**Effect of integrated nutrient management on growth, yield and quality of tomato (*Solanum lycopersicum* L.)**

**ABSTRACT**

The present study was conducted at the Horticulture Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan, during the 2023-24 growing season. The objective was to evaluate the effect of integrated nutrient management on the growth, yield, and quality of tomato (*Solanum lycopersicum* L.). The experiment was designed using a Randomized Block Design (RBD) and included 12 treatment combinations. viz; T1-Control (No treatment), T2- RDF (120:80:50), T3-(100%) FYM (Farmyard Manure) (25t/ha), T4- (100%) Vermicompost (VC) (10 t/ha), T5-*Azotobacter*, T6- *Azospirillum*, T7- 50% RDF + 50% FYM, T8- 50% RDF + 50% Vermicompost, T9- 50% RDF + *Azotobacter*, T10- 50% RDF + *Azospirillum,*T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* and T12- 50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum*and treatments were replicated three times. The treatment (T11) significantly affected various vegetative growth, yield and quality parameters. Results further indicated that the highest (3.49) benefit: cost ratio was observed intreatment (T11). Whereas, the lowest benefit: cost ratio (2.47) was recorded under control.

**Keywords:** Vermicompost, FYM, biofertilizer, nutrient management

**1. INTRODUCTION**

Tomato (*Lycopersicon esculentum*) is one of the most important vegetable crops grown widely all over the world. Tomato is an herbaceous plant belonging to family the Solanaceae. It is native to the Peru-Eucador and Bolivia regions. From its center of origin, it was first moved to Mexico for domestication and cultivation. Thus, Mexico is the region of origin of cultivation tomato that was transported to the old world. Tomato does not appear to be first cultivated in South America, but rather in Mexico, most likely in Aztec civilizations and probably in the form of small yellow fruits [1].

The word "tomato" may actually originate from the Nahautl word "tomatal" meaning "the swelling fruit." The immediate ancestor is probably *var.* cerasiforme. It is a self-pollinated crop but a considerable amount of cross pollination is noticed. Tomato is a warm season crop reasonably resistant to heat. It is a typical day neutral plant. Tomatoes are being used in sandwiches, salads and processed products like soup, sauce, juice, ketchup and drinks [2]. It is a good source of potassium, vitamin A (β- Carotene) and vitamin C. Tomato is one of the low calorie vegetables containing just 18 calories per 100 grams. They are also very low in fat content and have no cholesterol levels. 100 grams edible fruit of tomato contains- protein 0.9 g, fat 0.2 g, minerals 0.5 g, fiber 0.8 g, carbohydrates 3.6 g, energy (20 kcal), beta-carotene (590 µgm) vitamin C (27 mg) and potassium (146 mg) [3].

India is the world’s second largest producer of vegetable next to China. Tomato is grown of India in 8.49 lakh ha area with 204.02 lakh tonnes production. The major tomato producing states are Madhya Pradesh, Andhra Pradesh, Karnataka, Odisha, Gujarat, West Bengal and Tamil Nadu [4].

Organic and inorganic fertilizers are essential for plant growth. Both fertilizers supply plants with the nutrients required needed for optimum performance. Organic fertilizers have been used for many centuries whereas chemically synthesized inorganic fertilizers were only widely developed during the industrial revolution. Inorganic fertilizer has significantly supported global population growth, it has been estimated that almost half the people on the earth are currently fed as a result of artificial nitrogen fertilizer use [5].

Vermicompost is a mixture of worm casting, organic materials, humus, living earthworms, cocoons, and other organisms. Vermicompost is a slow nutrient releasing organic manure which have most of the macro as well as micro nutrients in chelated form and fulfill the nutrient requirement of plants for longer period. Vermicompost is being a stable fine granular organic matter, when added to soil, it loosens the soil and improves the passage to the entry of air. The organic carbon in vermicompost releases the nutrients slowly and steadily into the system and enables the plant to absorb the nutrients. The soil enriched with vermicompost provides additional substances that are not found in chemical fertilizers. It is also an added advantage of the vermicompost. Vermicompost is made up primarily of C, H and O and contains nutrients such as NO3, PO4, Ca, K, Mg, S and micronutrients which exhibit similar effects on plant growth and yield as inorganic fertilizers applied to soil [6]. Vermicompost an organic source of plant nutrients contains a higher percentage of nutrients necessary for plant growth in readily available forms [7].

The FYM enhances the physio-chemical characteristics of the soil and promotes soil microbial activity, which increases the soil's plant-food components' accessibility to the crop. Soil inoculation with FYM also results in increased nutrient availability, particularly for nitrogen and phosphorus, which is beneficial for the soil's residual value.

Biofertilizers are eco-friendly and help in improving the biological activities of desirable microorganisms in the soil and improve the crop yield and overall quality of the produce. Further, they can play an important role in reducing the dependence on chemical fertilizers. Biofertilizers are also of immense significance as their small dose is sufficient to produce desirable results because each gram of carrier of bio fertilizers contains at least 10 million viable cells of a specific strain [8]. *Azotobactor* and *Azospirillum* are the two most important non-symbiotic N-fixing bacteria which are widely used in vegetable crops. They not only enhance plant development but promote the yield of vegetable crops and reduce the input cost of fertilizer.

**2. MATERIAL AND METHODS**

The field experiment was conducted at the Horticulture Farm, Department of Horticulture, School of Agriculture, Suresh Gyan Vihar University, Jaipur (Rajasthan), during the kharif season of 2023. The experiment was laid out in Randomized Block Design with three replications and 12 treatments. Treatment combinations were viz; T1-Control (No treatment), T2- RDF (120:80:50), T3-(100%) FYM (Farmyard Manure) (25t/ha), T4- (100%) Vermicompost (VC) (10 t/ha), T5-*Azotobacter*, T6- *Azospirillum*, T7- 50% RDF + 50% FYM, T8- 50% RDF + 50% Vermicompost, T9- 50% RDF + *Azotobacter*, T10- 50% RDF + *Azospirillum,*T11- 50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* and T12- 50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum.* The plot size was 3.0 m × 2.25 m and the spacing followed was 60 × 45 cm to keep 25 plants per plot for each treatment. The land was brought to a fine tilth through tillage and ploughing. Bunds and irrigation channels were maintained properly. Different intercultural practices like gap filling, staking, irrigating, weeding, etc. were performed as per crop requirements. The five plants of each plot were randomly selected and tagged. The data were recorded for various growth, yield and quality parameters in tomato during the course of investigation subjected to statistical analysis by using factorial RBD for analysis of variance (ANOVA) as suggested by online OPSTAT software by [9].

**3. RESULTS AND DISCUSSION**

**3.1 Growth parameters**

The data showed that the adoption of different combinations of organic, inorganic fertilizers and biofertilizer had produced a significant effect on plant height of tomato (Table-1). The maximum plant height at 30, 60 and 90 days after transplanting (62.00 cm, 75.93 cm and 97.03 cm) was noted in treatment T11 (50% RDF + 50% FYM + *Azotobacter* + *Azospirillum*) followed by T12-50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum* (60.36 cm, 72.46 cm and 95.36 cm) while the minimum plant height at 30, 60 and 90 days after transplanting (41.83 cm, 55.40 cm and 70.40 cm) was recorded from treatment T0 (control). It might be due to the increase in the nutrient availability and preponderance of different groups of microorganisms in the soil, which create a favourable condition for proper vegetative growth in general and increased plant height in particular. The highest dose of nitrogen might have enhanced cell division and formation of more tissues resulting in luxuriant vegetative growth and thereby increasing plant height. Similar results were found by [10], [11] and [12] in tomato crop.

The data revealed that various treatments significantly enhanced the number of branches per plant at all stages of growth except at 90 days after transplanting and maximum number of branches per plant (16.33) branches were recorded with T11 (50% RDF + 50% FYM + *Azotobacter* + *Azospirillum*) followed by T12-50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum*with (15.67) branches while lowest number of branches per plant (8.33) were recorded with T0 (control). Similar results were obtained by [13] and [12] for tomatoes.

The minimum number of days to 50% flowering (24.33 days) was recorded with the application of T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum,* followed by T12-50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum* (27.67), and T7-50% RDF + 50% FYM (29.00). The maximum (39.33) number of days to 50% flowering was found under the treatment T0 (control). Early 50% flowering might be due to the enhanced production of growth positive influence on the physiological activity of the plants thereby resulting in early flowering. The results of this study are in agreement with those of [12] for tomatoes.

The number of flowers per plant significantly varied among different treatment combinations. The data presented in above table clearly indicated that the maximum number of flower per plant (40.32) were recorded with the application of T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* closely followed by T12-50% RDF + 50% Vermicompost + *Azotobacter*+ *Azospirillum* (39.58) and T7-50% RDF + 50% FYM (37.62). The minimum number of flower per plant (28.25) was found under the treatment T0 (control). The treatment consisting of 50% NPK (RDF) along with the application of 50% nitrogen through vermicompost, showed a higher number of flowers per plant compared to other treatments. Several factors contribute to this outcome. Firstly, the presence of beneficial microorganisms in the treatments promotes nutrient availability and uptake, leading to improved plant health and increased flower production. These microorganisms enhance nutrient cycling, fix atmospheric nitrogen and solubilize phosphorus, providing essential elements for flower development. Secondly, the addition of organic nitrogen through vermicompost stimulates overall plant growth and reproductive processes, including flower initiation and development. Additionally, the balanced nutrient supply from these treatments supports the plant's energy reserves, allowing it to produce a greater number of flowers. Overall, the combination of beneficial microorganisms and organic nitrogen sources in these treatments contributes to enhanced flower production in tomato plants. The findings were earlier published by [14] and [12] in tomato.

**3.2 Yield parameters**

The maximum fruit diameter (6.86 cm) was recorded under the treatment T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* followed by T12-50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum* with 6.83 cm. The minimum fruit yield per hectare (4.80 cm) was recorded for the T0 (control) treatment. This might be due to the combined application of organic manures and inorganic fertilizers, which might have acted complementary and supplementary to each other and resulted in an adequately slow but steady supply of nutrients. The availability of nutrients at the critical stages of crop growth resulted early establishment, vigorous growth and development of plants leading to longer and wider fruits. High value in fruit length and fruit diameter was observed due to integrated nutrients application by [14] in tomato.

The maximum fruit weight (44.84 g) was recorded under the treatment T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* followed by T12-50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum* with 44.33 cm. The minimum fruit weight (28.62g) were recorded in T0 (control) treatment. Similar findings have been reported by [14] in tomato.

The maximum fruit yield per plant (1.65 kg) was observed with treatment T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* followed by T12-50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum*(1.55 kg). The maximum (0.640 kg) fruit yield per plant was found under the treatment T0 (control). Similar findings have been reported by [12] in tomato.

The maximum fruit yield per plot (41.17 kg) was observed with treatment T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* followed by T12-50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum* with 38.87 kg/plot. Lower fruit yield per plot (16.79 kg) was observed at T0 (control). Similar findings have been reported by [11] and [12] in tomato.

The maximum fruit yield per hectare (60.99 t/ha) was recorded under the treatment T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* followed by T12-50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum* with 57.58 t/ha. The minimum fruit yield per hectare (23.03 t/ha) were recorded in T0 (control) treatment. The reason for increase in yield and yield attributing traits might be the solubilization effect of plant nutrients by the addition of RDF + FYM + *Azotobacter* + *Azospirillum*as evidenced by the increase in the uptake of N, P, K, Ca, and Mg, etc. These results are in accordance with those reported by [11] and [12] in tomato.

**3.3 Quality parameters**

The maximum ascorbic acid (16.14 mg/100g) was recorded under the treatment T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* followed by T12-50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum* with 15.62 mg/100g. The minimum ascorbic acid (11.85 mg/100g) were recorded in T0 (control) treatment. This might be due to the availability of nitrogen leading to balanced C:N ratio enhancing the vegetative growth resulting in high photosynthetic activity [12] found similarly in tomato crop.

The maximum T.S.S. (4.250Brix) was obtained by the use of T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* followed by T12-50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum* (4.22 0Brix). The minimum value (4.03 0Brix) was recorded under the treatment T0 (control) in the year of experimentation. These results are in accordance with those reported by [12] in tomato.

The maximum acidity (0.35) was recorded under the treatment T12-50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum* followed by T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* with 0.34. The minimum acidity (0.20) were recorded in T0 (control) treatment. These results are in accordance with those reported by [15] in tomato.

The maximum reducing sugar (13.34) was observed with treatment T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* followed by T12-50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum* with 13.26. The minimum reducing sugar (11.36) was observed in T0 (Control). These results are in accordance with those reported by [15] in tomato.

The maximum non-reducing sugar (4.21) was observed with treatment T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* followed by T12-50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum* with 4.09. The minimum non-reducing sugar (2.83) was observed in T0 (Control).

The maximum total sugar (17.55) was observed with treatment T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* followed by T12-50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum* with 17.35. The minimum total sugar (14.19) was observed in T0 (Control). These results are in accordance with those reported by [12] and [15] in tomato.

**4.4 Economic parameters**

Gross return quantifies the total revenue generated from tomato sales, providing an overall measure of financial income. Net return, on the other hand, deducts production costs from the gross return, reflecting the actual profit obtained from tomato production. It helps growers assess the profitability and economic viability of their cultivation practices. BC ratio compares the benefits (gross returns) to the costs incurred in tomato production, indicating the profitability and efficiency of the investment. These measurements assist growers in evaluating the financial performance of their tomato crops, making informed decisions regarding resource allocation, cost management, and assessing the economic feasibility of tomato cultivation. Maximum gross returns were recorded in treatment T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* with Rs. ₹.4, 26,930 ha-1 and the minimum (Rs. 1, 61,210 ha-1) was recorded in treatment T0 (Control). Maximum net returns were recorded in treatment T11-50% RDF + 50% FYM + *Azotobacter + Azospirillum* with (Rs. 3, 04, 745 ha-1) and the minimum (Rs. 95, 890 ha-1) was recorded in treatment T0 (Control). Maximum benefit: cost ratio was recorded in T11-50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* with (3.49) and the minimum (2.47) was recorded in treatment T0 (Control). These findings align with those reported by [12] and [15] in tomato.

**4. Conclusions**

The study revealed that the combined use of 50% RDF, 50% FYM, and biofertilizer (*Azotobacter and Azospirillum*) significantly improved the growth, yield, quality and economic performance of tomatoes. Among the treatments, T11 (50% RDF + 50% FYM + *Azotobacter* + *Azospirillum*) showed the best results, closely followed by T12 (50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum*). These treatments achieved the highest values in plant height, branching, fruit yield, quality attributes, and economic returns. Thus, T11 is highly recommended for maximizing tomato productivity and profitability.

**Disclaimer (Artificial Intelligence)**

 Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT,etc.) and text-to-image generators have been used during writing or editing of this manuscript.

**Competing Interests**

Authors have declared that no competing interests exist

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**Table 1. Effect of INM onplant height (cm) 30, 60, and 90 DAT, number of branches per plant, days to 50% flowering, fruit diameter (cm)and individual fruit weight (g) of tomato.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Plant Height (cm)** | **No. of Branch per plant** | **Days to 50 % flowering** | **Number of flowers per plant** | **Fruit Diameter (cm)** | **Fruit Weight (g)** |
| **30 DAT** | **60 DAT** | **90 DAT** |
|
| **T1-**Control (No treatment) | 41.83 | 55.40 | 70.40 | 8.33 | 39.33 | 28.25 | 4.80 | 28.62 |
| **T2-**RDF (120:80:50) | 56.40 | 68.63 | 90.46 | 13.67 | 30.33 | 35.62 | 6.10 | 42.41 |
| **T3-**(100%) FYM (Farmyard Manure) (25t/ha) | 48.30 | 58.70 | 76.46 | 12.33 | 37.67 | 26.35 | 5.13 | 31.44 |
| **T4-**(100%) Vermicompost (VC) (10 t/ha) | 53.70 | 64.33 | 87.13 | 12.33 | 32.00 | 35.25 | 5.55 | 41.21 |
| **T5-***Azotobacter*  | 44.93 | 56.56 | 82.33 | 10.00 | 34.33 | 31.52 | 5.50 | 36.37 |
| **T6-***Azospirillum*  | 44.13 | 56.63 | 79.53 | 10.33 | 35.67 | 32.33 | 5.30 | 33.66 |
| **T7-**50% RDF + 50% FYM | 58.10 | 71.30 | 92.26 | 15.00 | 29.00 | 37.62 | 6.36 | 43.18 |
| **T8-**50% RDF + 50% Vermicompost | 55.23 | 67.86 | 89.36 | 13.67 | 31.33 | 36.52 | 6.03 | 41.92 |
| **T9-**50% RDF + *Azotobacter* | 52.23 | 62.80 | 85.60 | 12.00 | 33.00 | 32.52 | 5.70 | 40.55 |
| **T10-**50% RDF + *Azospirillum* | 50.10 | 60.23 | 85.20 | 11.33 | 34.67 | 34.25 | 5.63 | 38.34 |
| **T11-**50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* | 62.00 | 75.93 | 97.03 | 16.33 | 24.33 | 40.32 | 6.86 | 44.84 |
| **T12-**50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum* | 60.36 | 72.46 | 95.36 | 15.67 | 27.67 | 39.58 | 6.83 | 44.33 |
| S.Em(±) | 1.62 | 1.90 | 2.58 | 0.509 | 1.80 | 1.70 | 0.33 | 1.69 |
| CD at 5% | 4.78 | 2.70 | 7.62 | 1.50 | 5.31 | 5.00 | 0.978 | 5.00 |

**Table 2. Effect of INM on yield and quality parameter of tomato.**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Yield** | **Ascorbic Acid (mg/100g)** | **TSS (0Brix)** | **Acidity (%)** | **Non-reducing Sugar** | **Reducing Sugar** | **Total Sugar** | **B:C****Ratio** |
| **(kg/plant)** | **(kg/plot)** | **(t/ha)** |
| **T1-**Control (No treatment) | 0.67 | 16.79 | 23.03 | 11.85 | 4.03 | 0.20 | 2.83 | 11.36 | 14.19 | 2.47 |
| **T2-**RDF (120:80:50) | 1.42 | 30.75 | 45.55 | 14.57 | 4.18 | 0.26 | 3.87 | 13.29 | 17.16 | 3.00 |
| **T3-**(100%) FYM (Farmyard Manure) (25t/ha) | 0.75 | 18.71 | 27.72 | 12.77 | 4.04 | 0.33 | 3 | 12.07 | 15.07 | 2.40 |
| **T4-**(100%) Vermicompost (VC) (10 t/ha) | 1.26 | 31.41 | 46.53 | 14.30 | 4.22 | 0.27 | 3.64 | 13.12 | 16.76 | 2.99 |
| **T5-***Azotobacter*  | 0.97 | 24.29 | 35.98 | 13.20 | 4.11 | 0.23 | 3.23 | 12.36 | 15.59 | 2.08 |
| **T6-***Azospirillum*  | 0.87 | 21.64 | 32.07 | 13.56 | 4.08 | 0.29 | 3.11 | 12.16 | 15.27 | 2.10 |
| **T7-**50% RDF + 50% FYM | 1.47 | 36.68 | 54.34 | 15.15 | 4.21 | 0.21 | 3.99 | 13.4 | 17.39 | 2.91 |
| **T8-**50% RDF + 50% Vermicompost | 1.37 | 34.30 | 50.82 | 14.74 | 4.17 | 0.20 | 3.71 | 13.25 | 16.96 | 2.75 |
| **T9-**50% RDF + *Azotobacter* | 1.20 | 29.95 | 44.38 | 14.04 | 4.14 | 0.21 | 3.55 | 12.51 | 16.06 | 2.29 |
| **T10-**50% RDF + *Azospirillum* | 1.05 | 26.31 | 38.97 | 13.71 | 4.12 | 0.28 | 3.4 | 12.5 | 15.9 | 2.23 |
| **T11-**50% RDF + 50% FYM + *Azotobacter* + *Azospirillum* | 1.65 | 41.17 | 60.99 | 16.14 | 4.25 | 0.34 | 4.21 | 13.34 | 17.55 | 3.49 |
| **T12-**50% RDF + 50% Vermicompost + *Azotobacter* + *Azospirillum* | 1.55 | 38.87 | 57.58 | 15.62 | 4.22 | 0.35 | 4.09 | 13.26 | 17.35 | 3.25 |
| S.Em(±) | 0.11 | 2.94 | 4.25 | 0.63 | 0.16 | 0.074 | 0.45 | 0.26 | 0.66 |  |
| CD at 5% | 0.348 | 8.69 | 12.55 | 1.87 | N/A | N/A | 0.85 | 0.76 | 1.94 |  |