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RESEARCH PAPER

Oviposition preference of *Zeugodacus cucurbitae* (Diptera: Tephritidae) on melon manis terengganu, *Cucumis melo* var. *inodorus*

Nur Syahida Wajdah Saidi[1], Salmah Mohamed[1], Nor Aminah Azizol Azeli[1], Nur Athiqah Md Yusof[1], Norhayati Ngah[1], & Nur Azura Adam[2,3]

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ABSTRACT

Understanding the ovipositional preferences of insect pests is essential for developing effective management strategies in agricultural systems. *Zeugodacus cucurbitae* (Coquillett) is a highly destructive tephritid fruit fly that infests fruits at various maturity stages, causing significant damage to economically important crops such as Melon Manis Terengganu (MMT). This study investigated the ovipositional preference of *Z. cucurbitae* across three fruit maturity stages—unripe, ripe, and fully ripe—under no-choice and choice experimental conditions. In the no-choice experiment, pupal formation (7.44 ± 2.10 pupae) and adult emergence (6.20 ± 2.03 flies) were significantly lower ($P < 0.05$) in unripe MMT, whereas the percentage of adult emergence and sex ratio did not differ significantly ($P > 0.05$) among fruit maturity stages. Under choice conditions, pupal formation was also significantly lower ($P < 0.05$) in unripe MMT (11.40 ± 4.68 pupae), while fully ripe fruits supported significantly higher ($P < 0.05$) male (51.70 ± 21.07%) and female (55.00 ± 26.59%) emergence. Correlation analysis revealed significant relationships ($P < 0.05$) between pupal formation, adult emergence, and fruit characteristics in the choice experiment. These findings demonstrate a strong preference of *Z. cucurbitae* for fully ripe MMT as oviposition sites, indicating that fruit maturity plays a critical role in host selection. This study provides valuable insights for the development of targeted pest management strategies, including early-stage fruit protection, to reduce infestation in MMT cultivation.

Keywords: *Cucumis melo*, development, host stage, melon fruit fly, sex ratio

INTRODUCTION

Melon Manis Terengganu (MMT) is a Malaysian variety of *Cucumis melo* grown exclusively in Terengganu and was officially recognized as the region's iconic fruit in 2015 (Tahir et al., 2020). This cultivar has gained popularity among local entrepreneurs and farmers due to its high economic returns. MMT is widely cultivated throughout Terengganu, with key planting areas including Taman Kekal Pengeluaran Makanan (TKPM) Tok Dor (Besut), TKPM Rhu Tapai (Setiu), and TKPM Peradong (Kuala Terengganu), in addition to production by private farmers (Jusoh et al., 2022; Tahir et al., 2020).

MMT fruits are well known for their musky aroma and distinctive characteristics, including yellow outer skin and orange-colored flesh (Muhamad & Redzuan, 2019). This rockmelon variety is also recognized as one of the sweetest types, with denser pulp compared to other melon cultivars (Chung et al., 2024). However, MMT is vulnerable to a wide range of pests from the early stages of crop development through the harvesting period. Pests may directly feed on and infest MMT fruits, thereby limiting productivity and reducing fruit quality (Jacob et al., 2024). Among the most serious pest problems affecting MMT is infestation by insect pests, particularly fruit flies.

Fruit flies, classified under the order Diptera and the family Tephritidae, comprise approximately 4500 species worldwide (Korneyev, 2021). They are considered polyphagous pests that primarily attack soft-bodied fruits and vegetables in various horticultural crops (Saeed et al., 2022). Studies conducted in different horticultural landscapes in Indonesia have shown that fruit fly communities are diverse and widely distributed, reflecting their high adaptability to various host plants and agroecosystems (Supratiwi et al., 2020). According to Mishra et al. (2012), more than 70 species within the genus *Bactrocera* are recognized as major agricultural pests globally.

Corresponding author:
Salmah (salmahmohamed@unisza.edu.my)

[1]Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin (UniSZA) Besut Campus, Besut, Terengganu, Malaysia 22200
[2]Faculty of Agriculture, Universiti Putra Malaysia, UPM Serdang, Selangor, Malaysia 43400
[3]Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), College, Los Baños, Laguna, Philippines 4031

For instance, in Mozambique, the establishment of *Zeugodacus cucurbitae* has resulted in severe infestations of cucumber, watermelon, and pumpkin, with reported yield losses ranging from 53% to 100%. These outbreaks have prompted the implementation of strict quarantine regulations to restrict fruit movement and prevent cross-regional spread (IPPC, 2023). Similarly, in India, *Z. cucurbitae* has become a major pest in smallholder farming systems, with infestation rates in bottle gourd, bitter gourd, and ridge gourd exceeding 43%, leading to substantial yield losses and economic hardship for local growers.(Sumanth, 2024).

In Malaysia, the highest infestation of *Z. cucurbitae,* averaging 28 pupae per kg of MMT fruit, was reported due to the fruit's thinner rind, firmer pulp, and higher concentrations of volatile compounds compared to other cucurbits (Azeli et al., 2022). Surveys conducted in Sarawak and a recent checklist of Borneo further confirmed the presence and distribution of *Z. cucurbitae* in Malaysia, although detailed infestation levels were not reported (Fu et al., 2013; Doorenweerd et al., 2025). The distribution and occurrence of fruit flies in agricultural areas are commonly assessed using attractant-based trapping systems such as methyl eugenol and cue lure, which have proven effective for monitoring tephritid populations in tropical regions (Saputra & Afriyansyah, 2021).

Fruit damage and infestation are primarily caused by the ovipositional behavior of female *Bactrocera* flies on their host fruits. This behavior is critical because females must select suitable hosts for egg laying to optimize offspring development and ensure adequate nutrient availability for larvae (Nor et al., 2018). Host selection is typically influenced by the physical characteristics of the fruit, including hardness, firmness, chewiness, and gumminess (Mawtham et al., 2020). In addition, fruit odor, color, and maturity stage play important roles in determining ovipositional preference (Cai et al., 2020). Fruit maturity provides favorable conditions for females to locate optimal oviposition sites (Komarov et al., 2025). Rattanapun et al. (2021) reported that fruit firmness and ripeness are key indicators of host quality during oviposition site selection. The maturity stage of the host fruit also affects both its physical and chemical properties (Cai et al., 2020). During the ripening process, fruits undergo substantial changes, including alterations in color, tissue firmness, volatile compound production, starch accumulation, and the concentration of various organic compounds (Busatto & Herrera, 2025).

The influence of fruit maturity stages on the preference and performance of *Z. cucurbitae* (formerly recognized as *Bactrocera cucurbitae*) has been extensively investigated. However, the ovipositional preference of *Z. cucurbitae* toward the local Malaysian melon variety, Melon Manis Terengganu, remains poorly understood. Understanding how different maturity stages of this specific melon variety influence *Z. cucurbitae* may provide valuable insights for developing effective pest management strategies and improving cultivation practices. Therefore, this study was conducted to evaluate the oviposition behavior *Z. cucurbitae* across different maturity stages of MMT. The findings of this study are expected to contribute useful information for future research and control efforts targeting this pest species.

MATERIALS AND METHODS

Research Site. The research was conducted in the Entomology Laboratory, Universiti Sultan Zainal Abidin (UniSZA), Besut Campus, Terengganu, Malaysia.

Adults of *Zeugodacus cucurbitae*. Adults *Z. cucurbitae* used in this experiment were obtained from the Quarantine Laboratory, Horticultural Research Centre, Malaysian Agricultural Research and Development Institute (MARDI), Serdang, Selangor. The fly colony (seventeenth generation) was maintained under laboratory conditions at 28 ± 2 ºC, 70–80% relative humidity (RH), and a 12:12 hours light:dark (L:D) photoperiod.

Ten pairs of newly emerged *Z. cucurbitae* adults from the stock culture were allowed to mate and were then released into a new adult rearing cage (30 × 45 × 30 cm). The adults were provided with water, sugar cubes, and dry yeast. Female adults aged 21 days were selected for the experiment, as this age is considered optimal for oviposition. Previous studies have shown that fruit fly females at this stage exhibit the highest egg-laying activity (Zhu et al., 2022).

Fruit Hosts. Three maturity stages of Melon Manis Terengganu (MMT) were used to assess the offspring performance of *Z. cucurbitae*. Fruits were obtained from an MMT farm at Taman Agropreneur, UniSZA Besut Kampus, Terengganu (5°75'62.3" N 102°62'42.5" E). Fruits were harvested at three developmental stages: unripe fruits, characterized by a hard green exterior, were collected at 41 days after sowing (DAS); ripe fruits, exhibiting a light green-yellow coloration, were collected at 48 DAS; and fully ripe fruits, characterized by a fully yellow skin, were collected at 55 DAS (Figure

1). Upon collection, the fruits were transported to the laboratory, individually washed, and labeled according to maturity stage. They fruits were then stored at 4 ºC for one day prior to use in the experiment.

Fruit Characteristics. The characteristics of MMT at different maturity stages were evaluated based on fruit weight, diameter, total soluble solids (TSS), and firmness. Fruit weight was measured using a digital weighing scale (Tanita, Malaysia), and fruit diameter was measured using a Vernier caliper (Mitutoyo, Series 533, Japan).

TSS was expressed as degrees Brix (ºBrix) and determined from freshly extracted fruit juice using a digital pocket refractometer (PAL-1, Atago, Japan). Fruit firmness was measured at the equatorial region using an Instron 5543 penetrometer (USA) fitted with a 5 mm stainless steel probe. For each maturity stage, five fruits were horizontally sliced at the midpoint into 15.0 mm-thick sections. Firmness was measured at three different points per fruit, and the average value was calculated.

No-Choice Experiment. Fruits at different maturity stages were placed individually into separate rearing cages (Figure 2A), with one fruit per cage. Three pairs of 21-day-old, sexed female and male flies from an established colony were introduced into each cage. The inclusion of males was considered important, as their presence may influence female oviposition behavior through courtship experience (Giudice et al., 2025).

The flies were provided with water, sugar cubes, and dry yeast in a 2:1:1 ratio, and the diet was replenished weekly prior to each replication. The flies were allowed to oviposit for 24 hours. After exposure, each fruit was examined under a microscope equipped with imaging software (Leica, Germany) to identify fresh puncture marks. These marks typically became visible within a few days as watery exudates, slight surface concavity, and eventually brown resinous deposits (Jacob et al., 2024).

Following observation, the fruits were removed and placed individually into separate plastic containers filled with sterilized fine vermiculite and incubated for 14 days until all larvae pupated. The pupae obtained from each fruit were counted and transferred to small plastic cups for monitoring adult emergence. Parameters recorded included: (1) number of pupae formed, (2) number of adults emerged, and (3) adult sex ratio (%). The experiment was replicated five times using fresh fruits and newly paired adults for each replicate. A one-week interval between replicates was maintained to minimize temporal bias.

Choice Experiment. Unripe, ripe, and fully ripe MMT fruits were placed together in a single rearing cage

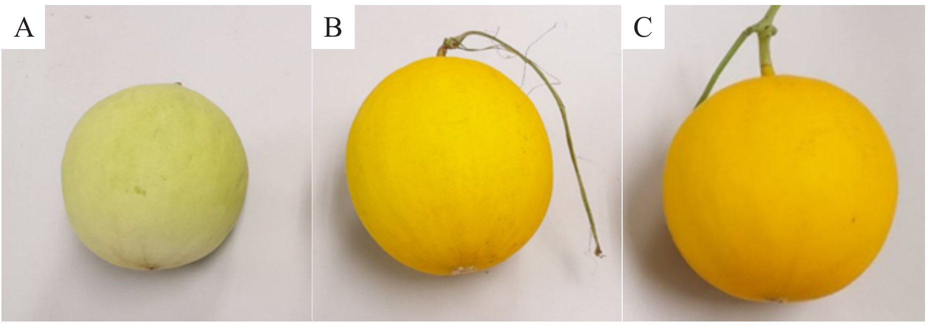

Figure 1. Different maturity stages of Melon Manis Terengganu (MMT). A. Unripe MMT, labeled as UR; B. Ripe MMT, labeled as R; C. Fully ripe MMT, labeled as FR.

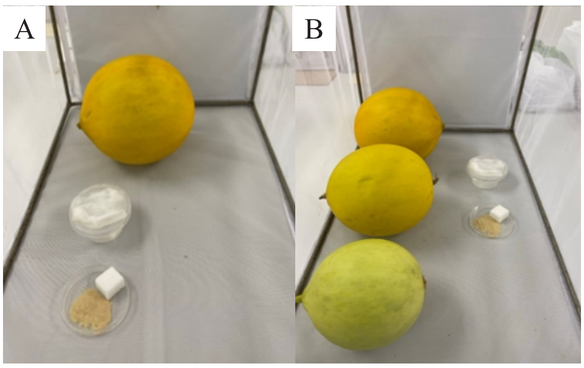

Figure 2. Experimental set-up for oviposition assays of *Zeugodacus cucurbitae*: A. Set-up for the no-choice experiment; B. Set-up for the choice experiment.

(Figure 2B). To reduce variation due to fruit size, fruits were standardized by weight: unripe (0.5–1.0 kg), ripe (1.5–2.0 kg), and fully ripe (1.7–2.2 kg). These weight ranges are consistent with maturity indices of average MMT fruit weights (1.0–1.8 kg at maturity) (Ong & Khandaker, 2021; TADC, 2025) and with a local grower's identification of the optimal maturity stage.

One pair of 21-day-old mated female and male from established rearing cages was released into each cage. The flies were provided with the same adult diet (2:1:1, water:sugar:yeast) and exposed to the fruits for 24 hours. Oviposition sites were examined prior to transferring the fruits into containers with vermiculite for larval development. Offspring parameters recorded were the same as those measured in the no-choice experiment. The choice experiment was also replicated five times, each using fresh fruits and newly paired flies.

Data Analysis. Data on ovipositional preference of *Z. cucurbitae* (number of pupae formed, number of adults emerged, and adult sex ratio) and fruit characteristics (weight, diameter, TSS, and firmness) obtained from the no-choice and choice experiments were sanalyzed using one-way analysis of variance (ANOVA) to compare differences among the three maturity stages. Correlation analyses was were performed to evaluate relationships between fruit characteristics and offspring parameters across different maturity stages in both experimental setups. Mean comparisons were conducted using Tukey's honestly significant difference (HSD) test at a significance level of P = 0.05. All statistical analyses were performed using SPSS software version 2021.

RESULTS AND DISCUSSION

Oviposition Preference and Offspring of *Z. cucurbitae* on Three MMT Maturity Stages. Figures 3 and 4 present the ovipositional and offspring parameters of *Z. cucurbitae* across three fruit maturity stages in the no-choice experiment. The number of

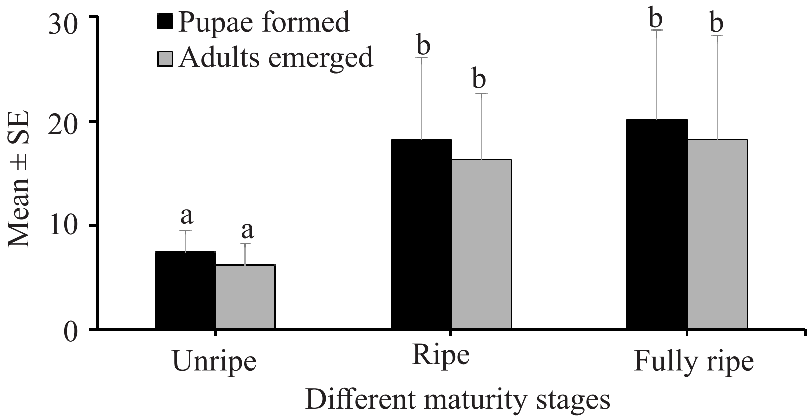

Figure 3. Mean (± SE) number of pupae formed and adults emerged at different MMT maturity stages in the no-choice experiment. Means sharing identical letters indicate no significant difference (P > 0.05) based on Tukey's honestly significant difference (HSD) test.

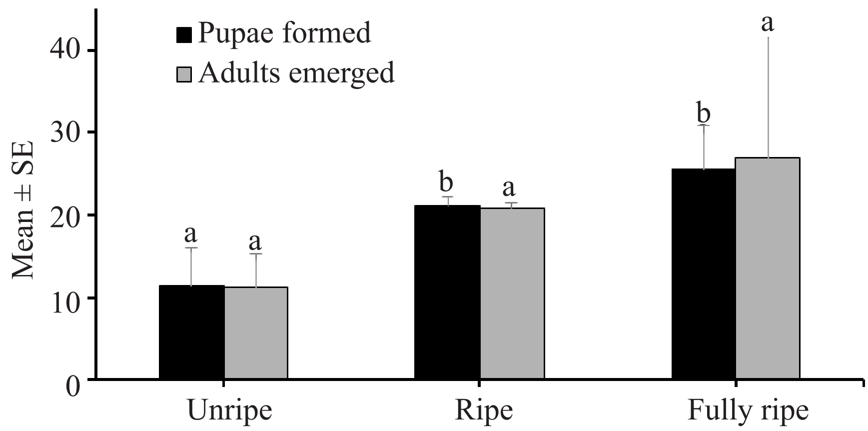

Figure 4. Mean (± SE) number of pupae formed and adults emerged at different MMT maturity stages in the choice experiment. Means sharing identical letters indicate no significant difference (P > 0.05) based on Tukey's honestly significant difference (HSD) test.

pupae formed differed significantly among maturity stages ($P < 0.05$), with unripe fruits producing the fewest pupae (7.44 ± 2.10) compared with ripe (18.27 ± 7.80) and fully ripe fruits (20.10 ± 8.59). A similar trend was observed for adult emergence, which was highest in fully ripe fruits (18.29 ± 9.90 flies), followed by ripe (16.34 ± 6.33 flies) and unripe fruits (6.20 ± 2.03 flies). However, the difference between ripe and fully ripe fruits was not statistically significant ($P > 0.05$).

In contrast, the percentage of adult emergence and male sex ratio did not differ significantly among fruit maturity stages ($P > 0.05$). Nevertheless, male emergence tended to be highest in fully ripe fruits (29.54 ± 7.54%), followed by ripe (28.60 ± 13.61%) and unripe fruits (23.70 ± 13.10%). Female emergence was significantly lower in unripe fruits (25.00 ± 11.02%) compared with ripe (33.62 ± 14.82%) and fully ripe fruits (38.34 ± 19.40%).

The offspring parameters of *Z. cucurbitae* in unripe, ripe, and fully ripe MMT under the choice experiment are illustrated in Figure 5 and 6. Pupal formation differed significantly among maturity stages ($P < 0.05$), with unripe fruits producing the fewest pupae (11.40 ± 4.68) compared with ripe (21.20 ± 0.97) and fully ripe fruits (25.65 ± 5.12). Although adult emergence did not differ significantly among maturity stages ($P > 0.05$), a clear increasing trend was observed, with 11.20 ± 4.07 adults emerging from unripe fruits, 20.78 ± 0.74 flies from ripe fruits, and 26.93 ± 15.13 flies from fully ripe fruits.

A similar trend was evident in the percentage of adult emergence, which increased from 45.3 ± 10.01% in unripe fruits to 55.03 ± 15.05% in ripe fruits and peaked at 70.2 ± 23.18% in fully ripe fruits. Sex ratio analysis revealed significant differences ($P < 0.05$) across maturity stages for both males and females. Male emergence was lowest in unripe fruits (23.76 ± 1.06%), whereas female emergence was highest in fully ripe fruits (38.34 ± 7.54 %), significantly exceeding that in unripe fruits.

The results from both no-choice and choice experiments demonstrate that *Z. cucurbitae* females oviposited on fruits at all maturity stages. However, a consistent trend was evident whereby increasing MMT maturity positively influenced pupal formation,

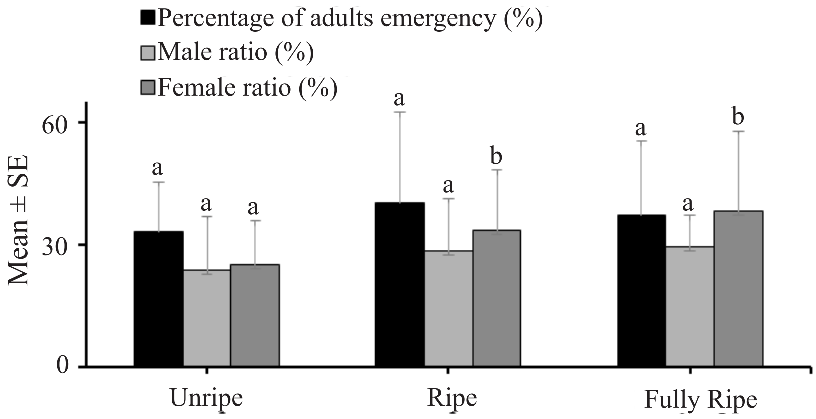

Figure 5. Mean (± SE) percentage of adults emergence, male and female ratios (%) at different MMT maturity stages under no-choice condition. Means sharing identical letters indicate no significant difference ($P > 0.05$) based on Tukey's (HSD) test.

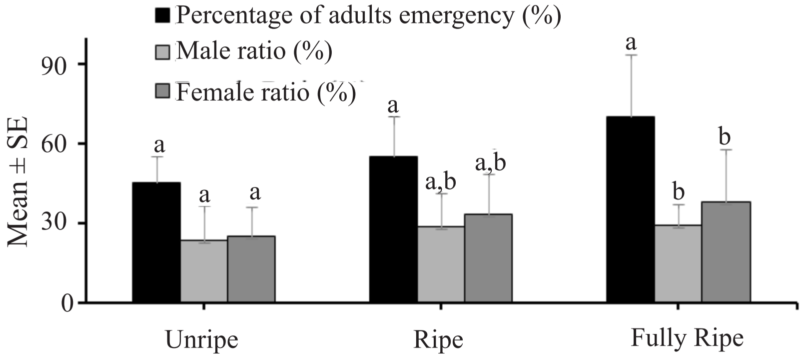

Figure 6. Mean (± SE) percentage of adults emergence, male and female ratios (%) at different MMT maturity stages under choice condition. Means sharing identical letters indicate no significant difference ($P > 0.05$) based on Tukey's (HSD) test.

adult emergence, and sex ratio, with fully ripe fruits supporting the highest values across all parameters. This pattern is consistent with Gómez et al. (2019), who reported higher oviposition activity on the ripest parts of *Vitis vinifera* L., where pupal viability ranged from 50.9% to 64.7%, regardless of berry maturity stage. Similarly, ripe guava has been identified as a more favorable host for *Bactrocera zonata*, yielding higher pupal recovery (128 pupae) and adult emergence (85.2%) (Ayaz et al., 2024).

Fully ripe *Cucumis melo* fruits provide a superior nutritional profile that enhances the developmental success of fruit flies, including *Z. cucurbitae.* As fruits mature, concentrations of soluble sugars—mainly sucrose, glucose, and fructose—increase significantly, supplying readily available metabolic energy essential for larval growth, faster development, and the formation of larger pupae and adults (Carpentier et al., 2024; Dinh et al., 2022). Additionally, fully ripe MMT offers a more favorable microenvironment due to softer fruit texture, which facilitates larval penetration and feeding while reducing the risk of desiccation (Louzeiro et al., 2020).

Lipids serve as long-term energy reserves and play a critical role in adult fecundity and survival, particularly during energy-intensive processes such as mating and oviposition (Morimoto et al., 2020). Furthermore, proteins and amino acids contribute to larval somatic tissue formation and are essential for reproductive tissue development in females, particularly for vitellogenin synthesis, a key precursor in egg production (Uchizono et al., 2017; Wu et al., 2021). These combined nutritional benefits support not only larval growth but also enhanced reproductive potential in adult females, consistent with the observed results.

The higher female proportion observed in fully ripe MMT suggests selective pressures favoring reproductive success under optimal developmental conditions (Mawtham et al., 2020). Females generally require greater resources to develop reproductive organs and attain larger body sizes (Aguilar et al., 2023). Similarly, Wijekoon et al. (2024) reported that fully ripe fruits result in a higher proportion of female flies due to superior nutritional quality and favorable developmental environments.

A review by Follet et al. (2021) highlighted that host selection and oviposition behavior in fruit flies are strongly influenced by fruit maturity, with a general preference for more mature fruits due to improved conditions for offspring development. This aligns with the present findings, which demonstrate a clear preference for fully ripe fruits. Jaleel et al. (2019) further demonstrated that volatile compounds emitted by fully ripe fruits significantly influence host preference in *Bactrocera* species. As fruits mature, they release increasing quantities of volatile organic compounds (VOCs), including esters, alcohols, and aldehydes, which are highly attractive to fruit flies (Grechi et al., 2022). These volatiles act as reliable cues enabling females to locate suitable oviposition sites, thereby enhancing reproductive success (Guillén et al., 2022).

MMT Characteristics. Table 1 summarizes the characteristics of MMT at three maturity stages. Fully ripe MMT fruits had significantly greater weight ($P < 0.05$) than unripe and ripe fruits, whereas no significant difference was observed between unripe and ripe fruits ($P > 0.05$). Fruit diameter differed significantly ($P < 0.05$) among maturity stages, increasing progressively with fruit development.

Total soluble solids (TSS) differed significantly ($P < 0.05$) among maturity stages, with the highest values recorded in fully ripe MMT (15.26 ± 0.38 ºBrix), followed by ripe (13.90 ± 0.17 ºBrix) and unripe fruits (6.38 ± 0.60 ºBrix), indicating increased sweetness with maturation (Mohamed et al., 2017). Fruit firmness declined significantly ($P < 0.05$) during maturation, decreasing from 51.38 ± 0.23 N in unripe fruits to 44.90 ± 0.90 N in ripe fruits, and 40.26 ± 0.38 N in fully ripe fruits.

The greater weight of fully ripe MMT reflects higher accumulation of sugars, water, and nutrients, which are critical for larval growth and development (Arena et al., 2023). Similar trends were reported by Cassiano et al. (2023), who observed increased fruit weight during melon maturation due to sugar and

Table 1. Characteristics of MMT at three maturity stages

MMT Stage	Weight (kg)	Diameter (cm)	TSS (ºBrix)	Firmness (N)
Unripe	0.88 ± 16.60 a	14.38 ± 0.46 a	6.38 ± 0.60 a	51.38 ± 0.23 a
Ripe	1.76 ± 12.08 a	18.90 ± 0.92 b	13.90 ± 0.17 b	44.90 ± 0.90 b
Fully ripe	2.01 ± 14.50 b	20.86 ± 0.44 c	15.26 ± 0.38 c	40.26 ± 0.38 c

Means within a column sharing identical letters indicate no significant difference ($P > 0.05$) based on Tukey's honestly significant difference (HSD) test.

water accumulation. Mature and heavier fruits with complete nutritional profiles are generally favored for oviposition, as they provide greater benefits for offspring development (Cavey et al., 2023). Larger fruits also offer more space for larval growth, reducing crowding and competition for resources (Silva-Soares et al., 2017; Kay et al., 2024).

There was a significant difference in Total Soluble Solid content among the three maturity stages. TSS level content increases significantly during maturing, contributing to the fruit's sweetness and overall quality (Seo et al., 2018). The significant increase in TSS during maturation reflects enhanced enzymatic activity, whereby enzymes such as amylase and invertase hydrolyze starch into simple sugars, including glucose, fructose, and sucrose (Durán-Soria et al., 2020; Li et al., 2020). As ripening progresses, sugar accumulation peaks, and slight reductions in water content further concentrate soluble solids, increasing sweetness (Li et al., 2023).

Although firmness declined progressively with fruit maturity, the overall trend reflects enzymatic degradation of cell wall polysaccharides during ripening, resulting in tissue softening (Farcuh et al., 2020; Nagashima et al., 2021). Increased sugar concentration may also disrupt cellular osmotic balance, contributing to reduced firmness (Ferdousi et al., 2024; Jia et al., 2023).

Collectively, unripe MMT fruits are small, have thicker pericarps, and contain low sugar levels, providing limited nutritional value and physical barriers to oviposition. Ripe fruits represent a transitional stage with moderate sugar accumulation and partial softening. Fully ripe MMT fruits, however, combine maximum size, peak sugar concentration, high nutrient availability, and softened tissues, creating optimal conditions for oviposition and larval development.

Correlation Between Fruit Characteristics and Ovipositional Preference of *Z. cucurbitae*. Correlation analysis (Table 2) revealed significant relationships ($P < 0.05$) between fruit weight and diameter and the number of pupae formed in the choice experiment. TSS was also significantly correlated ($P < 0.05$) with pupal formation and adult emergence under choice conditions, whereas no significant correlations were observed in the no-choice experiment ($P > 0.05$). Additionally, fruit firmness was significantly associated ($P < 0.05$) with the number of pupae recovered in the choice experiment.

These results indicate that fruit characteristics strongly influenced pupal formation and adult emergence in the choice experiment but not in the no-choice setup. This contrast suggests behavioral selectivity when females are presented with multiple host options, allowing them to compare fruit quality and preferentially oviposit in superior hosts (Calvo et al., 2022). Although, *Z. cucurbitae* can oviposit across all MMT maturity stages, a consistent preference for fully ripe fruits was evident across all measured parameters, emphasizing the central role of host maturity in shaping reproductive behavior.

To avoid conditioning effects, all flies used in this study were laboratory-reared and oviposition-naïve. This approach was critical, as prior oviposition experience can alter host preference through learned associations (Rattanapun et al., 2009). Experienced females often exhibit faster decision-making and stronger fidelity to familiar hosts, potentially biasing preference assessments (Mollá-Albaladejo & Sánchez-Alcañiz 2021; Otárola-Jiménez et al., 2024). By using naïve females, the observed preferences more accurately reflect innate host recognition mechanisms driven by fruit morphological and chemical cues (Benelli & Canale, 2012).

Understanding oviposition preferences is essential for developing effective pest management strategies. Targeting fruit stages that are less preferred for oviposition may reduce infestation levels. While biological control remains a key component of fruit fly management—employing predators, parasitoids, and microbial agents such as entomopathogens (González-

Table 2. Pearson correlation coefficients (r) between fruit characteristics and ovipositional preference of *Zeugodacus cucurbitae*

Fruit characteristics	No-choice experiment		Choice experiment	
	Pupae formed	Adults emerged	Pupae formed	Adults emerged
Weight	0.631	0.535	0.749*	0.680
Diameter	0.472	0.391	0.527*	0.419
TSS	0.296	0.188	0.550*	0.442*
Firmness	-0.343	-0.272	-0.593*	-0.376

Correlations are significant at the 0.05 level.

Fernández et al., 2023; Kaya & Vega, 2012)—its effectiveness alone is often limited. Consequently, Integrated Pest Management (IPM) strategies are preferred, as they combine multiple approaches. For example, pheromone traps equipped with cue lures mimic female pheromones to attract and eliminate male *Z. cucurbitae*, thereby reducing mating success and population growth (Stringer et al., 2019).

CONCLUSION

Female *Zeugodacus cucurbitae* exhibited a strong preference for fully ripe Melon Manis Terengganu (MMT) fruits for oviposition. The number of pupae formed was higher in fruits with greater diameter and weight. In addition, fully ripe MMT, characterized by higher total soluble solids content and reduced firmness, was more attractive to females, resulting in increased susceptibility to infestation and enhanced offspring development. Future studies should further investigate the ovipositional behavior of *Z. cucurbitae* under both laboratory and field conditions to provide a more comprehensive understanding of host maturity preferences.

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AUTHORS' CONTRIBUTIONS

NSWS conducted the research and drafted the original manuscript. SM provided supervised the study and reviewed and approved the final manuscript. NAAA contributed resources. NN, NAMY, and NAA were involved in validation, formal analysis, and project administration. All authors read and approved the final manuscript.

COMPETING INTEREST

The authors declare no competing interests.

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