Research Paper

Effectiveness of Mixing Natural Attractants for Trapping Fruit Flies in Snake Fruits Plantations

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Abstract

Snake fruit (Salacca zalacca) is an important Indonesian fruit commodity, yet its productivity has been declining due to infestations of fruit flies. This study evaluated the effectiveness of natural attractants, including methyl eugenol–containing fragrant leaf essential oil and fermented fruit juices, either applied singly or in combination, in trapping fruit flies. The experiment was conducted in Girikerto Village, Sleman, from March to May 2024 using a Completely Randomized Design (CRD) with eight treatments: fragrant leaf essential oil (2 mL), fermented snake fruit juice (2 mL), fermented pineapple juice (2 mL), fermented mango juice (2 mL), mixtures of 1 mL essential oil with 1 mL of each fermented fruit juice, and control. Data were analyzed using ANOVA followed by LSD test at 5%. Results showed that the combination of fragrant leaf essential oil and fermented mango juice (1 mL + 1 mL) was effective in trapping Bactrocera spp., and its performance was not significantly different from 2 mL essential oil. Three species of fruit flies were identified: Bactrocera papayae, B. carambolae, and B. umbrosa. These findings highlight the potential of combining natural attractants for sustainable fruit fly management in snake fruit plantations.

Keywords: *Bactrocera spp., attractants, methyl eugenol, fermented fruit, snake fruits*

INTRODUCTION

Snake fruit (Salacca zalacca) represents one of Indonesia's prominent horticultural commodities, with Sleman Regency, Yogyakarta, serving as a major production hub (BPS, 2022). Nevertheless, infestations by fruit flies remain a key barrier to both productivity and export quality. Female fruit flies lay eggs in ripening fruits, leading to larval infestation and premature fruit abscission (Pratiwi et al., 2022). Conventional management approaches, such as insecticide application and fruit bagging, have shown limited efficacy and are often associated with environmental concerns. In contrast, attractant-based trapping, particularly those utilizing methyl eugenol or fermented fruit substrates, offers a more sustainable alternative (Firmanto et al., 2021).

Methyl eugenol (ME) is widely recognized as a highly potent lure for male *Bactrocera dorsalis* complex fruit flies, whereas protein-rich and volatile-emitting fermented juices are capable of attracting both sexes (Siderhurst & Jang, 2006; Andiko et al., 2023). Essential oil extracted from *Mucuna bracteata* leaves has been reported to yield approximately 1.14% oil, with ME accounting for up to 76% of its composition, highlighting its potential as an efficient natural source of the compound (Shahabuddin, 2011).

Beyond fruit fermentations, plant-derived essential oils are increasingly explored as natural attractants or synergistic agents. Essential oils dominated by sesquiterpenes and phenylpropanoids, such as those obtained from *Piper betle*, have demonstrated strong olfactory responses in tephritid fruit flies (Zeni et al., 2021). The integration of essential oils with fermented fruit juices may broaden and intensify attractant efficacy by simultaneously providing long-range olfactory cues and food-related volatiles (Piñero et al., 2020). While fruit juices are commonly employed as trap lures, their short shelf life and vulnerability to microbial spoilage constrain their

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performance. Fermentation enhances the stability of fruit juices and stimulates the production of volatile alcohols, esters, and organic acids, which are particularly attractive to female fruit flies (Siderhurst & Jang, 2006; Andiko et al., 2023). Substrates enriched with sugars, protein hydrolysates, and yeast have consistently proven to be among the most effective female-oriented attractants for *B. dorsalis* (Natawigena et al., 2018).

Despite these findings, direct comparisons between single-component and combined natural attractant formulations in snake fruit orchards remain limited. This study was therefore conducted to identify the most effective natural attractant for trapping *Bactrocera spp.* in snake fruit plantations and to evaluate the efficacy of combining methyl eugenol–containing essential oil with fermented fruit juice. The present study aims to assess the comparative performance of natural attractants, applied individually and in mixtures, for trapping *Bactrocera spp.* in snake fruit plantations.

LITERATURE REVIEW

Fruit fly attraction is governed by olfactory responses to specific volatiles. ME serves as a potent male-targeted lure, metabolized into coniferyl alcohol and related phenylpropanoids that act as precursors of sex pheromones (Hiap et al., 2019), explaining its effectiveness in male suppression strategies. Conversely, yeast-fermented substrates (*Saccharomyces cerevisiae*) release ethanol, acetic acid, and esters that mimic natural host odors, thereby strongly attracting gravid females (Biasazin et al., 2022). Integrating these two attractant types is expected to expand the spectrum of attraction, with ME oils providing long-range male cues and fermentation volatiles supplying short-range feeding and oviposition signals for females.

From a methodological perspective, attractant efficiency was evaluated by calculating relative capture rates, expressed as the proportion of individuals trapped under each treatment relative to the total number captured across treatments (Sudjana, 1992). This approach provides a standardized metric for comparing lure formulations and directly links chemical ecological theory (odor-mediated attraction) with empirical field performance.

RESEARCH METHOD

Time and Location

The field experiment was conducted from March to May 2024 in a snake fruit (Salacca zalacca) plantation located in Girikerto Village, Turi District, Sleman Regency, Yogyakarta. Laboratory analyses, including essential oil extraction, fruit fermentation, and insect identification, were carried out at the Plant Protection Laboratory, Faculty of Agriculture, Universitas Pembangunan Nasional "Veteran" Yogyakarta, and the Chemistry Laboratory, Universitas Islam Indonesia.

Materials, Tools, and Experimental Design

The materials used in the study included essential oil of fragrant leaf (*Melaleuca bracteata*), snake fruit, pineapple (*Ananas comosus*), mango (*Mangifera indica*), baker's yeast (*Saccharomyces cerevisiae*), and distilled water. Plastic bottles (600 mL) were modified as trap containers by perforating the sides (0.5–1 cm diameter) and inserting cotton as an absorbent medium for the attractants.

The experiment followed a Completely Randomized Design (CRD) with eight treatments: (A) 2 mL fragrant leaf essential oil; (B) 2 mL fermented snake fruit juice; (C) 2 mL fermented pineapple juice; (D) 2 mL fermented mango juice; (E) 1 mL essential oil + 1 mL snake fruit juice; (F) 1 mL essential oil + 1 mL pineapple juice; (G) 1 mL essential oil + 1 mL mango juice; and (H) control (no attractant). Each treatment was replicated three times with two traps per replicate, resulting in a total of 48 traps.

Preparation of Attractants

Essential oil was obtained from M. bracteata leaves (Pavettia brand) through steam distillation. Fermented fruit juices were prepared by juicing fresh fruits, filtering the extracts, and fermenting them with yeast (2 g per 100 mL juice) at room temperature for four days.

Trap Installation

Two milliliters of the respective attractant solution were absorbed into cotton and placed inside the trap. Traps were installed in the orchard at a height of 1.5 m, with a spacing of 2 m between traps and 10 m between treatments. Installation was conducted in the morning (07:00–09:00) under shaded conditions, and observations were carried out weekly for eight consecutive weeks.

Observation Parameters

The number of fruit flies captured in each trap was recorded, and the sex of individuals was determined based on morphological features, such as the ovipositor. Species identification was conducted using morphological keys (Suputa et al., 2007; Larasati et al., 2016). Attractant effectiveness was expressed as the number and sex ratio of captured flies, calculated using the formula of Sudjana (1992).

$$Percentage\ of\ attractant\ effectiveness = \frac{A}{B} x100\%$$

where:

A = Total number of individuals captured by a given attractant

B = Total number of individuals captured by all atractants

Data Analysis

Data were analyzed using analysis of variance (ANOVA) at the 5% significance level, and treatment means were compared using the Least Significant Difference (LSD) test.

FINDINGS AND DISCUSSION

Number of Fruit Flies Captured

(A) 2 mL fragrant leaf essential oil; (B) 2 mL fermented snake fruit juice; (C) 2 mL fermented pineapple juice; (D) 2 mL fermented mango juice; (E) 1 mL essential oil + 1 mL snake fruit juice; (F) 1 mL essential oil + 1 mL pineapple juice; (G) 1 mL essential oil + 1 mL mango juice; and (H) control (no attractant). The treatments had a significant effect on the number of *Bactrocera* spp. captured (ANOVA, $p < 0.05$). The highest trap catches were recorded in treatment A (2 mL fragrant leaf essential oil) and treatment G (1 mL essential oil + 1 mL fermented mango juice), both of which consistently yielded greater captures than the other treatments throughout the observation period (Table 1). In contrast, treatments B (fermented snake fruit), C (fermented pineapple), D (fermented mango), and the control (H) resulted in very few captures. These findings indicate that methyl eugenol–based essential oil remains the most effective lure for attracting *Bactrocera* spp.

Table 1. Number of *Bactrocera* spp. trapped

Treatments	Observation Time							
	I	II	III	IV	V	VI	VII	VIII
A	142,67a	97,00a	135,33a	119,84a	44,67a	97,33a	66,67a	98,67a
B	0,00d	0,00d	0,33d	0,00d	0,00d	0,00d	0,67d	0,00d
C	0,00d	0,00d	0,00d	0,00d	0,33d	0,00d	0,00d	0,00d
D	0,00d	0,00d	0,33d	0,00d	0,00d	0,33d	0,00d	0,00d
E	68,67b	51,33b	88,00b	60,00b	33,67b	60,00b	38,00bc	63,33b
F	41,33c	24,67c	32,00c	33,00c	19,33c	28,33c	23,33c	32,00c
G	116,00a	57,00a	126,67a	86,50a	37,33a	78,00ab	41,33b	49,33b
H	0,00d	0,00d	0,00d	0,00d	0,00d	0,00d	0,00d	0,00d

Note: Numbers followed by different letters within the same column indicate significant differences according to the LSD test at the 5% level.

The results presented in **Table 2** show that the number of *Drosophila* sp. trapped varied among treatments. The highest number of captures was recorded in the treatment with fermented pineapple juice (Treatment C), followed by fermented mango juice (Treatment D). In contrast, traps baited with *Melaleuca bracteata* essential oil (Treatment A) and its combinations (E–G) caught very few *Drosophila* sp., and the control treatment (H) showed almost no captures.

Table 2. Number of *Drosophila* sp. trapped

Treatments	Observation Time							
	I	II	III	IV	V	VI	VII	VIII
A	0,00c	0, 00c	0,00c	0,00c	0,00c	0,00c	0,00c	0,00c
B	67,67a	39,67a	41,67a	50,00a	42,33a	40,33a	25,33a	35,00a
C	22,00b	11,00c	14,33b	12,33c	14,00b	11,67c	7,33b	7,33c
D	29,33b	23,00b	11,33b	20,67b	15,00b	24,60b	9,00b	12,67b
E	1,98c	0,67d	1,67c	2,00d	2,33c	1,33d	0,67c	0,00d
F	4,67c	0,33d	0,67c	0,67d	1,00c	0,33d	0,00c	0,00d
G	0,00c	0,00d	0, 00c	2,33d	1,00c	0,00d	0,00c	0,00d
H	0,00c	0,00d	0, 00c	0,00d	0,00c	0,00d	0,00c	0,00d

Note: Numbers followed by different letters within the same column indicate significant differences according to the LSD test at the 5% level. (A) 2 mL fragrant leaf essential oil; (B) 2 mL fermented snake fruit juice; (C) 2 mL fermented pineapple juice; (D) 2 mL fermented mango juice; (E) 1 mL essential oil + 1 mL snake fruit juice; (F) 1 mL essential oil + 1 mL pineapple juice; (G) 1 mL essential oil + 1 mL mango juice; and (H) control (no attractant)

4.1. Identification of Trapped Fruit Fly Species

The fruit flies trapped were identified based on their morphological characteristics, focusing on the caput, thorax, abdomen, and wings, using the identification key provided in Appendix 3 and the reference book *Fruit Fly Pests: Bioecology and Strategies for Population Management* (Putra & Suputa, 2013). The identification results revealed three fruit fly species belonging to the genus *Bactrocera* (Family: Tephritidae), namely *Bactrocera papayae* Drew & Hancock, *Bactrocera carambolae* Drew & Hancock, and *Bactrocera umbrosa* Fabricius. The morphological descriptions of each trapped *Bactrocera* species are presented in Tables 3–5.

Table 3. Morphological Description of *Bactrocera papayae*

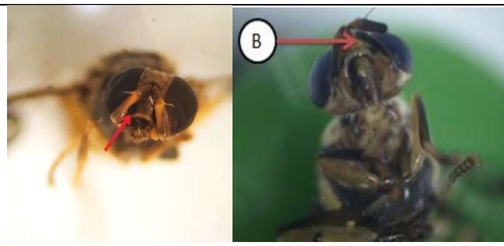
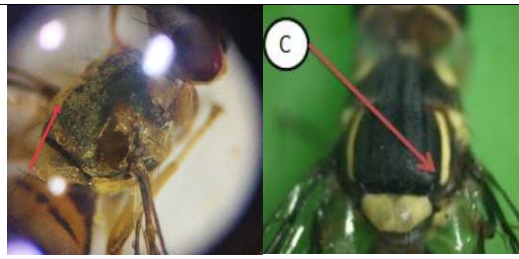
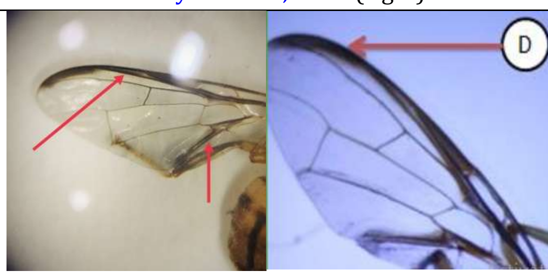
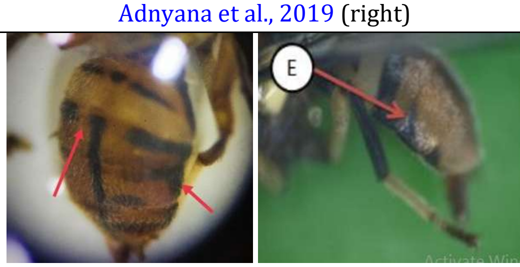
Morphological Characters	Descriptions
 Personal documentation (left) Adnyana et al., 2019 (right)	A spot is present on the face
 Personal documentation (left) Adnyana et al., 2019 (right)	The thorax is black and bears supraalar setae on the anterior side; there are yellow postsutural vittae, but no median postsutural vitta on the central thorax
 Personal documentation (left) Adnyana et al., 2019 (right)	The costal band extends to the wing apex, with its width not exceeding vein R 2+3, except at the wing tip where an anal streak is present.
 Personal documentation (left) Adnyana et al., 2019 (right)	There is a black pattern on the basal lateral side of the abdominal tergites forming an angled shape, and a distinct medial longitudinal black stripe is visible on the terga.

Table 4. Morphological Description of *Bactrocera carambolae*

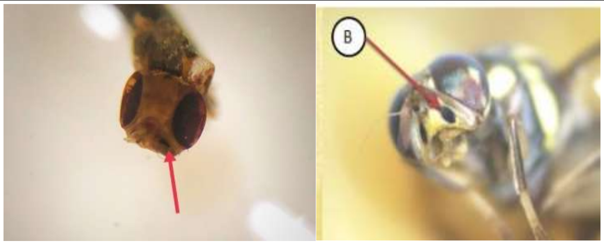
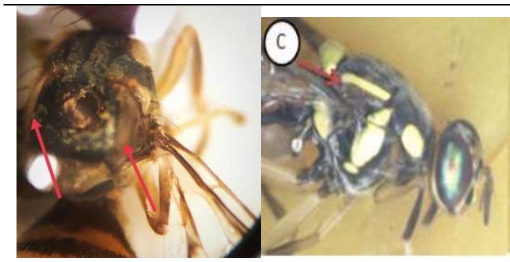
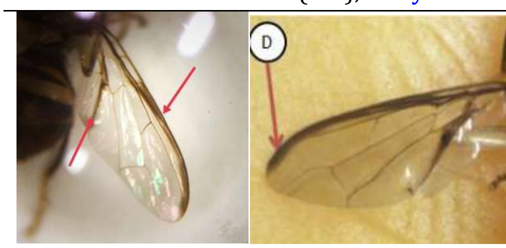
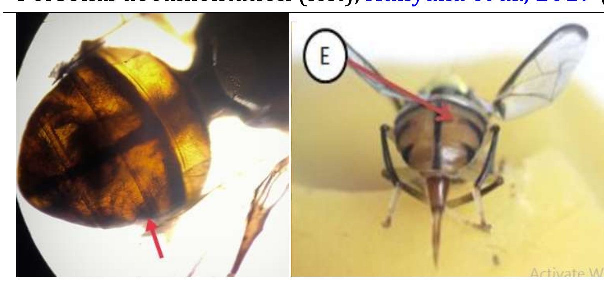
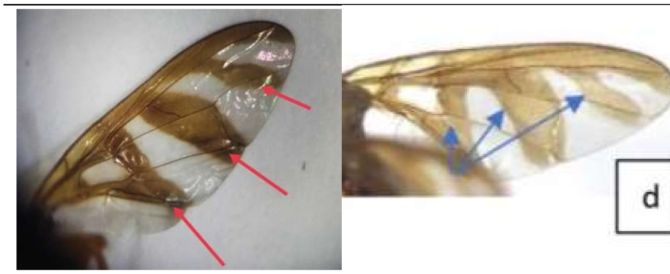
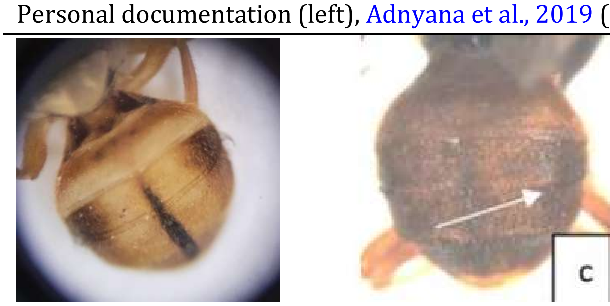
Morphological Characters	Descriptions
 Personal documentation (left), Adnyana et al., 2019 (right)	A oval spot is present on the face.
 Personal documentation (left), Adnyana et al., 2019 (right)	The thorax is predominantly black without a medial postsutural vitta, but with yellow lateral postsutural vittae; a yellow parallel band passes through the intra-alar setae.
 Personal documentation (left), Adnyana et al., 2019 (right)	The costal band reaches the wing apex, where the wing tip is hook-shaped, and an anal streak is present
 Personal documentation (left), Adnyana et al., 2019 (right)	It is brownish-orange with a longitudinal black stripe and a distinct square-shaped pattern on the basal lateral terga.

Table 5. Morphological Description of *Bactrocera umbrosa*

Morphological Characters	Descriptions
 Personal documentation (left), Adnyana et al., 2019 (right)	It has a small, oval-shaped black facial spot
 Personal documentation (left), Adnyana et al., 2019 (right)	The thorax is black with supra-alar setae on the anterior side; yellow postsutural vittae are present, but there is no median postsutural vitta on the central thorax.
 Personal documentation (left), Adnyana et al., 2019 (right)	The costal band extends to the wing apex, with three distinct transverse bands present.
 Personal documentation (left), Adnyana et al., 2019 (right)	The abdominal pattern is variable. Terga III–V are reddish-brown, with the lateral side of tergite III distinctly black.

4.2.Sex Ratio of Trapped Fruit Flies

The fruit flies captured in each trap were sexed based on the presence or absence of an ovipositor on the abdomen. The ovipositor functions as the organ for inserting eggs into host fruits. The morphological differences between male and female fruit flies are shown in **Figure 1.**

Figure 1. Sex determination of fruit fly, A) male; B) female

The sex ratio was determined by comparing the number of trapped females to the number of trapped males in each treatment. In snake fruit plantations in Turi Subdistrict, the fruit fly population was predominantly composed of male Bactrocera papayae (Table 6). The highest sex ratio value was observed in Treatment D (2 mL fermented mango). The overall sex ratio of fruit flies captured across all traps is presented in Table 7.

Table 6. Sex Ratio of Fruit Flies Species

Species Name	Number of males	Number of females
Bactrocera papayae	3465	7
Bactrocera carambolae	2647	-
Bactrocera umbrosa	12	-
Total	6124	7

Table 7. Sex Ratio of Trapped Fruit Flies

Treatments	Observation Time																Ratio ♂: ♀
	I		II		III		IV		V		VI		VII		VIII		
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
A	428	0	291	0	406	0	277	0	134	0	292	0	200	0	296	0	2324:0
B	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	3:2
C	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1:0
D	0	0	0	0	0	1	0	0	0	0	0	1	0	0	2	0	2:2
E	206	0	154	0	264	0	138	0	101	0	85	0	113	1	148	0	1209:1
F	124	0	74	0	96	0	84	0	58	0	180	0	70	0	96	0	782:0
G	348	0	171	0	380	0	246	0	112	0	232	2	124	0	190	0	1803:2
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0:0

Notes: M = Male F = Female. (A) 2 mL fragrant leaf essential oil; (B) 2 mL fermented snake fruit juice; (C) 2 mL fermented pineapple juice; (D) 2 mL fermented mango juice; (E) 1 mL essential oil + 1 mL snake fruit juice; (F) 1 mL essential oil + 1 mL pineapple juice; (G) 1 mL essential oil + 1 mL mango juice; and (H) control (no attractant)

Effectiveness of attractants

The attractant longevity test showed that treatments containing fragrant leaf (Melaleuca bracteata) essential oil (Treatments A, E, F, and G) were able to trap fruit flies for up to 7 days after application (DAA). In contrast, Treatments B (2 mL fermented snake fruit), C (2 mL fermented pineapple), and D (2 mL fermented mango) were only effective in capturing *Bactrocera* spp. for 2 days. The total number of fruit flies captured over the 7-day observation period is presented in **Figure 2**.

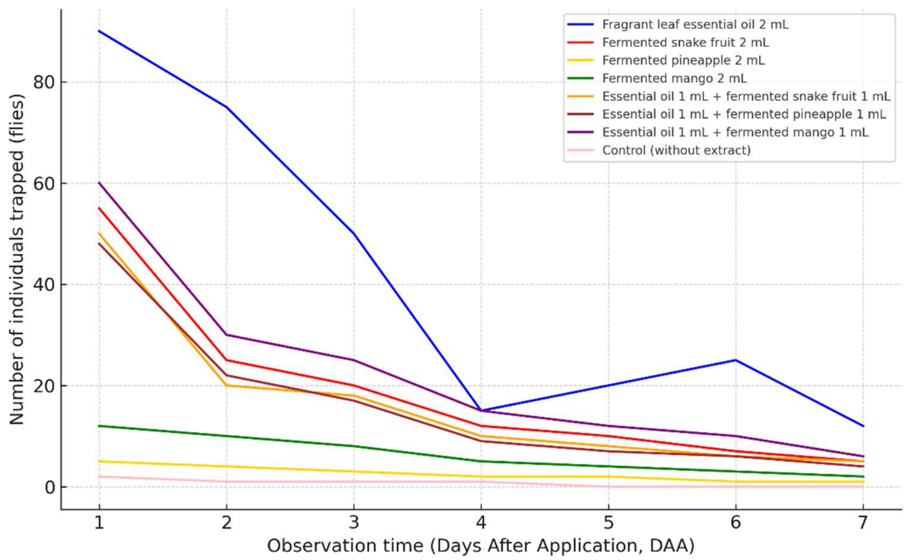


Figure 2. Effectiveness of attractants trapping fruit flies

Discussion

Fruit flies (*Diptera: Tephritidae*) are widely recognized as key pests in tropical horticultural systems due to their direct damage to fruits and their role in imposing quarantine restrictions on trade. In snake fruit (*Salacca zalacca*) cultivation, multiple *Bactrocera* species have been documented, with species composition varying across regions. In the present study, *B. papayae*, *B. carambolae*, and *B. umbrosa* were dominant in Girikerto Village, Sleman Regency, which is consistent with earlier reports of ME-responsive species in Indonesia (Aryuwandari et al., 2020). However, broader surveys indicate that the *B. dorsalis* complex and several other species may also be associated with snake fruit (Fitrah et al., 2020), underscoring the need for location-specific pest surveillance.

Seasonal monitoring revealed fluctuations in fruit fly abundance, with a peak during the third sampling period and a decline during the fifth. These temporal variations are strongly influenced by abiotic factors, particularly temperature, humidity, and wind, as well as biotic factors such as host availability (Bansode & Patel, 2020). Higher captures during periods of ripening fruit highlight the importance of host phenology in shaping population dynamics. The observed decline during resource-scarce periods can be linked to reduced fecundity and increased mortality at immature stages, reinforcing the value of aligning pest suppression strategies with periods of peak activity.

Attractant efficacy varied among treatments. Fragrant leaf essential oil, characterized by a high methyl eugenol (ME) content (80–86%), proved most effective in capturing males. This finding aligns with the biological role of ME as a precursor for sex pheromone synthesis in *Bactrocera* males, which enhances mating success and explains their strong evolutionary response to ME lures (ul Haq et al., 2018). Interestingly, combining essential oil with fermented mango juice did not yield higher captures, suggesting no synergistic interaction between ME and fermentation volatiles. This highlights the specific and dominant role of ME in male attraction.

In contrast, female captures were primarily associated with fermented substrates such as snake fruit and mango juice, both with and without essential oil. Female attraction is linked to volatile compounds released during fermentation, which not only signal fruit suitability for oviposition but also provide essential nutrients for ovarian development (Roh et al., 2021). Yeast-mediated fermentation further enriches these baits with volatile alcohols, esters, and protein content, enhancing their attractiveness (Biasazin et al., 2022). Thus, fermented baits hold potential as complementary tools targeting females, which are critical for population suppression.

Non-target captures were also observed. Fermented fruit baits were particularly attractive to *Drosophila* spp., with fermented snake fruit yielding the highest numbers. This observation is consistent with *Drosophila melanogaster*'s ecological association with yeast-fermented volatiles for food and oviposition (Lewis & Hamby, 2019). While not detrimental to the monitoring of *Bactrocera*, such bycatches highlight the broad ecological relevance of fermentation-based volatiles.

Attractant longevity emerged as another important consideration. Essential oil–based treatments retained their effectiveness for up to seven days, whereas fermented juices declined rapidly within two days. This difference is attributable to volatilization and microbial changes in fermenting substrates. Kardinan and Kurniawati (2021) demonstrated that blending essential oils could extend efficacy to several months, indicating that formulation improvements may substantially enhance field performance. Based on current findings, reapplication at seven-day intervals is recommended for maintaining essential oil effectiveness in snake fruit orchards.

The results provide valuable insights into optimizing fruit fly management in snake fruit production systems as an implications for Integrated Pest Management (IPM) trough 1) Male suppression through ME-based lures remains a cornerstone strategy due to their proven efficacy and species-specific attraction, 2) Proteinaceous fermented baits offer a complementary strategy by attracting females, thereby reducing the next generation of fruit fly populations, 3) Regular lure replacement or reapplication is critical, as attractant longevity is limited, particularly in tropical field conditions, 4) Species-specific monitoring is necessary to detect shifts in community composition and adjust management strategies accordingly. Integrating these strategies into an IPM framework, alongside orchard sanitation and host removal, will enhance the sustainability of snake fruit production and minimize pesticide reliance.

CONCLUSIONS

The results demonstrate that *Melaleuca bracteata* essential oil, rich in methyl eugenol, was the most effective attractant for *Bactrocera* spp. in snake fruit plantations. Its combination with fermented mango juice yielded comparable performance, indicating no reduction in efficacy. In contrast, fermented fruit juices alone were less effective against *Bactrocera* but captured relatively more females and non-target *Drosophila* spp., with fermented snake fruit showing the strongest response. Regarding attractant longevity, essential oil retained effectiveness for up to seven days, whereas fermented juices lost activity within two days, necessitating frequent replacement. Overall, these findings suggest that integrating essential oils with fermented fruit baits offers a complementary strategy by targeting both sexes, thereby supporting more sustainable fruit fly management in snake fruit production systems.

LIMITATION & FURTHER RESEARCH

Several limitations of this study should be acknowledged. First, the trapping trials were conducted in a single location and season, which may limit extrapolation to other agroecological zones. Second, while male and female captures were documented, the reproductive impact of lure-based suppression on field populations was not directly assessed. Finally, the chemical composition of fermented baits was not quantified in detail, preventing precise identification of the most attractive volatiles.

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