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

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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 Monacrostitichus (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.

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**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 (Petrogrenol) 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 aromaticum (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).

\[ H' = -\sum_{i=1}^{S} p_i \ln p_i \]

where \( p_i = \frac{n_i}{N} \)

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).

\[ F = \frac{n_i}{N} \]

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).

\[ Id = n \frac{\sum x^2 - N}{N(N-1)} \]

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

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>Number of trapped Bactrocera spp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gnetaceae</td>
<td>Gnetum (Gnetum gnemon)</td>
<td>349</td>
</tr>
<tr>
<td>Oxalidaceae</td>
<td>Belimming waluh (Averrhoa bilimbi)</td>
<td>624</td>
</tr>
<tr>
<td>Malvaceae</td>
<td>Durian (Dario zibethinus)</td>
<td>622</td>
</tr>
<tr>
<td>Caricaceae</td>
<td>Papaya (Carica papaya)</td>
<td>445</td>
</tr>
<tr>
<td>Oxalidaceae</td>
<td>Star fruit (Averrhoa carambola)</td>
<td>499</td>
</tr>
<tr>
<td>Myrtaeace</td>
<td>Guava (Psidium guajava)</td>
<td>1,068</td>
</tr>
<tr>
<td>Moraceae</td>
<td>Water guava (Syzygium aqueum)</td>
<td>1,076</td>
</tr>
<tr>
<td>Moraceae</td>
<td>Jackfruit (Artocarpus heterophyllus)</td>
<td>1,240</td>
</tr>
<tr>
<td>Anacardiaceae</td>
<td>Mango (Mangifera indica)</td>
<td>925</td>
</tr>
</tbody>
</table>

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

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

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

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

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 altillus (Parkinson) Fosberg (Krosh 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 0.00 <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

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 R2+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 carabola (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 Nurjanan (2017), Aryuwandari et al. (2020), Pujiausti 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 R4+5 and expands around the apex of R4+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-punctate, and it 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), Pujiausti 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 tibiae, 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 7. Morphological characteristics of *B. musae*. A. Abdomen having T pattern, B. Postpronotal 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, Pujastuti 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

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 Moracae 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* 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-alar 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.

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.

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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 vitæ; E. Intra alar setae; F. Scutellum; G. Transverse bands covering r-m and dm-cu; H. Black band on anal


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