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Research Article

Survey of Fruit Flies (Diptera: Tephritidae) from 23 Species of Fruits Collected in Sleman, Yogyakarta

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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. umbrosa*, *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

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 Afrotropical 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 favourable 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.

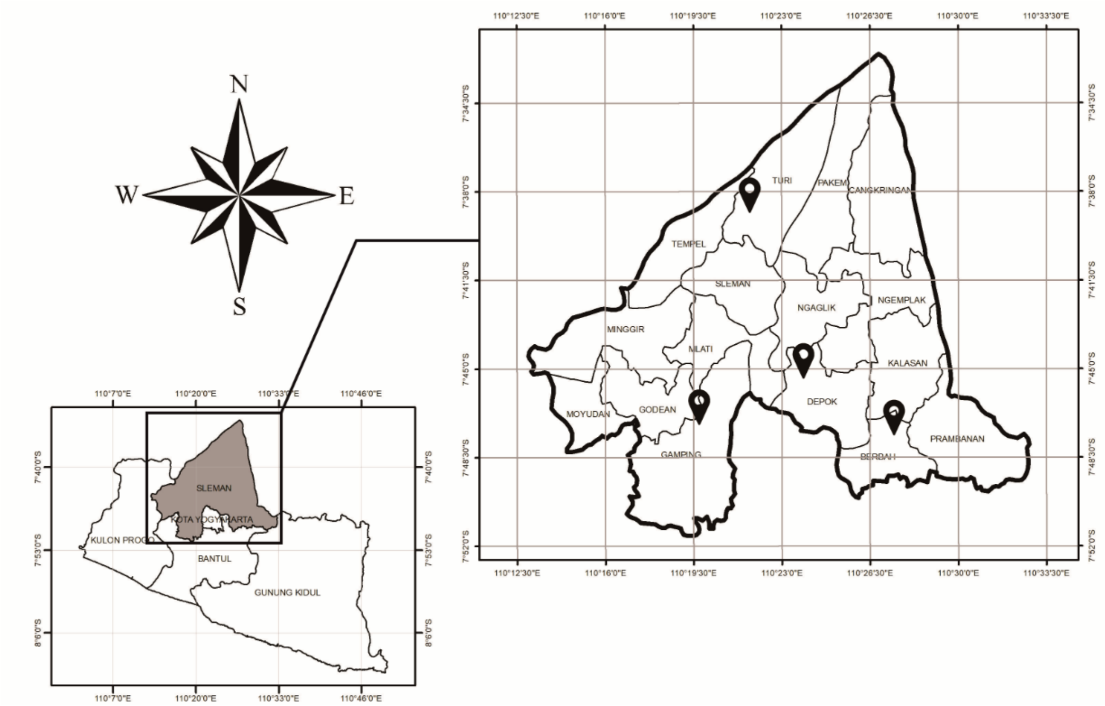

Figure 1. Selected sites for fruit collections in the Regency of Sleman, Yogyakarta

Table 1. Location for host collections in Sleman, Yogyakarta

Family	Species	Common name	Sub-district	Geographical Site
Anacardiaceae	*Mangifera indica*	Mango	Depok	7°46'02.2"S 110°22'50.4"E
	Spondias dulcis	Ambarella	Berbah	7°47'37.2"S 110°27'49.0"E
Annonaceae	*Annona muricata*	Soursop	Berbah	7°47'37.2"S 110°27'49.0"E
Arecaceae	*Salacca zalacca* cv. Pondoh	Salak Pondoh	Turi	7°37'24.1"S 110°23'09.5"E
Caricaeae	*Carica papaya*	Papaya	Berbah	7°47'37.2"S 110°27'49.0"E
Combretaceae	*Terminalia catappa*	Indian Almond	Depok	7°46'06.7"S 110°22'51.8"E
Cucurbitaceae	*Cucumis melo*	Melon	Gamping	7°48'01.1"S 110°19'22.3"E
	Cucumis sativus	Cucumber	Berbah	7°47'37.2"S 110°27'49.0"E
	Luffa acutangula	Ridge Gourd	Turi	7°37'36.5"S 110°23'22.7"E
	Momordica charantia	Bitter Melon	Turi	7°37'36.5"S 110°23'22.7"E
Gnetaceae	*Gnetum gnemon*	Melinjo	Berbah	7°47'52.1"S 110°27'52.1"E
Malpighiaceae	*Malpighia emarginata*	Barbados Cherry	Berbah	7°47'37.2"S 110°27'49.0"E
Moraceae	*Artocarpus integer*	Cempedak	Berbah	7°47'37.2"S 110°27'49.0"E
	Artocarpus heterophyllus	Jackfruit	Berbah	7°47'37.2"S 110°27'49.0"E
	Artocarpus altilis	Breadfruit	Berbah	7°47'37.2"S 110°27'49.0"E
Myrtaceae	*Syzygium aqueum*	Watery Rose Apple	Berbah	7°47'47.8"S 110°27'58.4"E
			Depok	7°46'03.1"S 110°22'57.2"E
	Syzygium cumini	Java Plum	Berbah	7°47'37.2"S 110°27'49.0"E
	Psidium guajava	Guava	Berbah	7°47'37.2"S 110°27'49.0"E
			Depok	7°46'47.4"S 110°26'37.1"E
	Eugenia uniflora	Surinam Cherry	Berbah	7°47'37.2"S 110°27'49.0"E
Oxalidaceae	*Averrhoa carambola*	Starfruit	Berbah	7°47'37.2"S 110°27'49.0"E
Rutaceae	*Citrus reticulata*	Tangerine	Gamping	7°48'01.1"S 110°19'22.3"E
Solanaceae	*Capsicum annuum*	Chilli	Depok	7°45'46.0"S 110°23'13.0"E
Thymelaeaceae	*Phaleria macrocarpa*	God's crown	Berbah	7°47'37.2"S 110°27'49.0"E

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

Table 2. The number of fruit flies pupae collected from host rearing and their survival to adult emergence

Family	Host Species	Common name	Collection Stage		No. Fruits	No. Pupae	Dead Pupae (%)		Adult Emergence (%)
			Source	Ripening			Parasitized	Non-parasitized	
Anacardiaceae	*Mangifera indica*	Mango	D	R, S	5	57	3.5	19.3	77.2
	Spondias dulcis	Red Ambarella	A, D	R, S	37	41	0.0	17.1	82.9
Annonaceae	*Annona muricata*	Soursop	A	R	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
Caricaeae	*Carica papaya*	Papaya	A	HY	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	R	1	82	0.0	3.7	96.3
	Cucumis sativus	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	R, S	26	7	28.6	42.9	28.6
Malpighiaceae	*Malpighia emarginata*	Barbados Cherry	A, D	R, S	16	11	0.0	18.2	81.8
Moraceae	*Artocarpus integer*	Cempedak	A	R	1	31	0.0	25.8	74.2
	Artocarpus heterophyllus	Jackfruit	A	R	1	24	0.0	16.7	83.3
	Artocarpus altilis	Breadfruit	D	R	1	4	0.0	50.0	50.0
Myrtaceae	*Syzygium aqueum*	Watery Rose Apple	D	R, S	13	28	0.0	17.9	82.1
	Syzygium cumini	Java Plum	A, D	R, S	62	14	0.0	57.1	42.9
	Psidium guajava	Guava	A, D	R, S	11	161	0.0	8.1	91.9
	Eugenia uniflora	Surinam Cherry	A, D	R, S	17	23	0.0	13.0	87.0
Oxalidaceae	*Averrhoa carambola*	Starfruit	A, D	R, S	27	143	4.9	17.5	77.6
Rutaceae	*Citrus reticulata*	Tangerine	D	R	7	11	0.0	45.5	54.5
Solanaceae	*Capsicum annuum*	Chilli	D	R	10	23	0.0	17.4	82.6
Thymelaeaceae	*Phaleria macrocarpa*	God's crown	D	R, S	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

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 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 (*Malphigia 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**
Arecaceae	*Salacca zalacca* cv. Pondoh	Salak Pondoh	-	+	+	-	-	-	**2**
Caricaeae	*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 altilis	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. caryeae*, *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*., 20011), 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. mcgregori*. 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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