INTRODUCTION

Fruit flies (Diptera: Tephritidae) are a major pest of fruits and vegetables in many countries, including Indonesia. The females lay their eggs in the fruit, and the larvae that hatch feed on the flesh, resulting in decay, discoloration, and a significant decrease in the economic value of harvested fruit. In addition, fruit flies are a major obstacle to international trade of fruits. Quarantine restrictions have been implemented by countries around the world to prevent the introduction of exotic fruit fly species. Knowledge of the fruit fly host range in a specific area is an important part of the area-wide pest management program to reduce the pest problem. The aim of this study was to extend and update the information on the host range of fruit flies in the Regency of Sleman, Yogyakarta. This area is one of the centers of fruit production, particularly snake fruit in Indonesia. Fruit sampling was conducted from August 2019 to February 2020 in four sub-districts in Sleman consisting of different types of agro-ecosystems. Fruit rearing was carried out in the laboratory followed by identification of the fruit and fruit flies that emerged to species level. From the 23 species of fruits belonging to 14 different families that were collected, the following 6 species of fruit flies emerged: Bactrocera dorsalis, B. carambolae, B. albistrigata, B. mcgregori, and Zeugodacus cucurbitae. Bactrocera dorsalis and B. carambolae utilized the widest range of hosts, 12 and 11 species of fruits, respectively. Syzygium cumini, Malpighia emarginata, and Phaleria macrocarpa were recorded for the first time as new hosts of B. carambolae in Indonesia. Additional data of B. dorsalis and B. carambolae infesting salak cv. pondoh is also reported.

Keywords: agricultural ecosystems; fruit collection; fruit fly; Salacca; urban areas

ABSTRACT

Fruit flies (Diptera: Tephritidae) are major pests of fruits and vegetables in many countries, including Indonesia. Knowledge of the fruit fly host range in a specific area is an important part of the area-wide pest management program to reduce the pest problem. The aim of this study was to extend and update the information on the host range of fruit flies in the Regency of Sleman, Yogyakarta. This area is one of the centers of fruit production, particularly snake fruit in Indonesia. Fruit sampling was conducted from August 2019 to February 2020 in four sub-districts in Sleman consisting of different types of agro-ecosystems. Fruit rearing was carried out in the laboratory followed by identification of the fruit and fruit flies that emerged to species level. From the 23 species of fruits belonging to 14 different families that were collected, the following 6 species of fruit flies emerged: Bactrocera dorsalis, B. carambolae, B. albistrigata, B. mcgregori, and Zeugodacus cucurbitae. Bactrocera dorsalis and B. carambolae utilized the widest range of hosts, 12 and 11 species of fruits, respectively. Syzygium cumini, Malpighia emarginata, and Phaleria macrocarpa were recorded for the first time as new hosts of B. carambolae in Indonesia. Additional data of B. dorsalis and B. carambolae infesting salak cv. pondoh is also reported.

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INTRODUCTION

Fruit flies (Diptera: Tephritidae) are a major pest of fruits and vegetables in many countries, including Indonesia. The females lay their eggs in the fruit, and the larvae that hatch feed on the flesh, resulting in decay, discoloration, and a significant decrease in the economic value of harvested fruit. In addition, fruit flies are a major obstacle to international trade of fruits. Quarantine restrictions have been implemented by countries around the world to prevent the introduction of exotic fruit fly species. Globally, there are many fruit fly species of economic importance, and these fall into 6 different genera, namely Anastrepha, Ceratitis, Rhagoletis, Dacus, Zeugodacus, and Bactrocera (Van Houdt et al., 2010; Virgilio et al., 2015). Pestiferous Anastrepha is native to tropical and subtropical America (CABI, 2019a; 2019b; 2019c; 2019d), Rhagoletis is native to North America (Bush, 1966), Ceratitis capitata is native to sub-Saharan Africa (CABI, 2019e), while Bactrocera, Zeugodacus, and Dacus are native to Asia, Oceania and Afro tropical region (White, 2000). The Oriental fruit fly, Bactrocera dorsalis is known as the world’s worst horticultural pest, highly invasive, and widely distributed in tropical Asia. It was introduced to Africa, Oceania, and parts of America and was recently reported in Europe (Vargas et al., 2015; Nugnes et al., 2018; CABI, 2019f).

In addition to the Oriental fruit fly, there are several other species of fruit flies in the genus Bactrocera that are of economic importance in Indonesia. Accurate knowledge of the larval host range and distribution of the various fruit fly species is essential for pest management programs and quarantine authorities.

Indonesia is an archipelago located in the tropical area of South-East Asia where fruits and vegetables are available throughout the year. Various ecosystems or habitats can be found on each island in Indonesia,
ranging from densely to sparsely populated areas, highland to lowland forests, and monoculture to polyculture. Most of the islands in Indonesia provide suitable habitats for fruit flies, especially *B. dorsalis*, due to the favorable climate and the availability of various types of tropical fruits that are good larval hosts for the species. The various types of larval host plants identified through surveys in some parts of Indonesia have been reported by Allwood *et al.* (1999) and Suputa *et al.* (2010).

These previous surveys employed two common methods: trapping, collection, and rearing from host fruits. The trapping method involved the use of plastic traps baited with a strong chemical lure that attracts male flies and a toxicant to kill them. The rearing method involved collecting fleshy fruits that have the potential to be infested by fruit flies and holding them in rearing cages in the laboratory until adult flies emerged (Allwood *et al.*, 1999; Suputa *et al.*, 2007). Rearing of flies from host is a very useful and sensitive tool in any survey of fruit flies, particularly for fly species such as *B. latifrons* that do not respond to the commonly used male attractants. Host rearing also provides information on the overlap in the host range of different species of fruit flies (Harris *et al.*, 2003).

Host records for fruit flies from a number of regions in Indonesia have been documented by Suputa *et al.* (2010). Our study aims to extend and update the previous data by surveying the District of Sleman, Special Province of Yogyakarta, a region that has different types of agro-ecosystems. Sleman is a district consisting of dryland and wetland zones, urban and suburban areas, and forest and grasslands on the slopes of Mt. Merapi. The agricultural and forest areas in the dry and wetland zones occupy almost 70% of this district. The crops grown in Sleman include rice, various vegetables, sugarcane, tobacco, coconut, salak (snake fruit), mango, and banana (BPS, 2018; 2019). Sleman is also known as one of the centers for salak or snake fruit (*Salacca zalacca*) production (Ministry of Agriculture, 2019). In 2018, fruit flies had been reported to infest salak plantations in Indonesia. Salak fruit exports to China now require quarantine treatments to ensure the absence of fruit flies (IAQA, 2014; Astuti *et al.*, 2019; DHCP, 2020). Recently, the European and Mediterranean Plant Protection Organization (EPPO) issued a non-compliance notification that listed *Bactrocera* found in salak exported from Indonesia to the Netherlands (EPPO, 2019). The host status and level of infestation in salak by *Bactrocera* fruit flies in Indonesia remains unclear and needs further studies to provide a better foundation for managing this pest. Considering the diversity of the ecosystem and the economic importance of salak, we selected the District of Sleman for extending and updating the information of fruit fly host. The findings of our study would be an essential element in fruit fly management deploying an area-wide approach.

**MATERIALS AND METHODS**

**Fruit Fly Collection from Host**

The study was conducted over a six month period from August 2019 to February 2020. Fruits were collected from four different sub-districts in the District of Sleman, Yogyakarta (Figure 1) with 15 species of fruits from the sub-district of Berbah, 5 from Depok, 3 from Turi, and 2 from Gamping (Table 1). Berbah sub-district consists of rural and semi-rural areas. In this sub-district, the fruit sampling was concentrated in the Agrotechnology Innovation Center of Universitas Gadjah Mada. This Center is a 35-hectare block of land with various trees, horticultural crops, rice fields, small farms, and an arboretum, which has more than 50 species of trees. Depok sub-district is a densely populated urban and suburban area with a mixture of trees growing in home gardens and parks. Turi sub-district is the center of salak production in Yogyakarta, mostly of the cultivar Pondoh. Thus, the area is dominated by salak plantations and clustered settlements. Gamping sub-district also consists of rural and semi-rural areas where the central fruit market in Yogyakarta Province is located. Ripe and senescing fruits from attached or detached fruits were collected from the various species of plants in each location. Ripe and senescing fruits were selected because they have a higher probability of being infested by fruit flies compared to immature or green fruits. However, for papaya (*Carica papaya*), it was not possible to obtain fully ripe fruits from the trees, thus we sampled that was between 40–50% yellow. Not all fruit types were available in equal numbers because of seasonality, thus the sample size of collected fruits varied widely between 1 to 62 with a total of 305 fruit samples collected in total.
Altogether 23 species of fruits belonging to 14 different plant families were sampled in this study. The collected fruits were then transferred to the laboratory for fruit fly rearing. The rearing method used followed Suputa et al. (2007) with a slight modification. Two different containers were used
depending on the size of the fruit. Large fruits were placed in 5 L plastic containers covered by gauze at the top of the container, with sterilized sawdust that served as a pupating medium. Smaller fruits were placed on top of gauze covered 90 mm plastic petri dish, and this was then placed above sterilized sawdust in a 750 mL plastic container. A petri dish was placed under the smaller fruits to contain liquids that oozed from the decaying fruit. Rectangular ventilation holes, (7 cm×3 cm) covered by gauze were made on each side of the plastic container. The number of pupae recovered from each species of fruit was counted and recorded. All pupae recovered from the containers were transferred into separate containers (a maximum of 5 pupae/container) for adult rearing. This separate container was a 500 mL clear plastic bowl with 2 gauze-covered rectangular holes (5 cm×3 cm) on opposite sides of the wall for ventilation. When adult flies emerged, they were fed sugar, yeast, and water for seven days at room temperature to mature and fully develop their body colours and be suitable for accurate identification. The number of flies and parasitoids that emerged were counted and recorded. Fruit flies were kept in the container and transferred to a freezer for a minimum of one hour to kill them before identification under a dissecting microscope.

Host Plant Identification

All host plants collected in the study were commonly known species.

Fruit Fly Identification

Adult flies that were successfully emerged were identified to species level based on morphological characters and keys published by Suputa et al. (2006), Drew & Romig (2013), and Plant Health Australia (2018). Following the internationally accepted revision of the putative species, B. papayae, B. philippinensis, and B. invadens described by Drew & Romig (2013) have now been synonymized with B. dorsalis. (Schutze et al., 2015; Plant Health Australia, 2018; CABI, 2019c; EPPO, 2020).

RESULTS AND DISCUSSION

Collected Fruit Flies from Host Rearing

Fruit fly pupae were recovered from all of the fruit species except papaya with adult emergence rates that varied between 0 to 96.3% (Table 2). Parasitoids were recorded from pupae obtained from mango (Mangifera indica), salak, Indian almond (Terminalia catappa), melinjo (Gnetum gnemon), starfruit (Averrhoa carambola), and God’s crown (Phaleria macrocarpa). Pupae collected from mango and Indian almond from an urban area in Depok had parasitism rates of 3.5 and 1.4%, respectively, while salak from the salak plantation in Turi had a higher level of parasitism (24.8%). The pupae collected from melinjo, starfruit, and God’s crown in the rural area in Berbah showed 28.6, 4.9, and 12.5% parasitism, respectively. Pupal mortality was high, at more than 50% from pupae reared from ridge gourd (Luffa acutangula), breadfruit (Artocarpus altilis), Java plum (Syzygium cumini), and God’s crown. No pupae were recovered from papaya which could be due to the immature state of the collected fruits. Only immature papaya was available for collection. It has been established that green unripe papaya is not attractive for fruit fly infestation (Seo et al., 1983) and ovipositing flies have been reported to be attracted to ripe papaya only (Jang & Light, 1991; Cugala et al., 2017).

The variation in pupal mortality and adult emergence might be due to the quality and variation in nutrients, and the growth environment within the host fruit. Nutrients in the host fruit affected the performance of immature flies including growth, development, survival, and adult fecundity as well as longevity (Bateman, 1972; Tsitsipis, 1989). The nutrient content within the same or different host(s) varies, which could affect insect development including pupal survival and adult emergence (Christenson & Foote, 1960; Tsitsipis, 1989). Newell & Haramoto (1986), also suggests that the natural mortality of B. dorsalis pupae from field-collected fruits might be caused by unfavourable conditions during larval development that in turn lead to decreased larval fitness which affects pupal survival. The pupae in different species of fruit flies also required different moisture conditions for survival, with some fly species preferring a humid environment while other species were not easily affected by relative humidity (Bateman, 1972).

Parasitism was observed in pupae recovered from mango, salak, Indian almond, melinjo, starfruit, and God’s crown. These fruits are widely cultivated and some are native to Indonesia. According to Clarke (2019), infested native fruits are more likely
to have a level of higher parasitism than exotic fruits because the searching mechanism of the parasitoids is more adapted to native host fruit. Regarding *B. carambolae* and *B. dorsalis* found infesting salak, both species of flies and salak are native to Indonesia. We are uncertain as to whether the infestation in salak has simply not been noted in the past or whether it is the result of a relatively recent expansion of the host utilization by these two fruit fly species. Based on the information from the leaders of farmer groups, many salak farmers do not use insecticide and some do so minimally. Thus, a relatively high rate of parasitism in salak could be attributed to the very low rate of insecticide use in salak cultivation.

**Host Utilization by Various Species of Fruit Flies**

Six species of fruit flies belong to the genus *Bactrocera* and *Zeugodacus* i.e. *B. dorsalis*, *B. carambolae*, *B. umbrosa*, *B. albistrigata*, *B. mcgregori*, and *Z. cucurbitae* were identified in this study (Table 3). These 6 species of fruit flies were

| Family               | Host Species                  | Common name  | Collection Stage | No. Fruits | No. Pupae | Dead Pupae (%) | Adult Emergence (%) |
|----------------------|-------------------------------|--------------|------------------|------------|-----------|----------------|---------------------|
| Anacardiaceae        | Mangifera indica             | Mango        | D, R, S          | 5          | 57        | 3.5            | 19.3                | 77.2               |
|                      | Spondias dulcis              | Red Ambarella| A, D             | 37         | 41        | 0.0            | 17.1                | 82.9               |
| Annonaceae           | Annona muricata              | Soursop      | A                | 2          | 28        | 0.0            | 35.7                | 64.3               |
| Arecaceae            | Salacca zalacca cv. Pondoh   | Salak Pondoh | D, R, S          | 16         | 101       | 24.8           | 6.9                 | 68.3               |
| Caricaceae           | Carica papaya                | Papaya       | A                | 4          | 0         | 0.0            | 0.0                 | 0.0                |
| Combretaceae         | Terminalia catappa           | Indian Almond| D, R, S          | 21         | 72        | 1.4            | 6.9                 | 91.7               |
| Cucurbitaceae        | Cucumis melo                 | Melon        | D                | 1          | 82        | 0.0            | 3.7                 | 96.3               |
|                      | Cucumis sativis              | Cucumber     | A, R, S          | 5          | 18        | 0.0            | 22.2                | 77.8               |
|                      | Luffa acutangula             | Ridge Gourd  | A, R, S          | 5          | 6         | 0.0            | 66.7                | 33.3               |
|                   | Momordica charantia           | Bitter Melon | A, R, S          | 5          | 51        | 0.0            | 15.7                | 84.3               |
| Gnetaceae            | Gnetum gnemon                | Melinjo      | D                | 26         | 7         | 28.6           | 42.9                | 28.6               |
| Malpighiaceae        | Malpighia emarginata         | Malpighia    | A, D             | 16         | 11        | 0.0            | 18.2                | 81.8               |
| Moraceae             | Artocarpus integer           | Cempedak     | A                | 1          | 31        | 0.0            | 25.8                | 74.2               |
|                      | Artocarpus heterophyllus     | Jackfruit    | A                | 1          | 24        | 0.0            | 16.7                | 83.3               |
|                      | Artocarpus altilis           | Breadfruit   | D                | 1          | 4         | 0.0            | 50.0                | 50.0               |
| Myrtaceae            | Syzygium aqueum              | Watery Rose  | D                | 13         | 28        | 0.0            | 17.9                | 82.1               |
|                     | Syzygium cumini              | Java Plum    | A, D             | 62         | 14        | 0.0            | 57.1                | 42.9               |
|                     | Psidium guajava              | Guava        | A, D             | 11         | 161       | 0.0            | 8.1                 | 91.9               |
|                     | Eugenia uniflora             | Surinam      | A, D             | 17         | 23        | 0.0            | 13.0                | 87.0               |
| Oxalidaceae          | Averrhoa carambola           | Starfruit    | A, D             | 27         | 143       | 4.9            | 17.5                | 77.6               |
| Rutaceae             | Citrus reticulata            | Tangerine    | D                | 7          | 11        | 0.0            | 45.5                | 54.5               |
| Solanaceae           | Capsicum annuum              | Chilli       | D                | 10         | 23        | 0.0            | 17.4                | 82.6               |
| Thymelaeaceae        | Phaleria macrocarpa          | God’s crown  | D                | 12         | 8         | 12.5           | 50.0                | 37.5               |

A: Attached to the tree; D: Detached from the tree; HF: Half Yellow; R: Ripe fruits; S: Senescing fruits
associated with 23 fruit species, while the 3 species of flies (B. dorsalis, B. carambolae, and B. albistrigata) showed an overlap in host utilization. The infestation of B. carambolae in Java plum, Barbados cherry (Malpighia emarginata), and God’s crown represented new records for Indonesia. Barbados cherry has been listed as a host for B. carambolae in Suriname (Allwood et al., 1999). However, Java plum and God’s crown have not been reported to be infested by B. carambolae in other countries. This study also provides further data to support the reports by DHCP (2020) and Astuti (2019) that B. dorsalis and B. carambolae were found to infest salak.

Bactrocera dorsalis infested the widest range of hosts, followed by B. carambolae, Z. cucurbitae, B. albistrigata, B. umbrosa, and B. mcgregori. In contrast, B. mcgregori was the most host-specific fruit fly species as it was only associated with melinjo. This record concurs with previous publications by White and Elson-Harris (1992), Allwood et al. (1999), Ranganath & Veenakumari (1999), Suputa et al. (2010), Drew & Romig (2013), and Larasati et al. (2013). However, the infestation of B. mcgregori in melinjo did not appear to be a serious threat and this species was still categorized as a non-pest (Doorenweerd et al., 2018). Melinjo, as fresh fruit was not exported from Indonesia and therefore not a quarantine issue (Cadiz & Florido, 2001). Bactrocera umbrosa and B. cucurbitae infested only one family of fruits, i.e. Moraceae and

Table 3. Host utilization by various fruit fly species in Sleman, Yogyakarta

| Family        | Host Species               | Common name    | B. alb | B. car | B. dor | B. mcg | B. umb | Z. cuc | No. FF Species |
|---------------|----------------------------|----------------|--------|--------|--------|--------|--------|--------|----------------|
| Anacardiaceae | Mangifera indica          | Mango          | -      | +      | +      | -      | -      | -      | 2               |
|               | Spondias dulcis           | Red Ambarella  | -      | +      | +      | -      | -      | -      | 2               |
| Annonaceae    | Annona muricata           | Soursop        | -      | -      | +      | -      | -      | -      | 1               |
| Arecaeae      | Salacca zalacca cv. Pondoh| Salak          | -      | +      | +      | -      | -      | -      | 2               |
| Caricaceae    | Carica papaya             | Papaya         | -      | -      | -      | -      | -      | -      | 0               |
| Combretaceae  | Terminalia catappa        | Indian Almond  | +      | +      | +      | -      | -      | -      | 3               |
| Cucurbitaceae | Cucumis melo              | Melon          | -      | -      | -      | -      | -      | +      | 1               |
|               | Cucumis sativus           | Cucumber       | -      | -      | -      | -      | -      | +      | 1               |
|               | Luffa acutangula          | Ridge Gourd    | -      | -      | -      | -      | -      | +      | 1               |
|               | Momordica charantia       | Bitter Melon   | -      | -      | -      | -      | -      | +      | 1               |
| Gnetaceae     | Gnetum gnemon             | Melinjo        | -      | -      | -      | +      | -      | -      | 1               |
| Malpighiaceae | Malpighia emarginata      | Barbados Cherry| -      | +      | +      | -      | -      | -      | 2               |
| Moraceae      | Artocarpus integer        | Cempedak       | -      | -      | -      | -      | -      | +      | 1               |
|               | Artocarpus heterophyllus  | Jackfruit      | -      | -      | -      | -      | -      | +      | 1               |
|               | Artocarpus altislis       | Breadfruit     | -      | -      | -      | -      | -      | +      | 1               |
| Myrtaceae     | Syzygium aqueum           | Watery Rose Apple| +      | -      | +      | -      | -      | -      | 2               |
|               | Syzygium cumini           | Java Plum      | -      | +      | -      | -      | -      | -      | 1               |
|               | Psidium guajava           | Guava          | +      | +      | +      | -      | -      | -      | 3               |
|               | Eugenia uniflora          | Surinam Cherry | -      | +      | -      | -      | -      | -      | 1               |
| Oxalidaceae   | Averrhoa carambola        | Starfruit      | -      | +      | +      | -      | -      | -      | 2               |
| Rutaceae      | Citrus reticulata         | Tangerine      | -      | +      | +      | -      | -      | -      | 2               |
| Solanaceae    | Capsicum annuum           | Chilli         | -      | -      | +      | -      | -      | -      | 1               |
| Thymelaeaceae | Phaleria macrocarpa       | God's crown    | -      | +      | +      | -      | -      | -      | 2               |

Total Host Species 3 11 12 1 3 4
B. alb: B. albistrigata; B. car: B. carambolae; B. dor: B. dorsalis; B. mcg: B. mcgregori; B. umb: B. umbrosa; Z. cuc: Z. cucurbitae.
Cucurbitaceae, respectively. *Bactrocera albistrigata* was found in three different fruit species belong to two different plant families.

*Bactrocera dorsalis* and *B. carambolae* infested the widest range of fruits. Indian almond and guava (*Psidium guajava*) were found to be hosts to three different species of *Bactrocera* i.e. *B. dorsalis*, *B. carambolae*, and *B. albistrigata*, whilst 8 fruits were the hosts of two species of flies, and 12 fruits were the host of one fly species. In this study, we were not able to justify whether there was more than one species per fruit because more than one fruit was placed in one container. The high frequency of overlapping hosts is evidence that the overlapping of host utilization by fruit flies is common particularly for *B. dorsalis* and *B. carambolae* as reported by Harris et al. (2003) and Danjuma et al. (2013). *Bactrocera dorsalis* and *B. carambolae* are known as sympatric sibling species, native to South-East Asia (Wee & Tan, 2005; Vargas et al., 2015), and frequently found in the same area (Clarke et al., 2001; Wee & Tan, 2005; Suputa et al., 2010; Larasati et al., 2013; Linda et al., 2018). Most of *B. carambolae* hosts are also the hosts of *B. dorsalis* (Allwood et al., 1999; CABI, 2019f, CABI, 2020).

The infestation of *B. carambolae* on *P. macrocarpa*, *M. emarginata*, and *S. cumini* is a new report. Previous works reported associated flies with *P. macrocarpa* were *B. papayae* (now *B. dorsalis*), *B. bullata*, and *B. trilobata* (Suputa et al., 2010; Drew & Hancock, 2016). Outside Indonesia, several species of flies were reported to be associated with *M. emarginata* such as *B. caryae*, *B. correcta*, *B. dorsalis*, *B. tryoni*, *B. jarvisi*, *B. neohumeralis*, and *B. zonata* (Allwood et al., 1999; CABI, 2019h) while associated flies with *S. cumini* were *B. correcta*, *B. tryoni*, and *B. dorsalis* (Allwood et al., 1999; CABI, 2019). This new report in Indonesia extends the host range of this species.

Salak is not commonly thought to be a host of *B. dorsalis* and *B. carambolae* in Indonesia although the infestation of fruit flies in salak was reported previously by IAQA (2013), EPPO (2019), and DHCP (2020). Salak was not originally thought to be a host of fruit flies since there have been no reports of fruit fly infestation in salak before 2013. We collected only detached salak, and it remains unclear how fruit fly oviposits through the hard outer skin and utilizes salak as a host. It is possible that the flies oviposit only in ripe or overripe fruits that tend to detach easily from the plant when they are ripe (Haryoto & Priyanto, 2018). We collected such detached fruits for our study and some being cracked open and increasing the possibility for the females to lay eggs. Thus, further research is required to determine the real host status of this fruit. On the other hand, Barbados cherry and Surinam cherry are non-native fruits that are mainly planted as a hedge or as ornamentals (Hanelt et al., 2001), and are not extensively cultivated and rarely sold in the markets in Indonesia. Barbados cherry, however, is a crop of major economic importance in the Mekong delta in South Vietnam. It was grown, processed, and exported to Japan (Vijaysegaran, 2016). Thus, Barbados cherry has the potential to develop into a crop of economic importance in the future in Indonesia. The infestation of fruit flies in these exotic or ornamental fruiting trees showed the possibility of utilization in non-commercial hosts that might affect the orchards.

*Bactrocera dorsalis* and *B. carambolae* are known as highly polyphagous fruit flies, *B. dorsalis* has been reported to utilize more than 300 species of plants (CABI, 2019f) and *B. carambolae* up to 75 species of plants (Allwood et al., 1999; CABI, 2020). Many tephritid fruit flies are polyphagous which is uncommon for herbivorous insects although the polyphagous trait of some fruit fly species still indicates the presence of the host preference between available fruits (Clarke et al., 2001; Clarke, 2017). *Bactrocera* is also classified as an opportunistic and broad-range exploiter of pulpy fruit (Aluja & Mangan, 2008). *Bactrocera* is native to Asia while the fruits of Asia are largely non-toxic, therefore the polyphagous *Bactrocera* is easier to switch and expand the host range as no or low fitness cost for this behaviour (Clarke, 2017).

Determining the host status of fruit fly is not a simple mechanism since the level of host utilization pattern also needs to be considered (Aluja et al., 1987). Ours was a preliminary study that recorded the host utilization by different species of fruit flies in Sleman, but with no information on infestation levels or regularity of host utilization. Further research is thus required to provide such data. Understanding the host use of *Bactrocera* is important since fruit conditions such as maturity levels or skin damage may influence the host utilization
by Bactrocera (Clarke, 2019). Fruit could be classified as a non-host or a conditional or potential host due to skin thickness of different varieties or when the fruit has a disease, physiological or mechanical damage (Clarke, 2019).

The international trading of fresh fruits and vegetables among countries is often severely restricted when these commodities were infested by fruit flies. Quarantine treatments have to be negotiated and applied for trade to commence. Tropical fruits such as banana (Musa domestica), guava, mango, melon (Cucumis melo), papaya, and Citrus spp. are hosts of fruit flies (Allwood et al., 1999; Suputa et al., 2010; Larasati et al., 2013; Leblanc et al., 2013) and are widely cultivated in Indonesia (BPS & Directorate General of Horticulture, 2020). These commodities are equally promoted in local and international trading (FAO, 2020; BPS, 2020). Therefore, Indonesia is obliged to follow the quarantine protocols to avoid the risk of introducing exotic fruit fly species into importing countries. The management of non-commercial/alternate hosts in the production area by removing or replacing non-economic host plants with non-host plants is recommended as a component of a systems approach for pest risk management of fruit flies (FAO/IPPC, 2012). Furthermore, the diversity of hosts for the economically important species of fruit flies supports the idea that the management of these insects should be based on the ecosystem approach e.g. area-wide pest management, rather than relying on managing a specific commodity in a particular area. The infestation levels of B. dorsalis and B. carambolae in host plants that have no economic importance should be monitored because of the possibility that these plants could serve as a breeding ground for pest fruit flies.

CONCLUSION

Six species of Bactrocera were associated with 23 different species of host plants collected from Sleman, Yogyakarta. The six fruit fly species are B. dorsalis, B. carambolae, B. albistrigata, B. umbrosa, and B. mcegregori. Two species of fruit flies, B. dorsalis and B. carambolae, utilized most of the collected fruits. Java plum and God’s crown were first reported to be infested by B. carambolae in the world while Barbados cherry was the first in Indonesia. Further studies to determine the susceptibility of this host should be determined. Rearing of B. dorsalis and B. carambolae from collected salak provided strong evidence that these two fruit fly species are extending their utilization of salak as a host and are likely to become a major pest problem in salak cultivation. A follow-up study involving periodic sampling of the various fruit types and detailed observations on host infestation by the different fly species is suggested to obtain additional information on fruit fly infestation levels and host preference in Sleman. Ours was a preliminary study and detailed information such as damage to the skin, cultivar, etc. was not collected. Further studies should include these categories to determine whether the hosts are good or poor.

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LITERATURE CITED

Allwood, A.J., A. Chinajariyawong, S. Kritsaneepaiboon, R.A.I. Drew, E.L. Hamacek, D.L. Hancock, C. Hengsawad, J.C. Jipanin, M. Jirasurat, C.T.S. Leong, & S. Vijaysegaran. 1999. Host Plant Records for Fruit Flies (Diptera: Tephritidae) in Southeast Asia. Raffles Bulletin of Zoology 47 (Supplement 7): 1–92.

Aluja, M. 1994. Bionomics and Management of Anastrepha. Annual Review of Entomology 39: 155–178.

Aluja, M., & R.L. Mangan. 2008. Fruit fly (Diptera: Tephritidae) Host Status Determination: Critical Conceptual, Methodological, and Regulatory Considerations. Annual Review of Entomology 53: 473–502.

Aluja, M., J. Guillen, G. de la Rosa, M. Cabrera, H. Celedonio, P. Liedo, & J. Hendrichs. 1987. Natural Host Plant Survey of The Economically Important Fruit Flies (Diptera: Tephritidae) of Chiapas, Mexico. The Florida Entomologist 70: 329–338.
Astuti, N.K., S. Suputa, N.S. Putra, & M. Indarwatmi. 2019. Gamma Irradiation Treatment of Bactrocera dorsalis Hendel (Diptera: Tephritidae) in Snake Fruit. Jurnal Perlindungan Tanaman Indonesia 23: 242–249.

Bateman, M.A. 1972. The Ecology of Fruit Flies. Annual Review of Entomology 17: 493–518.

BPS (Badan Pusat Statistik/Statistics Indonesia) & Directorate General of Horticulture. 2020. Luas Panen Buah-buahan di Indonesia, Tahun 2015–2019. Kementerian Pertanian. http://www.pertanian.go.id/home/index.php?show=repo&fileNum=319, accessed 17/06/2020.

BPS (Badan Pusat Statistik/Statistics Indonesia). 2018. Provinsi Daerah Istimewa Yogyakarta dalam Angka. BPS-Statistics Indonesia, Daerah Istimewa Yogyakarta. 464 p.

BPS (Badan Pusat Statistik/Statistics Indonesia). 2019. Provinsi Daerah Istimewa Yogyakarta dalam Angka. BPS-Statistics Indonesia, Daerah Istimewa Yogyakarta. 483 p.

BPS (Badan Pusat Statistik/Statistics Indonesia). 2020. Ekspor Komoditi Pertanian Berdasarkan Negara Tujuan, Subsektor: Hortikultura, Tahun 2019. Pusat Data dan Sistem Informasi Pertanian, Kementerian Pertanian. http://database.pertanian.go.id/eksim2012/hasilekspornegaratujuan.php., accessed 17/06/2020.

CABI (Centre for Agriculture and Bioscience International). 2019a. Anastrepha fraterculus (South American fruit fly) [original text by Allen Norrbom]. In Invasive Species Compendium. CAB International, Wallingford, UK. http://www.cabi.org/isc, accessed 17/06/2020.

CABI (Centre for Agriculture and Bioscience International). 2019b. Anastrepha ludens (Mexican fruit fly) [original text by Allen Norrbom]. In Invasive Species Compendium. CAB International, Wallingford, UK. http://www.cabi.org/isc, accessed 17/06/2020.

CABI (Centre for Agriculture and Bioscience International). 2019c. Anastrepha obliqua (West Indian fruit fly) [original text by Allen Norrbom]. In Invasive Species Compendium. CAB International, Wallingford, UK. http://www.cabi.org/isc, accessed 17/06/2020.

CABI (Centre for Agriculture and Bioscience International). 2019d. Anastrepha suspensa (Caribbean fruit fly) [original text by Allen Norrbom]. In Invasive Species Compendium. CAB International, Wallingford, UK. http://www.cabi.org/isc, accessed 17/06/2020.

CABI (Centre for Agriculture and Bioscience International). 2019e. Ceratitis capitata (Mediterranean fruit fly) [original text by Chris Weldon]. In Invasive Species Compendium. CAB International, Wallingford, UK. http://www.cabi.org/isc, accessed 25/04/2020.

CABI (Centre for Agriculture and Bioscience International). 2019f. Bactrocera dorsalis (Oriental fruit fly) [original text by Luc Leblanc]. In Invasive Species Compendium. CAB International, Wallingford, UK. http://www.cabi.org/isc, accessed 25/04/2020.

CABI (Centre for Agriculture and Bioscience International). 2019g. Syzygium cumini (Black Plum) [original text by Nick Pasiecznik]. In Invasive Species Compendium. CAB International, Wallingford, UK. http://www.cabi.org/isc, accessed 27/04/2020.

CABI (Centre for Agriculture and Bioscience International). 2019h. Malpighia emarginata. In Invasive Species Compendium. CAB International, Wallingford, UK. www.cabi.org/isc, accessed 27/04/2020.

CABI (Centre for Agriculture and Bioscience International). 2020. Bactrocera carambolae (Carambola Fruit Fly). In Invasive Species Compendium. CAB International, Wallingford, UK. http://www.cabi.org/isc, accessed 28/04/2020.

Cadiz, R. T., & H.B. Florido. 2001. Bago. Gnetum gnemon Linn. Research Information Series on Ecosystems 13: 2–6.

Christenson, L.D. & R.H. Foote. 1960. Biology of Fruit Flies. Annual Review of Entomology 5: 171–192.

Clarke, A.R. 2017. Why So Many Polyphagous Fruit Flies (Diptera: Tephritidae)? A Further Contribution to the ‘Generalism’ Debate. Biological Journal of the Linnean Society 120: 245–257.

Clarke, A.R. 2019. Biology and Management of Bactrocera and Related Fruit Flies. CAB International. Wallingford, UK. 269 p.

Clarke, A.R., A. Allwood, A. Chinajariyawong, R.A.I. Drew, C. Hensawad, M. Jirasurat, C.K. Krong, S. Kritsaneepalloon, & S. Vijaysegaran.
2001. Seasonal Abundance and Host Use Patterns of Seven Bactrocera Macquart Species (Diptera: Tephritidae) in Thailand and Peninsular Malaysia. *Raffles Bulletin of Zoology* 49: 207–220.

Cugala, D., J.J. Jordane, & S. Ekesi. 2017. Non-host Status of Papaya Cultivars to the Oriental Fruit Fly, *Bactrocera dorsalis* (Diptera: Tephritidae), in Relation to the Degree of Fruit Ripeness. *International Journal of Tropical Insect Science* 37: 19–29.

DHCP (Directorate of Horticultural Crop Protection). 2020. *Data Luas Komulatif Serangan OPT Salak Tahun 2018*. Direktorat Perlindungan Tanaman Hortikultura. http://ditlin.hortikultura.pertanian.go.id/index.php/page/index/DataLuas-Komulatif-Serangan-OPT-Salak-Tahun-2018, accessed 18/06/2020.

Doorenweerd, C., Leblanc, L., Norrbom, A.L., San Jose, M., & D. Rubinoff. 2018. A Global Checklist of the 932 Fruit Fly Species in the Tribe Dacini (Diptera, Tephritidae). *ZooKeys* 730: 19–56.

Drew, R.A.I. & D.L. Hancock. 2016. A Review of The Subgenus ‘Bulladacus’ Drew and Hancock of ‘Bactrocera’ Macquart (Diptera: Tephritidae: Dacinae), with Description of Two New Species from Papua New Guinea. *The Australian Entomologist* 43: 189–210.

Drew, R.A.I. & M. C. Romig. 2013. *Tropical Fruit Flies (Tephritidae: Dacinae) of South-East Asia: Indomalaya to North-West Australasia*. CAB International. Wallingford, UK. 653 p.

EPPO (European and Mediterranean Plant Protection Organization). 2019. *EPPO Report on Notifications of Non-Compliance (RS 2019/225)*. EPPO Reporting Service No. 11. http://gd.eppo.int/media/data/reporting/rs-2019-11-en.pdf, retrieved 23/06/2020.

EPPO (European and Mediterranean Plant Protection Organization). 2020. *Bactrocera dorsalis* (DACUDO). EPPO Global Database. http://gd.eppo.int/taxon/DACUDO, accessed 27/04/2020.

FAO (Food and Agriculture Organization). 2020. *FAOSTAT Database*. FAO, Rome, Italy. http://www.fao.org/faostat/en/#data/TP, retrieved 03/05/2020.

FAO/IPPC (Food and Agriculture Organization/International Plant Protection Convention). 2012. *Systems Approach for Pest Risk Management of Fruit Flies (Tephritidae)*. ISPM No. 35. IPPC.

FAO (Food and Agriculture Organization). 2020. *FAOSTAT Database*. FAO, Rome, Italy. http://www.fao.org/faostat/en/#data/TP, retrieved 03/05/2020.

IAQA (Indonesia Agricultural Quarantine Agency/Badan Karantina Pertanian Indonesia). 2013. *Laporan Tahunan Badan Karantina Pertanian 2013*. Ministry of Agriculture, Jakarta, Indonesia. 352 p.

IAQA (Indonesia Agricultural Quarantine Agency/Badan Karantina Pertanian Indonesia). 2014. *Pedoman Sertifikasi Fitosanitari Buah Salak ke China (Guidelines for Phytosanitary Certification of Salak to China)*. Ministry of Agriculture, Jakarta, Indonesia. 35 p.

Jang, E.B. & D.M. Light. 1991. Behavioral Responses of Female Oriental Fruit Flies to the Odor of Papayas at Three Ripeness Stages in a Laboratory Flight Tunnel (Diptera: Tephritidae). *Journal of Insect Behavior* 4: 751–762.

Larasati, A., P. Hidayat, & D. Buchori. 2013. Keanekaragaman dan Persebaran Lalat Buah Triba Dacini (Diptera: Tephritidae) di Kabupaten Bogor dan Sekitarnya. *Jurnal Entomologi Indonesia* 10: 51–59.

Linda, Wijtaksono, & Suputa. 2018. Species Composition of Fruit Flies (Diptera: Tephritidae) in Sorong and Raja Ampat, West Papua. *Jurnal Perlindungan Tanaman Indonesia* 22: 193–200.

Ministry of Agriculture (Kementerian Pertanian Republik Indonesia). 2019. *Outlook Salak*. Pusat Data dan Sistem Informasi Pertanian, Jakarta, Indonesia. 35 p.
Newell, I.M. & F.H. Haramoto. 1968. Biotic Factors Influencing Populations of Dacus dorsalis in Hawaii. *Proceedings of the Hawaiian Entomological Society* 20: 81–139.

Nugnes, F., E. Russo, G. Viggiani, & U. Bernardo. 2018. First Record of An Invasive Fruit Fly Belonging to Bactrocera dorsalis Complex (Diptera: Tephritidae) in Europe. *Insects* 9: 182.

Plant Health Australia. 2018. *The Australian Handbook for the Identification of Fruit Flies Version 3.1*. Plant Health Australia, Canberra. 158 p.

Ranganath, H.R. & K. Veenakumari. 1999. Notes on the Dacine Fruit Flies (Diptera: Tephritidae) of Andaman and Nicobar Islands-II. *Raffles Bulletin of Zoology* 47: 221–224.

Schutze, M.K., N. Aketarawong, W. Amornsak, K.F. Armstrong, A.A. Augustinos, N. Barr, W. Bo, K. Bourtzis, L.M. Boykin, C. Caceres, & S.L. Cameron. 2015. Synonymization of Key Pest Species within the Bactrocera dorsalis Species Complex (Diptera: Tephritidae): Taxonomic Changes Based on a Review of 20 Years of Integrative Morphological, Molecular, Cytogenetic, Behavioural, and Chemoecological Data. *Systematic Entomology* 40: 456–471.

Seo, S.T., C.S. Tang, S. Sanidad, & T.H. Takenaka. 1983. Hawaiian Fruit Flies (Diptera: Tephritidae): Variation of Index of Infestation with Benzyl Isothiocyanate Concentration and Color of Maturing Papaya. *Journal of Economic Entomology* 76: 535–538.

Suputa, Cahyaniati, A. Kustaryati., M. Railan, Issusilaningtyas, & W.P. Mardiasih. 2006. Pedoman Identifikasi Lalat Buah Hama. Direktorat Jenderal Hortikultura, Jakarta. 49 p.

Suputa, Cahyaniati, A.T. Arminudin, A. Kustaryati, M. Railan, & Issusilaningtyas. 2007. *Pedoman Koleksi dan Preservasi Lalat Buah (Diptera: Tephritidae)*. Kementerian Pertanian, Jakarta, Indonesia. 32 p.

Suputa, S., Y.A. Trisyono, E. Martono, & S.S. Siwi. 2010. Update on the Host Range of Different Species of Fruit Flies in Indonesia. *Jurnal Perlindungan Tanaman Indonesia* 16: 62–75.

Tsitsipis, J.A. 1989. Nutrition Requirements, p. 103–119. In W. Hell (ed.), *World Crop Pests: Fruit Flies: Their Biology, Natural Enemies and Control*, 3. Elsevier Science Publishers B.V., Amsterdam.

Van Houdt, J.K.J., F.C. Breman, M. Virgilio, & M. De Meyer. 2010. Recovering Full DNA Barcodes from Natural History Collections of Tephritid Fruitflies (Tephritidae, Diptera) Using Mini Barcodes. *Molecular Ecology Resources* 10: 459–465.

Vargas, R.I., J.C. Piñero, & L. Leblanc. 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.

Vijayasegaran, S. 2016. Bait Manufactured from Beer Yeast Waste and its Use for Fruit Fly Management, p. 227–248. In B. Sabater-Munoz, T. Vera, R. Pereira, & W. Orankanok (eds.), *Proceedings of the 9th International Symposium on Fruit Flies of Economic Importance*, Bangkok, Thailand, May 12–16, 2014.

Virgilio, M., K. Jordaens, C. Verwimp, I.M. White, & M. De Meyer. 2015. Higher Phylogeny of Frugivorous Flies (Diptera, Tephritidae, Dacini): Localised Partition Conflicts and a Novel Generic Classification. *Molecular Phylogenetics and Evolution* 85: 171–179.

Wee, S.L. & K.H. Tan. 2005. Evidence of Natural Hybridization Between Two Sympatric Sibling Species of Bactrocera dorsalis complex Based on Pheromone Analysis. *Journal of Chemical Ecology* 31: 845–858.

White, I., 2000. Morphological Features of the Tribe Dacini (Dacinae): Their Significance to Behavior and Classification, p. 505–533. In M. Aluja & A. Norrbom (eds.), *Fruit Flies (Tephritidae): Phylogeny and Evolution of Behavior*. CRC Press, Boca Raton.

White, I.M. & M.M. Elson-Harris. 1992. *Fruit Flies of Economic Significance: Their Identification and Bionomics*. CAB International, London. 601 p.