

Attractiveness of Fruit Flies (Diptera: Tephritidae) to Eco-Enzyme and Tape Yeast Mixtures on Cayenne Pepper (*Capsicum frutescens* L.)

Nazwa Nazelina[1*], Muhammad Indar Pramudi[1]
1 Department of Plant Protection, Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru, Indonesia

* Corresponding Author: nazwanazelina001@gmail.com

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Abstract
Fruit flies (Diptera: Tephritidae) are important pests of cayenne pepper that can reduce fruit quality and yield. This study aimed to evaluate the effectiveness of eco-enzyme and *ragi tape* mixtures as attractants for fruit flies on cayenne pepper (*Capsicum frutescens* L.) cv. ORI 212. The experiment was conducted from February to July 2026 at the Experimental Field Faculty of Agriculture Lambung Mangkurat University Banjarbaru Indonesia. A completely randomized design was used with six treatments and four replications. The treatments consisted of methyl eugenol (P0), eco-enzyme and *ragi tape* mixtures at ratios of 1:1 (P1), 1:2 (P2) and 2:1 (P3), eco-enzyme alone (P4) and *ragi tape* plus sugar (P5). Data were subjected to analysis of variance followed by the least significant difference test at the 5% level. Methyl eugenol (P0) produced the highest mean fruit fly catch (39.46 flies) and the longest attractant longevity (6.75 days). Among the fermentation-based treatments, P3 showed the best overall performance with a mean catch of 32.39 flies, the lowest mean infestation intensity (17.90%) and the highest total fruit yield (394.25 g). Four fruit fly species were identified with *Bactrocera dorsalis* being the dominant species, accounting for 67.07% of the total catch. These findings indicate that the 2:1 eco-enzyme and *ragi tape* mixture has potential as a fermentation-based attractant for integration into fruit fly management in cayenne pepper production.

Keywords: fruit fly; eco-enzyme; tape yeast; cayenne pepper; attractant.

1. Introduction

Cayenne pepper (*Capsicum frutescens* L.) is an important horticultural commodity in Indonesia due to its high economic value and continuous demand for household consumption and culinary purposes. ORI 212 is one of the cultivated cayenne pepper varieties characterized by its pungency, relatively uniform fruit characteristics and adaptability to tropical growing conditions (Mulyaningsih et al., 2022). However, cayenne pepper production is often constrained by pest infestation, particularly fruit flies (Diptera: Tephritidae) of the genus *Bactrocera*. Female fruit flies lay their eggs inside host fruits, and the developing larvae feed on the internal tissues, causing softening, decay, premature fruit drop and loss of marketable quality (Saputra et al., 2023). Severe fruit fly infestation can result in substantial yield losses when appropriate control measures are not applied (Jusmanto et al., 2019).

Fruit fly management in chilli cultivation commonly involves synthetic insecticides and attractant-based trapping. Methyl eugenol is widely used as a para-pheromone attractant because males of several *Bactrocera* species show a strong response to this compound (Food and Agriculture Organization of the United Nations & International Atomic Energy Agency, 2018; Patty, 2012; Susanto et al., 2021).. Although methyl eugenol can produce high trap catches its attraction is primarily directed toward male fruit flies. Therefore, the number of flies captured using methyl eugenol does not necessarily represent the abundance of females responsible for oviposition or directly indicate the level of fruit infestation. This limitation supports the need to investigate alternative attractants that may provide a different response to fruit fly populations.

Fermentation-based materials have potential for use as alternative fruit fly attractants because fermentation produces volatile compounds that can serve as olfactory cues for insects. Eco-enzyme is a fermented liquid produced from organic residues, sugar and water and is characterized by the formation of fermentation-derived compounds and odors (Rukmini & Herawati, 2023). *Ragi tape* is a traditional Indonesian fermentation starter containing a consortium of microorganisms, including yeasts such as *Saccharomyces cerevisiae* which participate in carbohydrate fermentation and the production of ethanol and other metabolites (Abe et al., 2004). Volatile compounds produced during fermentation may influence the olfactory response of tephritid fruit flies, while combinations of several volatile compounds can elicit different or stronger behavioural responses than individual compounds alone (Ishii et al., 2015; Jayanthi et al., 2012; Sasaki et al., 2019).

The combination of eco-enzyme and *ragi tape* is therefore of interest as a fermentation-based attractant for fruit flies. Eco-enzyme provides fermentation-derived compounds from organic materials, whereas *ragi tape* contributes microorganisms involved in further fermentation processes. Their combination may produce differences in odor characteristics and attractiveness compared with either material used separately. However,s the response of fruit flies to different ratios of eco-enzyme and *ragi tape* on ORI 212 cayenne pepper has not been established in the experimental system used in this study. Accordingly, three ratios of eco-enzyme and *ragi tape* were evaluated and compared with eco-enzyme alone, *ragi tape* plus sugar and methyl eugenol as a standard comparator. In addition to fruit fly catches, attractant longevity, fruit infestation intensity, fruit yield and the morphological identity of captured fruit flies were evaluated to provide supporting information on the performance of the tested attractants.

Therefore, this study aimed to determine the effectiveness of eco-enzyme and *ragi tape* mixtures in attracting fruit flies (Diptera: Tephritidae) on ORI 212 cayenne pepper (*Capsicum frutescens* L.). The study was based on the hypothesis that mixtures of eco-enzyme and *ragi tape* are effective in attracting fruit flies on ORI 212 cayenne pepper.

2. Methodology

Study Site and Experimental Design

The experiment was conducted from February to July 2026 at the Experimental Field of the Faculty of Agriculture Lambung Mangkurat University Banjarbaru South Kalimantan Indonesia. The study employed a non-factorial completely randomized design with six attractant treatments and four replications, resulting in 24 experimental units. Each experimental unit consisted of four ORI 212 cayenne pepper (*Capsicum frutescens* L.) plants and one fruit fly trap placed at the center of the unit. Thus a total of 96 plants and 24 fruit fly traps were used in the experiment. The treatments were randomly assigned to the experimental units.

The six treatments were as follows: P0 = methyl eugenol as the standard comparator; P1 = eco-enzyme and *ragi tape* solution at a 1:1 volume ratio; P2 = eco-enzyme and *ragi tape* solution at a 1:2 volume ratio; P3 = eco-enzyme and *ragi tape* solution at a 2:1 volume ratio; P4 = eco-enzyme without the addition of *ragi tape*; and P5 = *ragi tape* solution with sugar without the addition of eco-enzyme. The final volume of attractant applied to each trap was standardized at 1 mL for all treatments.

Plant Material and Crop Establishment

Seeds of ORI 212 cayenne pepper (*Capsicum frutescens* L.) were used as the plant material. The growing medium consisted of soil, rice-husk charcoal, and cattle manure mixed at a 1:1:1 ratio. The mixture was homogenized and placed into approximately 30 × 30 cm polybags to two-thirds of their capacity. The polybags were arranged at approximately 80 cm spacing. Before sowing, the seeds were soaked in warm water for several hours to promote germination and were subsequently sown in seedling trays containing the same growing medium. The seedlings were regularly watered and maintained for 21-30 days after sowing. Healthy and uniform seedlings with four to five fully expanded leaves were selected for transplanting.

Before transplanting, cattle manure was applied as basal fertilizer at a rate of 100 g per plant, equivalent to 400 g per experimental unit and mixed thoroughly with the growing medium. Selected seedlings were transplanted into approximately 10 cm deep planting holes while retaining the growing medium surrounding the roots. Immediately after transplanting, the plants were watered and provided with temporary shade to facilitate establishment.

Crop maintenance included regular watering, replacement of dead or abnormally growing plants, fertilization and weed removal. Fertilization and weed control were conducted periodically according to plant requirements. The polybags were subsequently organized into 24 experimental units according to the randomized treatment layout with each unit consisting of four plants and labeled according to treatment and replication.

Eco-Enzyme Preparation and Attractant Formulation

Eco-enzyme was prepared using brown sugar, organic fruit residues and water at a ratio of 1:3:10. The organic material consisted of watermelon, melon, banana, mango, pineapple and papaya peels. The fruit residues were cut into small pieces and thoroughly mixed with brown sugar and water. The mixture was then fermented in a closed plastic container for three months, with fermentation gas released periodically. After the fermentation period, the resulting brownish liquid with a characteristic acidic odor was filtered and stored in clean bottles until use.

For attractant preparation, the fermented eco-enzyme and *ragi tape* solution were mixed volumetrically at ratios of 1:1, 1:2, and 2:1 for treatments P1, P2 and P3 respectively. Methyl eugenol was used for P0, unamended eco-enzyme for P4 and *ragi tape* solution supplemented with sugar for P5. Each formulation was mixed thoroughly until homogeneous before application. A total of 1 mL of the designated attractant was applied to cotton using a syringe, and the treated cotton was subsequently placed inside the corresponding fruit fly trap.

Trap Construction, Installation, and Attractant Application

Fruit fly traps were constructed from used 1.5 L plastic water bottles. The upper portion of each bottle was cut, inverted and reattached to the bottle body to form a funnel-shaped entrance. Several openings were made on the sides of the bottle to facilitate fruit fly entry. A wire support was installed inside each trap to suspend the cotton containing the attractant. The traps were secured to stakes using raffia and installed at a height of approximately 90 cm to 1.5 m above ground, depending on plant height.

One trap was installed at the center of each experimental unit. Trap placement, attractant volume and cotton carrier were maintained consistently among treatments. The spacing between traps followed the experimental layout and was kept as uniform as possible to minimize interference among attractant odor sources. A total of 1 mL of the designated attractant was applied to cotton and placed inside each corresponding trap. Attractant activity was monitored daily, whereas fruit fly catches used for population observations were recorded weekly from 9 to 15 weeks after planting.

Observation Variables

Fruit Fly Population. Fruit fly population was determined by counting adult *Bactrocera* spp. captured in each trap. Observations were conducted once a week from 9 to 15 weeks after planting (WAP). The number of captured fruit flies was recorded as individuals per trap for each replication. The mean fruit fly population for each treatment was calculated based on four replications.

Attractant Longevity. Attractant longevity was monitored daily from the time of attractant application. The attractant was assigned a value of 1 when the trap continued to produce fruit fly captures and a value of 0 when no further captures were recorded. Attractant longevity was determined as the number of days during which the attractant remained active in each replication and was subsequently averaged for each treatment and expressed in days.

Fruit Fly Infestation Intensity. Fruit fly infestation intensity was assessed once a week from 9 to 15 WAP by counting infested and uninfested fruits in each experimental unit. Fruits were classified as infested when black puncture marks were visible on the fruit surface accompanied by symptoms of tissue deterioration or decay. Infestation intensity was calculated for each replication using the following equation:

$$I = \frac{A}{A+B} \times 100\%$$

Keterangan:

I : fruit fly infestation intensity (%)

A : number of infested fruits

B : number of uninfested fruits

Cayenne Pepper Harvest Weight. The first harvest was conducted when the cayenne pepper plants reached approximately 91-96 days after transplanting. The second and third harvests were conducted when the fruits reached harvest maturity. All fresh fruits from the four plants within each experimental unit were weighed using a digital balance. Harvest weight was recorded separately as Harvest I, Harvest II and Harvest III and expressed in grams per experimental unit.

Morphological Identification of Captured Fruit Flies

Captured fruit flies were separated from non-target insects and examined using a USB microscope. Identification was conducted based on observable morphological characteristics, including wing shape and pattern, thoracic coloration, abdominal characteristics and other diagnostic body features. The identification results were used as supporting data to verify the taxonomic composition of the fruit flies included in the trap-catch observations.

Statistical Analysis

Data on fruit fly population, attractant longevity, fruit fly infestation intensity, and harvest weight were tested for homogeneity of variance using Bartlett's test at the 5% significance level. Data that satisfied the homogeneity assumption were subjected to analysis of variance (ANOVA) according to the completely randomized design. When significant treatment effects were detected, mean separation was performed using the least significant difference (LSD) test at the 5% significance level.

Fruit fly population and infestation intensity were analyzed separately for each weekly observation from 9 to 15 weeks after planting (WAP). Harvest weight was analyzed separately for Harvest I, Harvest II and Harvest III, while accumulated harvest weight was calculated to compare the total yield among treatments. The relationship between mean fruit fly population and attractant longevity was evaluated using Pearson correlation and simple linear regression, with mean fruit fly population as the independent variable (X) and attractant longevity as the dependent variable (Y).

3. Results and Discussion

All quantitative response variables satisfied the homogeneity of variance assumption based on Bartlett's test and were subsequently subjected to analysis of variance. The attractant treatments significantly affected fruit fly population, attractant longevity, fruit fly infestation intensity, and cayenne pepper harvest weight. Morphological identification of the captured fruit flies was used as supporting information to determine the species composition recorded under the different attractant treatments.

Species Composition of Captured Fruit Flies

Morphological examination of the captured fruit flies identified four species namely *Bactrocera dorsalis*, *B. carambolae*, *B. latifrons* and *B. occipitalis*. Identification was based on morphological characteristics of the wings, abdomen, and thorax. *Bactrocera dorsalis* was characterized by a relatively narrow costal band and a narrow medial longitudinal band on the abdomen, with a triangular anterolateral corner of tergum IV. In contrast, *B. carambolae* exhibited a costal band extending slightly beyond vein R2+3 and becoming relatively wider toward the wing apex, together with a broader medial longitudinal abdominal band and a rectangular anterolateral corner of tergum IV. These observations are consistent with previous studies emphasizing the combined use of wing and abdominal characters for distinguishing species within the *B. dorsalis* complex (Isasawin et al., 2014; Taddei et al., 2023).

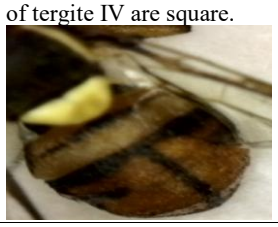
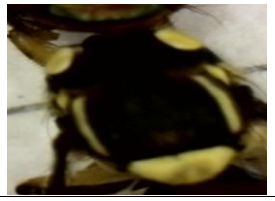
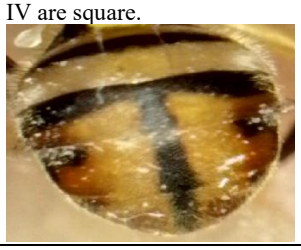
Species	Morphology		
	Wing	Abdomen	Thorax
Bactrocera dorsalis	The costal band is narrow and gradually tapers toward the tip, while the anal line is very narrow. 	Tergites III–IV show a broken "T"-shaped pattern, with a narrow medial longitudinal band, while the anterolateral corners of tergite IV are triangular. 	The scutum is predominantly black to reddish-brown, with yellow bands on the lateral sides. 
Bactrocera carambolae	The costal band covers part of the area, then widens around the vein to form a fishing-hook-like pattern. 	Tergites III–IV have a "T"-shaped pattern with a broad medial longitudinal band, while the anterolateral corners of tergite IV are square. 	The scutum is predominantly dull black, with yellow bands on the lateral sides. 
Bactrocera latifrons	The costal band is narrow, covering part of the vein area and slightly widening around the vein, but does not form a prominent hook-like curve. The wing cells are generally hyaline, with a distinct costal band pattern. 	Tergites III–V are predominantly reddish-brown to black, with a distinct "T"-shaped pattern on tergites III–IV. The medial longitudinal band is medium in width, while the anterolateral corners of tergite IV are triangular. 	The scutum is predominantly glossy black to dark brownish-black, with yellow bands extending along the lateral sides. The scutellum is bright yellow with a narrow black band at its base. 
Bactrocera occipitalis	The costal band covers part of the vein area and widens around the vein, forming a distinct fishing-hook-like curve, while the rest of the wing is generally hyaline. 	Tergites III–V are predominantly reddish-brown to black, with a distinct "T"-shaped pattern on tergites III–IV. The medial longitudinal band is broad, while the anterolateral corners of tergite IV are square. 	The scutum is predominantly black to dark brownish-black, with yellow bands extending along both lateral sides. The scutellum is bright yellow with a narrow black band at its base. 

Figure 1. Morphological characters of the fruit fly species identified from trap catches: (a) *Bactrocera dorsalis*; (b) *B. carambolae*; (c) *B. latifrons*; and (d) *B. occipitalis*.

Table 1. Number of individuals of each fruit fly species identified under the six attractant treatments.

Treatment	*B. dorsalis*	*B. carambolae*	*B. latifrons*	*B. occipitalis*	Total
P0	737	279	82	7	1,105
P1	441	168	51	0	660
P2	427	143	42	0	612
P3	603	232	72	0	907
P4	249	96	31	0	376
P5	311	116	40	0	467
Total	**2,768**	**1,034**	**318**	**7**	**4,127**
Proportion (%)	**67.07**	**25.05**	**7.71**	**0.17**	**100.00**

P0 = methyl eugenol; P1 = eco-enzyme + ragi tape (1:1); P2 = eco-enzyme + ragi tape (1:2); P3 = eco-enzyme + ragi tape (2:1); P4 = eco-enzyme; P5 = ragi tape + sugar. Species counts are descriptive data.

A total of 4,127 fruit flies were identified from all attractant treatments. *Bactrocera dorsalis* was the dominant species, accounting for 2,768 individuals (67.07% of the total catch), followed by *B. carambolae* with 1,034 individuals (25.05%), *B. latifrons* with 318 individuals (7.71%), and *B. occipitalis* with only seven individuals (0.17%). Thus, *B. dorsalis* represented the largest proportion of fruit flies captured during the observation period. This finding is consistent with a previous study using fruit and yeast based attractants in chilli plantations, which also reported a high representation of *B. dorsalis* (Andiko et al., 2023).

Rearing of infested cayenne pepper fruits yielded *B. dorsalis*, *B. carambolae*, and *B. latifrons*, whereas *B. occipitalis* was not recovered. Therefore, the occurrence of *B. occipitalis* in the traps alone does not confirm its involvement in fruit infestation in this study. The difference between trap captures and rearing results also indicates that the species composition recorded by attractant traps did not completely correspond to the species recovered from infested fruits.

Descriptively, P0 produced the highest total catch, with 1,105 individuals, whereas P4 produced the lowest total catch, with 376 individuals. Among the fermentation-based treatments, P3 produced the highest total catch, with 907 individuals, comprising *B. dorsalis*, *B. carambolae*, and *B. latifrons*. The higher catch obtained with P3 compared with the other fermentation-based formulations indicates that the 2:1 eco-enzyme and *ragi tape* mixture was attractive to several fruit fly species present in the experimental area. Nevertheless, the total catch obtained with P3 remained lower than that of methyl eugenol (P0). The high catch recorded for P0 is consistent with the strong response of males of several *Bactrocera* species to methyl eugenol (Food and Agriculture Organization of the United Nations & International Atomic Energy Agency, 2018; Susanto et al., 2021).

Temporal Pattern of Fruit Fly Catch

Analysis of variance showed significant effects of attractant treatment on fruit fly catches at each weekly observation from 9 to 15 weeks after planting (WAP). The relative pattern among treatments remained generally consistent throughout the observation period. P0 produced the highest mean catch at every observation, whereas P3 consistently produced the highest catch among the fermentation-based treatments. P4 and P5 had the lowest catches and did not differ significantly from each other at any weekly observation.

Table 2. Mean number of fruit flies captured from 9 to 15 weeks after planting.

Treatment	9 WAP	10 WAP	11 WAP	12 WAP	13 WAP	14 WAP	15 WAP
P0	27.50^{a}	34.00^{a}	36.25^{a}	38.25^{a}	41.00^{a}	47.00^{a}	52.25^{a}
P1	15.75^{c}	18.75^{c}	22.00^{c}	23.75^{c}	25.75^{c}	27.75^{c}	31.25^{c}
P2	15.25^{c}	17.25^{c}	19.75^{c}	22.25^{c}	23.75^{c}	26.25^{c}	28.50^{c}
P3	25.25^{b}	27.75^{b}	28.50^{b}	32.00^{b}	35.00^{b}	38.00^{b}	40.25^{b}
P4	8.25^{d}	6.25^{d}	10.50^{d}	12.25^{d}	16.75^{d}	18.75^{d}	21.25^{d}
P5	11.00^{d}	11.75^{d}	13.50^{d}	16.25^{d}	18.75^{d}	21.25^{d}	24.25^{d}

Means followed by the same letter within a column are not significantly different according to the least significant difference test at 5%. WAP = weeks after planting. Treatment definitions are provided in the Methodology section.

The mean catch in P0 increased from 27.50 flies per trap at 9 WAP to 52.25 flies per trap at 15 WAP. Over the same period, the mean catch in P3 increased from 25.25 to 40.25 flies per trap. P3 produced significantly higher catches than P1, P2, P4, and P5 at every weekly observation, with an overall mean of 32.39 flies across the seven observation periods. These results indicate that the 2:1 eco-enzyme and *ragi tape* mixture was the most attractive formulation among the fermentation-based treatments.

Fruit fly catches generally tended to increase from 9 to 15 WAP. This period corresponded to the generative stage of cayenne pepper development, during which increasing availability of host fruits may have contributed to the observed temporal pattern. Previous studies have reported that fruit fly abundance and infestation in chili can vary with crop age, fruiting stage, cultivar, fruit availability, and environmental conditions (Abdullah et al., 2020; Holis et al., 2023; Wattimena et al., 2026). However, fruit abundance, fruit maturity, and environmental variables were not quantified separately in the present study; therefore, their contribution to the increasing trap catches cannot be determined directly.

The consistently higher catches in P0 are consistent with the para-pheromonal activity of methyl eugenol, which strongly attracts males of several *Bactrocera* species (Food and Agriculture Organization of the United Nations & International Atomic Energy Agency, 2018; Mayasari et al., 2019; Patty, 2012; Susanto et al., 2021). Consequently, the high number of flies captured with methyl eugenol should not be interpreted as a direct estimate of the entire fruit fly population responsible for fruit infestation. P3 produced lower catches than P0 but

significantly higher catches than the other fermentation-based treatments. The differences among P1, P2, and P3 indicate that the proportion of eco-enzyme and *ragi tape* in the formulation was associated with differences in fruit fly attractiveness. Fermentation-derived volatile compounds and interactions among volatile components may influence olfactory responses in fruit flies (Ishii et al., 2015). However, the volatile composition of the tested formulations was not analyzed; therefore, the specific compounds or mechanisms responsible for the higher catches in P3 cannot be identified from the present study.

Trap construction, attractant volume, cotton carrier, and trap placement were maintained consistently across treatments. The traps were installed at approximately 90 cm to 1.5 m above ground, with the height adjusted according to plant height. Trap height has been reported to influence fruit fly capture because flight activity may vary with canopy position and the distribution of host fruits (Apriliyana et al., 2026; Said et al., 2017; Susanto et al., 2023). Standardizing the trapping procedure therefore helped reduce variation associated with trap configuration and placement, although differences in catch should still be interpreted primarily within the experimental design used in this study.



Figure 2. Field documentation of fruit fly trapping in ORI 212 cayenne pepper: (a) trap installation; (b) trap condition in the field; (c) captured fruit flies; and (d) collection of trap catches for identification.

Attractant Longevity

Analysis of variance showed that attractant formulation significantly affected attractant longevity. Methyl eugenol (P0) remained active for an average of 6.75 days and had a significantly longer active period than all fermentation-based treatments. Among the fermentation-based formulations, P1 and P3 remained active for an average of 2.75 days, P2 for 2.50 days, and P4 and P5 for 2.25 days. However, the differences in longevity among P1, P2, P3, P4, and P5 were not statistically significant. Thus, although the fermentation-based formulations differed markedly in their fruit fly catches, their active periods were statistically comparable.

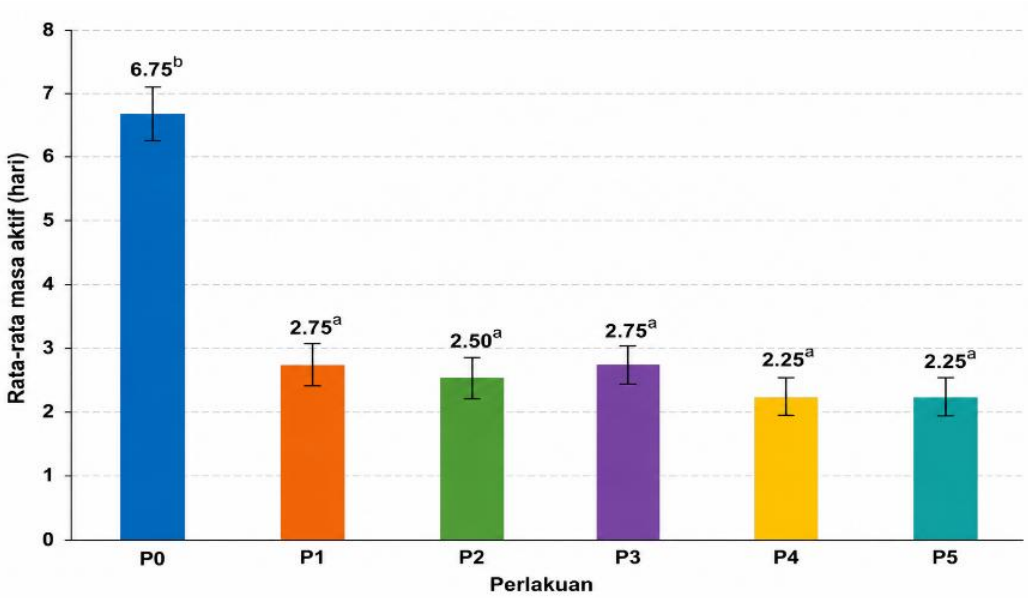


Figure 3. Mean active period of the six attractant treatments. Different letters indicate significant differences according to the least significant difference test at 5%. P0 = methyl eugenol; P1 = eco-enzyme + ragi tape (1:1); P2 = eco-enzyme + ragi tape (1:2); P3 = eco-enzyme + ragi tape (2:1); P4 = eco-enzyme; P5 = ragi tape + sugar. Species counts are descriptive data.

The relatively short longevity of the fermentation-based attractants may be associated with the characteristics of the formulations and their release from the cotton carrier. Volatilization, carrier properties, environmental conditions, and release systems can influence the persistence of attractants under field conditions. Previous studies have shown that liquid methyl eugenol applied to absorbent carriers may undergo substantial loss through evaporation, whereas slow-release matrices can maintain attractant release and field activity for longer periods (Shelly et al., 2024). Similarly, the field persistence of food-based tephritidae lures has been reported to vary according to lure formulation and release system (Enkerlin et al., 2025). These findings provide a relevant comparison, although the materials and release systems evaluated in those studies differed from the eco-enzyme and *ragi tape* formulations used in the present experiment.

P3 produced the highest fruit fly catch among the fermentation-based treatments despite having the same mean longevity as P1 (2.75 days). This result indicates that attractant longevity alone did not account for the differences in capture performance among the fermentation-based formulations. Differences in formulation characteristics and the odors released during the active period may have contributed to the higher catch observed in P3. However, the volatile composition of the tested formulations was not analyzed; therefore, the specific compounds responsible for the higher attractiveness of P3 cannot be identified from the present study.

Relationship between Fruit Fly Catch and Attractant Longevity

Pearson correlation and simple linear regression showed a positive relationship between mean fruit fly catch and attractant longevity. The fitted regression equation was Y^=−0.0811+0.1339X, where X represented mean fruit fly catch and Y represented attractant longevity. The Pearson correlation coefficient (r=0.755) indicated a strong positive relationship between the two variables. The coefficient of determination (R2=0.569) indicated that 56.9% of the variation in attractant longevity was explained by its linear relationship with mean fruit fly catch, while the remaining 43.1% was not explained by the fitted model. The relationship was statistically significant (p=0.00002044).

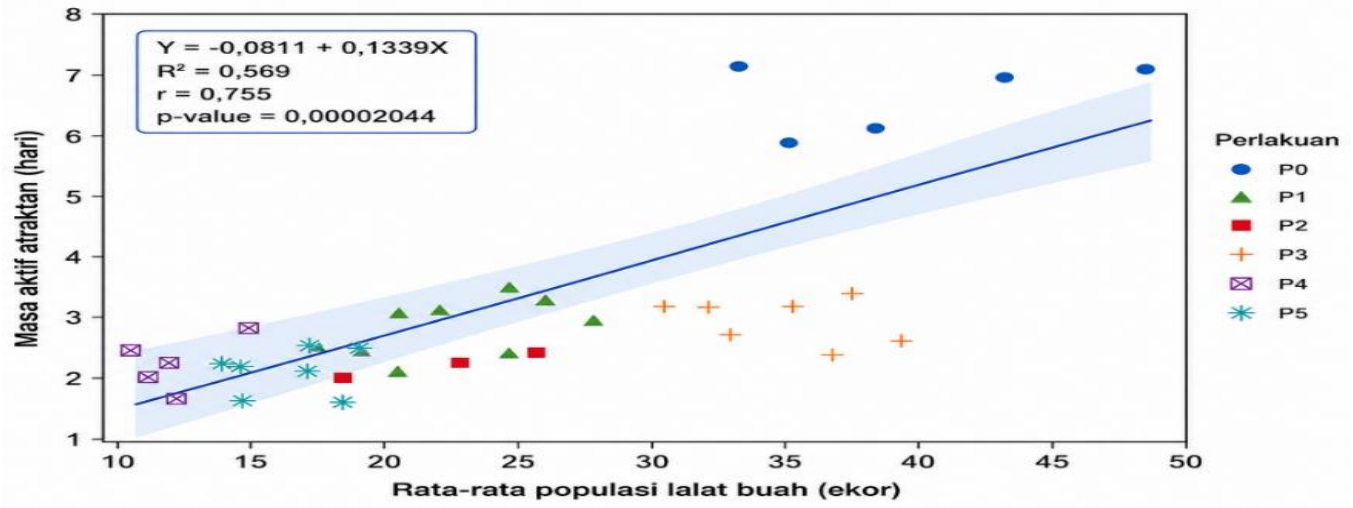


Figure 4. Relationship between mean fruit fly catch and attractant longevity across the six treatments. The fitted model was Y = -0.0811 + 0.1339X, R2 = 0.569, r = 0.755, and p = 0.00002044.

Despite this statistical relationship, the results do not demonstrate that higher fruit fly catches caused the attractant to remain active for a longer period, or that longer attractant longevity directly resulted in higher catches. This limitation is illustrated by P1 and P3, which had the same mean attractant longevity of 2.75 days but differed substantially in fruit fly catch, with P3 producing the higher catch. Thus, attractant longevity alone cannot account for differences in capture performance. Previous studies have similarly indicated that attractant persistence, residual quantity, or release characteristics do not necessarily correspond directly to the number of fruit flies captured (Enkerlin et al., 2025; Shelly et al., 2024).

Differences in attractant composition may also influence olfactory responses in fruit flies. Female *B. dorsalis* has been reported to respond to specific combinations of host-fruit volatiles (Jayanthi et al., 2012), while the addition of 1-butanol to a yeast-protein bait increased female response under laboratory conditions (Sasaki et al., 2019). These findings support the broader interpretation that changes in the composition of an attractant can modify fruit fly behavioral responses. However, they do not demonstrate that P3 contained 1-butanol or that P3 selectively attracted female fruit flies, because neither the volatile composition of the formulations nor the sex of the captured individuals was determined in the present study.

Fruit Fly Infestation Intensity

Analysis of variance showed that attractant treatment significantly affected fruit fly infestation intensity throughout the observation period. P3 consistently showed the lowest numerical infestation intensity, increasing from 6.75% at 9 weeks after planting (WAP) to 29.16% at 15 WAP. In contrast, P4 showed the highest infestation intensity, increasing from 26.14% to 71.13% over the same period. At 9-11 WAP, some treatments still shared the same significance groups, whereas from 12 to 15 WAP all treatments differed significantly from one another according to the least significant difference test at the 5% level.

Table 4. Mean fruit fly infestation intensity on ORI 212 cayenne pepper from 9 to 15 weeks after planting.

Treatment	9 WAP	10 WAP	11 WAP	12 WAP	13 WAP	14 WAP	15 WAP
P0	9.96^{a}	19.86^{c}	24.27^{c}	28.89^{d}	33.86^{d}	41.00^{d}	47.73^{d}
P1	10.65^{a}	15.69^{bc}	21.66^{bc}	25.68^{c}	30.55^{c}	35.61^{c}	41.38^{c}
P2	8.03^{a}	13.55^{ab}	17.35^{ab}	21.17^{b}	25.56^{b}	30.14^{b}	33.64^{b}
P3	6.75^{a}	9.47^{a}	13.81^{a}	17.92^{a}	21.92^{a}	26.25^{a}	29.16^{a}
P4	26.14^{b}	36.36^{e}	42.82^{e}	48.02^{f}	56.31^{f}	63.43^{f}	71.13^{f}
P5	21.53^{b}	27.27^{d}	32.25^{d}	37.49^{e}	46.05^{e}	52.96^{e}	59.99^{e}

Values are percentages. Means followed by the same letter within a column are not significantly different according to the least significant difference test at 5%. WAP = weeks after planting.

When the seven weekly observations were averaged descriptively, P3 had a mean infestation intensity of 17.90%, whereas P4 averaged 49.17%. Thus, the mean infestation recorded for P3 was approximately 63.6% lower than that of P4. P4 also produced the lowest fruit fly catches, whereas P3 produced the highest catches among the fermentation-based treatments. This combined pattern indicates that the 2:1 eco-enzyme and *ragi tape* formulation was associated with both higher trap catches and lower fruit infestation within the fermentation-based treatment group. However, no direct correlation or regression analysis between trap catch and infestation intensity was conducted; therefore, the observed pattern should not be interpreted as evidence that higher trap catches directly caused lower infestation.

Fruit fly infestation begins when females oviposit into host fruits and the developing larvae feed within fruit tissues. Fruit morphology, tissue characteristics, nutritional properties, and volatile cues may influence susceptibility to *B. dorsalis* (Syamsudin et al., 2022). All plants used in the present experiment belonged to the same ORI 212 cultivar, thereby limiting variation attributable to cultivar differences. Nevertheless, environmental conditions and unmeasured physiological differences among plants may also have contributed to the development of fruit infestation.

P0 produced the highest fruit fly catch and the longest attractant longevity but did not result in the lowest infestation intensity. This distinction between trap catch and fruit infestation is biologically relevant because methyl eugenol primarily attracts males of responsive *Bactrocera* species (Food and Agriculture Organization of the United Nations & International Atomic Energy Agency, 2018; Susanto et al., 2021). Consequently, a high methyl eugenol trap catch may indicate a strong male response without directly representing the abundance of females capable of oviposition. Previous field observations have likewise shown that fruit fly trap counts do not necessarily correspond directly to levels of fruit damage (Grové, 2017). Therefore, attractant performance should be evaluated using both trap catches and fruit infestation rather than interpreting trap catch alone as a direct measure of crop protection.

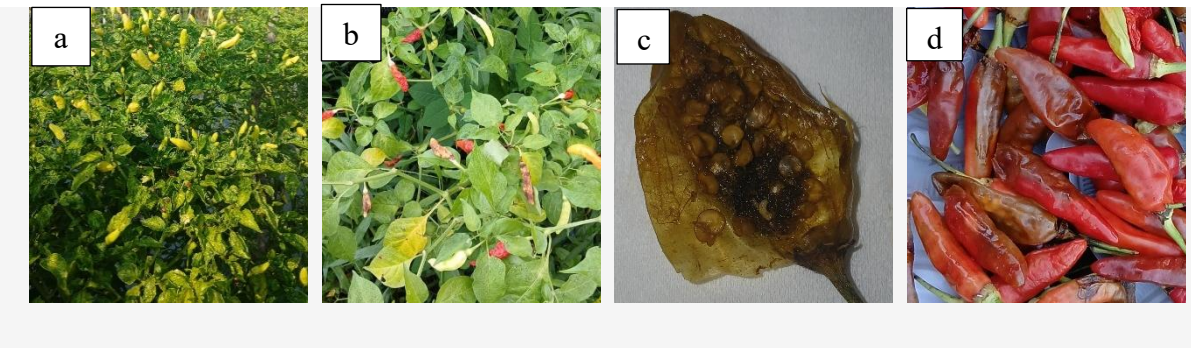


Figure 5. Field symptoms used for fruit fly infestation assessment: (a) fruit without visible attack symptoms; (b) fruit showing fruit fly attack symptoms; (c) damaged fruit tissue; and (d) infested fruit used in the infestation assessment.

Cayenne Pepper Harvest Weight

Attractant treatments significantly affected cayenne pepper harvest weight at each harvest. P0 produced the highest harvest weight at Harvest I, Harvest II and Harvest III whereas P3 consistently ranked second and produced the highest harvest weight among the fermentation-based treatments. P4 produced the lowest harvest weight at all three harvests. All treatments differed significantly from one another within each harvest according to the least significant difference test at the 5% level.

Table 5. Mean fruit yield at three harvests and accumulated total yield under the six attractant treatments.

Treatment	Harvest I (g)	Harvest II (g)	Harvest III (g)	Total (g)
P0	170.63[a]	147.25[a]	116.50[a]	434.38[a]
P1	147.75[c]	127.13[c]	97.88[c]	372.75[c]
P2	136.25[d]	116.25[d]	87.50[d]	340.00[d]
P3	155.25[b]	133.88[b]	105.13[b]	394.25[b]
P4	117.88[f]	98.50[f]	72.50[f]	288.88[f]
P5	131.25[e]	111.38[e]	83.88[e]	326.50[e]

Means followed by different letters within a column differ significantly according to the least significant difference test at 5%. Each value represents fruit weight per experimental unit of four plants.

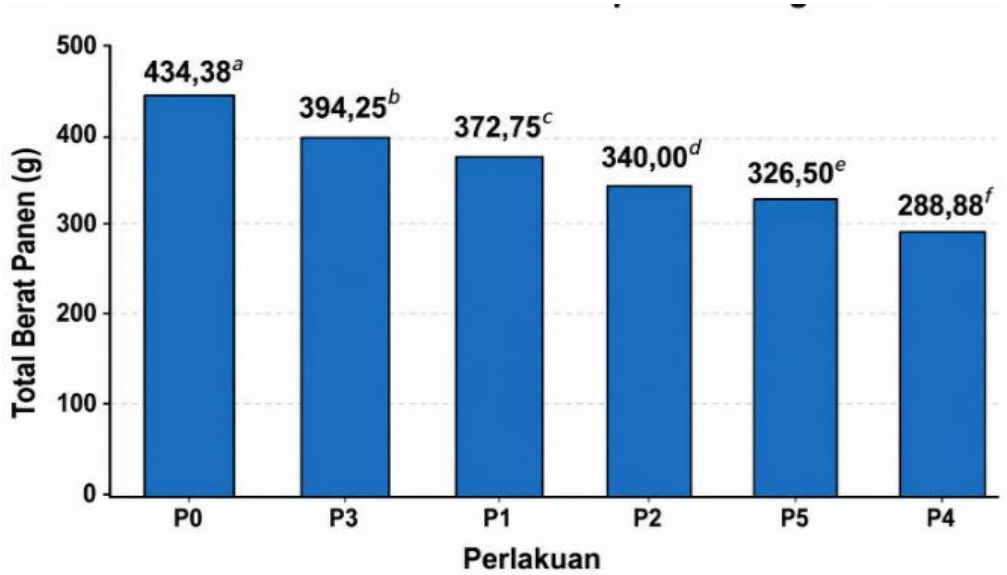


Figure 6. Accumulated fruit yield under the six attractant treatments. Different letters indicate significant differences according to the least significant difference test at 5%.

The accumulated harvest weight was highest in P0 at 434.38 g per experimental unit, followed by P3 at 394.25 g, whereas P4 produced the lowest accumulated weight at 288.88 g. The accumulated harvest weight of P3 was approximately 36.48% higher than that of P4. P3 also had the lowest mean infestation intensity among the treatments, whereas P4 had the highest. Within the fermentation-based treatment group, this pattern indicates an association between lower fruit fly infestation and greater harvest weight. However, no specific correlation or regression analysis between infestation intensity and harvest weight was conducted; therefore, this pattern should not be interpreted as evidence of a direct causal relationship.

Harvest weight decreased from Harvest I to Harvest III across all treatments without changing their relative ranking. Because this decline occurred across treatments, it cannot be attributed solely to differences in fruit fly infestation. Fruit number, individual fruit size, plant physiological status, and environmental conditions during the harvest period were not analyzed separately; therefore, the factors responsible for the temporal decline in harvest weight cannot be determined from the present study.

The accumulated harvest weight of P0 was higher than that of P1, P2, and P3 despite P0 having a higher mean infestation intensity than these treatments. This finding further indicates that harvest weight was influenced by factors other than fruit fly infestation alone. Therefore, differences in harvest weight among treatments should be interpreted as an overall crop response observed under the experimental conditions rather than as a direct consequence of infestation intensity.

Overall, P3 showed the most favorable performance among the fermentation-based formulations, combining the highest fruit fly catch within this group, the lowest mean infestation intensity, and the highest accumulated harvest weight. These results support the potential of the 2:1 eco-enzyme and *ragi tape* formulation as one component of integrated fruit fly management. However, its relatively short active period remains a limitation for field application. Further development should therefore consider improving attractant persistence and integrating trapping with field sanitation, removal of infested fruits, management of alternative host plants, and other compatible integrated pest management practices (Kumar et al., 2025; Muhlison et al., 2026).

4. Conclusion and Recommendations

The 2:1 eco-enzyme and *ragi tape* mixture (P3) was the best-performing fermentation-based formulation evaluated in this study. P3 produced a mean fruit fly catch of 32.39 flies per trap, the lowest mean fruit fly infestation intensity of 17.90%, and the highest accumulated harvest weight among the fermentation-based treatments at 394.25 g per experimental unit. Methyl eugenol (P0) produced the highest mean fruit fly catch overall at 39.46 flies per trap and had the longest attractant longevity of 6.75 days. Four fruit fly species were identified from the trap catches, namely *Bactrocera dorsalis*, *B. carambolae*, *B. latifrons*, and *B. occipitalis*, with *B. dorsalis* being the dominant species and accounting for 67.07% of the total identified catch.

Further research is needed to characterize the volatile compounds of the eco-enzyme and *ragi tape* mixture and to evaluate carrier materials that may extend its active period under field conditions. The use of attractant traps should also be combined with field sanitation and the collection and removal of infested fruits as part of fruit fly management in cayenne pepper cultivation.

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