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Effect of different management practices on sucking insect pests, disease incidence, and natural enemies in tomato plants

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Abstract

Tomato (*Solanum lycopersicum* L.) is a nutritionally important vegetable crop, rich in vitamins, minerals, fiber, and antioxidants; however, its production in Bangladesh is severely constrained by sucking insect pests, and various management practices have been adopted to address these challenges. In this study, a field experiment was conducted with five treatments-cultural, mechanical, biorational, sequential bio-pesticide application, and an untreated control to evaluate the effects of these management approaches on the population dynamics of sucking insect pests, namely aphids, whiteflies, and thrips, in tomato, as well as on the incidence of leaf curl disease and the abundance of their natural enemies. Among the treatments, sequential management maintained the lowest populations of sucking pests, reducing aphids to 7.8 plant^{-1} compared with 15.4 plant^{-1} in control and lowering whitefly to 8.4 plant^{-1} versus 16.4 plant^{-1}. Thrips were also minimized (3.0 plant^{-1}) compared with control (5.0 plant^{-1}). Leaf curl incidence was lowest under sequential (6.4%) and biorational (9.2%) treatments. Natural enemy abundance was highest in the control plots, while sequential and biorational treatments recorded comparatively lower population. Overall, sequential management proved most effective in suppressing pests and disease while maintaining ecological balance, suggesting its suitability as a sustainable tomato pest management strategy.

Keywords: Pest population dynamics, Bio-pesticide, Sequential management, Tomato production

Introduction

Tomato (*Solanum lycopersicum* L.) is a major vegetable crop widely cultivated worldwide, valued not only for its culinary versatility but also for its rich nutritional profile. It is an excellent source of simple sugars, dietary fiber (especially insoluble fiber), essential vitamins such as A, B-complex, and C, and important minerals including potassium, magnesium, and iron, contributing to human health and nutrition (Hossain *et al*. 2025). According to the Bangladesh Bureau of Statistics (BBS 2024), tomato production in Bangladesh during the 2023–2024 financial year reached 4.91 million metric tons, cultivated over an area of approximately 80,000 ha.

Tomato crops are exposed to numerous abiotic and biotic stresses that significantly limit yield. Among the biotic constraints, sucking insect pests, particularly whitefly (*Bemisia tabaci*), aphid (*Aphis gossypii)*, and thrips (*Thrips tabaci)* pose severe challenges, causing substantial damage to tomato plants. Aphids attack stems, shoots, petioles, flowers, and pods, and can transmit viruses such as tomato yellow leaf curl virus (TYLCV), potato virus Y (PVY), and cucumber mosaic virus (CMV) (Mondal *et al*. 2024). Whiteflies inflict direct feeding damage, excrete honeydew that promotes sooty mold, and transmit viral pathogens, causing yellowing, curling, and premature leaf drop, with infestation severity potentially resulting in 10–90% loss of tomato crops depending on the growth stage and pest density (Mondal *et al*. 2024). Thrips damage tomato fruits and leaves by rasping tissues and sucking sap, leading to scarring, discoloration, and deformation, which reduce both yield and market quality, with potential losses reaching 23.7% (Mondal *et al*. 2024).

The populations of the insect pests are strongly influenced by weather conditions, seasonal variations, the growth stages of the host plants, plant characteristics, and the presence of natural enemies. For instance, a study reported the presence of eight predator species belonging to the orders Acari, Hymenoptera, Coleoptera, Diptera, and Neuroptera in tomato fields (Rahman *et al*. 2018), highlighting the importance of biological control in pest management.

In Bangladesh, most tomato growers rely heavily on chemical pesticides, applying them frequently, while the adoption of alternative pest management strategies remains limited. Although previous studies have demonstrated the efficacy of bio-pesticides such as spinosad, Bio-Chamak, and neem-based formulations in suppressing major tomato pests (Islam *et al*. 2020), several challenges hinder their wider adoption. These include limited field-level validation under diverse agroecological conditions, inconsistent performance compared to conventional insecticides, lack of information on their economic viability, and low awareness among farmers regarding their proper use and integration into pest management programs. Furthermore, the compatibility of these bio-pesticides with natural enemies and their role in sustainable pest regulation remain insufficiently explored. Therefore, there is a need to evaluate these alternatives under field conditions to develop effective, economically viable, and environmentally sustainable pest management strategies. Accordingly, this study aimed to evaluate cultural, mechanical, and biorational approaches as environmentally sustainable strategies for managing major insect pests of tomato. Specifically, the objectives were to assess the effects of these management practices on the abundance of aphids, whiteflies, and thrips, the incidence of leaf virus diseases, and the populations of natural enemies in tomato cultivation.

Materials and methods

Experimental site and cultivation of tomato plants: The study was conducted from July 2024 to June 2025 at the Department of Entomology, Gazipur Agricultural University, Gazipur (25°25′N, 89°05′E), Bangladesh. The region has a tropical seasonal climate with dry (Feb–May), monsoon (Jun–Sep), and short winter (Dec–Jan) periods, mean annual temperature of 12.7–36 °C, 65.8% average humidity, and ~237.6 cm annual rainfall (Amin *et al*. 2016). Seeds of the tomato variety BARI Tomato-18 were collected from the Plant Genetic Resources Centre, Joydebpur, Gazipur, and seedlings were raised in a well-prepared seedbed. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The field comprised 15 plots (3 m × 2 m) with 1 m spacing between plots and blocks. Five treatments were assigned across three blocks, and tomato seedlings were transplanted on November 28, 2024. Fertilizers were applied as per FRG (2018), and regular intercultural practices were performed to ensure healthy plant growth.

Experimental treatments: The treatments evaluated in this study were T_1: Cultural management (Field sanitation and intercropping with sweet corn variety BU Sweet corn 1), T_2: Mechanical management (Hand picking, clipping infested parts, and setting yellow sticky trap), T_3: Biorational management (Spraying of Bio-chamak), T_4: Sequential application (Bio-chamak followed by water spray and bio-chamak), and T_5: Untreated control (Plots received no pest management interventions).

Data collection for the abundance of sucking insect pests and natural enemies: Data of the abundance of the sucking insect pests were collected at 7-day intervals starting from the early vegetative stage until the final harvest. Observations were carried out during the early morning hours, when insect activity was relatively stable and environmental disturbance was minimal. Aphid, whitefly, and thrips populations were recorded on a per plant basis by randomly selecting five plants and tagging them from each plot. Data of the natural enemies were recorded by visual observation, examining all plants within a plot to record the total number of natural enemies. The recorded data were expressed as number of individuals per plot.

Estimation of leaf curl index: The incidence of leaf curl disease incidence was evaluated by calculating the Leaf Curl Index (LCI) at different growth stages of the plant. Observations were recorded from the tagged plants in each replication. Each plant was visually assessed for leaf curling symptoms at 30-day intervals using a scoring scale: 0 = no symptoms; 1 = curling of 1–25% of leaves; 2 = curling of 26–50% of leaves; 3 = curling of 51–75% of leaves; and 4 = curling of more than 75% of leaves (Latha and Hunumanthraya 2018). The Leaf Curl Index was then calculated using the following formula-

$$\text{Leaf Curl Index (\%)} = \frac{\text{Sum of numerical ratings}}{\text{Highest grade of rating} \times \text{Total plants examined}} \times 100$$

Statistical analysis: Data analysis was performed using the statistical software IBM SPSS version 26.0. A one-way analysis of variance (ANOVA) was conducted to evaluate the variation in the abundance of insect pests. Tukey's HSD post-hoc test was applied at a 5% significance level to identify significant differences between treatments.

Results and discussion

Aphid populations on tomato varied significantly among pest management treatments from December 2024 to February 2025 (Figure 1). Initial aphid densities were low (3.6–5.4 aphids plant^{-1}) but increased steadily, reaching a peak between late December and January, which is consistent with typical seasonal trends (Khokhar and Rolania 2021).

The sequential application of bio-chamak alternated with water spray resulted in the lowest aphid abundance throughout the study, with a peak of 15.8 aphid plant^{-1} that declined sharply to 0.6 by late February. Biorational treatment also effectively suppressed aphids, whereas cultural and mechanical methods provided only moderate control. The untreated control recorded the highest infestation, peaking at 23 aphid plant^{-1}.

Monthly dynamics indicated population buildup during vegetative and early flowering stages, followed by a decline toward fruiting, likely due to management interventions and environmental factors (Landge *et al*. 2024). These results are consistent with previous studies demonstrating that sequential or integrated applications of botanical and biopesticide agents effectively reduce aphid populations compared to single-method treatments (Amin *et al*. 2017; Hasan and Das 2021).

Mean aphid abundance on tomato differed significantly among management practices (Figure 2). The untreated control recorded the highest population (15.4 ± 2.1 aphid plant^{-1}), reflecting rapid reproduction and unchecked infestation (Khokhar and Rolania 2021; Kwaifa *et al*. 2025).

Sequential management resulted in the lowest mean abundance (7.8 ± 1.4 aphid plant^{-1}), achieving nearly 50% reduction compared to the control. This treatment showed consistent suppression, likely due to repeated application of biorational inputs (Bio-chamak) alternated with water sprays. The biorational treatment also reduced aphid populations (10.3 ± 1.6 aphid plant^{-1}), though slightly less effectively than the sequential approach, indicating

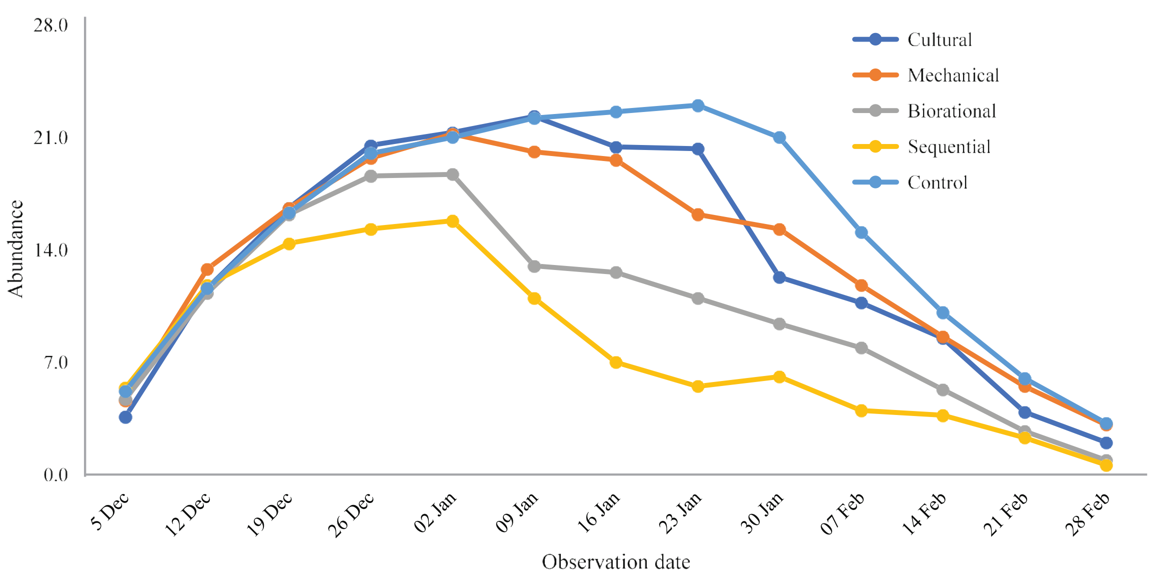

Figure 1. Monthly abundance (number plant^{-1}) of aphid in tomato plants cultivated under different management practices during November 2024 to March 2025 at Gazipur, Bangladesh.

some population recovery under single-method control. Cultural (13.5 ± 1.7 aphid plant^{-1}) and mechanical (13.4 ± 2.0 aphid plant^{-1}) practices provided moderate suppression with greater variability, suggesting limited effectiveness as standalone methods.

Whitefly populations on tomato differed significantly among pest-management treatments during December 2024-February 2025 (Figure 3). Populations increased from early December, peaking in January, consistent with typical seasonal trends (Khokhar and Rolania 2021).

Sequential application maintained the lowest whitefly densities throughout the study, reducing the population to 1.0 individual plant^{-1} by late February. In contrast, the untreated control recorded the highest density (27.2 whitefly plant^{-1}), demonstrating rapid population buildup in the absence of management.

Monthly dynamics indicated population increase during vegetative and early reproductive stages, followed by a decline, influenced by crop phenology and environmental conditions (Naranjo *et al*. 2010). The superior performance of sequential treatment suggests that repeated biorational applications provide sustained suppression while minimizing resurgence. Biorational treatment also reduced whitefly populations, whereas cultural and mechanical practices provided only partial control, highlighting the need for integrated approaches under field conditions (Horowitz *et al*. 2020).

Mean whitefly (*Bemisia tabaci*) abundance differed significantly among pest management treatments (Figure 4). The untreated control recorded the highest population (16.4 ± 2.4 adults plant^{-1}), reflecting rapid population buildup in the absence of management (Adam *et al*. 2025).

Sequential application of Bio-chamak alternated with water sprays resulted in the lowest whitefly density (8.4 ± 1.4 adults plant^{-1}), indicating consistent and effective suppression. The biorational treatment also performed well (9.6 ± 1.3 adults plant^{-1}), though slightly less effective than the sequential approach, suggesting some population recovery under single-method control (Hossain *et al*. 2025). Cultural (12.0 ± 1.8 adults plant^{-1}) and mechanical (11.4 ± 1.6 adults plant^{-1}) practices provided moderate suppression with greater variability, indicating limited reliability as standalone methods (Asiry *et al*. 2022).

Thrips populations on tomato varied significantly among pest management treatments from December 2024 to February 2025 (Figure 5). Initial densities were low (3.0-3.3 thrips plant^{-1}) and increased to a peak in mid-January before declining toward late February, consistent with typical seasonal patterns (Mouden *et al*. 2017).

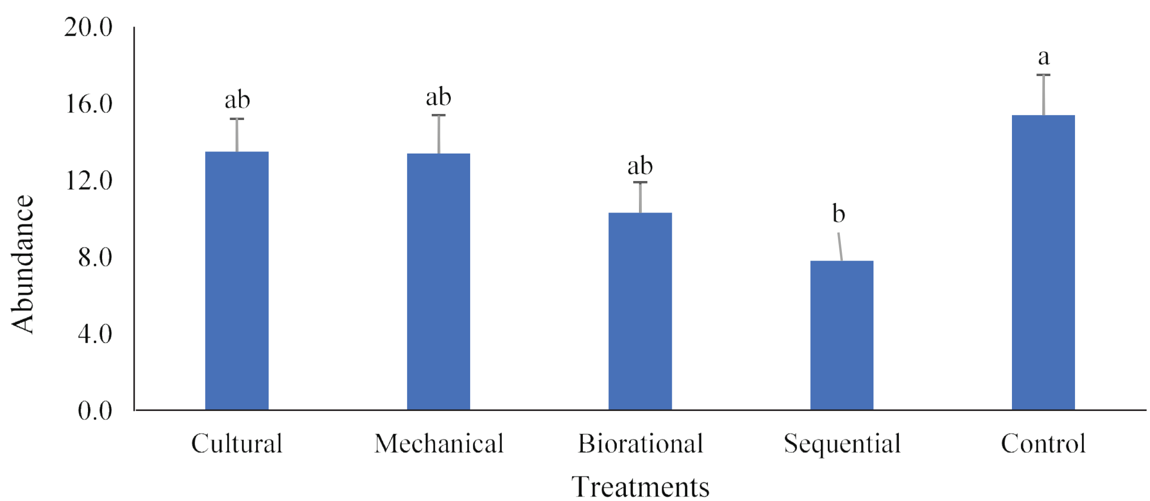

Figure 2. Mean abundance of aphid (number plant^{-1}) in tomato plants cultivated under different management practices during November 2024 to March 2025 at Gazipur, Bangladesh. Data expressed as mean ± SE. Bars with same letter (s) are not significantly different according to Tukey HSD posthoc statistic at p ≤0.05.

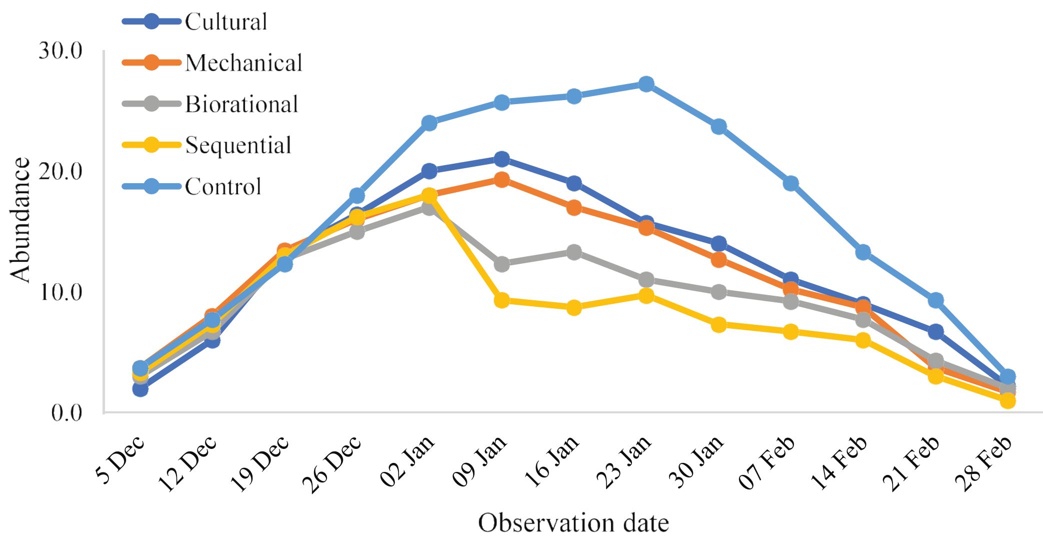

Figure 3. Monthly abundance (number plant^{-1}) of whitefly in tomato plants cultivated under different management practices during November 2024 to March 2025 at Gazipur in Bangladesh.

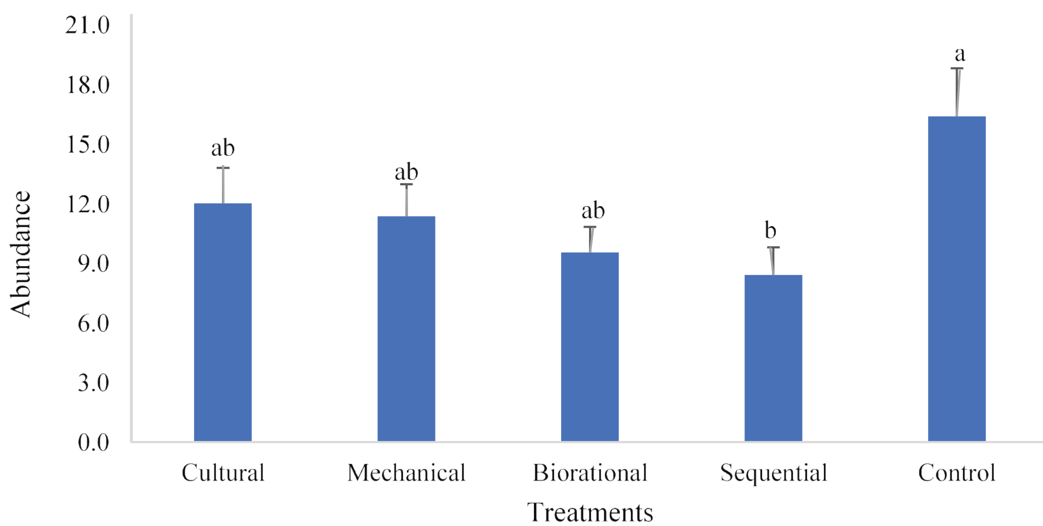

Figure 4. Mean Abundance (number plant^{-1}) of whitefly in tomato plants cultivated under different management practices during November 2024 to March 2025 at Gazipur in Bangladesh. Data expressed as mean ± SE. Bars with same letter (s) are not significantly different according to Tukey HSD posthoc statistic at $p \leq 0.05$.

Sequential application maintained the lowest thrips densities throughout the study, with populations declining rapidly after the peak to 0.6 thrips plant^{-1} by late February. The biorational treatment also effectively reduced thrips, whereas cultural and mechanical methods provided moderate suppression. The untreated control recorded the highest infestation, peaking at 7.5 thrips plant^{-1}.

Seasonal dynamics indicated population buildup during vegetative and early reproductive stages, followed by decline due to environmental factors and crop development. The superior performance of sequential treatment suggests sustained suppression through repeated biorational applications, supporting integrated pest management strategies for effective thrips control (Mouden *et al*. 2017).

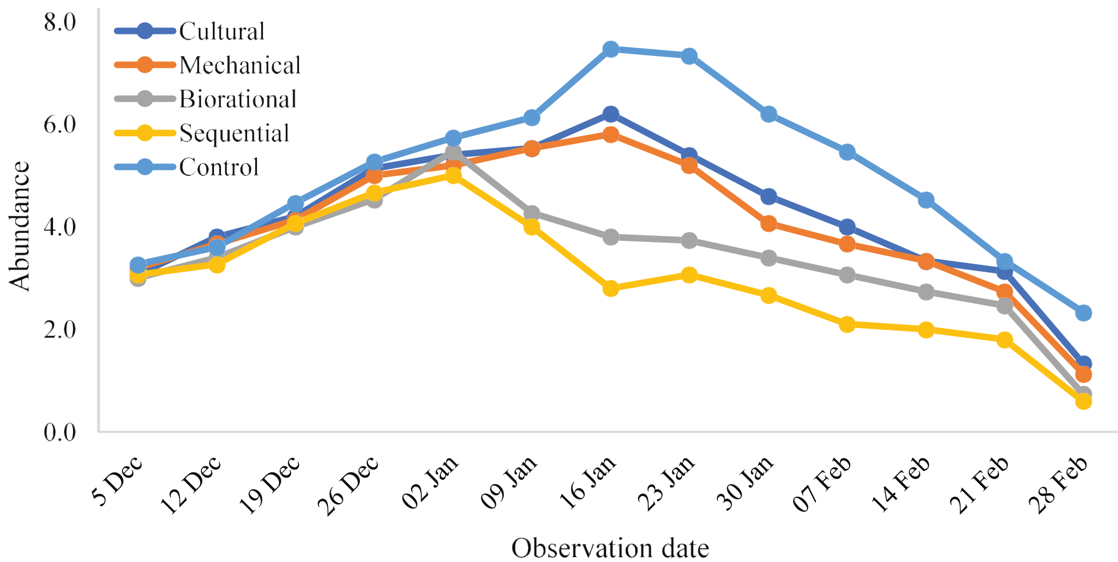

Figure 5. Monthly abundance (number plant^{-1}) of thrips in tomato plants cultivated under different management practices during November 2024 to March 2025 at Gazipur, Bangladesh.

Mean thrips abundance differed significantly among pest management treatments (Figure 6). The untreated control recorded the highest population (5.0 ± 0.44 thrips plant^{-1}), reflecting rapid population buildup in the absence of management (Ingole *et al*. 2024). Sequential application resulted in the lowest mean abundance (3.0 ± 0.34 thrips plant^{-1}), followed closely by the biorational treatment (3.4 ± 0.32 thrips plant^{-1}), both showing consistent and effective suppression. The slightly better performance of the sequential approach suggests that repeated application of biorational inputs provides more sustained control by limiting population recovery across generations (Khan *et al*. 2023). Cultural (4.2 ± 0.37 thrips plant^{-1}) and mechanical (4.0 ± 0.36 thrips plant^{-1}) practices provided moderate suppression and were statistically similar, indicating limited effectiveness as standalone methods.

Leaf curl incidence varied significantly among management practices at 30, 60, and 90 days after infestation (DAI), as well as overall mean values ($p < 0.05$) (Table 1). The untreated control showed the highest incidence, increasing from 19.21 ± 0.91% at 30 DAI to 43.31 ± 0.49% at 90 DAI, with a mean of 31.48 ± 0.58%, reflecting typical progression of tomato yellow leaf curl virus under unmanaged conditions.

Sequential management consistently resulted in the lowest incidence, recording 4.66 ± 0.37%, 6.10 ± 0.10%, and 8.57 ± 1.59% at 30, 60, and 90 DAI, respectively, with the lowest mean (6.44 ± 0.47%). The biorational treatment also effectively reduced incidence (9.23 ± 0.04%), outperforming cultural and mechanical approaches. Cultural (18.29 ± 0.11%) and mechanical (25.04 ± 0.30%) practices provided only moderate suppression and were less effective in limiting disease spread. These results highlight the effectiveness of combining multiple tactics to disrupt virus–vector interactions, which have been recommended for TYLCV control (Riley and Srinivasan 2019).

Abundance of natural enemies varied significantly ($p<0.05$) in tomato ecosystem under different eco-friendly management practices (Table 2). The maximum populations of natural enemies were recorded in untreated control, including Ladybird beetle (15.73±0.37/plot), Green lace wing (10.53±0.29/plot), Spider (29.80±0.75/plot), Black ant (23.13±0.46/plot), Dragonfly (7.13±0.46/plot), and Assassin bug (12.33±0.33/plot).

Ladybird beetle abundance was highest in the untreated control plots (15.73 ± 0.37 individuals per plot), followed by cultural management (12.80 ± 0.41). Sequential management recorded the lowest population (8.53 ± 0.29), while mechanical and biorational treatments

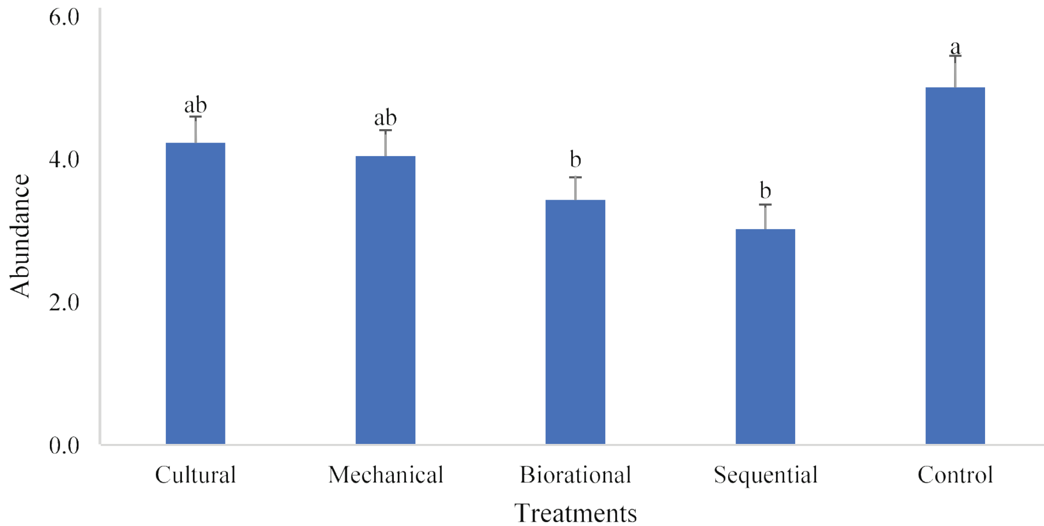

Figure 6. Mean Abundance (number plant^{-1}) of thrips in tomato plants cultivated under different management practices during November 2024 to March 2025 at Gazipur, Bangladesh. Data expressed as mean ± SE. Bars with same letter (s) are not significantly different according to Tukey HSD posthoc statistic at p ≤0.05.

Table 1. Effect of different management practices on leaf curl index (%) of tomato plants at different days after infestation (DAI)

Management practices	30 DAI	60 DAI	90 DAI	Mean
Cultural	11.60±0.50c	17.92±0.17c	25.34±0.34c	18.29±0.11c
Mechanical	15.10±0.32b	25.69±0.28b	34.33±0.47b	25.04±0.30b
Biorational	6.86±0.33d	9.02±0.16d	11.83±0.22d	9.23±0.04d
Sequential	4.66±0.37d	6.10±0.10e	8.57±1.59d	6.44±0.47e
Control	19.21±0.91a	31.94±0.98a	43.31±0.49a	31.48±0.58a

Data expressed as mean ± SE. Means within a column followed by same letter(s) are not significantly different by Tukey HSD posthoc statistic at p ≤0.05.

Table 2. Effect of different management practices on the abundance of natural enemies associated with tomato plants cultivated under different management practices during November 2024 to March 2025 at Gazipur, Bangladesh

Management practices	Abundance (Number plot^{-1})					
	Ladybird beetle	Green lace wing	Spider	Black ant	Dragonfly	Assassin bug
Cultural	12.80±0.41b	8.73±0.54ab	28.40±0.61ab	19.53±0.29b	5.86±0.46ab	11.00±0.57ab
Mechanical	11.60±0.30bc	8.26±0.63b	25.60±0.70b	18.06±0.54b	5.46±0.29ab	9.66±0.88bc
Biorational	10.20±0.50cd	5.80±0.441c	20.66±0.33c	14.93±0.17c	4.26±0.37bc	7.66±0.33cd
Sequential	8.53±0.29d	5.40±0.30c	17.00±0.52d	12.60±0.23d	3.40±0.30c	6.33±0.33d
Control	15.73±0.37a	10.53±0.29a	29.80±0.75a	23.13±0.46a	7.13±0.46a	12.33±0.33a

Data expressed as mean ± SE. Means within a column followed by same letter(s) are not significantly different by Tukey HSD posthoc statistic at p ≤0.05.

showed intermediate values. Green lacewings were also highest in the control (10.53 ± 0.29), followed by cultural and mechanical practices, whereas biorational (5.80 ± 0.44) and sequential (5.40 ± 0.30) treatments showed reduced populations. Spider abundance was greatest in the control (29.80 ± 0.75), with lower values under cultural and mechanical practices and the lowest under sequential management (17.00 ± 0.52). Similarly, black ants were highest in the control (23.13 ± 0.46) and cultural plots, but lowest under sequential management (12.60 ± 0.23). Overall, while biorational and sequential management reduced natural enemy abundance, the reductions were less severe compared to conventional chemical pesticide regimes, highlighting the relative safety of biorational inputs for beneficial arthropods (Sánchez-Bayo 2021; Samanta *et al.* 2023).

Conclusion

The study shows clear effects of different management practices on sucking insect pests, leaf curl incidence, and natural enemies in tomato. Sequential management was the most effective treatment, recording the lowest populations of aphids (7.8 plant^{-1}), whiteflies (8.4 plant^{-1}), thrips (3.0 plant^{-1}), and the lowest leaf curl incidence (6.44%). Biorational management also provided good suppression across all pest groups, while cultural and mechanical practices showed moderate effectiveness. In contrast, the untreated control consistently recorded the highest pest densities and disease incidence.

Regarding natural enemies, the highest abundances were observed in the untreated control, while sequential and biorational treatments reduced their populations moderately but maintained ecological function. Therefore, sequential management is recommended as the most effective and sustainable strategy for tomato pest management, with biorational inputs as a strong alternative where sequential application is not feasible.

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