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Effects of Bio-Green Fertilizers on Growth and Yield of Tomato in Net House Condition

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Abstrak

Tomato (*Solanum lycopersicum* L.) is a popular crop, but it is highly vulnerable to various stresses, including diseases, pests, and climate fluctuations, making it especially suitable for cultivation in net houses. This study aimed to assess how different levels of bio-green fertilizer affect the growth and yield of tomatoes under net house conditions, with the goal of determining the optimal fertilizer application for maximum productivity. The research was conducted in Thmor Kre Kandal Village, Kratie Province, from December 14, 2022, to May 10, 2023, using three tomato varieties: Phearum F1, Platinum F1, and Paetai. Employing a Randomized Complete Block Design (RCBD) with three replications and nine treatments, a total of 27 subplots were established. Data on stem height, branch number, fruit quality, fruit damage, and fruit weight were gathered at 10-day intervals throughout the experiment. Results showed that both fertilizer level and tomato variety significantly influenced plant growth and yield. Notably, the Platinum F1 variety in treatments T6 (S2F3) and T8 (S3F2) achieved the highest yields. Treatment T8 (S3F2), which used a moderate amount of bio-green fertilizer with balanced NPK, was especially effective and is recommended for net house tomato cultivation.

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INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is arguably the most extensively cultivated vegetable crop globally, valued for its economic significance and crucial contributions to human nutrition. Globally, tomato production spans over five million hectares, yielding hundreds of millions of tons annually, with major output coming from Asian countries like China, which often accounts for a fifth of the total global cultivation area (FAO, 2023, updated context). The widespread consumption of tomatoes is driven by their status as a nutritional powerhouse, providing essential nutrients such as vitamins, organic acids, minerals, and, most notably, the powerful antioxidant lycopene, which is associated with significant health benefits. Vegetables like the tomato play a critical role in enhancing food security and supplying these vital nutrients, particularly for smallholder farming communities in developing regions where diets often lack diversity (FAO, 2012). The need to ensure a stable, year-round supply of such a staple crop is paramount to support optimal physical growth, development, and mental well-being across populations.

Securing a consistent and high-quality vegetable supply is severely challenged by climate variability, particularly in tropical and subtropical zones. In response, Controlled Environment Agriculture (CEA), including greenhouses, plastic tunnels, and net houses, has emerged as a crucial protective measure. These structures are specifically designed with transparent roofing to allow sunlight penetration while maintaining a controlled microclimate, generally achieving higher internal temperatures than outdoor conditions. While temperate regions often rely on sophisticated technologies like heating, cooling, and computerized controls to optimize conditions, local practices in countries like Cambodia are still nascent, with farmers typically utilizing simple mesh and plastic-covered structures (Horticulture, 2020). Although these basic net houses effectively shield crops from key environmental stressors such as extreme sunlight, wind, heavy rain, and airborne pathogens, production during the hot and rainy seasons remains highly vulnerable. Cambodian vegetable production declines sharply during these periods due to overwhelming challenges, including flooding and the proliferation of pest infestations and diseases like stem and root rot, issues exacerbated by a persistent reliance on exposed, open-field cultivation for high-value crops like tomatoes.

Beyond environmental vulnerability, the efficacy and sustainability of nutrient delivery present a significant, systemic challenge to long-term crop productivity. The conventional approach often results in a dual problem: on one hand, the excessive or unbalanced application of inorganic fertilizers leads to environmental pollution, soil acidification, and potential health risks. On the other, poor nutrient management and insufficient incorporation of organic matter deplete soil fertility, resulting in reduced productivity over time (FAO, 2012). To bridge this gap, a balanced, Integrated Nutrient Management (INM) approach is required, combining the immediate yield-boosting benefits of readily available inorganic nutrients with the long-term soil health improvements provided by organic sources. Inorganic fertilizers provide essential elements like Nitrogen, Phosphorus, and Potassium (NPK), while organic fertilizers enhance soil structure, increase organic carbon content, and improve water retention. While continuous reliance solely on inorganic fertilizers can cause soil acidification, prolonged use of certain organic sources may push soil pH toward alkalinity (Mak, 2019). Therefore, integrating both organic and inorganic inputs ensur a more effective and sustainable nutrient profile, which is critical for maximizing crop performance, especially in fragile tropical soils. Despite the clear market value and high demand for tomatoes in Cambodia, local farmers continue to struggle with low yields, often due to limited knowledge of these modern, balanced cultivation and nutrient techniques (CARDI, 2007).

This study, therefore, aims to test the efficacy of a specific, natural organic fertilizer, bio-green, within an integrated framework. Specifically, the research aims to investigate the effect of bio-green on the growth and yield of tomato plants under controlled greenhouse conditions and compare the performance of different commercial tomato varieties when cultivated using this novel bio-green formulation versus a standard NPK 15-15-15 fertilizer, evaluating key growth parameters and overall yield outcomes to establish a more robust and sustainable cultivation protocol for local farmers.

MATERIALS AND METHOD

Study Area

The experiment was conducted in a net house facility located in Thmar Kre Kandal Village, Thmar Kre Commune, Chet Borei District, Kratie Province, Cambodia. The study spanned a total duration of 4 months and 24 days, starting on December 14, 2022, and concluding on May 10, 2023. This period covered the transplanting, growth, and harvesting phases of the tomato crop under controlled net house conditions.

Fertilizer Preparation

Commercial Bio-Green liquid fertilizer was purchased from the local agricultural supply market in Kratie Province, Cambodia (Biogreen Crops (Cambodia) Pvt. Ltd). According to the manufacturer's recommendation, the fertilizer was diluted at a ratio of 1 L of Bio-Green to 100 L of water before application. The diluted solution was then applied to tomato plants following the treatment specifications (0.50 L, 0.75 L, or 1.00 L per plant, depending on treatment level).

Experimental Design

The experiment followed a Factorial Randomized Complete Block Design (RCBD) with two factors: three tomato varieties (S) and three fertilizer treatment levels (F). The design included three replications (blocks) to account for environmental heterogeneity within the net house. This resulted in a total of nine treatment combinations and 27 experimental subplots (3 varieties × 3 fertilizer levels × 3replications). Each subplot measured 0.64 m² (80 cm × 80 cm) and contained four tomato plants, with one plant per pot. Spacing between individual plots and subplots was maintained at 0.60 meters to ensure adequate air circulation and ease of management. The total area utilized for the experiment, excluding border rows, was 43.2 square meters.

a. Fertilizer factor (F):

- F_1 = 2.50 g of NPK 15-15-15 + 0.50 liters of bio-green fertilizer
- F_2 = 2.50 g of NPK 15-15-15 + 0.75 liters of bio-green fertilizer
- F_3 = 2.50 g of NPK 15-15-15 + 1.00 liters of bio-green fertilizer

b. Varietal factor (S):

- S_1 = Phearum F1 variety
- S_2 = Platinum F1 variety
- S_3 = Paetai variety

c. Treatments and fertilizer application:

- All treatments are applied with 2.50 g of NPK 15-15-15 fertilizer.
- Treatment T1 = (S1F1) Phearum variety + 0.50 liters of bio-green fertilizer
- Treatment T2 = (S1F2) Phearum variety + 0.75 liters of bio-green fertilizer
- Treatment T3 = (S1F3) Phearum variety + 1 liter of bio-green fertilizer
- Treatment T4 = (S2F1) Platinum variety + 0.50 liters of bio-green fertilizer
- Treatment T5 = (S2F2) Platinum variety + 0.75 liters of bio-green fertilizer
- Treatment T6 = (S2F3) Platinum variety + 1 liter of bio-green fertilizer
- Treatment T7 = (S3F1) Paetai variety + 0.50 liters of bio-green fertilizer
- Treatment T8 = (S3F2) Paetai variety + 0.75 liters of bio-green fertilizer
- Treatment T9 = (S3F3) Paetai variety + 1 liter of bio-green fertilizer

d. Data collection methods

Primary data were collected through direct observation and measurement conducted throughout the experiment, which lasted for a total of six months. The following growth and yieldrelated parameters were recorded to evaluate the performance of tomato plants under different treatment conditions (Srinivasan, 2012):

1. Stem height: Stem height was measured using a measuring tape from the base of the plant at ground level to the tip of the apical leaf. Measurements were taken every 10 days after planting. All stems, including those from branches and shoots, were measured and recorded in the data table.
2. Number of branches: The number of lateral branches arising from the main stem was counted. Only branches that had developed from the primary stem were considered. Each branch and shoot were visually identified and counted systematically using a marking method to avoid repetition or omission.
3. Number of good fruits: This refers to the count of fruits harvested from the experimental plots that were well-formed, undamaged, and free from pest infestation or disease. These fruits were collected, sorted, and the total number was recorded.
4. Number of damaged fruits: Damaged fruits included those that were deformed, cracked, or affected by pests or diseases. These were separated from the good fruits and counted accordingly.
5. Weight of good fruits: The total weight of good fruits was determined by harvesting, sorting, and weighing them using an electronic scale. The results were recorded in grams or kilograms, depending on the quantity.
6. Weight of damaged fruits: Similarly, damaged fruits were weighed separately using an electronic scale after being sorted out from healthy ones. The weight was documented for each subplot.
7. Total number of fruits: The total number of fruits per subplot was calculated by summing the number of good fruits and damaged fruits together and recording the result.
8. Total weight of fruits: The total fruit yield per subplot was obtained by adding the weights of both good and damaged fruits. This value was used to assess overall productivity across treatments.

All measurements were repeated at regular intervals (every 10 days) to ensure consistency and accuracy in data collection. The recorded data were later analyzed statistically to determine the effects of different fertilizer treatments on the growth and yield of various tomato varieties under net house conditions.

e. Data Analysis

All data collected from the experiment—including stem height, number of branches, number of good fruits, number of spoiled fruits, weight of good fruits, weight of spoiled fruits, total number of fruits, and total fruit weight —were entered into the SPSS software for statistical analysis. Microsoft Excel 2010 was used to generate graphs and visual representations of the results, while Microsoft Word 2010 was utilized for writing and compiling the final thesis document.

- *Descriptive Data Analysis*

Descriptive statistics were employed to summarize and present the experimental data in a clear and interpretable format. Measures such as the mean, median, mode, and standard deviation were calculated for each variable. These values were then displayed using tables and graphs to facilitate visual interpretation and understanding of trends in stem height, branching patterns, fruit quality, and overall yield across different treatments.

- *Inferential Data Analysis*

Inferential statistics were applied to determine whether there were statistically significant differences between treatment groups for each measured variable. This included analyzing variations in stem height, number of branches, good and damaged fruit counts, fruit weights, and total yield. Statistical tests such as ANOVA (Analysis of Variance) or t-tests, where applicable, were used to assess the significance of observed differences among treatments.

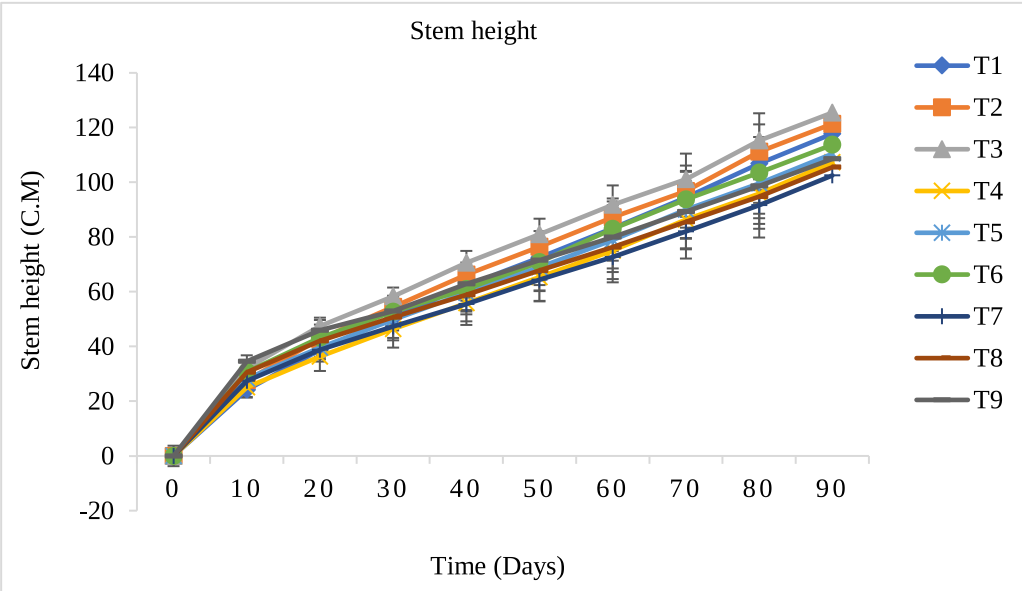
This analytical approach enabled a comprehensive evaluation of how different fertilizer levels and tomato varieties influenced plant growth and yield under net house conditions.

RESULT AND DISCUSSION

Results

Stem Height Growth

The study of stem height involved measuring the length from the base of the plant to the tip of the main stem. Measurements were taken every 10 days throughout the experimental period. All cultivars and sub-cultivars were measured on the same day to ensure consistency, with each sub-cultivar consisting of four individual plants.



Graph 1: Tomato stem height growth of each treatment

Graph 1 illustrates the steady growth trend in stem height across all tomato cultivars throughout the experimental period. In the first measurement, taken 10 days after planting, the T9 (S_3F_3) cultivar exhibited the highest average stem height at 108.54±11.79 cm, while the T4 (S_2F_1) cultivar had the lowest growth with an average of 107.25±11.02 cm.

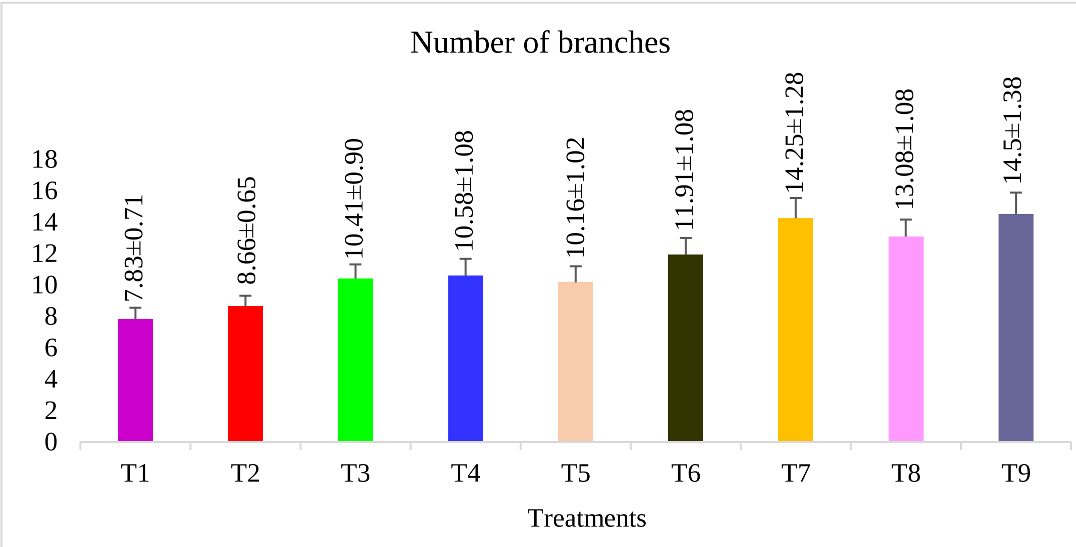
By the ninth measurement, conducted 90 days after planting, the T3 treatment —which combined bio-green fertilizer (1 liter) and NPK 15-15-15 fertilizer (2.5 g) with the Phearum tomato variety - achieved the highest average stem height of 125.45±10.02 cm, indicating superior growth performance compared to all other treatments. In contrast, the T7 treatment, which used bio-green fertilizer (0.50 liter) and NPK 15-15-15 fertilizer (2.5 g) with the Paetai tomato variety, showed the lowest average stem height of 102.50±11.76 cm.

A two-way ANOVA analysis was conducted using the Randomized Complete Block Design (RCBD) to evaluate the effects of fertilizer level and seed variety on stem height. The results revealed that for the fertilizer factor, the p-value was < 0.05 across all nine measurements, indicating a statistically significant effect of fertilizer level on stem height growth. Similarly, the seed factor also showed a p-value < 0.05 for all measurement periods, suggesting that different seed varieties significantly influenced plant height.

However, there was no significant interaction between the seed and fertilizer factors, as indicated by a p-value > 0.05 across all measurements. This suggests that the effect of fertilizer application was consistent across varieties, and the growth response of each variety was not dependent on the specific fertilizer level applied.

Number of branches

The study of branch growth was conducted every 10 days, with all seedlings measured on the same day to ensure consistency. Only branches that originated directly from the main stem were counted. Branching was recorded from the third to the ninth measurement period, allowing for the observation of branching patterns over time under different treatment conditions.



Graph 2: Number of branches of each treatment

Graph 2 illustrates the variation in average branch growth among different tomato seedlings under various treatment conditions. Among all treatments, seedling T9, which received bio-green fertilizer (1 liter) in combination with NPK 15-15-15 fertilizer (2.5 g) and was planted with the Paetai tomato variety, showed the highest average number of branches at 14.5±1.38 indicating the most vigorous branching growth.

In contrast, treatment T1, which used bio-green fertilizer (0.50 liters) and NPK 15-15-15 fertilizer (2.5 g) with the Phearum tomato variety, had the lowest average number of branches at 7.83±0.71, showing the least branching development compared to other treatments.

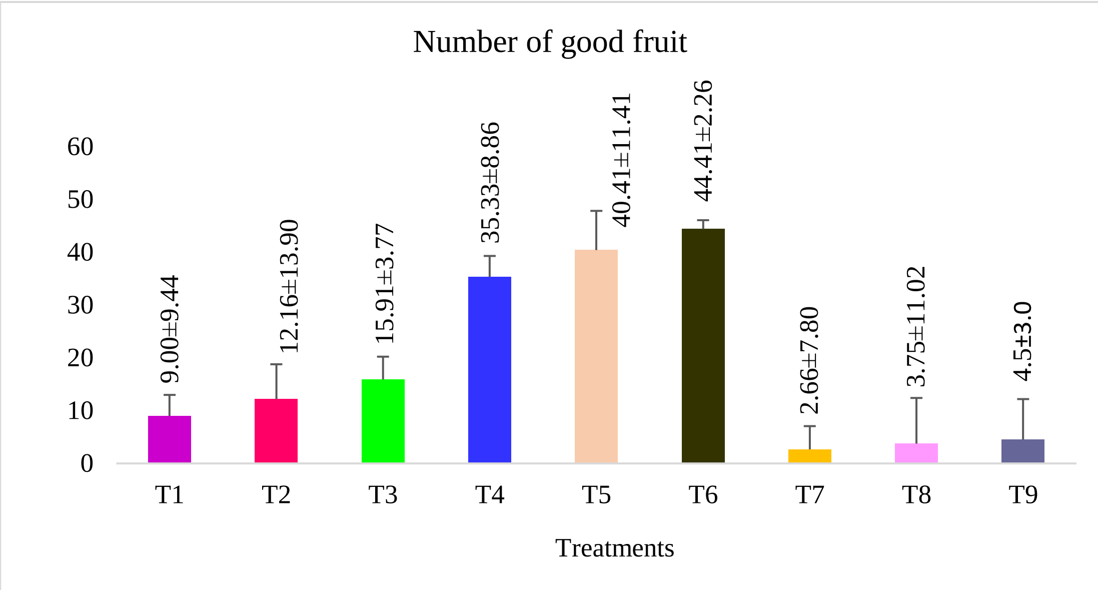
A two-way ANOVA analysis was conducted using the Randomized Complete Block Design (RCBD) to assess the effects of fertilizer level and seed variety on the number of branches. The results indicated that no branching occurred from the day of planting up to the 20th day. Branching began to appear from the 30th day onward, with variations observed across treatments.

For the fertilizer factor, the p-value was < 0.05 from the 3rd to the 9th measurement, indicating that fertilizer application significantly influenced branching. In contrast, for the seed factor, the p-values were greater than 0.05 at the 3rd, 6th, 7th, and 8th measurements, suggesting that the effect of seed variety on branching was not statistically significant during these periods.

However, there was a significant interaction between the seed and fertilizer factors at the 3rd, 6th, 7th, and 8th counts, indicating that the response of different varieties to fertilizer levels played an important role in determining branching patterns.

Number of good fruits

The study of the number of good fruits was conducted every 10 days, with all varieties assessed on the same day to ensure consistency. Fruit harvesting was carried out from the 8th to the 9th measurement period, corresponding to the later stages of plant maturity when fruiting peaked under the experimental conditions.



Graph 3: Number of good fruits recorded on the last day of the experiment

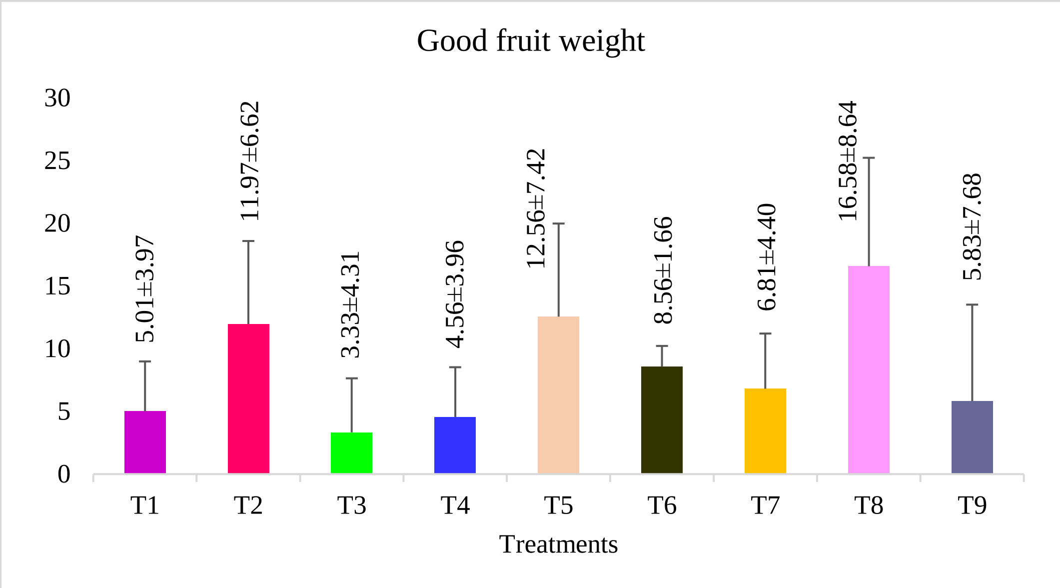
Graph 3 illustrates the variation in the average number of good fruits among different tomato varieties at the final measurement stage. Among all treatments, T6, which received bio-green fertilizer (0.75 liters) combined with NPK 15-15-15 fertilizer (2.5 g) and was planted with the Platinum tomato variety, produced the highest average number of good fruits at 44.41±2.26, indicating superior fruit quality and yield performance. In contrast, T7, which used bio-green fertilizer (1 liter) and NPK 15-15-15 fertilizer (2.5 g) with the Paetai tomato variety, had the lowest average number of good fruits at 2.66±7.80, showing significantly reduced fruiting performance compared to other treatments.

A two-way ANOVA analysis was conducted using the Randomized Complete Block Design (RCBD) to evaluate the effects of fertilizer level and seed variety on the number of good fruits. The results showed that for the fertilizer factor, the p-value was < 0.05 from the 8th to the 9th measurement, indicating a statistically significant effect of fertilizer application on fruit quality. Similarly, for the seed factor, the p-value was also < 0.05 during the same period, demonstrating that different tomato varieties significantly influenced the number of good fruits produced.

However, there was no significant interaction between the seed and fertilizer factors, as indicated by a p-value > 0.05 from the 8th to the 9th count. This suggests that the effect of fertilizer levels was consistent across varieties, and the performance of each variety was not dependent on a specific fertilizer treatment.

Weight of good fruits

The weight of good fruits was recorded every 10 days, with all cultivars and plants measured on the same day to ensure consistency. Harvesting and weighing were conducted during the 8th and 9th measurement periods, corresponding to the peak fruiting stage of the tomato plants under the experimental conditions.



Graph 4: Weight of good fruits of each treatment

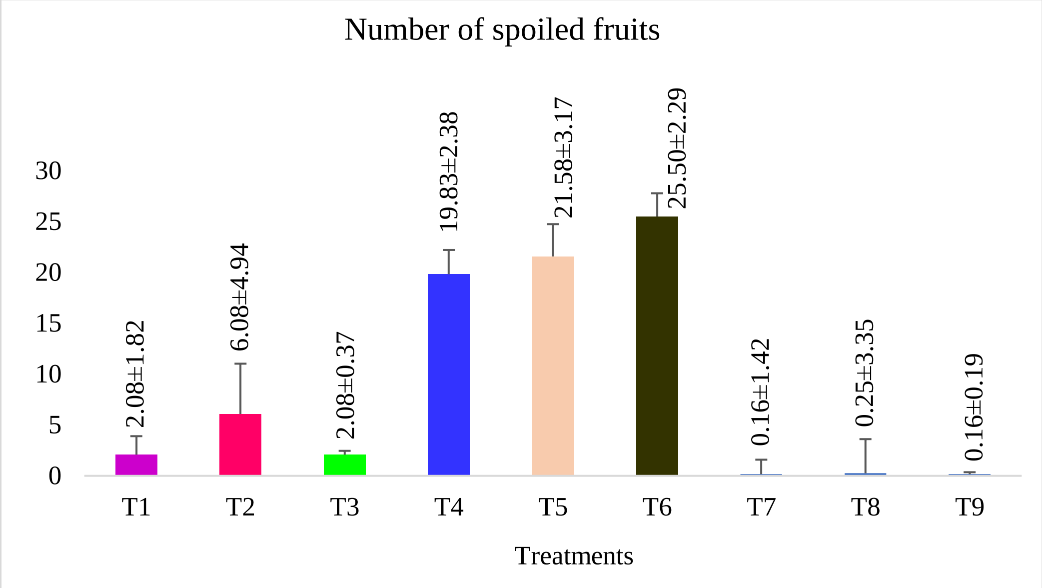
Graph 4 illustrates the variation in average good fruit weight among different tomato cultivars at the final measurement stage. Among all treatments, cultivar T8, which received bio-green fertilizer (0.75 liters) combined with NPK 15-15-15 fertilizer (2.5 g), produced the highest average good fruit weight of 16.58±8.64 g, indicating superior fruit development compared to other treatments. In contrast, cultivar T3, which was treated with bio-green fertilizer (0.50 liters) and NPK 15-15-15 fertilizer (2.5 g), had the lowest average good fruit weight at 3.33±4.31 g, showing significantly reduced performance in terms of fruit size and weight.

A two-way ANOVA analysis was conducted using the Randomized Complete Block Design (RCBD) to assess the effects of fertilizer level and seed variety on good fruit weight. The results indicated that for the fertilizer factor, the p-value was < 0.05 from the 8th to the 9th harvest, showing that fertilizer application had a statistically significant effect on fruit weight. Similarly, for the seed factor, the p-value was also < 0.05 during the same period, indicating that different tomato varieties significantly influenced fruit weight outcomes.

However, there was no significant interaction between the seed and fertilizer factors, as shown by a p-value > 0.05 from the 8th to the 9th harvest. This suggests that the effect of fertilizer levels was consistent across varieties, and the response of each variety to fertilization did not differ significantly.

Number of spoiled fruits

The number of spoiled fruits was recorded every 10 days for all plots, with assessments conducted on the same day to ensure consistency. Harvesting and counting of spoiled fruits were carried out from the 8th to the 9th measurement period, corresponding to the peak fruiting stage of the tomato plants.



Graph 5: Number of spoiled fruits of each treatment

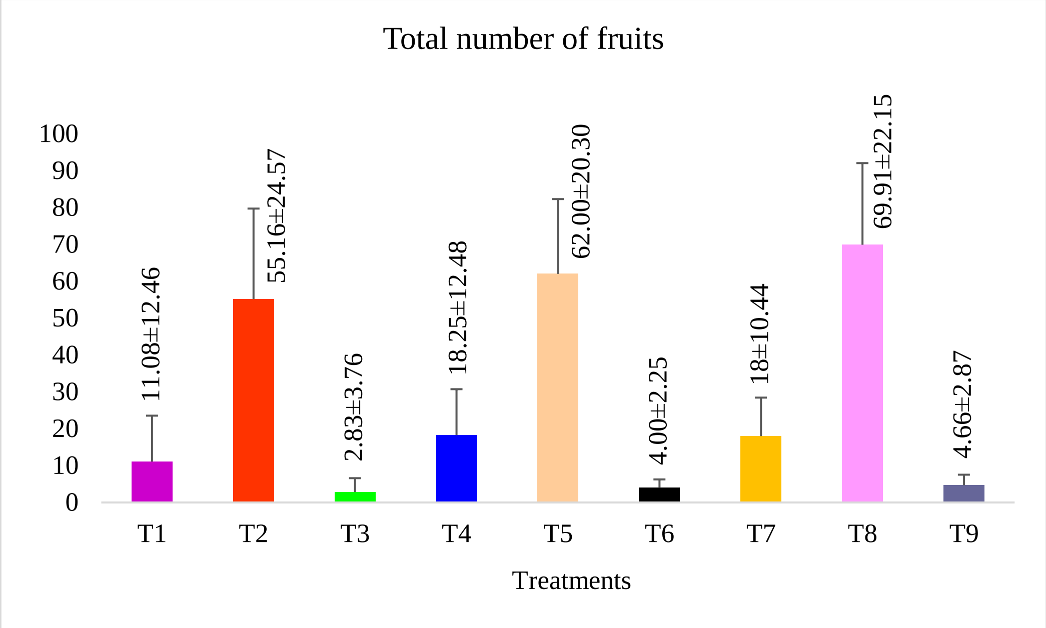
Graph 5 illustrates the variation in the average number of spoiled fruits among different plots at the final measurement stage. Among all treatments, plot T8, which received bio-green fertilizer (0.75 liters) combined with NPK 15-15-15 fertilizer (2.5 g) and was planted with the Platinum tomato variety, recorded the highest average number of spoiled fruits at 25.50±2.29, indicating a higher susceptibility to damage or disease under this treatment. In contrast, plot T9, treated with bio-green fertilizer (1 liter) and NPK 15-15-15 fertilizer (2.5 g) along with the Paetai tomato variety, had the lowest average number of spoiled fruits at 0.16±0.19, showing significantly better fruit quality and resistance to damage compared to other treatments.

A two-way ANOVA analysis was conducted using the Randomized Complete Block Design (RCBD) to evaluate the effects of fertilizer level and seed variety on the number of spoiled fruits. The results showed that for the fertilizer factor, the p-value was < 0.05 from the 8th to the 9th count, indicating a statistically significant effect of fertilizer application on fruit damage. Similarly, for the seed factor, the p-value was also < 0.05 during the same period, demonstrating that different tomato varieties responded differently in terms of fruit damage and quality.

However, there was no significant interaction between the seed and fertilizer factors, as shown by a p-value > 0.05 from the 8th to the 9th count. This suggests that the influence of fertilizer levels on fruit damage was consistent across varieties, and the response of each variety was not strongly dependent on a specific fertilizer treatment.

Total number of fruits

The total number of fruits was determined by summing the counts of both good fruits and damaged fruits for each plot. This measurement was conducted across all plots on the same day to ensure consistency. The final fruit count was recorded during the 8th and 9th harvest periods, which corresponded to the peak fruiting stage of the tomato plants under the experimental conditions.



Graph 6: Total number of fruits of each treatment

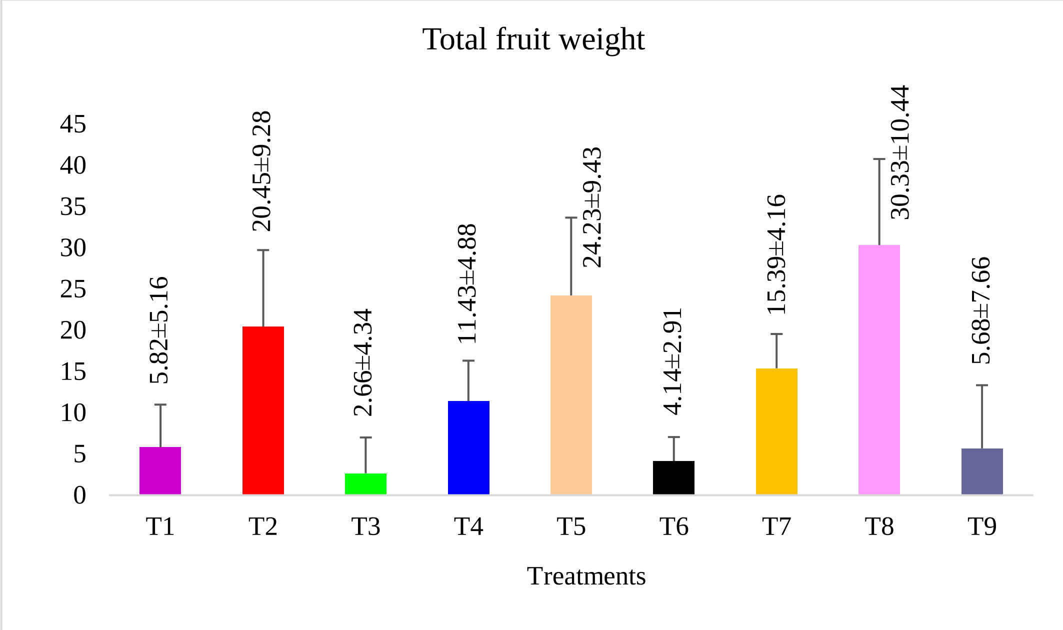
Graph 6 illustrates the variation in the average total number of fruits (i.e., the sum of good and spoiled fruits) among different treatments at the final measurement stage. Among all treatments, T8, which received bio-green fertilizer (0.75 liters) combined with NPK 15-15-15 fertilizer (2.5 g) and was planted with the Paetai tomato variety, produced the highest average total fruit number of 69.91±2.15, indicating superior overall productivity compared to other treatments. In contrast, T3, treated with bio-green fertilizer (1 liter) and NPK 15-15-15 fertilizer (2.5 g) along with the Phearum tomato variety, had the lowest average total fruit count at 2.83±3.76, showing significantly reduced yield performance.

A two-way ANOVA analysis was conducted using the Randomized Complete Block Design (RCBD) to assess the effects of fertilizer level and seed variety on total fruit number. The results showed that for the fertilizer factor, the p-value was < 0.05 from the 8th to the 9th count, indicating a statistically significant effect of fertilizer application on total fruit production.
Similarly, for the seed factor, the p-value was also < 0.05 during the same period, demonstrating that different tomato varieties had significantly different impacts on total fruit yield.

However, there was no significant interaction between the seed and fertilizer factors, as shown by a p-value > 0.05 from the 8^{th} to the 9^{th} count. This suggests that the response of each variety to fertilizer application was consistent and not dependent on a specific treatment combination.

Total fruit weight

The total fruit weight was calculated by summing the weights of both spoiled fruits and good fruits for each cultivar. This measurement was conducted across all cultivars on the same day to ensure consistency in data collection. The final weighing was performed during the 8^{th} and 9^{th} harvest periods, which corresponded to the peak fruiting stage of the tomato plants under the experimental conditions.



Graph 7: Total fruit weight of each treatment

Graph 7 illustrates the variation in average total fruit weight among different treatments at the final measurement stage. Among all treatments, T8, which received bio-green fertilizer (0.75 liters) combined with NPK 15-15-15 fertilizer (2.5 g) and was planted with the Paetai tomato variety, recorded the highest average total fruit weight of 30.33±10.44 g, indicating superior overall yield performance compared to other interactions. In contrast, T3, treated with bio-green fertilizer (1 liter) and NPK 15-15-15 fertilizer (2.5 g) along with the Phearum tomato variety, had the lowest average total fruit weight at 2.66±4.34 g, showing significantly reduced productivity under this treatment.

A two-way ANOVA analysis was conducted using the Randomized Complete Block Design (RCBD) to evaluate the effects of fertilizer level and seed variety on total fruit weight. The results showed that for the fertilizer factor, the p-value was < 0.05 from the 8^{th} to the 9^{th} count, indicating a statistically significant effect of fertilizer application on fruit weight. Similarly, for the seed factor, the p-value was also < 0.05 during the same period, demonstrating that different tomato varieties significantly influenced total fruit yield.

However, there was no significant interaction between the seed and fertilizer factors, as shown by a p-value > 0.05 from the 8^{th} to the 9^{th} count. This suggests that the influence of fertilizer levels on fruit weight was consistent across varieties, and the response of each variety did not strongly depend on a specific fertilizer treatment.

Discussion

This study was conducted to investigate the effect of bio-green fertilizer levels on the growth and yield of tomato plants under greenhouse conditions, with the aim of identifying which combination of bio-green fertilizer level yields the highest productivity. According to the above data, it can be concluded that the interaction between fertilizer level and variety is statistically significant and has a measurable impact on the growth and yield parameters of tomato plants.

The highest stem height (125.45±10.02 cm) was observed in the treatment T9 (S_3F_3), which involved the application of 1 liter of bio-green fertilizer combined with 2.5 g of NPK 15-15-15 fertilizer for the Phearum T3 variety. Similarly, the same treatment (T9) also recorded the highest number of branches (14.5±1.38). These results suggest that higher doses of bio-green fertilizer, when supplemented with balanced NPK, significantly enhance vegetative growth. This aligns with the findings of Khan et al. (2021), who reported that integrated use of organic and inorganic fertilizers promotes plant biomass accumulation by improving nutrient uptake and root development.

In terms of fruit production, the interaction between the Platinum tomato cultivar and T6 (S_2F_3) - involving 0.75 liters of bio-green fertilizer and 2.5 g of NPK 15-15-15 - produced the highest number of good-quality fruits (44.41±2.26). Moreover, the treatment T8 (S_3F_2), which used 0.75 liters of bio-green fertilizer and 1.5 g of NPK fertilizer with the Paetai cultivar, showed the highest average fruit weight (16.58±8.64 g). This indicates that while higher fertilizer levels stimulate vegetative growth, moderate applications may optimize fruit quality and weight, possibly due to better nutrient balance and reduced toxicity risks (Amin et al., 2020).

Interestingly, the interaction between 0.75 liters of bio-green fertilizer and 2.5 g of NPK 15-15-15 with the Paetai cultivar (T8, S_3F_2) resulted in the highest total number of fruits (69.91±2.15) and the heaviest total fruit weight (30.33±10.44 g). These findings support the hypothesis that optimal combinations of bio-green and mineral fertilizers can maximize both quantity and quality of tomato yield, as previously documented by Hossain et al. (2019) and Singh & Reddy (2022).

Overall, these results demonstrate that integrating bio-green fertilizer with conventional NPK can significantly enhance both growth and yield characteristics of tomatoes, depending on the cultivar used. Future studies should explore long-term effects and field-scale applications to validate these findings under open-field conditions.

CONCLUSION

Based on the experimental results, it can be concluded that the interaction between fertilizer levels and tomato varieties significantly influenced crop performance under net house conditions. The study's primary finding is that Treatment T8—the combination of the Paetai variety and a medium application of 0.75 liters of bio-green organic fertilizer alongside the standard NPK base—yielded the most superior results across all metrics, recording the highest good fruit weight, total fruit number, and overall yield. This research strongly establishes this integrated approach as an effective and sustainable Integrated Nutrient Management (INM) strategy. It is recommended that local farmers and agricultural practitioners adopt this specific nutrient and varietal combination for optimizing regional greenhouse tomato production. Future research should focus on validating these findings in open-field conditions and integrating advanced technology, such as automated fertigation systems, to further optimize input efficiency and scalability.

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