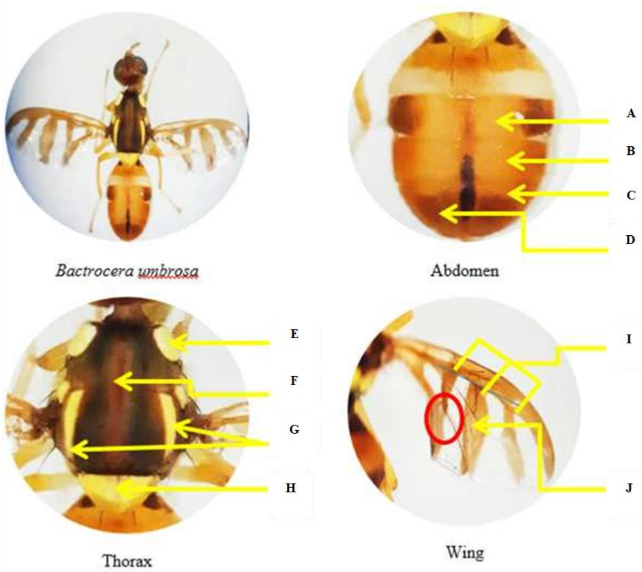

Figure 9. Morphological characteristics of *B. umbrosa.* A. Tergum III, B. Tergum IV, C. Tergum V, D. Posterior lobe, E. Post-pronotal lobe, F. Scutum, G. Lateral post-sutural vittae, H. Scutellum, I. Fuscous costal band, J. Three bands across the wing

Saputra and Afriyansyah (2021) reported that *B. umbrosa* had been attracted to methyl eugenol lure traps on Bangka Island, but there are no reports of its infection in locally important fruits. Doorenweerd et al. (2018) classified *B. umbrosa* as a monophagous pest species. This fruit fly has been recorded on four hosts in the Moraceae family, including breadfruit, jackfruit, and chempedak (Plant Health Australia 2018). Manwan and Nurjanani (2017) also found that *B. umbrosa* only infected breadfruit and jackfruit in several locations in Soppeng Regency, South Sulawesi, which is consistent with the species being monophagous. However, Haryono et al. (2016) reported *B. umbrosa* from mango, guava, rose apple, star fruit, and jackfruit collected from several villages on Madura Island. Additionally, Pujiastuti et al. (2020) reported that *B. umbrosa* was obtained from 23 out of 24 infected fruits, including jackfruit, in South Sumatra Province. Although we found no individual of *B. umbrosa* in the collected infected fruit (water guava and mango), our study used methyl eugenol lure traps on nine potential commercial fruit plants, including jackfruit plants. We found that all traps placed on the nine potential commercial fruit plants trapped *B. umbrosa* (ranging from 31-81 individuals), with the jackfruit plant trapping the highest number of *B. umbrosa* (94 individuals). The above data suggest this species may have a wider host range than predicted.

Bactrocera albistrigata

In this study, *Bactrocera albistrigata* (Meijere 1911) was isolated from an infected guava fruit. This species is characterized by a blackish scutum with a yellow lateral line and a yellow scutellum. The anterior intra-allar hairs are present, and the wings have a broad anal streak and a very pale costal band that extends to the apex. In addition, there is a blackish-brown band that runs through the r-m and dm-cu, making it easily distinguishable from other species. On the black abdomen, there is a wide black pattern on the lateral side and a yellow band across the terga (Figure 10). Finally, each leg is yellow-brown and consists of four tarsi.

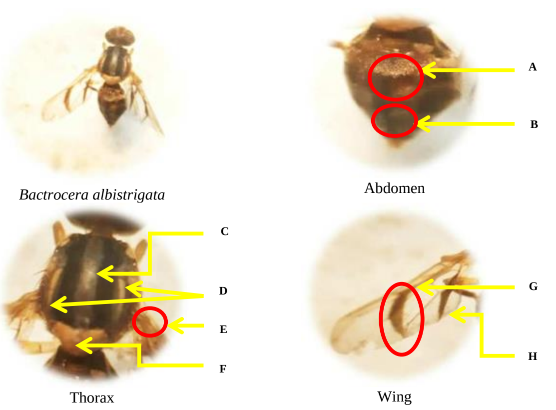

Figure 10. Morphological characteristics of *B. albistrigata.* A. Yellow band across the tergum; B. Wide black band on the lateral side of the abdomen; C. Scutum; D. Lateral post sutural vitae; E. Intra alar setae; F. Scutellum; G. Transverse bands covering r-m and dm-cu; H. Black band on anal

According to Manwan and Nurjanani (2017), *B. albistrigata* was found to only infect guava fruit in several locations in Soppeng Regency, South Sulawesi. On the other hand, Haryono et al. (2016) and Saputra and Afriyansyah (2021) reported the attraction of *B. albistrigata* using cue lure attractants in several locations in Madura and Bangka Island, respectively, which is in line with the findings of Doorenweerd et al. (2018). However, Haryono et al. (2016) found no individuals of B. albistrigata in the collected infected edible fruits, including guava. This contrasts with the results of Sari et al. (2020), who found *B. albistrigata* in all 24 collected infected fruits, including guava. These conflicting findings suggest that the host range of this species may be more complex than previously thought or possibly due to the impact of pesticides used by farmers. Consequently, further research is needed to clarify the host specificity of *B. albistrigata*.

The information provided in this study suggests that all five *Bactrocera* species, particularly *B. dorsalis*, can cause significant damage to crops. Insect trapping with attractants like methyl eugenol effectively controls fruit fly populations, including *B. dorsalis*, *B. umbrosa*, and *B. musae*. However, the effectiveness of these attractants may vary depending on the species and the concentration of the attractant. Further research is necessarily better to understand the behavior and preferences of these pests. The availability of alternative host plants can increase the adaptability of fruit fly populations, making them harder to control. The distribution pattern of fruit flies can be influenced by host plant availability and pheromone trails, leading to clustering in certain areas. Future research should focus on refining attractant use and exploring other methods, such as biological control. These studies could have practical implications for agriculture, as fruit flies can cause farmers significant crop damage and economic losses. Knowledge about the diversity of pest insects and regularly monitoring them in fields is essential for crop protection and is a fundamental aspect of effective pest control management.

ACKNOWLEDGEMENTS

This research was funded by the Directorate of Research and Development, Universitas Indonesia, Indonesia under Hibah PUTI Pascasarjana 2022 (Grant No. NKB-294/UN2.RST/HKP.05.00/2022) granted to Yasman.

REFERENCES

Aryuwandari VEF, Trisyono YA, Suputa, De Faveri S, Vijaysegaran S. 2020. Survey of fruit flies (Diptera: Tephritidae) from 23 Species of fruits collected in Sleman, Yogyakarta. Jurnal Perlindungan Tanaman Indonesia 24 (2): 122-132. DOI: 10.22146/jpti.57634. [Indonesian]

Biasazin TD, Karlsson MF, Hillbur Y, Seyoum E, Dekker T. 2014. Identification of host blends that attract the African invasive fruit fly, *Bactrocera invadens*. J Chem Ecol 40 (9): 966-976. DOI 10.1007/s10886-014-0501-6.

Blande JD. 2021. Effects of air pollution on plant-insect interactions mediated by olfactory and visual cues. Curr Opin Environ Sci Health 19: 1-6. DOI: 10.1016/j.coesh.2020.100228.

Chieng ACT, Hee AKW, Wee SL. 2018. Involvement of the antennal and maxillary palp structures in detection and response to methyl eugenol by male *Bactrocera dorsalis* (Diptera: Tephritidae). J Insect Sci 18 (5): 1-5. DOI: 10.1093/jisesa/iey10.

Christenson LD, Foote RH. 1960. Biology of fruit flies. Annu Rev Entomol 5: 171-192. DOI: 10.1146/annurev.en.05.010160.001131.

Cunningham JP, Carlsson MA, Villa TF, Dekker T, Anthony R Clarke AR. 2016. Do fruit ripening volatiles enable resource specialism in polyphagous fruit flies? J Chem Ecol 42: 931-940. DOI 10.1007/s10886-016-0752-5.

Dara SK. 2019. The new integrated pest management paradigm for the modern age. J Integr Pest Manag 10 (1): 1-9. DOI: 10.1093/jipm/pmz010.

Doorenweerd C, Leblanc L, Norrbom AL, Jose MS, Rubinoff D. 2018. A global checklist of the 932 fruit fly species in the tribe Dacini (Diptera, Tephritidae). ZooKeys 730: 19-56. DOI: 10.3897/zookeys.730.21786.

Douglas AE. 2018. Strategies for enhanced crop resistance to insect pests. Annu Rev Plant Biol 69: 637-660. DOI: 10.1146/annurev-arplant-042817-040248.

Fan Y, Zhang C, Qin Y, Yin X, Dong Xinyi, Desneux N and Zhou H. 2022. Monitoring the methyl eugenol response and non-responsiveness mechanisms in oriental fruit fly *Bactrocera dorsalis* in China. Insects 13: 1004. DOI: 10.3390/insects13111004.

Faria FA, Perre P, Zucchi RA, Jorge LR, Lewinsohn TM, Rocha A, Torres RS. 2014. Automatic identification of fruit flies (Diptera: Tephritidae). J Vis Commun Image R 25: 1516-1527. DOI: 10.1016/j.jvcir.2014.06.014.

Golay J, Leuenberger M, Kanevski M. 2017. Feature selection for regression problems based on the Morisita Estimator of intrinsic dimension. Pattern Recognition 70 (2017): 126-138. DOI: 10.1016/j.patcog.2017.05.008.

Gu X, Cai Pumo, Yang Y, Yang Q, Yao M, Idrees A, Ji Q, Yang J, Chen J. 2018. The response of four braconid parasitoid species to methyl eugenol: Optimization of a biocontrol tactic to suppress *Bactrocera dorsa*lis. Biol Cont 122: 101-110. DOI: 10.1016/j.biocontrol.2018.04.002.

Haq I, Caceres C, Meza JS, Hendrichs JM, Vreysen JB. 2018. Diferent methods ofmethyl eugenol application enhance the mating success of male oriental fruit fly (Dipera: Tephritidae). Sci Rep 8: 6033. DOI: 10.1038/s41598-018-24518-5.

Haryono T, Sastrahidayat IR, Mudjiono G, Himawan T. 2016. The exploration of fruit flies *Bactrocera* (Diptera:Tephritidae) and its parasitoid in Madura Island regions. J Biol Res 21 (2): 75-80. DOI: 10.23869/bphjbr.21.2.20165.

Hee AKW, Ooi YS, Wee SL, Tan KH. 2015. Comparative sensitivity to methyl eugenol of four putative *Bactrocera dorsalis* complex sibling species-further evidence that they belong to one and the same species *B. dorsalis*. In: De Meyer M, Clarke AR, Vera MT, Hendrichs J (Eds). resolution of cryptic species complexes of tephritid pests to enhance sit application and facilitate international trade. ZooKeys 540: 313-321. DOI: 10.3897/zookeys.540.6099.

Huan L, Dong-ju Z, Yi-juan X, Lei W, Dai-feng C, Yi-xiang Q, Ling Z, Yong-yue L. 2019. Invasion, expansion, and control of *Bactrocera dorsalis* (Hendel) in China. J Integr Agric 18 (4): 771-787. DOI: 10.1016/S2095-3119(18)62015-5.

Hudiwaku S, Himawan T, Rizali A. 2021. Diversity and species composition of fruit flies (Diptera: Tephritidae) in Lombok Island, Indonesia. Biodiversitas 22 (10): 1-9. DOI: 10.13057/biodiv/d221054.

Ilyafad S, Permana AD, Susanto A. 2022. Fluktuasi populasi dan identifikasi lalat buah *Bactrocera* spp. pada pertanaman mangga varietas gedong gincu di Jatigede Sumedang. Jurnal Agrikultura 33 (1): 83-88. DOI: 10.24198/agrikultura.v33i1.37796. [Indonesian]

Jaleel W, Heb Y, Lü L. 2019. The response of two *Bactrocera* species (Diptera: Tephritidae) to fruit volatiles. J Asia Pac Entomol 22: 758-765. DOI: 10.1016/j.aspen.2019.05.011.

Jaleel W, Saeed R, Shabbir MZ, Azad R, Ali S, Sial MU, Aljedani DM, Ghramh HA, Khan KA, Wang D, He Y. 2021. Olfactory response of two different *Bactrocera* fruit flies (Diptera: Tephritidae) on banana, guava, and mango fruits. J King Saud Univ Sci 33: 101455. DOI: 10.1016/j.jksus.2021.101455.

Jaleel W, Tao X, Wang D, Lu L, He Y. 2018. Using two-sex life table traits to assess the fruit preference and fitness of *Bactrocera dorsalis* (Diptera: Tephritidae). J Econ Entomol 20 (10): 1-10. DOI: 10.1093/jee/toy243.

Jayanthi PDK, Kumar PS, Vyas M. 2021. Odour cues from fruit arils of *Artocarpus heterophyllus* attract both sexes of oriental fruit flies. J Chem Ecol 47: 552-563. DOI: 10.1007/s10886-021-01269-8.

Kardinan A, Bintoro MH, Syakir M, Amin A. 2009. Penggunaan selasih dalam pengendalian hama lalat buah pada mangga. Littri 15: 101-109. DOI: 10.21082/jlittri.v15n3.2009.101-109. [Indonesian]

Krosch MN, Schutze MK, Newman J, Strutt F, Bryant LM, Mahon JM, Clarke AR. 2018. Influence of fruit traits on oviposition preference and offspring performance of *Bactrocera tryoni* (Froggatt) (Diptera: Tephritidae) on three tomato (*Lycopersicon lycopersicum*) cultivars. Austral Entomol 44 (2): 97-103. DOI: 10.1111/aen.12375.

Linda, Witjaksono, Suputa. 2018. Species composition of fruit flies (Diptera: Tephritidae) in Sorong and Raja Ampat, West Papua. Jurnal Perlindungan Tanaman Indonesia 22 (2): 193-200. DOI: 10.22146/jpti.25280. [Indonesian]

Liu L, Zhou Q. 2016. Olfactory response of female *Bactrocera minax* to chemical components of the preference host citrus volatile oils. J Asia Pac Entomol 19: 37-642. DOI: 10.1016/j.aspen.2016.05.008.

Manwan SW, Nurjanani. 2017. Identifikasi dan karakteristik morfologi lalat buah di Kabupaten Soppeng. Jurnal Agrotan 3 (1): 1-17. [Indonesian]

Mutamiswa R, Nyamukondiwa C, Chikowore G, Chidawanyika F. 2021. Overview of oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) in Africa: From invasion, bio-ecology to sustainable management. Crop Prot 141: 105492. DOI: 10.1016/j.cropro.2020.105492.

Nebapure SM, Sagar D. 2015. Insect-plant interaction: A road map from knowledge to novel technology. Karnataka J Agric Sci 28 (1): 1-7.

Ocitti P, Ndlela S, Akol AM, Muyinza H, Mohamed SA. 2021. Non-chemical post-harvest disinfestation of *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) in Tommy Atkins mango using hot-water immersion treatment. Afr Entomol 29 (1): 238-247. DOI: DOI: 10.4001/003.029.0238.

Omayio D, Mzungu E. 2019. Modification of Shannon-wiener diversity index towards quantitative estimation of environmental wellness and biodiversity levels under a non-comparative scenario. J Environ Earth Sci 9 (9): 1-12. DOI: 10.7176/JEES.

Ono H, Hee AK, Jiang H. 2021. Recent advancements in studies on chemosensory mechanisms underlying detection of semiochemicals in Dacini fruit flies of economic importance (Diptera: Tephritidae). Insects 12: 106. DOI: 10.3390/insects12020106.

Park SJ, De Faveri SG, Cheesman J, Hanssen BL, Cameron DNS, Jamie IM, Taylor PW. 2020. Zingerone in the flower of *Passiflora maliformis* attracts an Australian fruit fly, *Bactrocera jarvisi* (Tryon). Molecules 25: 2877. DOI: 10.3390/molecules25122877.

Plant Health Australia. 2018. The Australian Handbook for the Identification of Fruit Flies: Version 3.1. ACT, Canberra.

Pujiastuti Y, Irsan C, Herlinda S, Kartini L, Yulistin E. 2020. Identification of fruit flies (Diptera: Tephritidae) and their distribution in South Sumatera Province. Indones J Entomol 17 (3): 125-135. DOI: 10.5994/jei.17.3.125.

Putra NS. 1997. Hama Lalat Buah dan Pengendaliannya. Kanisius, Yogyakarta. [Indonesian]

Rattanapun W, Amornsaki W, Clarke AR. 2009. *Bactrocera dorsalis* preference for and performance on two mango varieties at three stages of ripeness. Entomol Exp Appl 131: 243-253. DOI: 10.1111/j.1570-7458.2009.00850.x.

Royer JE, Mayer DG. 2018. Combining cue-lure and methyl eugenol in traps significantly decreases catches of most *Bactrocera*, *Zeugodacus* and *Dacus* species (Diptera: Tephritidae: Dacinae) in Australia and Papua New Guinea. J Econ Entomol 111 (1): 298-303. DOI: 10.1093/jee/tox334.

Sa RF De, Castellani MA, Riberio AEL, Perez-Maluf R, Moreira AA, Nagamoto NS, Nascimento ASD. 2012. Faunal analysis of the species *Anastrepha* in the fruit growing complex Gaviao River, Bahia, Brazil. Bull Insectol 65: 37-42.

Saeed M, Ahmad T, Alam M, Shuraym LAA, Ahmed N. 2022. Preference and performance of peach fruit fly (*Bactrocera zonata*) and melon fruit fly (*Bactrocera cucurbitae*) under laboratory conditions. Saudi J Biol Sci 29: 2402-2408. DOI: 10.1016/j.sjbs.2021.12.001.

Saputra HM, Afriyansyah B. 2021. Distribution and identification of fruit flies (Diptera: Tephritidae) attracted on methyl euganol and cue lure in central Bangka regency, Bangka Belitung. Jurnal Hama dan Penyakit Tumbuhan Tropika 21 (1): 72-81. DOI: 10.23960/j.hptt.12172-81. [Indonesian]

Sari EKA, Affandi M, Hariyanto S. 2020. Diversity of fruit flies (Tephritidae: *Bactrocera* spp.) in campus C of Airlangga University, Surabaya, Indonesia. Treubia 47 (2): 111-122. DOI: 10.14203/treubia.v47i2.3982.
Sastono IW, Wijaya IN, Adnyana IMM. 2017. Uji efektivitas perangkap kuning berperekat dan atraktan terhadap serangan lalat buah pada pertanaman jeruk di Desa Katung, Kecamatan Kintamani, Kabupaten Bangli. Agroekoteknologi Tropika 6 (4): 1-8. [Indonesian]
Scolari F, Valerio F, Benelli G, Papadopoulos NT, Vaníˇcková L. 2021. Tephritid fruit fly semiochemicals: Current knowledge and future perspectives. Insects 12: 408. DOI: 10.3390/insects12050408.
Siwi SS, Hidayat P. 2006. Taksonomi dan Bioekologi Lalat Buah Penting *Bactrocera* spp. (Diptera: Tephritidae) di Indonesia. Kerjasama Balai Besar Penelitian dan Pengembangan Bioteknologi dan Sumberdaya Genetik Pertanian dengan Department of Agriculture, Fisheries and Forestry Australia, Jakarta. [Indonesian]
Siwi SS. 2005. Eko-biologi Hama Lalat Buah. BB-Biogen, Bogor. [Indonesian]
Soares GKA, Fidelis EG, Farias ES, Rodrigues G S, Paes JLA. 2023. Range expansion and population dynamics of *Bactrocera carambolae* in Roraima, Brazil. Crop Prot 165: 1-8. DOI: 10.1016/j.cropro.2022.106167.
Song SL, Yong HS, Chua KO, Limb PE, Eamsobhana P. 2022 **.** Data set on the diversity and core members of bacterial community associated with two specialist fruit flies *Bactrocera melastomatos* and *B. umbrosa* (Insecta, Tephritidae). Data in Brief 45: 1-8. DOI: 10.1016/j.dib.2022.108727.
Sunarno, Popoko S. 2013. Keragaman jenis lalat buah (*Bactrocera* spp) di Tobelo Kabupaten Halmahera Utara. Jurnal Agroforestri 8 (4): 269-276. [Indonesian]
Supratiwi R, Apriyadi R, Asriani E. 2020. Fruit flies (Diptera: Tephritidae) diversity in horticultural farm of Merawang Sub-District, Bangka District, Bangka Belitung Islands. Jurnal Hama dan Penyakit Tumbuhan Tropika 20 (1): 61-70. DOI: 10.23960/j.hptt.12061-70.
Susanto A, Yuliastari PED, Ferliansyah KM, Hersanti, Widiantini F, Maelani S, Permana AD. 2022. The abundance of fruit flies (*Bactrocera* spp.) on some varieties of mango from three selling sources. Intl J Fruit Sci 22 (1): 110-120. DOI: 10.1080/15538362.2021.2023934.
Tan KH, Nishida R. 2012. Methyl eugenol: Its occurrence, distribution, and role in nature, especially in relation to insect behavior and pollination. J Insect Sci 12: 56. DOI: 10.1673/031.012.5601.
Tan KH. 2020. Recaptures of feral *Bactrocera dorsalis* and *B. umbrosa* (Diptera: Tephritidae) males after feeding on methyl eugenol. Bull Entomol Res 110: 15-21. DOI: 10.1017/S0007485319000208.
Vargas RI, Mau RL, Jang EB. 2007. The Hawaii fruit fly area-wide pest management program: accomplishments and future directions. Proc Hawaii Entomol Soc 39: 99-104.
Vargas RI, Pinero JC, 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. DOI: 10.3390/insects6020297.
Vayssieres JF, Korie S, Coulibaly O, Temple L, Boueyi Sp. 2008. The mango tree in northern Benin: cultivar inventory, yield assessment, infested stages and loss due to fruit flies (Diptera Tephritidae). Fruits 63: 1-8. DOI: 10.1051/fruits:2008035.
Wee SL, Abdul Munir MZ, Hee AKW. 2018. Attraction and consumption of methyl eugenol by male *Bactrocera umbrosa* Fabricius (Diptera: Tephritidae) promotes conspecific sexual communication and mating performance. Bull Entomol Res 108: 116-124. DOI: 10.1017/S0007485317000554.
Wee SL, Shelly T. 2013. Capture of *Bactrocera* fruit flies in traps baited with liquid versus solid formulations of male lures in Malaysia. J Asia Pac Entomol 16: 37-42. DOI: 10.1016/j.aspen.2012.09.006.
Yudistira DH, Tanjung IS, Rizkie L. 2020. Preferensi inang lalat buah *Bactrocera cucurbitae* (Coquillet) dan *Bactrocera dorsalis* (Hendel) pada berbagai jenis buah. Bioma 9 (2): 1-11. DOI: 10.26877/bioma.v9i2.7058. [Indonesian]
Zheng W, Zhu C, Peng T, Zhang H. 2012. Odorant receptor co-receptor Orco is upregulated by methyl eugenol in male *Bactrocera dorsalis* (Diptera: Tephritidae). J Insect Physiol 58: 1122-1127. DOI: 10.1016/j.jinsphys.2012.05.011.