Annals of Bangladesh Agriculture
Journal homepage: gau.edu.bd/aba

ORIGINAL ARTICLE

Comparative evaluation of management strategies for *Bactrocera cucurbitae* (Coquillett) in ash gourd

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ARTICLE INFO.

Keywords:

Bactrocera cucurbitae, wax gourd, trap cropping, cypermethrin, integrated pest management.

Received : 26 August 2025
Revised : 30 October 2025
Accepted : 2 December 2025
Published : 05 January 2026

Citation:

Mazed, M. K., M. S. Hossain, S. Ahammed, E. Ara and M. M. Rahman. 2026. Comparative evaluation of management strategies for *Bactrocera cucurbitae* (Coquillett) in ash gourd. *Ann. Bangladesh Agric.* 29(2): 141-155

ABSTRACT

The cucurbit fruit fly *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae) is a key pest that causes substantial yield losses 30–100% depending on host species, season, and infestation pressure in ash gourd (also known as wax gourd; *Benincasa hispida*) (Thunb.) Cogn. production. This study evaluated the efficacy of integrating trap cropping (Local ash gourd germplasm “363”) along with chemical control (cypermethrin) compared with chemical control (cypermethrin) alone, trap cropping alone, and an untreated control in suppressing fruit fly populations and fruit infestations. A field experiment was conducted following a randomized complete block design with four treatments during the period of 90 days. Fruit fly populations and infestation levels were monitored at 45, 60, 75, and 90 days after treatment. The results demonstrated that the combination of trap cropping and chemical insecticide application significantly reduced fruit fly density (2.25 fruit fly/plot) and fruit damage (0.875 infested fruits/plot) compared to the other treatments, while the highest fruit fly density (14.2 fruit fly/plot) and fruit damage (3.75 infested fruits/plot) were recorded in the untreated control. Chemical control alone provided moderate suppression, whereas trap cropping alone showed limited effectiveness. The untreated control sustained the highest pest populations and fruit infestations.

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https://doi.org/10.3329/aba.v29i2.83974
ISSN 1025-482X (Print)/2521-5477 (Online)

Introduction

Ash gourd (also known as wax gourd; *Benincasa hispida*) (*Benincasa hispida*), a widely cultivated cucurbit in South and Southeast Asia, has considerable economic and nutritional importance. Various parts of the plant, including fruit peel, flowers, seeds, and leaves, are utilized for food and medicinal purposes. The fruit exhibits diverse biochemical activities, such as antioxidative, anti-inflammatory, antiangiogenic, detoxifying, and curative effects for multiple ailments (Gupta *et al*., 2019). In Bangladesh, ash gourd is extensively grown, covering approximately 26,191.44 acres and producing approximately 101,815.14 metric tons annually (BBS, 2023). Morphologically, it is a large climbing herb with slabby, fast-growing stems, bears cylindrical fruits 30-45 cm long and is coated with a waxy layer (Doharey *et al*., 2021).

Ash gourd fruit is rich in moisture (approximately 96%) and is a valuable source of vitamins B1, B3, and C; carbohydrates; and essential minerals such as calcium, sodium, zinc, iron, and phosphorus (Amin *et al*., 2017). Phytochemical analyses have identified key constituents, including volatile oils, glycosides, saccharides, proteins, carotenes, flavonoids, vitamins, minerals, β-sitosterol, and uranic acid (Doharey *et al*., 2021). The chemical composition of seeds includes high dietary fiber (58.43%), crude protein (11.63%), and crude fat (20.70%), with seed oil comprising predominantly linoleic acid (67.37%), palmitic acid (17.11%), oleic acid (10.21%), and stearic acid (4.83%) (Sew *et al*., 2010). Owing to its high potassium content, ash gourd is beneficial for maintaining healthy blood pressure (Tamilnayagan *et al*., 2017). Additionally, bioactive compounds such as phenolics, sterols, and glycosides have therapeutic effects on epilepsy, ulcers, and other nervous disorders, and their antacid properties help regulate body pH (Gupta *et al*., 2019).

Beyond its nutritional and medicinal value, ash gourd holds significant agronomic importance in Bangladesh as a major summer vegetable, particularly during periods when the diversity and availability of vegetables are limited. Its extended fruiting period and high consumer demand during this lean season make it a vital crop for ensuring household nutrition and farmer income stability.

Despite these benefits, ash gourd produces considerable yield losses due to insect pests and diseases, particularly the cucurbit fruit fly *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae), which can cause a 30–100% yield reduction (Dhillon *et al*., 2005). Conventional management primarily relies on synthetic insecticides, such as cypermethrin-based formulations, but these pose significant challenges, including the development of resistance, pesticide residues, the resurgence of secondary pests, and detrimental effects on nontarget beneficial organisms such as pollinators (Rahaman and Prodhan, 2007; Munmun, 2017). Moreover, pesticide use raises concerns regarding human health, environmental safety, and biodiversity loss. Conventional management primarily relies on synthetic insecticides, such as cypermethrin-based formulations, but these pose significant challenges, including the development of insecticide resistance (Sparks and Nauen, 2015; Isman, 2020), pesticide residues on edible parts (Aktar *et al*., 2009; Islam *et al*., 2020), the resurgence of secondary pests following natural enemy disruption (Thomson and Hoffmann, 2006; Prasad and Prabhakar, 2012) and detrimental effects on nontarget beneficial organisms such as pollinators and parasitoids (Desneux *et al*., 2007; Stanley *et al*., 2015). Moreover, pesticide use raises concerns regarding human health (Damalas and Eleftherohorinos, 2011) and environmental safety, contributing to biodiversity loss and ecological imbalance (Geiger *et al*., 2010; Pisa *et al*., 2015).

Ash gourd is vulnerable to a wide spectrum of insect pests, including fruit flies, red pumpkin beetles, striped and twelve-spotted cucumber beetles, spider mites, melon aphids, squash borers, squash bugs, and leaf miners (Dhillon *et al*., 2005). Among these bacteria, *Bactrocera cucurbitae* is the most destructive, causing 20-100% infestation depending on the cucurbit species, climate, and season (Sapkota *et al*., 2010). In Bangladesh, fruit infestation rates of 71.5% and 21.0% have been reported for sweet gourd and ridge gourd, respectively (Amin *et al*., 2011). However, studies investigating the use of ash gourd germplasm as a trap crop against cucurbit fruit flies are limited.

Therefore, there is an urgent need to develop eco-friendly, sustainable pest management strategies to reduce reliance on hazardous chemicals. Among alternative approaches, trap cropping has gained attention. This method involves planting more attractive or susceptible crops adjacent to the main crop to divert pest populations and minimize damage, reducing the need for chemical control. Trap cropping is an eco-friendly pest management strategy that involves planting a more attractive or susceptible crop near the main crop to divert pests and minimize damage (Dhillon *et al*., 2005). In Bangladesh, *Bactrocera cucurbitae* is a major pest affecting cucurbits such as bitter gourd, ridge gourd, and snake gourd, with infestation rates varying among crops (Amin *et al*., 2011). Common trap crops include blue hubbard squash, which attracts squash bugs and cucumber beetles, and ribbed gourd, which is highly effective against cucurbit fruit flies (Sapkota *et al*., 2010; Alam *et al*., 2021). These trap crops reduce the need for chemical pesticides, protecting beneficial organisms and promoting biodiversity (Dhillon *et al*., 2005). However, their effectiveness depends on pest species, local agroecological conditions, and the timing and placement of trap crops (Sapkota *et al*., 2010). Research gaps remain in optimizing trap crop strategies for specific pest complexes and agroecosystems, as well as in integrating trap cropping with other pest management practices to maximize efficacy (Alam *et al*., 2021).

This study aims to assess whether integrating trap cropping with conventional farming

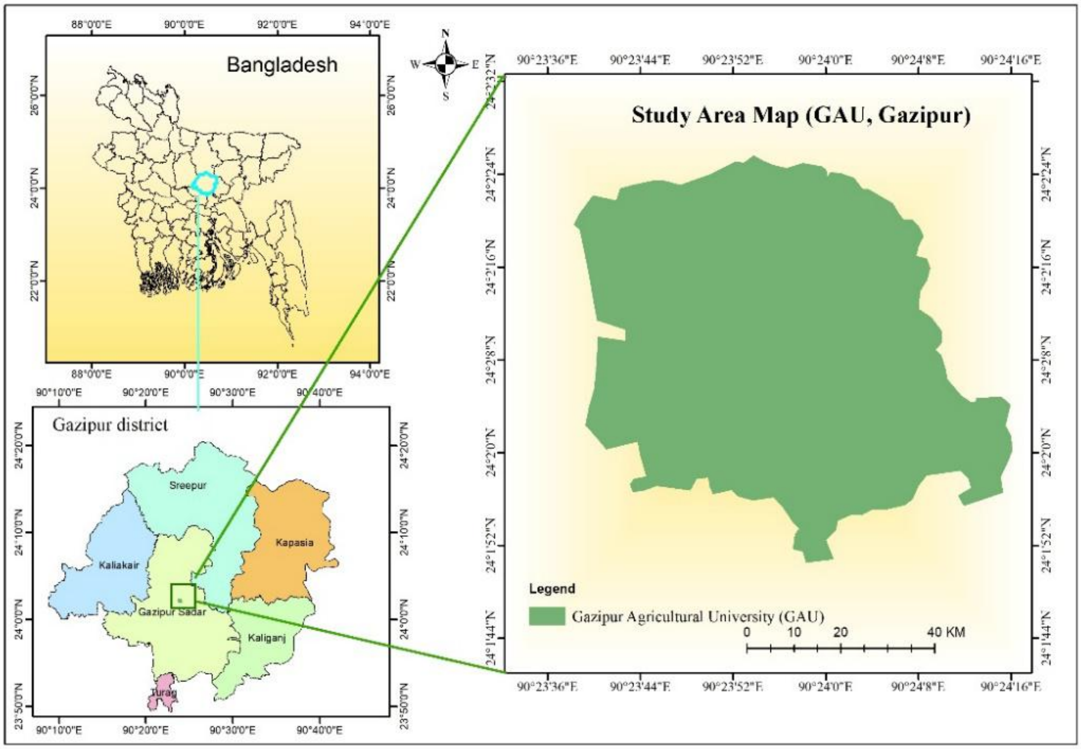

Fig. 1. **Study area map.** (The map was created using software ArcGIS version 10.8.2)

practices can effectively reduce *Bactrocera cucurbitae* infestations on ash gourd, thereby protecting the main crop and promoting sustainable, environmentally safe pest management.

Materials and methods

Study site and conditions

The present study was carried out in the crop fields of the Department of Entomology, Gazipur Agricultural University, Gazipur, Bangladesh, during the ash gourd growing season (from January 2023 to June 2024). The site is located at 25°25′ N and 89°5′ E and has a mean maximum temperature of 36.0°C, a mean minimum temperature of 12.7°C, 65.8% relative humidity, and 237.6 cm of annual rainfall.

Treatments

Four pest management strategies were evaluated in this experiment. Treatment 1 (T1) employed an integrated approach combining trap cropping with chemical control, where cypermethrin 10 EC (Ripcord) was applied @ 1 mL L^{-1} of water with trap cropping. Treatment 2 (T2) relied solely on chemical control with Cypermethrin 10 EC at the same concentration @ 1 mL L^{-1} of water, without the inclusion of trap crops. Treatment 3 (T3) consisted exclusively of trap cropping and Treatment 4 (T4) served as the untreated control with no pest management intervention.

Trap crop

The trap crop consisted of the local ash gourd (*Benincasa hispida*) germplasm "363," which is maintained by the Bangladesh Agricultural Research Institute and is highly susceptible to cucurbit fruit fly (*Bactrocera cucurbitae*) infestation. This germplasm was selected for its proven attractiveness to fruit flies, acting as a pest sink to divert oviposition away from the main crop. The trap crops were established along the outer borders of the experimental plots at a density of one plant per square meter (spacing 1.0 m × 1.0 m), ensuring continuous perimeter coverage. Chemical applications in T1 and T2 commenced 30 days after transplanting and were repeated at 15-day intervals until crop termination, in accordance with standard agronomic recommendations.

Crop management

The experiment was conducted using a Randomized Complete Block Design (RCBD) with three replications. Each plot measured 3 m × 3 m, accommodating 36 ash gourd (*Benincasa hispida*) plants at a spacing of 50 cm × 50 cm. Standard crop management practices, including irrigation, fertilization, and weed control, were uniformly applied to ensure optimal growth and minimize confounding effects. Irrigation was provided regularly, with increased frequency during flowering and fruiting stages, while fertilization included both organic and inorganic nutrients based on soil test recommendations. Weed management was carried out through timely manual weeding and mulching, consistent with standard cultivation practices in Bangladesh (Amin *et al*., 2011; Islam *et al*., 2015; Hossain *et al*., 2018).

Data collection

Fruit fly populations were monitored at 45, 60, 75, and 90 days after treatment (DAT) via sweeping, and visual counting of fruit and foliage. Adult fruit flies were counted per plot during each sampling event. Concurrently, fruit infestation was assessed by randomly selecting 20 fruits per plot and examining them for oviposition punctures and larval damage to determine the number of infested fruits.

Statistical analysis

The data were analyzed via R software version 4.3.0 (R Core Team, 2023). Analysis of variance (ANOVA) was performed via the "aov ()" function to evaluate the effects of treatments on fruit fly populations and infestation levels. Mean comparisons were conducted via Tukey's honest significant difference (HSD) test via the "Tukey HSD ()" function at a significance threshold of $p < 0.05$. Prior to analysis, data normality was assessed via the Shapiro-Wilk test, and homogeneity of variance was examined via Levene's test implemented through the car package. When necessary, the data were transformed (e.g., log or square root transformation) to satisfy ANOVA assumptions. Pearson's correlation coefficient was calculated via the "cor. test()" function to determine the relationship between fruit fly population density and fruit infestation. All the statistical tests were two-tailed.

Results and Discussion

Fruit fly population dynamics

This study assessed the efficacy of four management strategies against *Bactrocera cucurbitae* on ash gourd across four observation periods of 45, 60, 75, and 90 days after treatment (DAT). The treatments included the following: T1, trap cropping combined with farmer practices using cypermethrin; T2, farmer practices with cypermethrin alone; T3, trap cropping alone; and T4, an untreated control. Across all the sampling dates, T1 consistently presented the lowest number of fruit fly populations, ranging from 2.5 ± 1.91 at 45 DAT to 1.5 ± 1.29 at 75 DAT, with an overall mean of 2.25 flies per plot. This superior performance is likely attributable to the synergistic interaction between trap cropping, which diverts ovipositing females from the main crop, and cypermethrin, a pyrethroid insecticide with proven efficacy against fruit flies (Shelton and Nault, 2004; Galic *et al*., 2010). In contrast, T2 (cypermethrin alone) achieved only moderate suppression, with fly populations ranging from 5.5 ± 2.65 at 45 DAT to 6.25 ± 1.50 at 90 DAT (mean = 5.75). The reduced and less consistent efficacy compared with T1 may be linked to the absence of a trap crop component and the relatively short residual activity of cypermethrin under field conditions (Elliott *et al*., 2019), which permits partial pest resurgence. Trap cropping alone (T3) yielded greater mean fruit fly numbers (8.67 per plot), suggesting that while trap crops can reduce pest pressure, the absence of a lethal control measure allows population recovery through uninterrupted reproductive cycles (Kossou *et al*., 2009). As expected, the untreated control (T4) harbored the greatest

Table 1. Effects of different treatments on the reduction of fruit fly populations

Treatments	No of fruit fly/plot				Mean
	45 DAT	60 DAT	75 DAT	90 DAT	
T1	2.5 ±1.9 ef	2.5± 1.29 ef	1.5 ± 1.29 f	2.5 ± 1.29 ef	2.25 ± 0.63d
T2	5.5 ± 2.65 ef	6.5 ± 2.65 cde	4.75±1.26 ef	6.25 ±1.5 def	5.75 ± 0.63c
T3	9 ± 2.16 abcde	7.75 ± 1.5 bcdef	9.5 ± 1.29 abcde	8.5 ± 2.38 abcdef	8.67 ± 0.63b
T4	13.5±3.42 abcd	14±5.23 ab	15.5±2.08 a	13.8±5.74 abc	14.2 ± 0.63a

[Treatment 1: Trap cropping + Farmer's practice (Ripcord 10 EC (cypermethrin) @ 1 ml/l of water), Treatment 2: Farmer's practice {Ripcord 10 EC (cypermethrin) @ 1 ml/l of water}, Treatment 3: Trap cropping, Treatment 4: Untreated control] number of infestations (mean = 14.2 flies per plot) (Table 1), confirming the susceptibility of ash gourd to heavy infestations in the absence of intervention (Elzinga *et al*., 2007). Statistical analyses confirmed that T1 was significantly more effective than all other treatments were, providing robust evidence that integrating trap cropping with chemical control delivers superior suppression of *B. cucurbitae* populations compared with either strategy alone.

Infestation levels of fruit flies

The extent of fruit infestation strongly corresponded with the observed fruit fly population dynamics. As shown in Table 2, the number of infested fruits per plot varied markedly among the treatments across the four observation periods. The integrated approach (T1: trap cropping combined with cypermethrin application) consistently resulted in the lowest mean infestation (0.875 fruits per plot), with values ranging from 0.5 ± 0.58 at 60 DAT to 1.25 ± 0.50 at 90 DAT. This substantial reduction can be attributed to the synergistic effect of trap cropping, which diverts gravid females away from the main crop, and targeted insecticide application, which suppresses residual pest populations. Such integration not only disrupts *Bactrocera cucurbitae* oviposition behavior but also mitigates subsequent larval establishment, thereby minimizing crop damage (Srinivasan, 2010; Shelton *et al*., 2014). These findings corroborate previous reports that combining behavioral manipulation with chemical suppression enhances overall pest control efficacy while lowering the likelihood of economic loss (Barzman *et al.,* 2015).

T2, which involved the application of cypermethrin alone, moderately reduced fruit infestation, with a mean of 1.44 infested fruits per plot (Table 2). However, this chemical-only approach did not achieve the enhanced suppression observed when trap cropping was integrated. Trap cropping alone (T3) resulted in a mean infestation of 1.67 fruits per plot, indicating that while trap crops can partially divert pests, they do not provide sufficient control without lethal treatment. The untreated control (T4) consistently presented the highest

Table 2. Impact of different treatments on reducing the number of infested fruits

Treatments	No of infested fruit/plot				Mean
	45 DAT	60 DAT	75 DAT	90 DAT	
T1	0.75 ± 0.5 d	0.5 ± 0.577 d	1 ± 0.8160 d	1.25 ± 0.5 d	0.875 ± 0.16c
T2	1.5 ± 0.577 cd	1.25 ± 0.5 d	1.25 ± 0.5 d	1.75 ± 0.5 cd	1.44 ± 0.16b
T3	1.75 ± 0.5 cd	2 ± 0.816 bcd	1.5 ± 0.577 cd	1.5 ± 0.577 cd	1.67 ± 0.16b
T4	4 ± 0.816 a	4.5 ± 0.577a	3.5 ± 0.577 ab	3 ± 0.816 abc	3.75 ± 0.16a

[Treatment 1: Trap cropping + Farmer’s practice (Ripcord 10 EC (cypermethrin) @ 1 ml/l of water), Treatment 2: Farmer’s practice {Ripcord 10 EC (cypermethrin) @ 1 ml/l of water}, Treatment 3: Trap cropping, Treatment 4: Untreated control] infestation levels, averaging 3.75 infested fruits per plot, underscoring the significant economic risks posed by unmanaged fruit fly populations. The untreated control (T4) presented the highest infestation level, with an average of 3.75 infested fruits per plot, highlighting the economic risk of unmanaged fruit fly populations.

A comparative analysis of the efficacy of the four pest management strategies (T1–T4) in reducing fruit fly infestations on ash gourd, measured as the number of infested fruits per plot at 45, 60, 75, and 90 days after transplanting (DAT). The integrated treatment T1, which combines trap cropping with chemical control, consistently achieved the most effective reduction throughout the study period, with a mean of 0.875 infested fruits per plot, ranging from 0.75 ± 0.5 at 45 DAT to 1.25 ± 0.5 at 90 DAT (Table 2). This consistently low infestation highlights the strength of an integrated pest management approach, where trap cropping diverts pests from the main crop and chemical agents suppress population buildup. These findings align with those of Shelton *et al*. (2014), who emphasized the benefits of combining trap cropping with additional control methods to maximize pest suppression.

The statistical separation of treatments, indicated by distinct lowercase letters in Table 2, further emphasized the significant superiority of T1 over the other treatments. In contrast, the untreated control (T4) presented the highest infestation level, peaking at approximately 60 DAT and averaging 3.75 infested fruits per plot. The T2 treatment (cypermethrin alone) had moderate effectiveness but was markedly less effective than the integrated approach (T1), suggesting that chemical control alone may be insufficient without complementary strategies such as trap cropping. Treatment T3 (trapping alone) had intermediate and somewhat variable efficacy, with a mean infestation of 1.67 fruits per plot, indicating that trap cropping alone may not consistently suppress fruit fly populations under field conditions. Overall, the data and graphical results affirm that integrated pest management, especially the combination of trap cropping and chemical application, offers a sustainable and superior strategy for managing cucurbit fruit fly infestations in ash gourd cultivation.

Fig. 4 presents a correlation matrix illustrating the relationships between two key variables: the number of fruit flies per plot (NFFP) and the number of infested fruits per plot (NIFP). The upper right panel displays a Pearson correlation coefficient of 0.76 ($p < 0.001$), indicating a strong, statistically significant positive correlation. This implies that an increase in fruit fly abundance is closely associated with increased fruit infestation levels. The lower left panel shows a scatter plot of NFFP versus NIFP, overlaid with a regression line and its 95% confidence interval, visually confirming the positive association. The diagonal panels depict histograms of each variable's distribution, revealing a slightly right-skewed pattern for

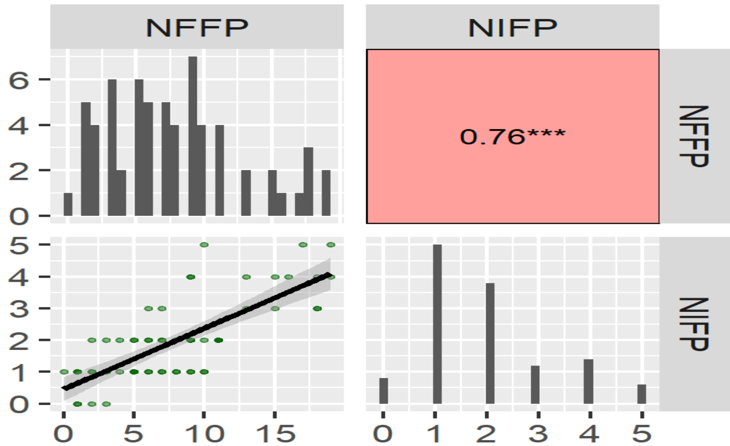

Fig. 4. Relationship between treatment and infested fruits at multiple time points: correlation analysis. (where NFFP = the number of fruit flies/plot and NIFP = the number of infested fruits/plot).

NFFP and a left-skewed distribution for NIFP. These distributional insights aid in assessing data normality and potential biases relevant for correlation and regression analyses.

Collectively, these data demonstrate that fruit fly population density directly influences the extent of fruit infestation, supporting the biological premise that greater adult fruit fly populations increase oviposition rates and consequently fruit damage. This strong and significant correlation underscores the critical need for effective fruit fly population management to mitigate crop losses. These findings support integrated pest management (IPM) strategies that combine ecological methods such as trap cropping with chemical control to effectively suppress fruit fly populations, thereby increasing crop health and yield. Overall, Fig. 4 highlights the utility of monitoring NFFP as a predictive and preventive tool for managing NIFP within ash gourd production systems.

Fig. 5 presents a multivariate heatmap and dendrogram illustrating the clustering of treatments on the basis of pest infestation level and crop yield. The T1 treatment resulted in a distinct cluster characterized by the lowest infestation and the highest yield (35.71 t/ha). In contrast, treatment T4 clustered separately, with the highest infestation rate and the lowest yield (18.91 t/ha). Treatments T2 and T3 were grouped together in an intermediate cluster, reflecting their moderate efficacy in pest control. The observed negative correlation between pest growth and productivity.

The present study demonstrated that integrating trap cropping with cypermethrin application (T1) provided the most effective and consistent suppression of *Bactrocera cucurbitae* populations and fruit infestation in ash gourd. This integrated approach likely achieves superior results through the combined action of behavioral diversion to

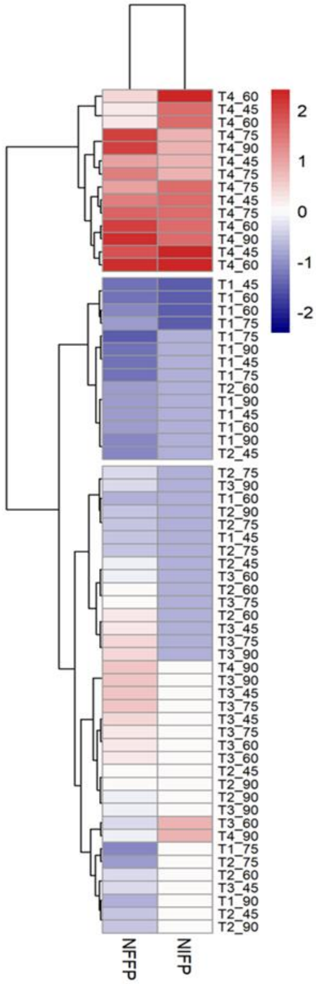

Fig. 5. Heatmap of infestation levels in response to treatments across four time points [treatments: T1, T2, T3 and T4; days after sowing (DAT): 45, 60, 75 and 90; NFFP = number of fruit flies/plot; NIFP = number of infested fruits/plots].

reduce pest pressure on the main crop, and chemical lethality eliminates a significant proportion of adults attracted to the treated area. Similarly, previous studies have reported that combining trap cropping with insecticides or other control measures can substantially increase the management efficacy in cucurbit agroecosystems (Shelton and Nault, 2004; Srinivasan *et al*., 2007; Hasyim *et al*., 2014).

The effectiveness of T1 over T2 (cypermethrin alone) underscores a key limitation of sole chemical reliance: without diversionary tactics, pest pressure remains concentrated on the main crop, leading to faster reinfestation.

Moreover, pyrethroids such as cypermethrin, although effective in the short term, are susceptible to environmental degradation via photolysis and hydrolysis, which decreases their residual activity under tropical field conditions (Elliott *et al.,* 2019; Isman, 2020). The reduced residual efficacy, combined with the absence of pest diversion, likely explains the less consistent suppression in T2.

Trap cropping alone (T3) yielded intermediate control, supporting the hypothesis that while trap crops can significantly divert pests, they can also act as reservoirs for pest reproduction in the absence of lethal measures (Kossou *et al*., 2009; Hasyim *et al*., 2014). This aligns with studies on cucurbit fruit fly ecology, which suggest that females attracted to trap crops may continue oviposition, sustaining pest populations if trap plants are not regularly destroyed or treated (Dhillon *et al*., 2005).

The untreated control (T4) sustained the greatest pest abundance and fruit damage, reinforcing the severe vulnerability of ash gourd to *B. cucurbitae*. The yield reduction in this treatment (18.91 t/ha) aligns with reported economic losses exceeding 30–60% in cucurbit crops under unmanaged conditions (Dhillon *et al*., 2005; Vayssières *et al*., 2009).

The strong positive correlation between adult fruit fly density and infestation level ($r = 0.76$, $p < 0.001$) is consistent with pest biology: higher adult abundance increases oviposition frequency, leading to proportionally greater fruit damage (Ekesi *et al*., 2007). This correlation highlights the value of adult monitoring as an early warning tool in IPM programs, allowing timely interventions before infestation levels exceed economic thresholds.

From a broader integrated pest management (IPM) perspective, integrating trap cropping with targeted insecticide applications offers multiple advantages, including reduced dependence on chemical control, which can lower both the application frequency and dosage, thereby minimizing environmental impacts and production costs (Pretty and Bharucha, 2015). Furthermore, this approach can slow the evolution of insecticide resistance in pest populations (Mota-Sanchez and Wise, 2023). Trapping is also compatible with ecological control measures, supporting the conservation of beneficial biological control agents and pollinators (Hooks and Johnson, 2003). However, the effectiveness of this integrated strategy relies on several critical factors, such as the optimal placement of trap crops, the selection of highly attractive cultivars, and synchronized management practices such as targeted spraying or timely destruction of trap plants to prevent pest buildup. For sustainable adoption, long-term field validation across diverse agroecological zones, coupled with comprehensive cost-benefit analyses, is essential to ensure both effectiveness and farmer acceptance.

Overall, these findings provide strong empirical support for IPM strategies that combine ecological and chemical tactics to achieve sustainable control of *B. cucurbitae*.

The approach used here aligns with global trends toward environmentally sound pest management, balancing productivity with reduced reliance on broad-spectrum insecticides.

Conclusion

This study demonstrated that trap cropping + cypermethrin (T1) is the most effective treatment for both reducing fruit fly populations and preventing fruit infestations. T2 (cypermethrin alone) was also effective but to a lesser degree, whereas T3 (trap cropping alone) and T4 (untreated control) were significantly less effective. These findings suggest that integrated pest management strategies that combine biological control (trapping) and chemical control (cypermethrin) offer the most reliable approach for managing fruit fly populations and minimizing crop damage. Future studies should focus on optimizing the timing, dosage, and combination of pest management strategies to increase their effectiveness under different environmental conditions.

Acknowledgment

The authors gratefully acknowledge the financial support provided by the Research Management Wing, Gazipur Agricultural University, Gazipur-1706, Bangladesh, under the Innovation Project Fund (2023–2024; Project No. 01; Memorandum No. 37.12.0000.133.34.003.20). The authors also thank the Department of Entomology, Gazipur Agricultural University, for providing technical assistance and research facilities throughout the study.

Conflict of Interest

The authors affirm that no financial or commercial relationships that might be construed as a potential conflict of interest existed during the course of the research.

Author Contributions

Conceptualization, Md. Khairul Mazed and Md. Mamunur Rahman; methodology, Md. Khairul Mazed; software, Sohag Ahammed; validation, Effat Ara, Md. Mamunur Rahman, and Md. Shamim Hossain; resources, Md. Khairul Mazed; data curation, Md. Khairul Mazed; writing-original draft preparation, Md. Khairul Mazed; writing- review and editing, Effat Ara; visualization, Md. Shamim Hossain; supervision, Md. Mamunur Rahman; project administration, Md. Khairul Mazed; revenue acquisition, Md. Khairul Mazed. All authors have read and approved the final version of the manuscript.

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