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Optimizing Lure-Based Monitoring of Tephritid Fruit Flies: Insights from Trap Performance, Seasonal Trends, and Species Composition in Bangladesh

Otimização do Monitoramento de Moscas-das-Frutas Tefritídeas Baseado em Atrativos: Perspectivas sobre Desempenho de Armadilhas, Tendências Sazonais e Composição de Espécies em Bangladesh

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Abstract

Tephritid fruit flies are major pests of fruits and vegetables in tropical regions, causing significant economic losses. Effective monitoring using male lure-based traps, such as methyl eugenol (ME) and cue-lure (CL), is essential for integrated pest management. This study evaluated the influence of lure type, trap height, storage condition, and seasonal dynamics on fruit fly captures at two sites (AERE and Jahangirnagar University) in the Savar region of Bangladesh. Methyl eugenol (ME) and cue-lure (CL) traps were deployed at three heights (2, 3, and 5 ft) over a one-year period (August 2023–July 2024). A total of 36,107 male fruit flies, representing nine *Bactrocera*, *Dacus* and *Zeugodacus* species, were recorded. ME traps consistently captured significantly more males than CL traps ($p < 0.05$), confirming strong lure-specific selectivity—*B. dorsalis* and *B. zonata* dominated ME catches, whereas *Z. cucurbitae* and *Z. tau* predominated in CL traps. Trap height showed no significant

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effect on captures, suggesting that low-level deployment (~1–1.5 m) is adequate for field monitoring. Fruit fly abundance peaked during summer (June–July) and declined in winter (December–February), reflecting climatic influences on population activity. Lure longevity tests demonstrated that cold storage (4°C) substantially prolonged lure efficacy compared to storage at room temperature or sunlight exposure. Collectively, these findings highlight that lure type, seasonal timing, and proper storage are key determinants of trapping success, while trap height plays a minor role. The results provide practical recommendations for optimizing fruit fly surveillance and integrated pest management strategies in Bangladesh.

Keywords: Methyl eugenol, Cue-lure, Lure efficacy, Fruit fly monitoring.

Resumo

As moscas-das-frutas tefritídeas são pragas importantes de frutas e hortaliças em regiões tropicais, causando perdas econômicas significativas. O monitoramento eficaz por meio de armadilhas baseadas em atrativos masculinos, como o metil eugenol (ME) e o cue-lure (CL), é essencial para o manejo integrado de pragas. Este estudo avaliou a influência do tipo de atrativo, altura da armadilha, condição de armazenamento e dinâmica sazonal sobre as capturas de moscas-das-frutas em dois locais (AERE e Universidade de Jahangirnagar) na região de Savar, Bangladesh. Armadilhas ME e CL foram instaladas em três alturas (2, 3 e 5 pés) durante um período de um ano (agosto de 2023–julho de 2024). Um total de 36.107 machos foi registrado, representando nove espécies dos gêneros *Bactrocera*, *Dacus* e *Zeugodacus*. As armadilhas com ME capturaram significativamente mais machos do que as com CL ($p < 0,05$), confirmando forte seletividade do atrativo — *B. dorsalis* e *B. zonata* predominaram nas capturas com ME, enquanto *Z. cucurbitae* e *Z. tau* foram mais frequentes nas com CL. A altura da armadilha não influenciou significativamente as capturas, indicando que a instalação a cerca de 1–1,5 m é adequada para o monitoramento. A abundância das moscas atingiu o pico no verão (junho–julho) e diminuiu no inverno (dezembro–fevereiro), refletindo a influência climática na atividade populacional. O armazenamento a 4°C prolongou significativamente a eficácia dos atrativos. Estes resultados destacam que o tipo de atrativo, a época do ano e o armazenamento adequado são fatores-chave para o sucesso do monitoramento.

Palavras-chave: Metil eugenol, Cue-lure, Eficácia do atrativo, Monitoramento de moscas-das-frutas.

INTRODUCTION

Tephritidae (Diptera) encompasses more than 4,000 described species worldwide, of which nearly 700 species are dacine fruit flies (Doorenweerd et al., 2018). Within this group, the genus *Bactrocera* is the most diverse, comprising over 440 species, mostly distributed in tropical and subtropical Asia, the South Pacific, and Australia (Leblanc et al., 2019; Hossain et al., 2024). Among them, the Oriental fruit fly (*Bactrocera dorsalis*) and the Melon fly (*Zeugodacus cucurbitae*) are recognized as two of the most destructive pests worldwide, including in Bangladesh (Hossain et al., 2019; Leblanc et al., 2021). *B. dorsalis* is responsible for losses that are estimated to be 10–30% annually, and in some cases, depending on the season and the place, the losses can reach up to 50% in mango, papaya, guava, and cucurbits (Naqvi, 2005; Dhillon et al., 2005). The female fruit flies lay their eggs under the fruit skin, and the larvae feed on the pulp causing the fruit to rot and become infected with microbes which are the infected fruit that are dropped. Thus, these infestations lead to the loss of marketable yield, reduced shelf life, and the imposition of strict quarantine barriers to trade (Vargas et al., 2010; Clarke et al., 2019; Shelly et al., 2024).

The primary focus of fruit fly suppression and eradication programs is, characteristically, monitoring the population effectively. In the past, chemical insecticides and bait sprays were the main methods used, but their risks to the environment and human health have actually resulted in a change in the management strategy towards the use of more environmentally friendly methods, such as trapping systems with male lures or the use of para-pheromones (Chambers, 1977; Sivinski & Calkins, 1986; Drew & Romig, 2013). The most extensively used lures are methyl eugenol (ME) and cue-lure (CL) which are very effective along with the male *B. dorsalis* complex and male *Z. cucurbitae*, respectively (Vargas et al., 2010; Hossain et al., 2019; Shelly et al., 2024). Area-wide management programs, including methods like male annihilation and mass-trapping, are implemented in many countries backed by these lures (Clarke et al., 2019; Ahmad et al., 2023).

The effectiveness of ME and CL does not rely solely on the laboratory; it is a matter of environmental conditions and operational factors. Among the various environmental factors, temperature, humidity, sunlight and storage have their effects on lure potency and longevity (Madhura & Viraktamath, 2001; Siddiqui et al., 2003; Shelly et al., 2024), On the other hand, trap height can either positively or negatively influence capture efficiency since fruit fly activity differs in intensity across different vertical strata (Bausin et al., 2024). Therefore, all these factors together determine the monitoring outcomes. However, in spite of this, systematic studies in Bangladesh are still lacking, and no research has been conducted to explore the impact of storage temperature or trap height on the performance of lures in local conditions.

Taking into account the economic significance of fruits and vegetables and their vulnerability to quarantine restrictions, the deployment of lures has to be optimized using scientific methods and thus evidence-based research is urgently needed.

This gap is thus filled by the current research that looks into (1) the impact of storage temperature on ME and CL and (2) the role that trap height plays in the number of fruit flies caught. As far as we know, this is the first study in Bangladesh that combines lure storage conditions and trap placement within the same experimental setup. Through the generation of evidence-based recommendations, the research contributes to the efficiency of surveillance, fortification of quarantine protections, and the promotion of sustainable management of fruit flies in the systems of tropical fruits production.

MATERIALS AND METHODS

Study sites and experimental period

Field experiments were conducted at two contrasting locations: the Jahangirnagar University (JU) campus (23.88° N, 90.26° E) and the Atomic Energy Research Establishment (AERE) campus (23.96° N, 90.28° E), both selected for their diverse fruit-bearing plants that attract tephritid fruit flies. The JU campus represents a semi-natural environment with scattered wild fruit-bearing plants, patches of secondary vegetation, and open grassy areas, resembling a heterogeneous agroforestry mosaic, whereas the AERE campus is a managed agricultural site with orchards and cultivated crops in open fields. Both sites are moderately isolated from dense forests or urban areas, although small tree patches and nearby gardens may influence local tephritid diversity. This setup allowed comparison of lure efficiency, seasonal trends, and species composition under differing environmental contexts, with occasional captures of *Bactrocera rubigina* at JU likely linked to semi-forested patches, while *Zeugodacus cucurbitae* predominated in the open agricultural areas of AERE, reflecting habitat-specific preferences. Laboratory experiments were conducted in the Insect Biotechnology Division (IBD) laboratory, Institute of Food and Radiation Biology (IFRB), AERE, Savar, Dhaka, and the study spanned one year from August 2023 to July 2024.

Collection of lures

The Methyl eugenol (ME) and cue-lure (CL) were acquired from the Sigma Aldrich Company, located in the United States of America. The kappa carrageenan a water-soluble polymer used for the lure formation was obtained from the Insect Biotechnology Division (IBD).

Preparation of traps baited with formulated sex lures

The baited traps were made of two-liter plastic drinking bottles with two triangular openings (about 25 × 30 × 30 mm) on the sides at a height of one half of the bottle. The lures of the sex pheromone were prepared by soaking small cotton threads in about 2 ml of either the ME or the CL, and then the threads were suspended at the center of each trap as lure sticks. There was also a 10 × 10 mm piece of the dichlorvos (DDVP) insecticide strip (Varotape II, Hercon Environmental, USA) inside every trap to kill the flies that were caught. DDVP strips were replaced every month during the experimental period.

Storage conditions of lures

To assess the effect of storage on lure efficacy, ME and CL were stored separately under three conditions: refrigerator (4ºC), room temperature (20–25ºC), and direct sunlight (>25ºC). After three months, traps were baited with lures from each storage condition.

Trap heights

For finding out the best trap height, traps with formulated ME and CL were set up at three different heights above the ground: 2 feet (60.96 cm), 3 feet (91.44 cm), and 5 feet (152.4 cm). The trap-height experiment followed a randomized complete block design (RCBD). Each sampling date served as a block, and all three trap-height treatments were included within every block. Trap positions within each block were randomly assigned to minimize spatial bias and ensure equal exposure to environmental variation.

Insect collection and identification

Every 15-day intervals, the fruit flies caught in the traps were collected and identified. Species identification was conducted using the taxonomic key of Drew and Romig (2013), with verification based on descriptions in Leblanc et al. (2019), which provide detailed guidance for distinguishing closely related tephritid species in Bangladesh. Three traps were set up for each site in all the experiments and trap capture rates were computed accordingly. To keep the lures effective, formulated lure sticks were changed every 15 days.

Statistical analyses

Data obtained from the fruit fly trapping experiments were organized and analyzed to identify month-wise and trap-wise variations in species abundance. The computation of descriptive statistics was done, and the summarized findings were revealed in Tables 1 and 2. Trap-height data were analyzed under a randomized complete block design (RCBD), with sampling date treated as the blocking factor. ANOVA assumptions (normality and homogeneity of variance) were checked prior to analysis, and Tukey's HSD was applied for post-hoc mean separation where appropriate. For the assessment of lure type, trap height, and their interaction on fruit fly capture rates, data were subject to two-way analysis of variance (ANOVA) in R statistical software where the statistical threshold for significance was set at $p < 0.05$. Outcomes have been given in terms of F-values and associated p-values for judging the importance of each factor relatively. The use of base R functions (heatmap(), plot(type = "l"), boxplot(), and barplot()) and additional use of ggplot2, dplyr, and tidyr packages for improved graphical representation and visualization of ANOVA results was the method of choice for the data visualization which included heatmaps, line graphs, box plots, and bar charts (R Core Team, 2025).

Table 1. Number of adult male fruit flies captured monthly in ME- and CL-baited traps hung at different heights at AERE campus.

Tabela 1. Número de moscas-das-frutas machos adultas capturadas mensalmente em armadilhas com isca ME e CL, instaladas em diferentes alturas no campus da AERE.

Months and year	Height of traps and name of lures						Mean (±SE) captured fly / trap	
	2 feet (60.96 cm)		3 feet (91.44 cm)		5 feet (152.4 cm)			
	ME	CL	ME	CL	ME	CL	ME	CL
Aug, 2023	1895	1093	1954	1153	1550	1162	1799.67 ± 126	1136.00 ± 21
Sep, 2023	1365	870	1421	891	1288	920	1358.00 ± 38	893.67 ± 14
Oct, 2023	859	446	976	476	725	505	853.33 ± 72	475.67 ± 17
Nov, 2023	453	220	470	234	545	255	489.33 ± 28	236.33 ± 10
Dec, 2023	253	162	270	163	318	163	280.33 ± 19	162.67 ± 0.3
Jan, 2024	102	72	142	82	166	90	136.67 ± 18	81.33±5
Feb, 2024	74	28	110	36	120	45	101.33 ± 13	36.33±4
Mar, 2024	276	76	103	91	119	99	166.00 ± 55	88.67±6
Apr, 2024	936	232	1017	262	347	285	766.67 ± 211	259.67±15
May, 2024	1313	1461	1382	1488	1525	1513	1406.33 ± 62	1487.33 ± 15
Jun, 2024	1753	1153	1825	1185	1518	1208	1698.67 ± 92	1182 ± 15
Jul, 2024	2105	608	2148	682	2031	721	2094.67 ± 34	670.33 ± 33
Mean (± SE) fly/trap	948.7±210.9	535.1±142.7	984.8±219.8	561.9±145.9	854.3±187.9	580.5±147	--	--

Table 2. Number of adult male fruit flies captured monthly in ME- and CL-baited traps hung at different heights at JU campus.

Tabela 2. Número de moscas-das-frutas adultas do sexo masculino capturadas mensalmente em armadilhas com isca ME e CL, instaladas em diferentes alturas no campus da JU.

Months and year	Height of traps and name of lures						Mean (±SE) captured fly / trap	
	2 feet (60.96 cm)		3 feet (91.44 cm)		5 feet (152.4 cm)			
	ME	CL	ME	CL	ME	CL	ME	CL
Aug, 2023	1594	893	1653	932	1650	941	1632.33±19	922±15
Sep, 2023	1165	670	1221	693	1258	718	1214.67±27	693.67±13
Oct, 2023	559	346	676	366	705	400	646.67±44	370.67±15
Nov, 2023	420	192	434	214	445	215	433±7	207±7
Dec, 2023	253	132	270	133	308	133	277±16	132.67±0.33
Jan, 2024	102	60	142	82	156	90	133.33±16	77.33±8
Feb, 2024	74	28	110	38	110	48	98±12	38±5
Mar, 2024	76	66	103	91	109	98	96±10	85±9
Apr, 2024	236	222	317	254	337	269	296.67±30	248.33±13
May, 2024	1308	1301	1382	1328	1521	1345	1403.67±62	1324.67 ± 12
Jun, 2024	1453	1052	1485	1083	1508	1101	1482±15	1078.67±14
Jul, 2024	1965	587	1988	640	2041	661	1998±22	629.33 ± 22
Mean (± SE) fly/trap	767.1±187	462.41±124	815.08±198	487.83±126	845.7±202.5	501.58±127	--	--

Diversity indices of fruit fly communities

To quantify the variation in tephritid fruit fly community composition among sites and lure types, we calculated species diversity using Shannon-Wiener (H′) and Simpson (D) indices. Calculations were based on the relative abundance of each species captured in ME and CL traps across all trap heights at AERE and JU campuses. Diversity indices were computed using the vegan package in R (Oksanen et al., 2022). Since trap height did not significantly affect species composition, indices were calculated per site × lure combination.

RESULTS

Male fruit fly captures with ME and CL at different trap heights

Tables 1 and 2 present the summary of adult male fruit flies collected in traps baited with methyl eugenol (ME) and cue-lure (CL) at different heights from the two study sites (AERE and JU campus). At both sites, ME-baited traps captured a significantly higher number of males compared to CL-baited traps throughout the study, while trap height did not show any significant impact.

At the AERE campus, ME-baited traps had noticeably higher number of captures during the entire study period (Table 1). The highest number of males (2,148) was trapped in July 2024 using ME traps, while the lowest (28 males) was trapped in CL traps in February 2024. Mean captures per trap across heights were 948.7 ± 210.9, 984.8 ± 219.8, and 854.3 ± 187.9 for ME, compared with 535.1 ± 142.7, 561.9 ± 145.9, and 580.5 ± 147.0 for CL.

The performance of the trap at Jahangirnagar University (JU) campus exhibited an identical pattern (Table 2). The traps that were baited with ME captured a considerably higher number of males as compared to the CL traps, whereas the height of the trap did not have a significant impact yet again. Mean captures were 767.1 ± 187.0, 815.1 ± 198.0, and 845.7 ± 202.5 for ME, compared with 462.4 ± 124.0, 487.8 ± 126.0, and 501.6 ± 127.0 for CL. At the AERE site, the maximum and minimum catches were the same as in the ME and CL traps, respectively, which caught 2,041 flies in July 2024 and 28 flies in February 2024, respectively.

Effects of lure type and trap height on fruit fly capture rates

The two-way ANOVA revealed consistent statistical patterns (Figure 1), the fruit fly capture rates were significantly influenced by the lure type in both the AERE site ($F = 6.32$, $p = 0.014$) and JU site ($F = 5.69$, $p = 0.020$) while the trap height had no considerable impact in either case (AERE: $F = 0.05$, $p = 0.953$; JU: $F = 0.06$, $p = 0.939$) nor was there any significant interaction between the two factors (AERE: $F = 0.11$, $p = 0.898$; JU: $F = 0.01$, $p = 0.993$). The results support the view that the selection of the chemical attractant is the most important factor in trapping effectiveness, while trap positioning in a vertical orientation does not significantly contribute to or hinder fruit fly capture in the range of 2 to 5 feet. It is, therefore, suggested that lure chemistry rather than physical position should be the focus of optimization in fruit fly monitoring programs.

Seasonal dynamics of fruit fly captures

A heatmap (Figure 2) depicts monthly fluctuations in ME- and CL-baited traps, from August 2023 to July 2024. The traps along the x-axis show monthly catches, and the lure type is indicated on the y-axis, with individual panels for each site. The intensity of the color represents the average number of catches per trap, from low (<100 in February 2024) to high (>2000 in July 2024). Of the different types of traps used, ME traps caught significantly more than CL traps. The highest catches were recorded in July 2024 (AERE: ~2095 in ME, 670 in CL; JU: ~1998 in ME, 629 in CL), whereas the lowest were in February 2024 (AERE: ~101 in ME, 36 in CL; JU: ~98 in ME, 38 in CL).

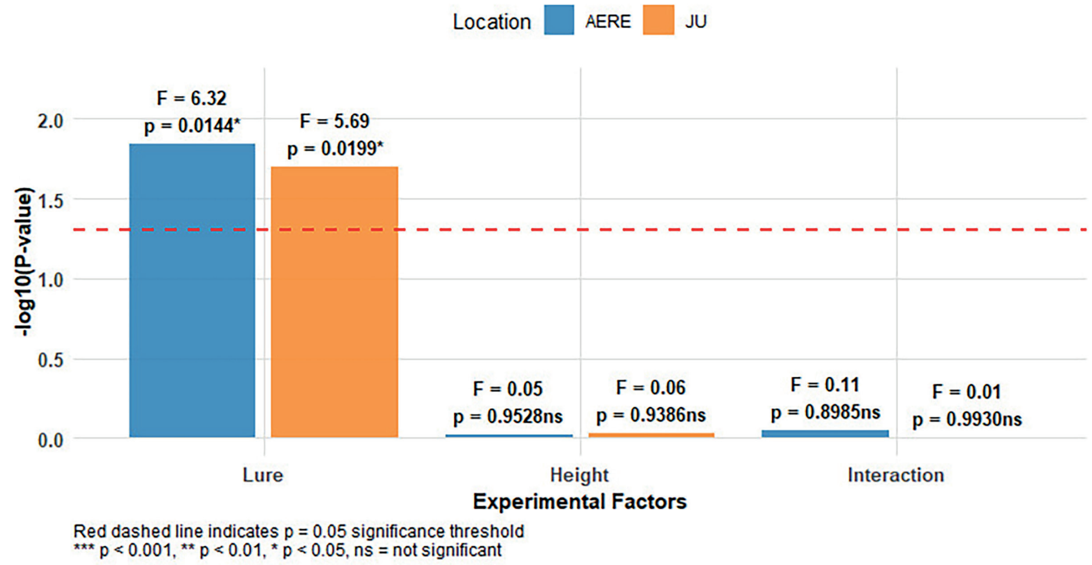

Figure 1. Comparison of the effects of lure type, trap height, and their interaction on fruit fly capture rates at AERE and JU locations. Bars represent $-\log_{10}$(p-values) from two-way ANOVA, with the red dashed line indicating the 0.05 significance threshold.

Figura 1. Comparação dos efeitos do tipo de isca, altura da armadilha e sua interação nas taxas de captura de moscas-das-frutas nas localidades AERE e JU. As barras representam −log10(valores de p) da ANOVA de duas vias, com a linha tracejada vermelha indicando o limiar de significância de 0,05.

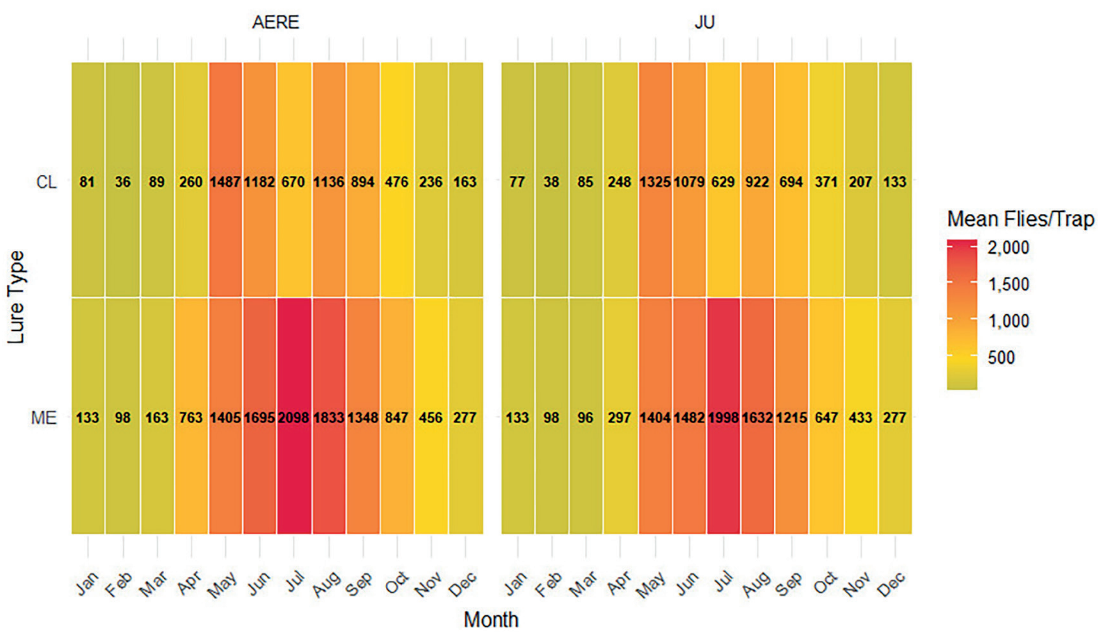

Figure 2. Heatmap showing monthly variation in mean captures of adult male fruit flies in methyl eugenol (ME) and cue-lure (CL) baited traps at AERE and JU campuses from August 2023 to July 2024.

Figura 2. Mapa de calor mostrando a variação mensal na média de capturas de moscas-das-frutas machos adultas em armadilhas com isca de metil eugenol (ME) e isca de sinalização (CL) nos campi da AERE e da JU, de agosto de 2023 a julho de 2024.

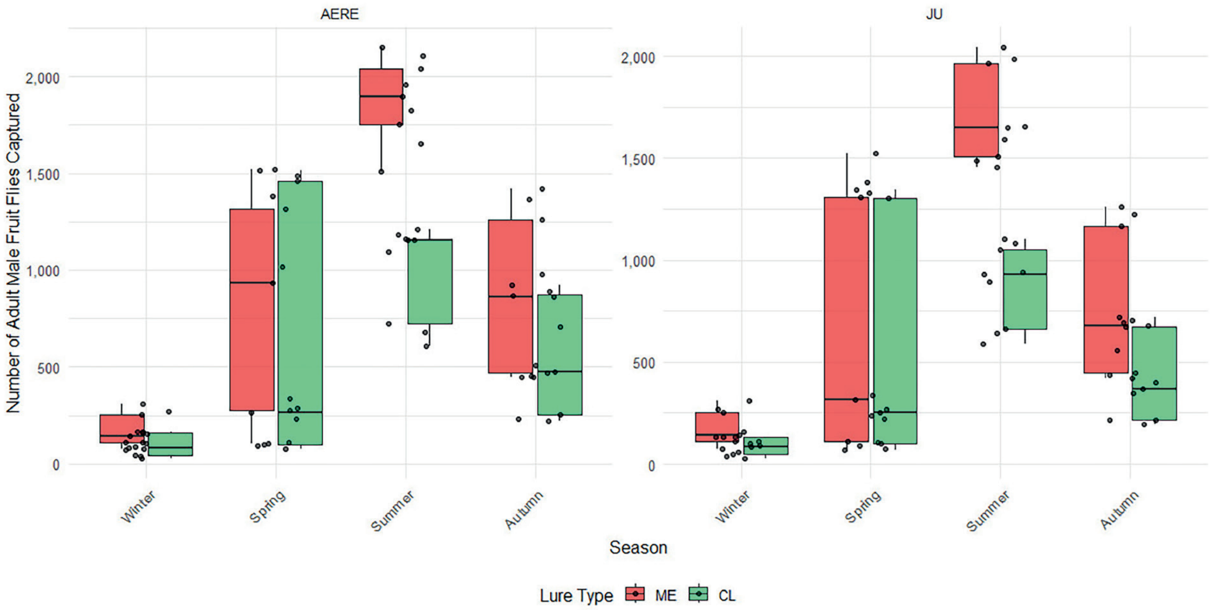

Figure 3. Seasonal variation in adult male fruit fly captures in ME and CL baited traps at AERE and JU campuses during winter, spring, summer, and autumn (August 2023–July 2024).

Figura 3. Variação sazonal na captura de moscas-das-frutas machos adultos em armadilhas com isca ME e CL nos campi da AERE e da JU durante o inverno, primavera, verão e outono (agosto de 2023 a julho de 2024).

The seasonal analysis (Figure 3) confirmed the observed trends. During the winter (December–February), the catches were the least (CL: 28–45; ME: 74–166), then during spring (March–May) there was a drastic rise (ME: >1,300; CL: 1,200–1,500), and summer (June–July) had the maximum abundance (ME: 2,148 at AERE; 2,041 at JU). Autumn (September–November) showed a decline in numbers but the numbers were still above the winter level. It can be concluded that the fruit fly activity is very much dependent on the seasonal climatic conditions.

Trap type comparison across sites

Boxplot analysis (Figure 4) showed that the ME traps caught significantly more flies than the CL traps at both locations. At AERE, average captures varied between 948.7–984.8 (ME) and 535.1–580.5 (CL) respectively. At JU, ME traps had an average of 767.1–845.7 flies, whereas CL attracted 462.4–501.6. The variability in ME captures was greater, while CL captures were always lower and stable. These findings demonstrate the superiority of ME over CL and endorse lure-specific placement tactics.

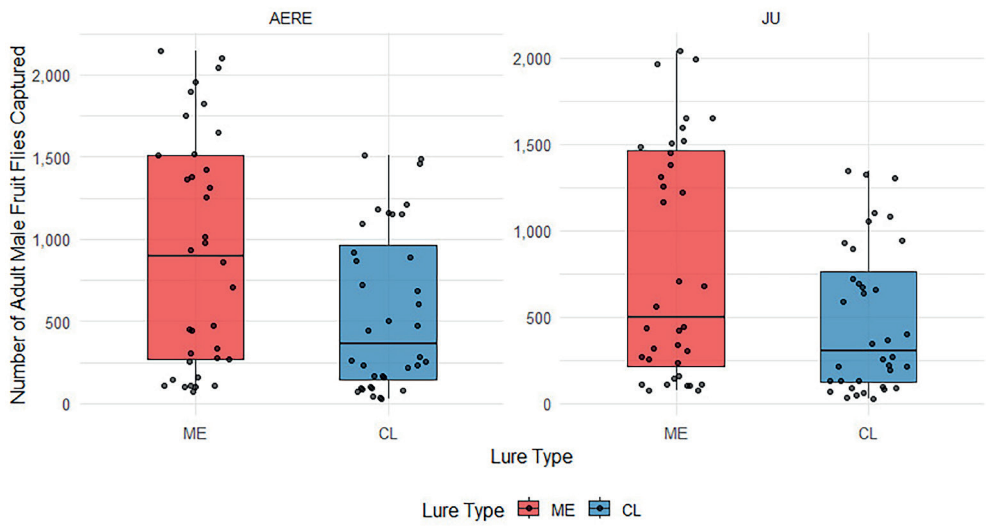

Figure 4. Comparative distribution of adult male fruit fly captures in ME and CL baited traps at AERE and JU campuses across all trap heights from August 2023 to July 2024.

Figura 4. Distribuição comparativa da captura de moscas-das-frutas machos adultos em armadilhas com isca ME e CL nos campi da AERE e da JU em todas as alturas das armadilhas, de agosto de 2023 a julho de 2024.

Temporal trend of trap captures at different heights

Temporal analysis of captures at different trap heights (Figure 5) corroborated that ME at all times captured more males than CL, and the trap height did not have any significant impact on results. Captures declined from September 2023 to February 2024 (28 flies in CL; 74–120 in ME), then increased steadily, peaking in July 2024 (2,148 at AERE; 2,041 at JU).

Lure efficacy under different storage conditions

Figure 6 shows the mean capture of adult male fruit flies per trap using methyl eugenol (ME) and cue-lure (CL) over eight weeks under three storage conditions: refrigerator (red dashed line), room temperature (green dashed line), and sunlight (blue dashed line). Initial captures were highest for CL in the refrigerator (220 flies) and ME (180 flies), declining sharply over time to 3 and 5 flies, respectively, by week 8. Room temperature lures showed a similar trend, dropping from 140 (CL) and 110 (ME) to 2 and 1 flies by week 8. Sunlight-exposed lures declined most rapidly, reaching 1 fly for both CL and ME by week 8. Overall, efficacy decreased under all storage conditions, with refrigerator-stored lures maintaining higher captures longer than those stored at room temperature or under sunlight.

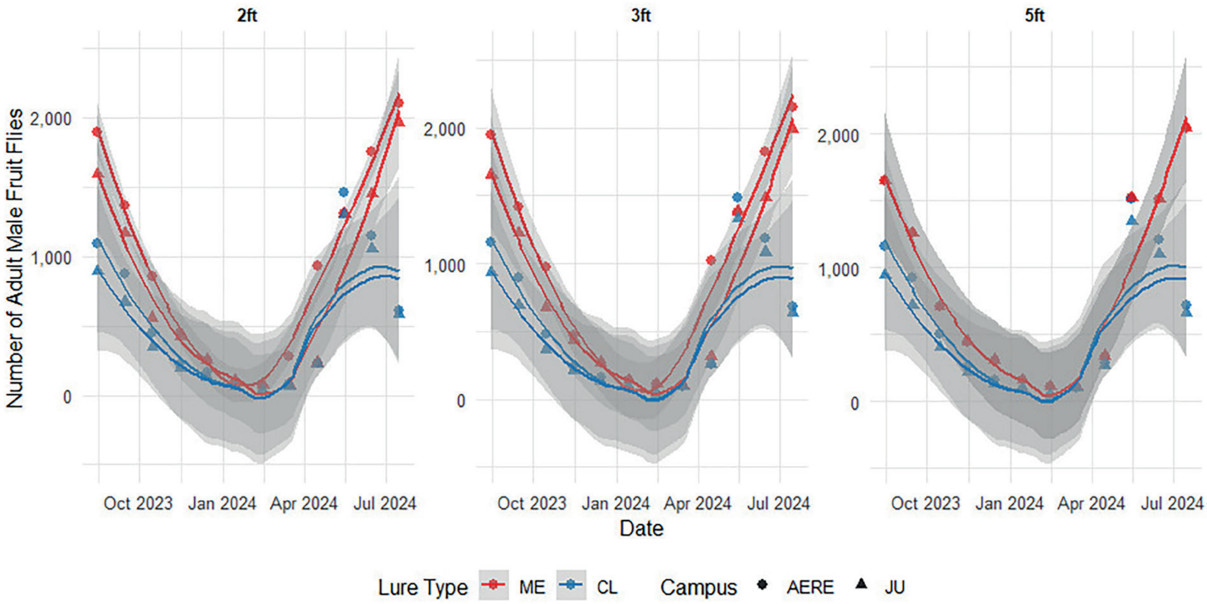

Figure 5. Temporal trend of adult male fruit fly captures in methyl eugenol (ME) and cue-lure (CL) baited traps placed at three heights (2, 3, and 5 ft) across AERE and JU campuses from August 2023 to July 2024.

Figura 5. Tendência temporal da captura de moscas-das-frutas machos adultas em armadilhas com isca de metil eugenol (ME) e isca de sinalização (CL), colocadas em três alturas (2, 3 e 5 pés) nos campi da AERE e da JU, de agosto de 2023 a julho de 2024.

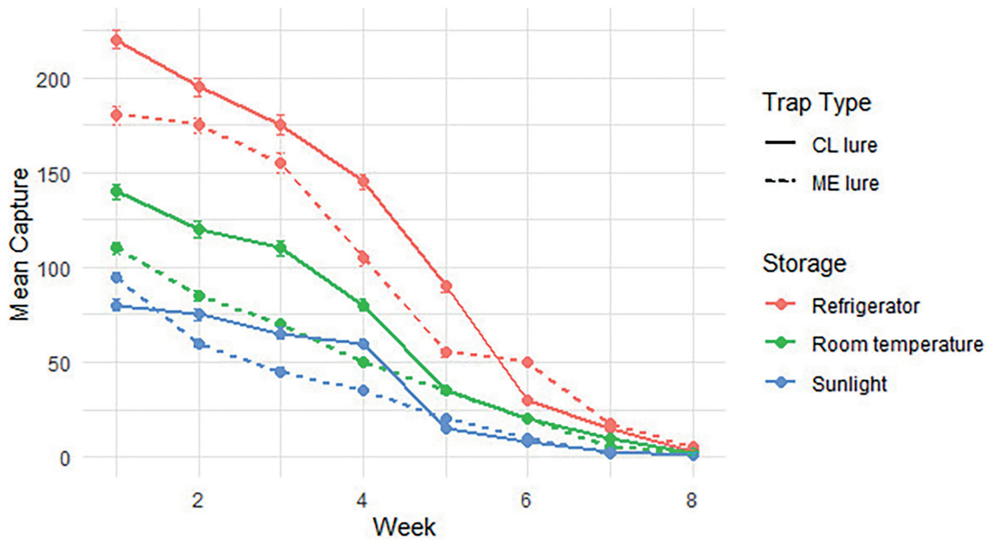

Figure 6. Decline in efficacy of ME and CL baits under different storage conditions over 8 weeks.

Figura 6. Diminuição da eficácia das iscas ME e CL sob diferentes condições de armazenamento ao longo de 8 semanas.

Tephritid species survey in the savar area

The enormous collection of tephritid flies from AERE and JU campuses reached the amazing number of 36,107 using ME and CL traps. At AERE, ME traps caught 11,049 flies and CL traps caught 7,434; at JU, ME and CL traps caught 10,401 and 7,223 flies, respectively. Nine species were recorded: *B. dorsalis*, *Z. diversus*, *B. correcta*, *B. zonata*, *Z. cucurbitae*, *D. longicornis*, *Z. tau*, *B. rubigina*, and *B. nigrifacia* (Figure 7). This highlights high species richness and provides baseline data for monitoring.

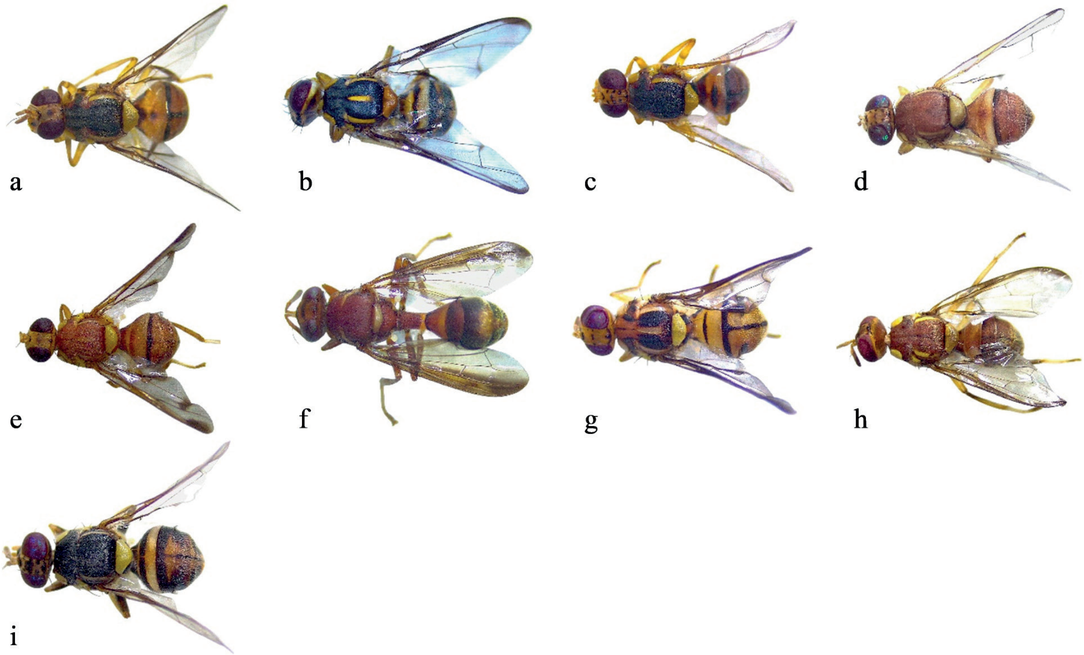

Figure 7. Morphology of tephritid fruit flies (a. *B. dorsalis*, b. *Z. diversus*, c. *B. correcta*, d. *B. zonata*, e. *Z. cucurbitae*, f. *D. longicornis*, g. *Z. tau*, h. *B. rubigina*, i. *B. nigrifacia*).

Figura 7. Morfologia das moscas da fruta tefritídeos (a. *B. dorsalis*, b. *Z. diversus*, c. *B. correcta*, d. *B. zonata*, e. *Z. cucurbitae*, f. *D. longicornis*, g. *Z. tau*, h. *B. rubigina*, i. *B. nigrifacia*).

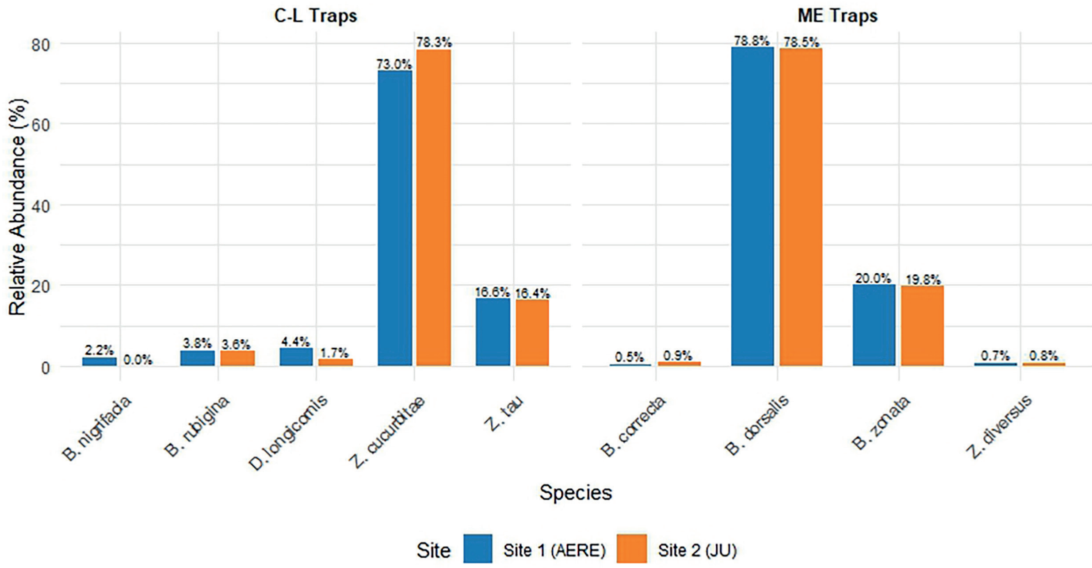

Figure 8. Relative abundance of tephritid fruit fly species captured by ME and CL traps at two distinct sites (AERE and JU).

Figura 8. Abundância relativa de espécies de moscas-das-frutas da família Tephritidae capturadas por armadilhas ME e CL em dois locais distintos (AERE e JU).

Relative abundance of species by trap type

The composition of species varied according to the type of lure used (Figure 8). ME traps were mostly occupied by B. dorsalis (78.84% at AERE; 78.45% at JU) and *B. zonata* (20.02% at AERE; 19.76% at JU), while <1% was other species. *Z. cucurbitae* (73.01% at AERE; 78.31% at JU) and Z. tau (16.65% at AERE; 16.38% at JU) were the main species in CL traps naturally, while other species were either very rare or not present at all. This indicates a distinct trap-specific species selectivity.

Species diversity

Table 3 summarizes the diversity indices for each site and lure type. ME traps at both sites were dominated by *B. dorsalis* and *B. zonata*, resulting in lower Shannon-Wiener indices (H′ = 0.52–0.53) and lower Simpson values (D = 0.31–0.32), reflecting lower diversity but higher dominance. CL traps showed higher Shannon-Wiener indices (H′ = 0.49–0.50) and slightly higher Simpson indices (D = 0.36), indicating a more balanced distribution among multiple species.

Table 3. Shannon-Wiener (H') and Simpson (D) diversity indices of tephritid fruit flies captured in methyl eugenol (ME) and cue-lure (CL) traps at different sites (August 2023–July 2024).

Tabela 3. Índices de diversidade de Shannon-Wiener (H') e Simpson (D) de moscas-das-frutas tefritídeas capturadas em armadilhas de metil eugenol (ME) e de isca-de-cauda (CL) em diferentes locais (agosto de 2023 a julho de 2024).

Site	Lure	Shannon-Wiener H'	Simpson D
AERE	ME	0.53	0.32
AERE	CL	0.49	0.36
JU	ME	0.52	0.31
JU	CL	0.50	0.36

DISCUSSION

The findings of this research reveal the underlying causes of male lure-based trapping for tephritid fruit flies in Bangladesh, particularly trap height, lure storage conditions, seasonal changes and species-specific reactions, which all can be regarded as factors influencing the efficacy of this method. The results of our study give crucial, evidence-based recommendations for the improvement of monitoring and control programs in this area.

Our research suggests that the height of the traps (2–5 feet) did not significantly influence the number of captures of *Bactrocera* and *Zeugodacus*, even though previously higher traps (6–15 feet or at canopy level) were reported to attract more flies (Bausin et al., 2024; Holbrook & Fujimoto, 1969; Madhura & Viraktamath, 2001). The likely reason for this discrepancy is ecological differences. The earlier studies were in orchards with thick canopies, where fly activity was concentrated in the layers of the host fruit, while our sites had a mixed vegetation structure with more scattered fly movement. In such cases, the odour plumes from the traps at ground level may also be equally powerful in attracting flies at different heights. Our findings align with those of Tan (1984) and Shelly et al. (2024), who also noted that height had little effect under certain circumstances. From a practical standpoint, this means that traps set at lower and more accessible heights (~1–1.5 m) can still be used for monitoring programs, thus providing both efficiency and convenience for tropical agro-ecosystem growers and surveyors.

Lure type, nonetheless, was a key factor in determining how effective the trap was. In both study sites, the traps with methyl eugenol (ME) lured much more flies on a steady basis compared to those with cue-lure (CL). These findings are consistent with earlier work showing the high responsiveness of *B. dorsalis* and related species to ME, compared with the strong affinity of *Z. cucurbitae* and *Z. tau* to CL (Shelly et al., 2024; Tan & Nishida, 2012). Fluctuations due to seasons also affected the number of catches very much, with summer (June - July) being the period of highest abundances and winter (December - February) the period of sharpest declines.

The mentioned temporal patterns can be explained by climatic factors, mainly temperature and humidity, which determine the fruit fly's activity, breeding, and orchard's fruit availability (Reddy et al., 2022).

Our study revealed strong species-specific selectivity of male lures. ME traps were dominated by *Bactrocera dorsalis* and *B. zonata*, reflecting the polyphagy and high abundance of *B. dorsalis* (>78% of ME catches) (Clarke et al., 2019). CL traps mainly captured *Zeugodacus cucurbitae* and *Z. tau*, consistent with their cucurbit-specific host range (>73% of CL catches) (Dhillon et al., 2005). Minor species were rare, likely due to limited hosts or localized distributions (Krosch et al., 2012; Leblanc et al., 2021; Tan & Nishida, 2012; Vargas et al., 2010). These findings confirm the high specificity of ME and CL and underscore the need to deploy both lures for comprehensive monitoring of tephritid diversity. Diversity indices show that ME traps were dominated by *B. dorsalis* and *B. zonata* (lower diversity), while CL traps captured a more balanced species mix (higher diversity). Trap height (2–5 ft) did not affect species diversity, confirming that lure type, not vertical position, drives community composition. Our lure longevity experiments further demonstrated that storage conditions critically affect efficacy. Lures stored in refrigerators (≈4°C) retained activity longer, whereas those exposed to sunlight degraded rapidly. These outcomes support earlier findings documenting reductions in lure activity due to volatilization and photodegradation under field conditions (Shelly et al., 2024; Vargas et al., 2010). Previous work has similarly recommended cold storage to enhance para-pheromone longevity and field effectiveness (Hiramoto et al., 2006; Vargas et al., 2009). Proper refrigeration before deployment is therefore critical to ensuring consistent, cost-effective monitoring.

In summary, the present findings underscore the critical importance of lure type, seasonal timing, and storage conditions in optimizing tephritid fruit fly monitoring. Although trap height (2–5 ft) showed minimal influence on capture efficiency, both methyl eugenol (ME) and cue-lure (CL) proved highly effective in attracting species-specific fruit flies, supporting a dual-lure approach for comprehensive surveillance. The preservation of lure potency under cool storage (4°C) further emphasizes the role of proper pre-deployment handling in maintaining field efficacy. Seasonal variations in captures reflect the ecological dynamics of fruit fly populations, reinforcing the need for seasonally informed monitoring and management. Although formal correlation or time-lag analyses were not conducted, the observed seasonal patterns in adult male captures closely follow regional rainfall trends, consistent with the known 2–3 weeks developmental lag between rainfall events and adult emergence in tephritid fruit flies (Drew & Romig, 2013). Collectively, these results contribute to the development of a standardized, cost-effective, and ecologically sound monitoring framework that can enhance integrated pest management (IPM) strategies, reduce economic losses, and strengthen sustainable fruit production systems in tropical agroecosystems such as those of Bangladesh.

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PARTICIPATION

NA, SRD, MTR, MAH, and AFMA contributed equally to the conceptualization, experimental design, and writing – original draft. NA, SRD carried out the field work and data collection. MTR performed the statistical analysis. AFMA supervised the study and contributed to writing – review & editing. MAH provided guidance on fieldwork logistics and resource management.

CONFLICTS OF INTEREST

Authors declare no conflict of interest.

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