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INFLUENCE OF BIOFERTILIZERS AND ORGANIC MULCHES ON FRUIT QUALITY OF STRAWBERRY (*Fragaria × ananassa* Duch.) IN THE SOUTH-EAST ZONE OF RAJASTHAN INDIA

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ABSTRACT

The present investigation was conducted to assess the influence of different biofertilizers and organic mulching materials on the physical and chemical characteristics of strawberry fruits. The experiment comprised thirteen treatments involving Azotobacter, phosphate-solubilizing bacteria (PSB), *Trichoderma harzianum*, and organic mulches (paddy straw and dried leaves), along with a control (FYM @ 10 kg/bed). The study revealed significant variations among treatments for all parameters studied. Among the treatments, T_{12} (Azotobacter 8 g/plant + PSB 8 g/plant + *Trichoderma harzianum* 6 g/plant with dried leaves) exhibited superior performance. It recorded maximum fruit length (3.61 cm), diameter (24.47 mm), and weight (17.92 g), along with higher fruit volume (21.96 cc), specific gravity (0.81 g/cm³), and juice content (66.06%). The pulp content was minimum (33.93%) and juice:pulp ratio was maximum (1.96), indicating better fruit quality. Shelf life was also improved (2.91 days) compared to the control (1.20 days). In terms of chemical parameters, T_{12} recorded significantly higher total soluble solids (11.71 °Brix), total sugars (10.92%), TSS:acid ratio (15.21), fruit pH (3.53), and ascorbic acid content (59.25 mg/100 g), along with the lowest titratable acidity (0.79%). The control treatment (T_{13}) consistently showed inferior performance across all parameters. The enhanced performance under T_{12} may be attributed to the synergistic effect of biofertilizers, where Azotobacter improves nitrogen fixation, PSB enhances phosphorus availability, and *Trichoderma harzianum* promotes plant growth through phytohormone production. Additionally, organic mulches improve soil moisture retention and microbial activity, resulting in better nutrient uptake and fruit development. Thus, the combined application of biofertilizers with dried leaf mulch significantly improves fruit quality and overall performance of strawberry under the given agro-climatic conditions.
***Keywords*:** *Azotobacter, Fruit, Juice, Quality.*

Introduction

The strawberry (*Fragaria* × *ananassa* Duch.), an aggregate fruit belongs to the family Rosaceae, holds a significant position in the fruit industry. The strawberry has a special place among all the cultivated berry fruits. Due to high nutritional content, delicious flavour and wide range of culinary uses, strawberries are highly valued in both the agricultural and culinary fields (Bardone, 2013). Finding ways to improve strawberry growth, output and quality through organic techniques is very crucial as customer prefer it more. Customers of all ages increasingly favour strawberries because of their therapeutic qualities (anti-carcinogenic, anti-diabetic and antioxidant). Natural antioxidants include phenols, carotenoids, flavonoids, dietary glutathione and metabolites that are abundant in strawberries and have a high antioxidant capacity against various groups of free radicals such as superoxide, hydrogen peroxide, hydrogen radicals and single oxygen. The antioxidant activity of strawberry is impacted by cultural practices, growth temperature and genotype (Wang and lin, 2002).

Conventional farming methods frequently include extensive use of chemical pesticides and synthetic fertilizers, which harm the environment and human health. On the other hand, eco-friendly substitutes like organic mulch and bio-fertilizers support microbial diversity, soil health and ecosystem resilience while preserving or increasing crop output. Use of various microorganisms including fungi, bacteria, algae, along with bio-fertilizers enhances soil structure, promote nutrient uptake and reduce the risk of soil borne diseases. When used wisely, they improve nutrient availability, encourage plant development and support sustainable agriculture methods. Natural materials like straw, compost or shreds of leaf litter can be used to create organic mulches for retaining moisture, controlling weed growth, regulating temperature and preventing soil erosion. They also enrich the soil with organic matter, which improves its fertility and microbial activity. Now a days biofertilizers are emerged as an economically attractive and ecologically sound solution to reduce reliance on external inputs and improve the quality of soil with maximum outputs. Biofertilizers serve as carriers containing beneficial microorganisms in a viable state, intended for seed or soil application, designed to enhance soil fertility status and promote plant growth by increasing the biological activity of desired microorganisms in the root environment. Furthermore, they can fix atmospheric nitrogen in the range of 20–200 kg N/ha/year, solubilize phosphorus in the range of 30–50 kg P_2O_5/ha/year and mobilize phosphorus, zinc, iron and molybdenum to varying extents. Numerous bacterial species, primarily associated with the plant rhizosphere have been tested and found beneficial for plant growth, yield and fruit quality.

Being a surface feeder crop growth, development, fruit yield, quality and runner production are all significantly impacted by the use of fertilizers, although the yield per unit area has increased with the use of synthetic fertilizers. To increase productivity, inorganic fertilizers are combined with a balanced application of organic manure and biofertilizers. Today's intensive crop cultivation practices lead to a massive application of chemical fertilizers, which are costly and damage the environment, soil and water. Therefore, a different source of nutrition which is non-chemical in nature is required to maintain the lands production capacity.

Materials and Methods

Location

Kota district is located at 25.18° N to 75.83° E Latitude in South Eastern Rajasthan. It covers an area of 221.36 km^2. Agro-climatically, the district falls in Zone V, known as Humid South Eastern Plain. The average rainfall in the region is 660.6. mm. Maximum temperature range in the summer is 40 to 48°C and minimum 1.0-2.6°C during winter.

Treatment details

The experiment comprised thirteen treatments involving different combinations of biofertilizers, biocontrol agents, and organic mulching materials. Treatment T_1 consisted of Azotobacter (4 g/plant) and *Trichoderma harzianum* (4 g/plant) applied along with paddy straw, whereas T_2 included Azotobacter (7 g/plant) and *Trichoderma harzianum* (10 g/plant) with paddy straw. Treatment T_3 comprised Azotobacter (4 g/plant) and *Trichoderma harzianum* (4 g/plant) with dried leaves, while T_4 involved Azotobacter (7 g/plant) and *Trichoderma harzianum* (10 g/plant) along with dried leaves. In T_5, Azotobacter (8 g/plant) was combined with PSB (8 g/plant) and applied with paddy straw, whereas T_6 included Azotobacter (10 g/plant) and PSB (10 g/plant) with paddy straw. Treatment T_7 consisted of Azotobacter (8 g/plant) and PSB (8 g/plant) with dried leaves, while T_8 included Azotobacter (10 g/plant) and PSB (10 g/plant) along with dried leaves. Treatment T_9 comprised Azotobacter (7 g/plant), PSB (7 g/plant), and *Trichoderma harzianum* (7 g/plant) applied with paddy straw, whereas T_{10} included Azotobacter (10 g/plant), PSB (10 g/plant), and *Trichoderma harzianum* (10 g/plant) with paddy straw. Similarly, T_{11} consisted of Azotobacter (7 g/plant), PSB (7 g/plant), and *Trichoderma harzianum* (7 g/plant) along with dried leaves, while T_{12} included Azotobacter (10 g/plant), PSB (10 g/plant), and *Trichoderma harzianum* (10 g/plant) with dried leaves. Finally, T_{13} served as the control, where only farmyard manure (FYM) was applied at the rate of 10 kg per bed.

Experimental Details

Treatments application

The weighed treatments, *Azotobacter*, PSB and *Trichoderma harzianum* were combined with FYM and Gur (jaggery powder) and applied to strawberry plants after transplanting. 1st application after 50 days of transplanting and 2nd application after 100 days of transplanting. All treatments were given manually to each plant. Paddy straw and dried leaves were laid after 45 days of transplanting.

Field preparation

Following the correct ploughing in the field using a disc harrow, the land was pulverized with a combination of discing and harrowing. After making the experimental field adequately levelled with the assistance of a large wooden planker, all of the weeds, grasses and plant remnants were removed from the field. For the purpose of runners planting, raised beds with a height of 10-15 cm were created. For performing various operation easily, the plots were constructed in accordance with the layout design.

Manures and biofertilizers

Well rotted farm yard manure at a rate of 5 kg per bed was applied uniformly and mixed well before planting of strawberry plants.

Planting of runners

Healthy, disease-free, and uniform one-year-old runners of the cultivar 'Winter Dawn' will obtain from the Center of Excellence Nanta Farm Bundi Road Kota. The runners will transplant on beds of 90 × 60 cm size at a spacing of 45 × 20 cm using a khurpi on 25 October 2025. Immediately after transplanting, light irrigation will provide to ensure proper establishment of the plants.

Irrigation

A number of elements, including the kinds of soil, organic content in the soil, weather conditions and so on, all play a role in determining the appropriate time to water strawberries. The roots of the plant do not penetrate in the soil to an excessive degree. Irrigation must be performed on a consistent basis at regular intervals. The initial watering was carried out right after the planting was completed. After that, irrigation was performed at an interval of 3-4 days during the summer and on intervals of 9-10 days during the winter.

Weeding and mulching

Strawberry plants are extremely sensitive to weeds, particularly in the early stages after planting. In order to manage weeds, timely weeding and hoeing were performed during both years of the experiment. One of the most essential gardening practices for strawberry production is the application of mulch. To conserve soil moisture, protect the direct contact of fruits with soil and prevent the growth of weeds, mulching material of paddy straw and dried leaves were utilized.

Plant protection

Prompt and appropriate plant protection measures were implemented to safeguard the crop against insects, pests and diseases. During the years of inquiry, termites were the most common pest thats were seen in the experimental field. In order to eliminate termites, raw hing (asafoetida) is used in conjunction with irrigation water. As *Trichoderma harzianum* was already given with treatments, so that no fungal infestation was reported.

Measurement of Physical attributes of strawberry

All the physical and quality parameters of strawberry fruits were studied using standard methods. Fruit characters included fruit length, fruit diameter, fruit weight, fruit volume, and specific gravity. Fruit length was measured in centimeters using a Vernier calliper by aligning it from the base to the tip of the fruit, while fruit diameter was recorded in millimeters by measuring the widest portion of the fruit. Fruit weight was determined using a digital weighing balance and expressed in grams, whereas fruit volume was measured by the water displacement method and recorded in cubic centimeters. Specific gravity was calculated by dividing fruit weight by its volume.

Measurement of chemical attributes of strawberry

Quality parameters comprised total soluble solids (TSS), juice content, ascorbic acid, titratable acidity, pulp content, TSS: acid ratio, juice: pulp ratio, and total sugars. TSS was measured using a hand refractometer and expressed in °Brix after temperature correction as per AOAC (1980). Juice content was determined by extracting juice from a known weight of fruit and expressing it as a percentage. Ascorbic acid content was estimated by titration with 2,6-dichlorophenol indophenol dye following the method described by Ranganna (1986) and expressed as mg per 100 g pulp. Titratable acidity was determined by titrating fruit juice with standard NaOH using phenolphthalein as an indicator as per Ranganna (1986) and expressed as a percentage. Pulp content was calculated as the percentage of pulp weight relative to total fruit weight. The TSS: acid ratio was obtained by dividing TSS by acidity, while the juice: pulp ratio was calculated by dividing juice weight by pulp weight. Total sugars were estimated using Fehling's solution after hydrolysis and neutralization of the sample, and values were expressed on a fresh pulp weight basis.

Results

Effect of bio-fertilizers and organic mulch on fruit physical parameters

The observations recorded in Table 1 showed that the maximum fruit length (3.67 cm) was recorded under treatment T_{12}, followed by T_{10} (3.61 cm). The minimum fruit length (1.39 cm) was observed under control treatment T_{13}. The improvement in fruit size may be attributed to better nutrient availability and enhanced metabolic activity. The data presented in Table 4.15 indicated that the maximum fruit diameter was recorded under treatment T_{12}, followed by T_{10}, whereas the minimum was recorded under control treatment T_{13}. This indicates improved fruit development under integrated nutrient management practices.

The fruit weight was significantly influenced by different combinations of bio-fertilizers and organic mulch treatments during both years of experimentation as well as in pooled analysis. Among all the treatments, the maximum fruit weight (17.98 g) was recorded under treatment T_{12} (Azotobacter 10 g plant^{-1} + PSB 10 g plant^{-1} + *Trichoderma harzianum* 10 g plant^{-1} + dried leaves mulch), which proved to be statistically superior over all other treatments. This was closely followed by treatment T_{10} (15.49 g), indicating that the same combination of bio-fertilizers with paddy straw mulch also had a pronounced positive effect on fruit development. The increased fruit weight under these treatments may be attributed to enhanced nutrient availability, improved root activity, and efficient translocation of assimilates from source to sink due to the synergistic action of beneficial microorganisms and mulch-induced soil moisture conservation. In contrast, the minimum fruit weight (8.68 g) was recorded under control treatment T_{13} (FYM @ 10 kg bed^{-1}), which lacked integrated nutrient supply. The results clearly demonstrate the superiority of integrated bio-fertilizer and mulch application in improving fruit weight.

The observations recorded in Table 1 indicated that fruit volume was significantly influenced by various treatments. The maximum fruit volume (22.02 cc) was recorded under treatment T_{12}, which was found to be statistically at par with treatments T_{10} (20.93 cc) and T_{11} (20.80 cc). The increase in fruit volume under these treatments may be attributed to improved cell division and enlargement, enhanced nutrient uptake, and better physiological efficiency of plants resulting from bio-fertilizer application and improved soil conditions due to mulching. On the other hand, the minimum fruit volume (16.67 cc) was recorded under control treatment T_{13}, indicating inferior fruit development due to lack of integrated nutrient management. The results clearly highlight the beneficial effect of bio-fertilizers and organic mulch on fruit size.

The data presented in Table 2 revealed that specific gravity of fruits was significantly affected by different treatments. The highest specific gravity (0.81 g cm^{-3}) was recorded under treatment T_{12}, followed by T_{10} (0.74 g cm^{-3}) and T_{11} (0.72 g cm^{-3}), which were statistically at par. The increase in specific gravity under these treatments indicates better accumulation of soluble solids and improved fruit density, which may be attributed to enhanced nutrient uptake and metabolic activities. In contrast, the lowest specific gravity (0.52 g cm^{-3}) was recorded under control treatment T_{13}, indicating poor fruit quality. The results clearly demonstrate that integrated nutrient management improves internal fruit composition.

The juice content was significantly influenced by different treatment combinations. The maximum juice content (67.49%) was recorded under treatment T_{12}, followed by T_{10} (66.16%) and T_{11} (65.45%). The increase in juice content under these treatments may be attributed to improved water uptake, enhanced cellular hydration, and better physiological activity of plants under bio-fertilizer application. Conversely, the minimum juice content (57.83%) was recorded under control treatment T_{13}, indicating reduced fruit succulence. These findings clearly suggest that integrated application of bio-fertilizers and organic mulch enhances fruit juiciness and overall quality (Table 2).

The data presented in Table 2 revealed that pulp content exhibited an inverse relationship with juice content. The maximum pulp content (45.02%) was recorded under control treatment T_{13}, whereas the minimum pulp content (35.36%) was recorded under treatment T_{12}, followed by T_{10} (36.70%). The higher pulp content under control conditions may be due to comparatively lower juice accumulation. Although variations were observed among treatments, the differences were reported as statistically non-significant. However, the reduction in pulp content under bio-fertilizer treatments indicates improved fruit quality in terms of higher juice proportion.

The data presented in Table 3 revealed that total soluble solids content was significantly influenced by different treatments. The maximum TSS (11.79 °Brix) was recorded under treatment T_{12}, followed by T_{10} (11.19 °Brix) and T_{11} (10.84 °Brix). The increase in TSS under these treatments may be attributed to enhanced carbohydrate metabolism and accumulation of soluble sugars due to improved nutrient availability. The minimum TSS (7.73 °Brix) was recorded under control treatment T_{13}, indicating poor fruit sweetness. The results clearly demonstrate that bio-fertilizer application improves fruit quality.

The data presented in Table 3 indicated that total sugar content was significantly influenced by different treatments. The maximum total sugars (10.98%) were recorded under treatment T_{12}, followed by T_{10} (10.30%) and T_{11} (9.93%). The increase in sugar content may be attributed to improved photosynthetic activity and efficient translocation of sugars to fruits. In contrast, the minimum sugar content (6.25%) was recorded under control treatment T_{13}. These findings clearly indicate that integrated nutrient management enhances sweetness and overall fruit quality.

The data presented in Table 4 revealed that titratable acidity was reduced under bio-fertilizer treatments. The minimum acidity (0.78%) was recorded under treatment T_{12}, followed by T_{10} (0.86%) and T_{11} (0.88%). In contrast, the maximum acidity (1.65%) was recorded under control treatment T_{13}. Lower acidity under integrated treatments indicates better taste and improved fruit quality. However, the differences were reported as statistically non-significant.

The TSS: acid ratio was significantly influenced by treatments. The maximum ratio (15.12) was recorded under treatment T_{12}, followed by T_{10} (13.01) and T_{11} (12.32). The higher ratio indicates improved sweetness, better palatability, and superior fruit quality. In contrast, the minimum ratio (4.68) was recorded under control treatment T_{13}.

The data presented in Table 4 revealed that ascorbic acid content was significantly influenced by different treatments. The maximum ascorbic acid content (60.57 mg 100 g^{-1} pulp) was recorded under treatment T_{12}, followed by T_{10} (58.60 mg 100 g^{-1} pulp) and T_{11} (56.84 mg 100 g^{-1} pulp). The increase in vitamin C content may be attributed to enhanced metabolic activity and improved nutrient uptake. The minimum value (51.01 mg 100 g^{-1} pulp) was recorded under control treatment T_{13}.

Discussion

Physical characters of fruit

In the present investigation it can be elucidate that T_{12}, *Azotobacter* (8g/plant) + PSB (8g/plant) + *Trichoderma harzianum* (6g/plant) with dried leaves gave significant maximum length (3.61 cm), diameter (24.47 mm) and weight (17.92 g) of strawberry fruits. The lowest values for length (1.33 cm), diameter (15.25 mm) and weight (8.62 g) recorded in plants kept under control (T_{13}) treatment. Similar results were obtained by Gupta and Tripathi (2012), Tripathi *et al.* (2015), Tripathi *et al.* (2016), Tripathi *et al.* (2017), Kumar *et al.* (2020) in strawberry. *Azotobacter* is responsible for fixing atmospheric nitrogen in the root zone, which in turn promotes vegetative growth and supplies all the necessary nutrients for fruit development. Increasing the availability of phosphorus, which is essential for the development of powerful root systems and absorption of nutrients, which helps in stimulating the formation of larger fruits (Bhakare *et al*., 2008).

It is possible that the improved photosynthetic capacity of plants that were fertilized with *Azotobacter* + PSB and *Trichoderma harzianum*, which in turn may have encouraged and increased the accumulation of dry matter content, was the cause of this rise in berry size and weight that occurred during the current experimentation period. Dry matter content and the balance level of hormones and nitrogen fixers are known to be associated with the accumulation of dry matter and their translocation (Pandey *et al*., 2016). Additionally, the presence of nitrogen fixers is known to favour the synthesis of various growth regulators. Fruit size and weight are closely correlated with dry matter content or balance level in the plants.

In the present investigation it also noticed that T_{12}-*Azotobacter* (8g/plant) + PSB (8g/plant) + *Trichoderma harzianum* (6g/plant) with dried leaves produced significant maximum fruit volume, specific gravity and juice content at 21.96 cc, 0.81 g/cm^3, 66.06 %, respectively. The control (T_{13}) treatment showed minimum values regarding presented parameters. The combined application of *Azotobacter*, PSB (Phosphate-Solubilizing Bacteria) and *Trichoderma harzianum* with organic mulch, such as paddy straw and dried leaves, significantly enhances strawberry fruit characteristics. *Azotobacter* fixes more nitrogen, boosting plant growth, food formation and fruit cell expansion. PSB solubilizes phosphorus, vital for energy transfer and cell division, resulting in larger fruit volume. *Trichoderma harzianum* produces growth-promoting hormones, which increases fruit size. This improved nutrient uptake from these microbes enhances fruit density. Higher specific gravity indicates a healthier fruit with more sugars and nutrients in it. Gupta and Tripathi (2012), Tripathi *et al.* (2015), Tripathi *et al.* (2016), Tripathi *et al.* (2017) and Kumar *et al.* (2020) in strawberry also reported more or less results. The organic mulch retains soil moisture and promotes microbial activity, increasing water and nutrient absorption by the plant, which directly enhances juice content in the fruits.

The pulp content was founded significantly minimum in T_{12}-*Azotobacter* (8g/plant) + PSB (8g/plant) + *Trichoderma harzianum* (6g/plant) with dried leaves at 33.93%. The maximum pulp content was found in fruits produced from the control (T_{13}) treatment with the value of 43.59%. Similarly, significantly maximum juice: pulp ratio was recorded in T_{10}-*Azotobacter* (8g/plant) + PSB (8g/plant) + *Trichoderma harzianum* (6g/plant) with dried leaves at 1.96 and minimum in control (T_{13}) plants at 1.31 However, no such reports are available from the literature and thus warrant further more studies for these parameters.

Chemical characters

On the basis of present investigation, it is recorded that fruits with significant maximum TSS and total sugars was produced from plants treated with T_{12}-*Azotobacter* (8g/plant) + PSB (8g/plant) + *Trichoderma harzianum* (6g/plant) with dried leaves with the value of 11.71 °Brix and 10.92 %, respectively. The minimum values for the parameters were recorded in control (T_{13}). The rapid metabolic transformation of starch and pectin into soluble substances along with rapid translocation of sugars from leaves to developing fruits may be responsible for the increase in total sugars and total soluble solids (TSS) contents that's may be attributed due to the application of *Azotobacter*, PSB and *Trichoderma harzianum*. Several scientists such as Gupta and Tripathi (2012), Tripathi *et al.* (2015), Tripathi *et al.* (2016a), Tripathi *et al.* (2017) and Kumar *et al.* (2020), all came to the same conclusion about strawberry and mentioned above findings are in agreement with their findings.

The significantly minimum titratable acidity content in fruits was recorded in T_{12}-*Azotobacter* (8g/plant) + PSB (8g/plant) + *Trichoderma harzianum* (6g/plant) with dried leaves at 0.79%, whereas the maximum titratable acidity content was recorded in control (T_{13}). The views were corroborated with the observations of Mishra and Tripathi (2011), Gupta and Tripathi (2012), Tripathi *et al.* (2015) and Tripathi *et al.* (2017) in strawberry.

In the present investigation plants treated with T_{12}-*Azotobacter* (8g/plant) + PSB (8g/plant) + *Trichoderma harzianum* (6g/plant) with dried leaves produced fruits with significantly maximum TSS: acid ratio (15.21). The plants in control treatment (T_{13}) shows minimum TSS: acid ratio (4.64). *Azotobacter*, a free-living nitrogen-fixing bacterium, provides an additional nitrogen source to the plants, which is crucial for vegetative growth and fruiting. By promoting chlorophyll content and photosynthesis, *Azotobacter* helps in synthesizing essential sugars and organic acids that directly contribute to the sweetness (higher TSS) and flavour (TSS: acid ratio) of the fruit. PSB plays a vital role in solubilizing insoluble phosphates in the soil, making phosphorus readily available to the plant. Phosphorus is essential for energy transfer and sugar metabolism, which directly impacting on fruit quality. These findings were close to the reports of Sahoo and Singh (2005), Tripathi and Babu (2008), Tripathi *et al.* (2010), Mishra and Tripathi (2011), Tripathi *et al.* (2014) of strawberry.

In the present investigation it is also founded that significantly maximum fruit pH was recorded in fruits treated by the application of T_{12}-*Azotobacter* (8g/plant) + PSB (8g/plant) + *Trichoderma harzianum* (6g/plant) with dried leaves at 3.53 and minimum in control (T_{13}) at 2.57. *Trichoderma harzianum* and PSB can modify the rhizosphere pH through the production of organic acids and enzymes. This pH adjustment in the soil can indirectly affect the plant's nutrient uptake, especially of calcium and potassium, which play key roles in reducing acidity by promoting sugar synthesis and accumulation. *Trichoderma harzianum* produces phytohormones, such as auxins, gibberellins and cytokinins, which promote overall plant growth, flowers and fruit development. These hormones influences the metabolic processes within the plant, including the conversion of starches and acids into sugars during fruit ripening (Patuk *et al*., 2024).

Significantly maximum ascorbic acid was founded in T_{12}-*Azotobacter* (8g/plant) + PSB (8g/plant) + *Trichoderma harzianum* (6g/plant) with dried leaves at 59.25 mg/100g and minimum in control (T_{13}) plants. The improved nutrient uptake facilitated by *Azotobacter*, PSB and *Trichoderma harzianum* along with the organic mulch optimizes plant metabolism and boosted ascorbic acid synthesis in strawberries. It is possible that the increase in ascorbic acid content may be due to the increased efficiency of microbial inoculants to fix atmospheric nitrogen. The increase in the availability of phosphorous and secretion of growth promoting substances helps in the physiological process such as the synthesis of carbohydrates among fruits. The results also got the support with the findings of Gupta and Tripathi (2012), Tripathi *et al.* (2015), Tripathi *et al.* (2016), Tripathi *et al.* (2017) and Kumar *et al.* (2020) in strawberry.

Conclusion

The study concludes that integrated nutrient management significantly improves the growth and yield of tomato. The treatment T_8 (NPK 50% + FYM 25% + VC 25%) was found to be the most effective, recording the highest values for all growth and yield parameters. This improvement is attributed to better nutrient availability, enhanced soil health, and improved nutrient uptake. Therefore, the combined use of organic and inorganic fertilizers is recommended as a sustainable approach for higher productivity in tomato cultivation.

Table 1 : Effect of bio-fertilizers and organic mulch on fruit length (cm), fruit weight (g) and Fruit volume (cc)

Treatments	***Fruit length (cm)***	***Fruit weight (g)***	***Fruit volume (cc)***
T1- Azotobacter (4g/plant) + Trichoderma harzianum (4g/plant) + Paddy straw	1.68	11.26	18.53
T2- Azotobacter (7g/plant) + Trichoderma harzianum (10g/plant) + paddy straw	1.75	11.45	19.29
T3- Azotobacter (4g/plant) + Trichoderma harzianum (4g/plant) + dried leaves	2.13	11.63	19.68
T4- Azotobacter (7g/plant) + Trichoderma harzianum (10g/plant) + dried leaves	2.50	12.05	19.08
T5- Azotobacter (8g/plant) + PSB (8g/plant) + paddy straw	2.32	12.32	18.72
T6- Azotobacter (10g/plant) + PSB (10g/plant) + paddy straw	2.67	12.21	18.35
T7- Azotobacter (8g/plant) + PSB (8g/plant) + dried leaves	2.78	11.50	18.66
T8- Azotobacter (10g/plant) + PSB (10g/plant) + dried leaves	3.15	13.67	19.94
T9- Azotobacter (7g/plant) + PSB (7g/plant) + Trichoderma harzianum (7g/plant) + paddy straw	3.28	14.44	20.42
T10- Azotobacter (10g/plant) + PSB (10g/plant) + Trichoderma harzianum (10g/plant) + paddy straw	3.61	15.49	20.93
T11- Azotobacter (7g/plant) + PSB (7g/plant) + Trichoderma harzianum (7g/plant) + dried leaves	3.45	14.96	20.80
T12- Azotobacter (10g/plant) + PSB (10g/plant) + Trichoderma harzianum (10g/plant) + dried leaves	3.67	17.98	22.02
T13- Control (10 kg FYM per bed)	1.39	8.68	16.67
S.E.±	0.19	0.68	0.49
CD at 5% level	0.58	2.10	1.52

Table 2 : Effect of bio-fertilizers and organic mulch on specific gravity (g/cm^3), Juice content (%) and Pulp content (%)

Treatments	***Specific gravity (g/cm^3)***	***Juice content (%)***	***Pulp content (%)***
T1- Azotobacter (4g/plant) + Trichoderma harzianum (4g/plant) + Paddy straw	0.61	62.11	40.74
T2- Azotobacter (7g/plant) + Trichoderma harzianum (10g/plant) + paddy straw	0.59	62.81	40.04
T3- Azotobacter (4g/plant) + Trichoderma harzianum (4g/plant) + dried leaves	0.59	63.06	39.80
T4- Azotobacter (7g/plant) + Trichoderma harzianum (10g/plant) + dried leaves	0.63	63.42	39.44
T5- Azotobacter (8g/plant) + PSB (8g/plant) + paddy straw	0.66	62.47	40.38
T6- Azotobacter (10g/plant) + PSB (10g/plant) + paddy straw	0.66	63.33	39.53
T7- Azotobacter (8g/plant) + PSB (8g/plant) + dried leaves	0.61	64.27	38.58
T8- Azotobacter (10g/plant) + PSB (10g/plant) + dried leaves	0.68	64.50	38.35
T9- Azotobacter (7g/plant) + PSB (7g/plant) + Trichoderma harzianum (7g/plant) + paddy straw	0.70	65.18	37.68
T10- Azotobacter (10g/plant) + PSB (10g/plant) + Trichoderma harzianum (10g/plant) + paddy straw	0.74	66.16	36.70
T11- Azotobacter (7g/plant) + PSB (7g/plant) + Trichoderma harzianum (7g/plant) + dried leaves	0.72	65.45	37.41
T12- Azotobacter (10g/plant) + PSB (10g/plant) + Trichoderma harzianum (10g/plant) + dried leaves	0.81	67.49	35.36
T13- Control (10 kg FYM per bed)	0.52	57.83	45.02
S.E.±	0.04	0.45	0.45
CD at 5% level	0.12	1.38	1.38

Table 3 : Effect of bio-fertilizers and organic mulch on TSS (^{o}Brix) and Total sugars (%)

Treatments	***TSS (^{o}Brix)***	***Total sugars (%)***
T1- Azotobacter (4g/plant) + Trichoderma harzianum (4g/plant) + Paddy straw	10.13	8.81
T2- Azotobacter (7g/plant) + Trichoderma harzianum (10g/plant) + paddy straw	10.19	8.80
T3- Azotobacter (4g/plant) + Trichoderma harzianum (4g/plant) + dried leaves	10.37	8.81
T4- Azotobacter (7g/plant) + Trichoderma harzianum (10g/plant) + dried leaves	10.27	8.85
T5- Azotobacter (8g/plant) + PSB (8g/plant) + paddy straw	10.29	9.28
T6- Azotobacter (10g/plant) + PSB (10g/plant) + paddy straw	10.10	8.96

T7- Azotobacter (8g/plant) + PSB (8g/plant) + dried leaves	10.25	9.19
T8- Azotobacter (10g/plant) + PSB (10g/plant) + dried leaves	10.43	9.21
T9- Azotobacter (7g/plant) + PSB (7g/plant) + Trichoderma harzianum (7g/plant) + paddy straw	10.65	9.67
T10- Azotobacter (10g/plant) + PSB (10g/plant) + Trichoderma harzianum (10g/plant) + paddy straw	11.19	10.30
T11- Azotobacter (7g/plant) + PSB (7g/plant) + Trichoderma harzianum (7g/plant) + dried leaves	10.84	9.93
T12- Azotobacter (10g/plant) + PSB (10g/plant) + Trichoderma harzianum (10g/plant) + dried leaves	11.79	10.98
T13- Control (10 kg FYM per bed)	7.73	6.25
S.E.±	0.34	0.35
CD at 5% level	1.05	1.08

Table 4 : Effect of bio-fertilizers and organic mulch on titratable acidity (%),TSS: acid ratio and Ascorbic acid (mg/100g pulp)

Treatments	***Titratable acidity (%)***	***TSS: acid ratio***	***Ascorbic acid (mg/100g pulp)***
T1- Azotobacter (4g/plant) + Trichoderma harzianum (4g/plant) + Paddy straw	1.29	7.85	52.49
T2- Azotobacter (7g/plant) + Trichoderma harzianum (10g/plant) + paddy straw	1.36	7.49	54.13
T3- Azotobacter (4g/plant) + Trichoderma harzianum (4g/plant) + dried leaves	1.53	6.78	53.99
T4- Azotobacter (7g/plant) + Trichoderma harzianum (10g/plant) + dried leaves	1.38	7.44	55.15
T5- Azotobacter (8g/plant) + PSB (8g/plant) + paddy straw	0.98	10.50	54.70
T6- Azotobacter (10g/plant) + PSB (10g/plant) + paddy straw	1.10	9.18	55.04
T7- Azotobacter (8g/plant) + PSB (8g/plant) + dried leaves	1.03	9.95	54.97
T8- Azotobacter (10g/plant) + PSB (10g/plant) + dried leaves	1.19	8.76	51.94
T9- Azotobacter (7g/plant) + PSB (7g/plant) + Trichoderma harzianum (7g/plant) + paddy straw	0.95	11.21	55.43
T10- Azotobacter (10g/plant) + PSB (10g/plant) + Trichoderma harzianum (10g/plant) + paddy straw	0.86	13.01	58.60
T11- Azotobacter (7g/plant) + PSB (7g/plant) + Trichoderma harzianum (7g/plant) + dried leaves	0.88	12.32	56.84
T12- Azotobacter (10g/plant) + PSB (10g/plant) + Trichoderma harzianum (10g/plant) + dried leaves	0.78	15.12	60.57
T13- Control (10 kg FYM per bed)	1.65	4.68	51.01
S.E.±	0.17	1.19	1.34
CD at 5% level	0.52	3.68	4.12

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Declaration of Competing Interest

No interests to declare.

References

A.O.A.C. (1980). Method of analysis, Association of official Analysis Chemists, Washington, D.C. USA.

Bardone, E. (2013). Strawberry fields forever?, *Ethnologia Europaea*, **43**(2), 30-46.

Bhakare, G. C., Deokar, C. D., Navale, A. M. and Sonawane, R. B. (2008). Comparative performance of *Azotobacter* biofertilizers on growth and yield of brinjal. *Asian Journal of Horticulture*, **3**(2), 377-379.

Gupta, A. K. and Tripathi, V. K. (2012). Efficacy of *Azotobacter* and vermicompost alone and in combination on vegetative growth, flowering and yield of strawberry (*Fragaria x ananassa* Duch.) cv. Chandler. *Progressive Horticulture*, **44**(2), 256- 261.

Kumar, Anurag and Tripathi, V. (2020). Effect of *Azotobacter*, PSB and vermicompost on growth, flowering, yield and quality of strawberry (*Fragaria x ananassa* Duch.) cv. Chandler. *Progressive Horticulture*, **52**(2), 157-161.

Mishra, A. N. and Tripathi, V. K. (2011). Influence of different levels of *Azotobacter*, PSB alone and in combination on vegetative growth, flowering, yield and quality of strawberry cv. Chandler. *International Journal of Applied Agricultural Research*, **6**(3), 203-210.

Patuk, O., Singh, Y. S. and Momin, K. C. (2024). Influence of organic inputs on the performance of strawberry (*Fragaria x ananassa* Duch.) cv.

Festival. *Environment and Ecology*, **42**(2B), 897-901.

Ranganna, S. (1986). *Handbook of analysis and quality control for fruit and vegetable products*. Tata McGraw-Hill Education.

Sahoo, S. K. and D. B. Singh (2005). Effect of different levels of bio-fertilizers on growth, yield and quality of strawberry (*Fragaria* × *ananassa* Duch.) cv. Sweet Charley. *Orissa Journal of Horticulture*, **33**(2), 82-85.

Tripathi, V. K., Jain, A., Kumar, S., Dubey, V. and Kumar, A. (2017). Efficacy of bio- fertilizers and mulching on growth, yield and quality of strawberry (*Fragaria* × *ananassa*) cv. Chandler. *Indian Journal of Agricultural Sciences*, **87**(9), 1179-1183.

Tripathi, V. K., Kumar, S. and Gupta, A. K. (2015). Influence of *Azotobacter* and vermicompost on growth, flowering, yield and quality of strawberry cv. Chandler. *Indian Journal of Horticulture*, **72**(2), 201-205.

Tripathi, V. K., Kumar, S., Kumar, K., Kumar, S. and Dubey, V. (2016). Influence of *Azotobacter*, *Azospirillum* and PSB on vegetative growth, flowering, yield and quality of strawberry cv. Chandler. *Progressive Horticulture*, **48**(1), 48-52.

Tripathi, V.K. and Babu, S. (2008). Effect of biofertilizer on growth, yield and quality of strawberry cv. Chandler. In 3rd Indian Horticulture on "New R & D Initiatives in Horticulture for Accelerated Growth and prosperity" organized by the Horticultural Society of India at O.U.A.T. Bhuvaneshwar, Orissa, from Nov 6th to 9th, pp 5.

Tripathi, V. K., Kumar, N., Shukla, H. S. and Mishra, A. N. (2010). Influence of *Azotobacter*, *Azospirillum* and PSB on growth, yield and quality of strawberry cv. *Chandler*, *paper presented in National Symposium on Conservation Horticulture, during March* (pp. 21-23).

Tripathi, V. K., Mishra, A. N., Kumar, S. and Tiwari, B. (2014). Efficacy of *Azotobacter* and PSB on vegetative growth, flowering, yield and quality of strawberry cv. Chandler. *Progressive Horticulture*, **46**(1), 48-53.

Wang, S. Y. and Lin, S. S. (2002). Composts as soil supplement enhanced plant growth and fruit quality of strawberry. *Journal of Plant Nutrition*, **25**(10), 2243-2259.