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Assessment of Fruit Fly Infestation on Melon Manis Terengganu (*Cucumis melo* var. *inodorus*) at Different Fruit Ripening Stages

Nor Aminah Azizol Azeli, Salmah Mohamed*, and Nur Athiqah Md Yusof

Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Besut Campus, 22200 Besut, Terengganu, Malaysia

***Corresponding author: salmahmohamed@unisza.edu.my**

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ABSTRACT

Cucumis melo var *inodorus* or known as Melon Manis Terengganu (MMT) is a new variety of rockmelon and has been developed and grown exclusively in Terengganu since 2015. However, pest infestations such as fruit flies have reduced melon production yields, and research on fruit flies is still poorly studied in this new variety. Therefore, this study was aimed to identify the fruit fly's species infested MMT as well as to determine the infestation rate of fruit flies on MMT at different ripening stages. The infested MMT fruits were randomly collected for three consecutive weeks prior to harvest and each week was represented as unripe stage (Week 1), ripe stage (Week 2) and fully-ripe stage (Week 3). Each week, 10 fruit samples were brought to the laboratory and weighed individually before being placed in plastic containers. The fruits were reared until all larvae transformed into pupae for determination of infestation rates and emergence of adult fruit flies for species identification. A total of 232 of fruit flies adults emerged from 30 MMT fruit samples collected and all the flies were identified as *Zeugodacus cucurbitae* (previously known as *Bactrocera cucurbitae).* Unripe stage fruits recorded the highest infestation rate of fruit flies at 28.24 ± 18.58 pupae/kg and followed by ripe stage at 24.47 ± 8.17 pupae/kg. Whilst the fully-ripe stage had the lowest infestation rate of flies at 13.5 ± 5.07 pupae/kg. However, no significant difference ($p>0.05$) of infestation rate was recorded among the different fruit stages. This study contributes new information on the fruit fly's species that attack MMT and its infestation rate. Hence, these findings are expected to help better management of MMT fruit flies in the future.

Keywords: *Cucumis melo*, fruit flies, infestation rate

INTRODUCTION

Melons production has been widely cultivated and distributed in Malaysia. Although there are over 500 varieties of melons and 150 varieties of watermelons in the world, the most common ones in Malaysia are Super Dragon

(watermelon), Jade Dew (honeydew), and Glamour (rockmelon). Among them, the rockmelon is the sweetest type, with a more compact pulp than watermelon (Masdek & Muhammad, 2016).

Cucumis melo var. *inodorus* cv. Manis Terengganu 1, or also known as Melon Manis Terengganu (MMT), was introduced into Terengganu in 2015 (Amirah et al., 2020). The melon has a musky scent and a yellow-skinned background of orange flesh (Muhamad et al., 2019). This cultivar is popular among Terengganu entrepreneurs and planters because it provides local farmers with a high profit margin (Zainol et al., 2021). Moreover, it has shorter growth cycle which took only 60 days of maturity period with 2 weeks shelf life, depending on storage conditions (Muhamad et al., 2019) compared to the other rockmelon cropping cycle that usually covers a period of between 75 to 80 days (Perak Agricultural Development Corporation, 2017).

Currently, Terengganu is the largest producer of MMT fruit in Malaysia, and the seeds can only be planted in Terengganu as a result of the mandate from the former Terengganu State Director of Agriculture (David, 2015). A total of 444 Rain Protective Structure (RPS) with a capacity of 222,000 trees were set up at Taman Kekal Pengeluaran Makanan (TKPM) in Besut, Terengganu, capable of producing 666 metric tonnes of melons worth RM2 million per round or RM6 million per year (DOA Terengganu, 2016). Since then, the Terengganu state government has committed to opening more areas and expanding MMT cultivation because it can help locaL farmers increase their income. Thus, the government has launched ten MMT projects totaling 5.7 hectares with 52 participants, yielding 40 to 60 tonnes to date (Amirah et al., 2020).

However, MMT like other cucurbits is vulnerable to a wide variety of insects from the early until harvest stages of crop production. Since this plant belongs to the same family Cucurbitaceae as other cucurbitaceous plants, it has similar cultural requirements and is susceptible to the same insect populations. For instance, a study by Amirah et al. (2020) reported that numerous insect pests have been recorded to attack MMT plants, including the red pumpkin beetle (RPB), melon worm, leaf miner fly, Hudda beetle, jassids, and aphids but they did not reported any fruit flies attack on MMT. Nonetheless, the tephritids fruit flies such as melon fruit fly, *Bactrocera cucurbitae* (currently known as *Zeugodacus cucurbitae*) is widely regarded as the most damaging pest of melons and allied crops, severely limiting the output of melons, cucumbers, and tomatoes (Steck, 2015). Previous reports have shown that damage by these pests is capable of causing 30% to 100% loss to cucurbits crops (Devi et al., 2018). Sohel et al. (2019) stated that the damage caused by fruit fly is the most serious in melon and this may be up to 100 percent of yield loss. The issue with the proliferation of melon flies has gotten increasingly severe in the previous years, and the problem with this pest is more serious than before (Toyzhigitova et al., 2019). Normally, the increase in pest population during the fruiting stage has caused negative effects on the fruit such as bruising and rot. As a result, the fruits are less suitable for consumption and reduce their marketability.

Due to these issues, it is important to conduct detailed studies on the fruit flies that commonly attack MMT in order to manage the pests effectively. Furthermore, since MMT is a new rockmelon variety, the literature on fruit flies is still lacking. Therefore, the main objective of this study was to identify the fruit flies species infested MMT and to determine their infestation rate on MMT at different ripening stages. It is hoped that the data obtained can be used to help better management of MMT pests in the future.

MATERIALS AND METHODS

Study area and time of sampling

This study was conducted at Melon Manis Terengganu (MMT) farms located in Taman Agropreneur, Universiti Sultan Zainal Abidin (UniSZA), Besut Campus, Terengganu (5°75'62.3" N,102°62'42.5" E). The study area consists of two plots of MMT crops planted inside the greenhouses (100x60 ft), where each plot consisted of 11 rows of beds. The study was conducted in June 2021 during dry season with average temperature between 32-33ºC for three consecutive weeks prior the MMT harvest time.

Cultivation and management practices of MMT

MMT plants are grown using a fertigation system which involves giving controlled water and AB fertilizer at a ratio of 1:250 with an average of 2100-2300 ml/plant/day to increase crop yields. Automatic drip fertigation systems have been used to irrigate crops on a regular basis. There were no additional plants grown in the greenhouses at the time of this experiment.

The MMT seeds were raised in germination trays filled with coco peat before the germinated MMT seeds were placed in the soil on day 8. One week before planting, the top soil bed was sprayed with fungicides and herbicides to minimize plant disease and insect infestation. Plants were sprayed with foliar spray (average at 11ml per plant) in the fifth and sixth weeks to increase nutrient uptake by MMT. Biopesticides such as wood vinegar and neem foliar oil have also been used to control pests and diseases (2-3 times per month or when necessary).

Infested fruit collection

Ten infested MMT fruits were randomly collected every week for three consecutive weeks. Each week represents MMT at three different ripening stages as follows; Week 1 for the unripe stage (UR) with light green colour, Week 2 for the ripe stage(R) with light green-yellow colour and Week 3 for the fully-ripe stage (FR) with totally yellow in colour (Fig. 1). Details of MMT plants and fruits age at each sampling week are shown in Table 1. The fruits were considered infested when fruit fly oviposition punctures were present on fruit's skin (Fig. 1).

Fig. 1. MMT at different ripening stages and the sign of fruit flies' oviposition punctures. From left to right; U- Unripe stage, R- Ripe stage, FR- Fully-ripe stage.

Table 1. MMT plant and fruit age for each sampling week.

Sampling Week	Fruit Stage	Plant Age (days)	Fruit Age (days)	Fruit Colour
1	Unripe	44	9	Light green
2	Ripe	51	16	Light green-yellow
3	Fully-ripe	58	23	Yellow

All the fruit samples collected were transferred to the Entomology Laboratory, Faculty of Bioresources and Food Industry, UniSZA Besut Campus where they were individually weighed using a kitchen scale (Tanita, Malaysia) and categorised by fruit stage and sampling date.

Infested fruit rearing

The infested fruit rearing procedure was adopted and modified from Salmah et al. (2017a). Each MMT fruit was placed in a plastic container (26x16x21cm) and a screened, tight-fitting net lid covered the container to prevent interference and entry from other pests. About 2 cm of moistened and sterilized vermiculite was layered at the bottom of the container as pupation media. The vermiculite was sterilized in the dryer (Protech FDD-720, Malaysia) at 50˚C for three days, then cooled to room temperature before being utilized.

The containers were then left for an incubation period for 14 days in the laboratory (28 ± 2ºC, 60-70% RH, 12:12 h L:D) to allow all fruit flies larvae in fruits to fall into vermiculite and pupate. Any remaining larvae were manually removed and placed into containers using fine forceps. After the incubation period, the vermiculite was sieved and the recovered fly's pupae were calculated, recorded and transferred into small plastic cups (4x3x4cm) layered by tissue paper. The plastic cups containing fly pupae were transferred to the adult rearing cage (12x9x12cm) until all the adult flies emerged. The emerged adults were kept in the cage for 3-4 days until the adults are fully developed. The number of adults that had emerged were recorded and preserved in specimen vials containing 70% ethanol for further identification process.

Fruit fly identification

All fruit flies adults emerged from infested MMT were sorted using forceps according to their species. The samples were examined under stereoscopy microscope (Olympus SZ51, Japan) based on their external morphologically characteristics. The fruit fly's species were identified based on DORSALIS LUCID v3.3 software (Lawson et al., 2003) and Drew and Hancock (1994).

Data collection

Data on fruit weight, total of pupae recovered, and the number of fruit fly species obtained were recorded and labelled accordingly to each sampling date. Fruit flies' infestation rate was recorded as the total number of pupae recovered per total of weight (kg) fruits collected from each sampling date (Steck et al., 1986).

Data analysis

One-Way Analysis of Variance (ANOVA) was used to analyse the fruit weight, pupae recovered, and infestation rate according to the different fruit stage. Means were separated with Tukey's Range (HSD) Test at 0.05 level of significance. All data analyses were performed using MINITAB® 19 software version 2021.

RESULTS AND DISCUSSION

Identification of fruit flies infesting MMT

A total of 232 of fruit flies adults emerged from 30 MMT fruit samples (Table 2). All adults were identified as *Zeugodacus cucurbitae* (Fig. 2). This species is the common fruit fly species infested melon fruits and are reported as major economic threat to cucurbits with its wider distribution throughout the tropical, sub-tropical and temperate regions of world (Begum & Mubarak, 2018). According to Mir et al. (2014), this species developed their characteristic reddish-brown colouration and fuscous shadings on the wings' outer borders and transverse coloured mark on the wing (Fig. 2B). Moreover, this fly had abdomen that is not waisted like a wasp. Tergite 3 has a transverse band across it, while the tergite 4 is dark laterally and it has a medial longitudinal stripe (White & Hancock, 1997) (Fig. 2A).

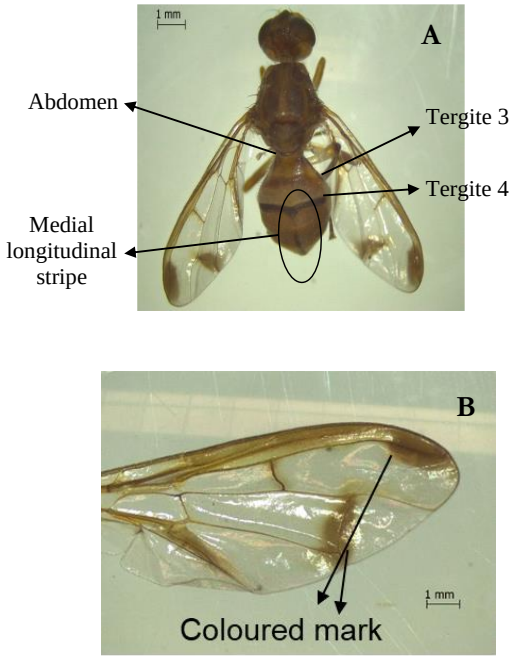

Fig. 2. Dorsal view of *Zeugodacus cucurbitae* (A) and it's wing coloured mark (B).

Infestation rate of fruit flies on MMT

Table 2 shows the number of MMT fruit samples and fruit weight, as well as the total number of *Z. cucurbitae* pupae recovered, infestation rate, and emerging adults at different stages of MMT fruit. The results showed that a total of 30 MMT fruits weighing 11.32 kg were collected from three weeks of fruit sampling. It was found that the MMT fruit weight and total of *Z. cucurbitae* pupae recovered showed not significantly difference (*p>0.05*) between different fruit stages.

Table 2. Total of *Zeugodacus cucurbitae* pupae and adults collected at different ripening MMT fruit stage.

Fruit Stage	Infested Fruit Sampled	Total Fruit Weight (kg)	Fruit Weight (kg) (Mean±SE)	Total Pupae Recovered (Mean±SE)	Infestation Rate (pupae/kg) (Mean±SE)	Total Adults Emergence (individuals)
Unripe	10	3.37	0.34 ± 0.04[a]	9.10 ± 7.04[a]	28.24 ± 18.58[a]	91
Ripe	10	2.87	0.29 ± 0.03[a]	7.10 ± 2.82[a]	24.47 ± 8.17[a]	71
Fully-ripe	10	5.08	0.51 ± 0.09[a]	7.00 ± 2.11[a]	13.5 ± 5.07[a]	70
Total	**30**	**11.32**				**232**

Means with the same letters in different columns were not significantly different (P>0.05) by Tukey's (HSD) test.

Meanwhile, the unripe stage recorded the highest infestation rate at 28.24 ± 18.58 pupae/kg, followed by ripe stage at 24.47 ± 8.17 pupae/kg and fully-ripe stage had the lowest infestation rate of fly at 13.5 ± 5.07 pupae/kg.

However, no significant difference ($p>0.05$) of fruit flies infestation rate was recorded among the different fruit stages (Table 2).

Based on the findings, the infestation rate of *Z. cucurbitae* was recorded to decrease gradually over fruit ripening stages. The results of this study differ from most previous studies where the infestation rate of fruit flies, particularly the tephritids species was reported to typically increase as the fruit matured. For instance, *B. dorsalis* was found to oviposit more eggs on fully-ripe mangoes than ripe and unripe mangoes (Salmah et. al. 2017b; Rattanapun et al. 2009) while odors of mature guava (*Psidium guajava*) attracted *B. tryoni* flies more strongly than unripe stages (Cunningham et al. 2016).

Basically, fruit flies are attracted to fruit volatile compounds (Mahmoud et al., 2022) particularly during fruits ripening stage which the fruits will change in its attributes such as colour, tissue firmness, volatile aroma production, starch accumulation and in terms of quantities of other organic compounds (Yashoda et al., 2007). However, in this study, it was found that *Z. cucurbitae* fruit flies are able to attack MMT fruit at the unripe stage or as early as nine days after fruiting. This shows that farmers need to take early control measures to avoid fruit fly attacks. Moreover, the declining trend of infestation rate of *Z. cucurbitae* from this study might be also due to the application of pesticides during fruit sampling. According to the farm's owner, no insect control was done in week one, but biopesticides were sprayed in week two and week three. This findings is in line with Sunil et al. (2016) which they recorded less fruit infestation and fewer fruit fly's maggots per fruit recorded after pesticide treatment.

CONCLUSION

The result demonstrated that fruit flies emerged from the damaged MMT fruits was identified as *Zeugodacus cucurbitae*, which the common fruit fly species infested melon. The highest fruit fly's infestation rate was recorded at the unripe fruit stage due to no pesticide treatment followed by the pesticide-treated ripe and fully ripe fruit stage. Further studies need to be conducted in the future to obtain more detailed data of *Z. cucurbitae* attack on MMT. For example, by studying the behavior of *Z. cucurbitae* fruit flies, especially the oviposition preference in choosing the best host and what factors drive the selection. Nevertheless, the data obtained from this study could be the basis for helping better MMT pest management in the future.

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