**Impact of *Trichoderma*, manure and fertilizer on flower yield and postharvest traits in rose under polyhouse**

**Abstract**

The floriculture sector in India is experiencing rapid expansion driven by heightened demand, export opportunities and improvements in cultivation techniques. Among the most commercially valuable crops are roses, often referred to as the 'King of Flowers,' whose quality and yield are significantly affected by soil fertility and nutrient management practices. This research was carried out in a naturally ventilated polyhouse at Horticulture Research Farm, Institute of Agricultural Sciences, Banaras Hindu University from 2023 to 2025 in rose variety Top Secret. The findings indicated that treatment T8 (50% Vermicompost + 50% RDF with *Trichoderma* inoculation) significantly enhanced plant spread (47.12 cm) and leaf area (1283.82 cm²). Treatment T7 (50% FYM + 50% RDF with *Trichoderma* inoculation) achieved the maximum flower diameter (112.28 mm) and stem length (70.52 cm), while T7 (50% FYM + 50% RDF with *Trichoderma* inoculation) produced the maximum petals per flower (78.72). Additionally, postharvest quality was improved, with T7 exhibiting the least weight loss (5.01%) and the highest MDA content (8.08 nmol/g FW), highest flower yield (380.68), stem diameter (5.34 mm) and branch number (6.52). The combination of organic and inorganic nutrient sources, particularly with *Trichoderma*, resulted in notable enhancements in overall plant performance and postharvest durability.

**Keywords**: Inoculation, postharvest quality, rose, *Trichoderma*, vermicompost.

**Introduction**

Roses, often called the “King of Flowers,” are admired for their aesthetic beauty, fragrance and versatility. The global trade of cut roses accounts for about 24% of the total cut flower market, making them one of the most demanded flowers worldwide. In India, rose cultivation is concentrated in states like Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra, and Gujarat. The total area under rose cultivation in India during 2023-24 was 42.9 thousand hectares, producing 181.25 thousand tons of loose flowers and 320.3 thousand tons of cut flowers (Anonymous, 2024).

The negative impacts of chemical fertilizers and pesticides have led researchers to explore organic alternatives like vermicompost, which boosts crop yield and protects against pests without harming the environment. Vermicompost serves as both a nutrient-rich compost and a natural pest control agent, while also providing an efficient solution for solid waste management. Compared to traditional composting and landfilling, vermicomposting offers greater benefits for soil health. Moreover, landfilling is costly (Ahlberg *et al*. 2006) and poses a risk of toxic compound leaching (Senesi *et al*. 2007). To increase yield potential, the use of organic manure and bio-agents plays a key role in improving flowering and corm production. The application of farmyard manure has proven effective in promoting plant growth, enhancing flowering, and boosting corm yield, making it one of the best practices for successful crop cultivation (Gupta *et al*. 2008).

Organic manures such as Farm Yard Manure (FYM), vermicompost and bioagents such as *Trichoderma* have been found to have a significantly beneficial impact on floriculture crops. The use of these eco-friendly inputs is a way to ensure good soil health and sustainable cultivation while reducing the use of chemical fertilizers (Singh, *et al*., 2015). FYM is a rich source of macro and micronutrients while also improving the physio-chemical properties of soil, resulting in enhanced productivity and fertility of crops (Sendhilnathan, *et al*., 2019). Worm compost improves soil structure, supports microbial activity and supplies plant growth hormones, such as auxins, gibberellins (GA) and cytokinin that initiate flowering and prolong post-harvest life. However, high concentrations may inhibit growth due to increased soluble salts (Pena, *et al*., 2025). The *Trichoderma* species act as effective biocontrol agents by suppressing pathogens and inducing plant growth through competitive, antimicrobial and resistance-based mechanisms (Athinuwat, *et al*., 2024). Thus, the combined usage of these agents improves flower quality and yield and promises eco-friendly and sustainable floriculture practice.

**Materials and Methods**

The study was conducted in a naturally ventilated polyhouse at the Horticulture Research Farm and Post-harvest Laboratory, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, from 2023 (November 2023 to March 2024) to 2025 (October 2024 to March 2025). The research focused on the Top Secret rose variety, a well-known red rose that is highly sought after and well-suited for polyhouse cultivation. Uniformly healthy plants with consistent height and bud development (2 years old grafted plant) were selected for research work. The experiment was arranged in a Complete Randomised Design (CRD) involving nine different treatments, including various combinations of organic and inorganic fertilizers, on rose plants. Each treatment was divided into two groups: half the plants were inoculated with *Trichoderma* @25ml/plant, while the other half were left uninoculated. This design allowed for the comparison of the *Trichoderma* inoculation effect across various treatment conditions on rose plants. The nine treatments were T1 (100% RDF), T2 (100% FYM), T3 (100% Vermicompost), T4 (75% FYM + 25% Vermicompost), T5 (50% FYM + 50% Vermicompost), T6 (25% FYM + 75% Vermicompost), T7 (50% FYM + 50% RDF), T8 (50% Vermicompost + 50% RDF) and T9 (Control, with no fertilizer). The plants were arranged in a single row on elevated beds, according to recommendation, spaced 30 cm × 30 cm apart, with fertilizers applied according to the designated treatments. Different amounts of fertilizers were used based on the treatments. For FYM, the amounts were 100% (2.08 kg/m²), 75% (1.56 kg/m²), 50% (1.04 kg/m²) and 25% (0.52 kg/m²); the same quantities were used for vermicompost. Urea was applied at 100% (2 g/plant) and 50% (1 g/plant), while Single Super Phosphate (SSP) was applied at 100% (1 g/plant) and 50% (0.5 g/plant). Observations were recorded on various growth, flowering and post-harvest parameters. The results obtained were subjected to statistical analysis as suggested by Panse and Sukhatme (1978).

**Results and Discussion**

**Growth parameters**

Plant spread is an important growth indicator influencing the overall yield of rose plants. This study revealed (Table 1) significant variation in plant spread under different nutrient treatments and *Trichoderma* inoculation. The first flush recorded the greatest plant spread, with the highest in the T8 (50% Vermicompost + 50% RDF with *Trichoderma*) treatment at 47.12 cm. Which was followed by T7 (50% FYM + 50% RDF with *Trichoderma* inoculation) at 45.79 cm, and T6 (25% FYM + 75% Vermicompost with *Trichoderma*) at 45.79 cm. Organic manures improve soil health, enhance microbial activity and support root growth; whereas, inorganic fertilizers promote rapid shoot development, while *Trichoderma* boosts nutrient uptake and disease resistance, improving rose vegetative growth and plant spread. The findings are in lent credence with the studies of previous researchers (Patel *et al*., 2017 and Kumar *et al*., 2022) who reported vermicompost as a key factor in enhancing the growth and yield in rose.

Leaf area is a vital growth parameter that directly affects the yield of rose plants. This study showed (Table 1) significant differences in leaf area under varying nutrient treatments and *Trichoderma* inoculation. The first flush recorded the maximum leaf area, with the highest in T8 (50% Vermicompost + 50% RDF with *Trichoderma*) at 1283.82 cm². This was followed by T7 (50% FYM + 50% RDF with *Trichoderma* inoculation) at 1259.35 cm² and T8 (50% Vermicompost + 50% RDF without *Trichoderma*) at 1226.07 cm². *Trichoderma* produces growth-promoting substances like auxins, stimulating leaf and shoot development while enhancing nutrient uptake. Inorganic fertilizers supply readily available nitrogen, boosting chlorophyll formation and rapid foliage growth. Organic manure promotes microbial activity and releases balanced nutrients for healthy leaf area. These findings align with those reported by Singh and Jauhari (2005) and Singh and Singh (2010) in rose.

The number of branches per plant is a key factor influencing rose growth and yield. (Table 2) The highest branch count was recorded in the first flush under treatment T8 (50% Vermicompost + 50% RDF with *Trichoderma*) at 6.52, followed by the same treatment without inoculation (6.18) and T7 (50% FYM + 50% RDF with *Trichoderma*) at 6.12. When applied together, organic and inorganic manure with *Trichoderma* work synergistically to promote strong root systems, improve nutrient efficiency, and enhance hormonal activity resulting in a significant increase in the number of branches in rose plants. These findings are consistent with those of Preethi *et al*. (1999), Singh and Jauhari (2005) and Singh and Singh (2010) in rose.

Leaf area index (LAI) is a vital indicator of plant growth and yield potential in roses (Table 2). The highest value was observed (Fig. 1) during the first flush with T7 (50% FYM + 50% RDF with *Trichoderma*) at 5.53, followed by T7 without inoculation (5.07) and T8 (50% Vermicompost + 50% RDF with *Trichoderma*) at 4.79. Using FYM, vermicompost, inorganic fertilizers and *Trichoderma* together creates an ideal root-zone environment, supports continuous nutrient availability, and enhances leaf expansion, resulting in a significant improvement in leaf area index in roses. These results are in correlation with Preethi *et al*. (1999) and Singh (2005). Preethi *et al*. (1999) showed that the combination of nitrogen and Azospirillum applied at the sixth month of planting produced the greatest leaf area index.

**Flowering parameters**

The early opening of flowers is crucial for rose blooming and overall yield. The current study indicated (Table 3) notable differences in the time taken for flower opening among different nutrient treatments, both with and without *Trichoderma* inoculation. The first flush had the earliest flower opening, with the quickest time noted in T7 (50% FYM + 50% RDF without *Trichoderma*) at 9.72 days. This was closely followed by T7 (50% FYM + 50% RDF with *Trichoderma*) at 10.32 days and T8 (50% Vermicompost + 50% RDF with *Trichoderma*) at 10.38 days. The joint use of *Trichoderma* and vermicompost seems effective in controlling diseases like die-back and black spot. Moreover, it appears to aid in plant growth, which contributes to earlier flowering and floret opening. These results align with the findings of Kukde *et al*. (2006) and Dubey *et al*. (2008). The outcomes are also in agreement with research by Patil *et al*. (2008), Neelima *et al*. (2013) and Yadav *et al*. (2023) in rose.

The flower diameter is an important factor that affects the blooming and yield of roses. This research revealed (Table 3) differences in flower size based on nutrient treatments with and without *Trichoderma* inoculated plants. The largest flower diameter recorded during the first flush was with treatment T7 (50% FYM + 50% RDF with *Trichoderma*) at 112.28 mm. Next was T8 (50% Vermicompost + 50% RDF with *Trichoderma*) at 109.04 mm, followed by T3 (100% Vermicompost with *Trichoderma*) at 107.08 mm. Organic fertilizers help beneficial soil microbes, which improve nutrient availability. *Trichoderma*, a helpful microorganism, enhances productivity by fixing nutrients and releasing amino acids, positively affecting flowering, yield and overall health of rose plants. The growth and development of plants are linked to the presence of humic acids (Arancon *et al*., 2005) and the availability of key micro and macronutrients (Atiyeh *et al*., 2002). These results align with previous studies by Kolambe (2008), Naik *et al*. (2008) and Rathva (2011), who found that using vermicompost and FYM increased flower diameter in roses.

The timing of full bloom is a crucial factor influencing flowering efficiency and overall rose yield. The study revealed significant variation in (Table 4) bloom timing across different nutrient treatments and *Trichoderma* application. The earliest bloom occurred during the first flush with treatment T5 (50% FYM + 50% vermicompost with *Trichoderma*) at 12.06 days, followed by T6 (25% FYM + 75% vermicompost with *Trichoderma*) at 12.50 days, and T4 (75% FYM + 25% vermicompost with *Trichoderma*) in the second flush at 12.60 days. The combined application of *Trichoderma*, vermicompost and FYM proved effective in controlling rose diseases like die-back and black spot. Additionally, this combination enhanced overall plant growth by improving nutrient uptake and soil health, which ultimately led to early flowering and faster floret opening, improving ornamental quality and yield. The results align with previous studies by Singh *et al*. (2006) and Gaurav *et al*. (2008) in rose.

Delayed flower withering is considered a desirable trait in roses, as it directly affects bloom longevity and yield. Present study observed significant differences in (Table 4) flower withering across various nutrient treatments and *Trichoderma* application. The longest withering period was recorded in the third flush with T7 (50% FYM + 50% RDF without *Trichoderma*) at 21.90 days, followed by the same treatment with inoculation (21.65 days) and T6 (25% FYM + 75% Vermicompost with *Trichoderma*) at 21.50 days. Slow-release nutrients from organic sources support consistent growth and strengthen flower tissues. Potassium improves petal durability, reducing weathering. *Trichoderma* enhances resistance to biotic and abiotic stress by activating plant defences, helping maintain turgor and delay early flower senescence. The results are consistent with previous studies of Dubey *et al*. (2013) in petunia.

Stem width directly affecting bloom quality and yield. The highest stem width was recorded in (Table 5) the first flush under treatment T7 (50% FYM + 50% RDF with *Trichoderma*) at 5.34 mm, followed by the same treatment without inoculation (5.08 mm) and T8 (50% Vermicompost + 50% RDF without inoculation) at 4.92 mm. Organic manure promotes steady stem growth and strength, while macronutrients like nitrogen, phosphorus, and potassium enhance vegetative and tissue development. *Trichoderma* supports robust stem formation, resulting in thicker, healthier stems ideal for high-quality cut rose flowers. The results are consistent with previous studies of Jhon *et al.* (2007) in tulip and Yadav *et al.* (2023) in tuberose and Abdou *et al*. (2025) in snapdragon.

Flower yield in rose cultivation directly affecting bloom quality and overall productivity. This study showed notable differences in (Table 5) flower yield across nutrient treatments and *Trichoderma* application. The highest yield in the first flush was observed with T7 (50% FYM + 50% RDF with *Trichoderma* inoculation) at 380.06 flowers, followed by T8 (50% Vermicompost + 50% RDF with *Trichoderma* inoculation) at 366.56 flowers, and T8 (50% Vermicompost + 50% RDF without *Trichoderma* inoculation) at 351.56 flowers. The increased flower yield from using FYM, vermicompost, *Trichoderma* or nitrogen is due to improved nutrient availability and enhanced soil health. FYM and vermicompost supply essential nutrients and boost microbial activity. *Trichoderma* enhances nutrient uptake and plant growth, while nitrogen supports vigorous vegetative growth, all contributing to higher flowering and yield. The results are consistent with previous studies of Kolambe (2008), Singh *et al.* (2006) and Rathva (2011) and Lambat and Pal (2012).

Stem length in roses is directly affecting bloom quality and yield. This study observed (Table 6) notable differences in stem length across various nutrient treatments and *Trichoderma* applications. The first flowering flush showed the longest stems, with the highest recorded in treatment T7 (50% FYM + 50% RDF with *Trichoderma*) at 70.52 cm. This was followed by T7 without *Trichoderma* (64.75 cm) and T8 (50% Vermicompost + 50% RDF with *Trichoderma*) at 64.26 cm. Organic manures improve soil health by adding organic compounds and supporting beneficial microbes that enhance nutrient availability. In nutrient-deficient soils, they create a favourable rhizosphere. Bio-fertilizers like *Trichoderma* and *Azotobacter* further boost nutrient uptake and amino acid synthesis, enhancing rose flowering and yield. The findings align with earlier research by Kolambe (2008) and Gaurav *et al*. (2008), supporting the role of integrated nutrient management in improving rose stem length.

The number of petals per flower is a vital trait in roses, influencing both bloom quality and yield. This study revealed (Table 6) significant differences in petal numbers under various nutrient treatments and *Trichoderma* applications. The maximum petal number was observed in treatment T7 (50% FYM + 50% RDF with *Trichoderma*) during the first and third flushes, reaching 78.84 petals per flower. This was followed by T3 100% Vermicompost with inoculation (78.72 petals) and T3 (100% Vermicompost without *Trichoderma*) (78.08 petals). This positive effect may also be due to the fact that, after proper decomposition and mineralization, farmyard manure provides readily available nutrients to plants and helps solubilize fixed nutrients in the soil. Its beneficial impact on rose growth and flowering is likely attributed to the additional nutrient supply and the enhancement of the soil's physical and biological properties (Majumdar *et al*., 2002). The results support earlier studies by Kolambe (2008) and Rathva (2011) in rose with the combined application of vermicompost, castor cake and FYM.

**Post-harvest parameters**

Weight loss significantly impacts after harvest on quality and yield of roses. This study showed (Table 7 and Figure 1) variations in weight loss across different nutrient treatments and *Trichoderma* inoculation. The second flush had the least weight loss, with T7 (50% FYM + 50% RDF with *Trichoderma*) at 5.01%, followed by T7 50% FYM + 50% RDF without *Trichoderma* (5.02%) and T8 50% Vermicompost + 50% RDF with *Trichoderma* (5.22%) in first flush. When used together, organic manure, inorganic fertilizers and *Trichoderma* can balance growth, strengthen tissues and maintain flower moisture content minimizing weight loss during postharvest handling and storage in roses. These findings align with Nagaraju *et al*. (2003), Kolambe (2008) and Trivedi *et al*. (2016). Anzu-Man-Ara *et al*. (2022) noted that soil, coco dust, vermicompost and leaf compost improved fresh weight and dry weight of cut flowers.

Malondialdehyde (MDA) is a key indicator of oxidative stress and lipid peroxidation in plants. It helps assess postharvest quality and stress response in roses. This study showed (Table 7 and Figure 2) significant variations in MDA levels across treatments. The highest MDA content was recorded during the first flush in T7 (50% FYM + 50% RDF with *Trichoderma*) at 8.08 nmol/g, followed by T8 (50% Vermicompost + 50% RDF with *Trichoderma*) at 7.90 nmol/g, and T3 (100 % Vermicompost with *Trichoderma*) at 7.62 nmol/g. Using organic manure, balanced inorganic fertilizers and *Trichoderma* together enhances antioxidant defences, reduces membrane lipid peroxidation and thus significantly lowers MDA content, preserving the postharvest quality of rose flowers. Similar findings were reported by Lou *et al*. (2020) and Abou Obaid *et al*. (2022) studied saffron plants and found that the combined application of inorganic fertilizer and 1% organic matter had a slight impact on MDA content.

Water uptake is vital for maintaining the postharvest quality and yield of roses. This study revealed significant differences in water absorption across nutrient treatments shown in Table 8 and with *Trichoderma* inoculation. The highest water uptake (41.33 ml) was observed in the first flush with T7 50% FYM + 50% RDF with *Trichoderma* inoculation, followed by the second flush T3 100% Vermicompost (38.33 ml) with *Trichoderma* inoculation, and in the first flush with T8 50% Vermicompost + 50% RDF (36.52 ml). Applying organic and inorganic manure alongside *Trichoderma* enhances plant vigour and xylem efficiency, promotes vascular development and water absorption, sustains stem freshness and turgidity, and ultimately prolongs the postharvest vase life of roses. Similar results were reported by Bharathi *et al*. (2023) in gladiolus and Srivastava *et al*. (2007) in tuberose.

Figure 1 Effect of Trichoderma, manure and fertilizers on water loss (%) in rose

Figure 2 Effect of Trichoderma, manure and fertilizers on Malondialdehyde content (nmol/g FW)

**Table 1 Effect of *Trichoderma*, manureand fertilizer on growth parameters in rose var. Top Secret.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment**  ***Trichoderma***  **Nutrients** | **Plant spread (cm2)** | | | | | | **Leaf area (cm2)** | | | | | |
| **1st Flush** | | **2nd Flush** | | **3rd Flush** | | **1st Flush** | | **2nd Flush** | | **3rd Flush** | |
| **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** |
| T1=100% RDF | 35.14 | 37.21 | 21.66 | 21.80 | 31.29 | 30.74 | 962.46 | 908.95 | 441.50 | 549.70 | 448.12 | 564.27 |
| T2=100% FYM | 36.19 | 38.16 | 24.91 | 21.88 | 36.58 | 37.10 | 1,149.48 | 1,138.37 | 541.00 | 567.74 | 607.78 | 579.93 |
| T3=100% Vermicompost | 41.67 | 44.47 | 24.35 | 27.71 | 35.86 | 42.34 | 1,148.00 | 1,159.16 | 531.00 | 535.52 | 541.70 | 562.34 |
| T4=75% FYM + 25% Vermicompost | 33.25 | 36.14 | 22.26 | 25.44 | 35.43 | 41.45 | 1,125.00 | 1,093.12 | 435.05 | 473.88 | 480.69 | 478.04 |
| T5=50% FYM + 50% Vermicompost | 36.71 | 38.10 | 21.69 | 26.19 | 37.94 | 33.93 | 1,108.36 | 1,096.21 | 440.40 | 511.00 | 501.84 | 533.51 |
| T6=25% FYM + 75% Vermicompost | 40.38 | 45.94 | 23.83 | 23.37 | 39.78 | 40.59 | 1,022.64 | 1,078.94 | 515.42 | 553.80 | 543.22 | 511.48 |
| T7=50% FYM + 50 % RDF | 42.31 | 45.79 | 25.99 | 29.68 | 39.94 | 41.71 | 1,136.26 | 1,259.35 | 481.46 | 546.56 | 503.80 | 590.40 |
| T8=50% Vermicompost + 50% RDF | 42.54 | 47.12 | 26.82 | 28.22 | 41.96 | 42.12 | 1,226.07 | 1,283.82 | 581.32 | 605.37 | 544.15 | 526.71 |
| T9=Control | 30.30 | 30.30 | 23.44 | 23.44 | 27.35 | 27.35 | 933.38 | 933.38 | 391.68 | 391.68 | 392.30 | 392.30 |
| Mean | 37.61 | 40.36 | 23.88 | 25.30 | 36.24 | 37.48 | 1,090.18 | 1,108.69 | 484.76 | 523.25 | 507.07 | 526.55 |
| **CD at 5%** |  | | | | | |  | | | | | |
| T | 1.84 | | 1.21 | | NS | | NS | | NS | | NS | |
| N | 3.91 | | 2.58 | | 4.27 | | NS | | NS | | 103.19 | |

**Table 2 Effect of *Trichoderma*, manureand fertilizers on growth parameters in rose in cv. Top Secret**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment**  ***Trichoderma***  **Nutrients** | **Number of branches per plant** | | | | | | **Leaf area index** | | | | | |
| **1st Flush** | | **2nd Flush** | | **3rd Flush** | | **1st Flush** | | **2nd Flush** | | **3rd Flush** | |
| **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** |
| T1=100% RDF | 3.40 | 4.31 | 3.42 | 4.02 | 2.42 | 3.64 | 4.13 | 4.63 | 3.54 | 3.56 | 3.44 | 3.63 |
| T2=100% FYM | 3.20 | 5.68 | 3.66 | 5.10 | 2.88 | 3.72 | 3.84 | 4.59 | 3.43 | 3.84 | 4.45 | 4.31 |
| T3=100% Vermicompost | 4.92 | 5.36 | 4.18 | 5.58 | 3.46 | 4.52 | 4.34 | 4.57 | 4.25 | 4.17 | 4.56 | 4.66 |
| T4=75% FYM + 25% Vermicompost | 4.60 | 4.60 | 4.24 | 5.18 | 4.42 | 4.12 | 4.79 | 4.66 | 4.25 | 3.86 | 4.18 | 4.53 |
| T5=50% FYM + 50% Vermicompost | 4.34 | 4.56 | 4.90 | 4.70 | 3.32 | 3.96 | 4.69 | 3.98 | 4.32 | 4.34 | 3.52 | 4.20 |
| T6=25% FYM + 75% Vermicompost | 4.78 | 4.38 | 5.06 | 4.78 | 3.30 | 3.76 | 4.13 | 4.22 | 3.73 | 3.58 | 3.62 | 3.81 |
| T7=50% FYM + 50 % RDF | 5.96 | 6.12 | 5.42 | 5.66 | 4.62 | 4.78 | 5.07 | 5.53 | 4.28 | 4.79 | 4.10 | 4.85 |
| T8=50% Vermicompost + 50% RDF | 6.18 | 6.52 | 4.62 | 4.52 | 3.30 | 4.66 | 4.62 | 4.79 | 4.54 | 4.60 | 4.46 | 4.70 |
| T9=Control | 3.16 | 3.16 | 3.26 | 3.26 | 2.06 | 2.06 | 4.28 | 4.28 | 3.46 | 3.46 | 3.23 | 3.23 |
| Mean | 4.50 | 4.96 | 4.30 | 4.75 | 3.28 | 3.80 | 4.43 | 4.58 | 3.98 | 4.02 | 3.98 | 4.19 |
| **CD at 5%** |  | | | | | |  | | | | | |
| T | 0.61 | | NS | | 0.47 | | 0.21 | | 0.13 | | 0.16 | |
| N | 1.05 | | 1.06 | | 1.00 | | 0.69 | | 0.52 | | 0.49 | |

**Table 3 Effect of *Trichoderma*, manureand fertilizers on flowering parameters [Days to flower opening and Flowering diameter (mm)] in rose var. Top Secret.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment**  ***Trichoderma***  **Nutrients** | **Days to flower opening** | | | | | | **Flowering diameter (mm)** | | | | | |
| **1st Flush** | | **2nd Flush** | | **3rd Flush** | | **1st Flush** | | **2nd Flush** | | **3rd Flush** | |
| **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** |
| T1=100% RDF | 11.54 | 11.72 | 12.84 | 11.66 | 12.98 | 13.52 | 91.92 | 95.14 | 46.22 | 54.06 | 57.58 | 59.89 |
| T2=100% FYM | 10.72 | 14.32 | 12.78 | 11.20 | 11.78 | 12.99 | 101.68 | 107.26 | 61.48 | 69.86 | 57.34 | 54.45 |
| T3=100% Vermicompost | 14.12 | 12.46 | 13.56 | 13.06 | 12.99 | 12.91 | 101.77 | 103.08 | 65.82 | 71.10 | 69.09 | 62.97 |
| T4=75% FYM + 25% Vermicompost | 13.32 | 11.42 | 12.74 | 13.46 | 12.92 | 13.15 | 99.22 | 100.04 | 52.88 | 53.86 | 67.26 | 57.02 |
| T5=50% FYM + 50% Vermicompost | 12.86 | 11.71 | 13.98 | 12.94 | 13.23 | 13.69 | 95.32 | 95.86 | 54.02 | 56.24 | 68.74 | 62.84 |
| T6=25% FYM + 75% Vermicompost | 10.72 | 13.36 | 12.94 | 13.30 | 11.25 | 13.28 | 92.27 | 98.12 | 52.62 | 69.06 | 58.06 | 64.76 |
| T7=50% FYM + 50 % RDF | 9.72 | 10.38 | 11.38 | 11.08 | 10.53 | 12.59 | 103.11 | 112.28 | 71.64 | 71.48 | 58.69 | 67.54 |
| T8=50% Vermicompost + 50% RDF | 10.66 | 10.18 | 12.16 | 11.12 | 11.61 | 11.28 | 101.91 | 109.72 | 66.84 | 70.26 | 72.37 | 64.04 |
| T9=Control | 14.66 | 14.66 | 14.08 | 14.08 | 14.64 | 14.64 | 80.47 | 80.47 | 46.04 | 46.04 | 54.04 | 54.04 |
| Mean | 12.03 | 12.36 | 12.94 | 12.43 | 12.33 | 13.23 | 96.40 | 100.22 | 57.50 | 62.10 | 62.79 | 59.72 |
| **CD at 5%** |  | | | | | |  | | | | | |
| T | NS | | 0.31 | | 0.55 | | 3.70 | | 2.84 | | 2.86 | |
| N | 1.49 | | 1.50 | | 1.47 | | 7.86 | | 6.03 | | 6.07 | |

**Table 4 Effect of *Trichoderma*, manureand fertilizers on flowering parameters (Days to full flower bloom and Days to flower withering) in rose in cv. Top Secret**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment**  ***Trichoderma***  **Nutrients** | **Days to full flower bloom** | | | | | | **Days to flower withering** | | | | | |
| **1st Flush** | | **2nd Flush** | | **3rd Flush** | | **1st Flush** | | **2nd Flush** | | **3rd Flush** | |
| **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** |
| T1=100% RDF | 14.46 | 13.79 | 14.82 | 13.20 | 13.18 | 14.20 | 17.90 | 19.17 | 15.82 | 18.22 | 18.48 | 18.55 |
| T2=100% FYM | 14.80 | 13.59 | 15.22 | 15.60 | 14.05 | 14.14 | 17.80 | 19.86 | 19.45 | 19.86 | 18.70 | 19.30 |
| T3=100% Vermicompost | 14.00 | 13.86 | 14.63 | 14.40 | 14.21 | 14.36 | 20.12 | 19.68 | 19.89 | 20.50 | 17.92 | 20.50 |
| T4=75% FYM + 25% Vermicompost | 14.60 | 14.36 | 12.92 | 12.60 | 13.95 | 16.17 | 18.66 | 17.52 | 15.83 | 16.02 | 19.10 | 20.18 |
| T5=50% FYM + 50% Vermicompost | 13.60 | 12.06 | 14.63 | 13.00 | 13.29 | 12.84 | 18.40 | 20.47 | 16.23 | 16.23 | 18.49 | 20.50 |
| T6=25% FYM + 75% Vermicompost | 14.60 | 12.50 | 16.16 | 15.60 | 13.94 | 14.37 | 18.77 | 20.60 | 15.63 | 19.52 | 19.91 | 21.50 |
| T7=50% FYM + 50 % RDF | 13.40 | 13.16 | 16.30 | 15.40 | 13.26 | 14.64 | 20.92 | 21.00 | 20.82 | 21.02 | 21.90 | 21.65 |
| T8=50% Vermicompost + 50% RDF | 15.40 | 12.96 | 14.42 | 13.00 | 14.02 | 13.76 | 19.27 | 18.60 | 18.46 | 18.72 | 19.24 | 20.28 |
| T9=Control | 14.40 | 14.40 | 14.60 | 14.60 | 15.97 | 15.97 | 17.20 | 17.20 | 15.84 | 15.84 | 19.04 | 19.04 |
| Mean | 14.33 | 13.41 | 14.85 | 14.15 | 13.99 | 14.49 | 18.78 | 19.34 | 17.55 | 18.44 | 19.20 | 20.17 |
| **CD at 5%** |  | | | | | |  | | | | | |
| T | 0.13 | | 0.62 | | 0.23 | | 0.34 | | 0.85 | | 0.96 | |
| N | 0.74 | | 1.33 | | 1.28 | | 2.01 | | 1.82 | | 0.21 | |

**Table 5 Effect of *Trichoderma*, manureand fertilizers on flowering parameters [ Stem diameter (cm2) and Flower yield per plot] in rose in cv. Top Secret**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment**  ***Trichoderma***  **Nutrients** | **Stem diameter (cm2)** | | | | | | **Flower yield per plot** | | | | | |
| **1st Flush** | | **2nd Flush** | | **3rd Flush** | | **1st Flush** | | **2nd Flush** | | **3rd Flush** | |
| **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** |
| T1=100% RDF | 3.22 | 3.46 | 3.01 | 3.17 | 3.50 | 2.82 | 259.71 | 252.60 | 259.57 | 265.78 | 255.85 | 270.65 |
| T2=100% FYM | 3.96 | 4.80 | 3.16 | 3.38 | 3.94 | 3.72 | 289.86 | 300.14 | 281.88 | 272.69 | 266.71 | 280.61 |
| T3=100% Vermicompost | 4.08 | 4.18 | 3.52 | 3.86 | 3.64 | 3.52 | 290.74 | 333.69 | 286.72 | 305.11 | 285.95 | 303.64 |
| T4=75% FYM + 25% Vermicompost | 3.34 | 3.52 | 3.09 | 3.24 | 2.66 | 2.96 | 306.45 | 307.18 | 287.35 | 293.78 | 264.93 | 275.79 |
| T5=50% FYM + 50% Vermicompost | 3.12 | 4.66 | 3.24 | 3.81 | 3.28 | 3.12 | 275.96 | 305.56 | 281.69 | 289.54 | 254.54 | 264.79 |
| T6=25% FYM + 75% Vermicompost | 4.16 | 4.16 | 3.49 | 3.36 | 3.65 | 3.40 | 301.56 | 315.08 | 279.22 | 296.71 | 268.51 | 276.52 |
| T7=50% FYM + 50 % RDF | 5.08 | 5.34 | 3.76 | 4.12 | 4.30 | 4.71 | 333.49 | 380.06 | 287.11 | 302.53 | 305.23 | 308.47 |
| T8=50% Vermicompost + 50% RDF | 4.92 | 4.71 | 3.72 | 3.93 | 3.81 | 3.83 | 351.56 | 366.68 | 283.42 | 292.29 | 253.25 | 275.65 |
| T9=Control | 3.08 | 3.08 | 3.10 | 3.10 | 2.58 | 2.58 | 246.01 | 246.01 | 209.73 | 209.73 | 217.52 | 217.52 |
| Mean | 3.88 | 4.21 | 3.34 | 3.55 | 3.48 | 3.41 | 296.70 | 310.21 | 272.97 | 280.90 | 263.61 | 274.85 |
| **CD at 5%** |  | | | | | |  | | | | | |
| T | 0.33 | | 0.11 | | NS | | 12.03 | | 7.51 | | 13.00 | |
| N | 0.70 | | 0.48 | | 0.58 | | 25.52 | | 15.93 | | 6.13 | |

**Table 6 Effect of *Trichoderma*, manureand fertilizers on flowering parameters [Stem length (cm2) and Number of petals per flower] in rose var. Top Secret.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment**  ***Trichoderma***  **Nutrients** | **Stem length (cm2)** | | | | | | **Number of petals per flower** | | | | | |
| **1st Flush** | | **2nd Flush** | | **3rd Flush** | | **1st Flush** | | **2nd Flush** | | **3rd Flush** | |
| **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** |
| T1=100% RDF | 45.79 | 41.37 | 28.75 | 31.43 | 37.30 | 39.44 | 64.27 | 64.06 | 55.05 | 58.07 | 70.26 | 68.24 |
| T2=100% FYM | 36.13 | 54.54 | 32.96 | 32.46 | 42.20 | 50.18 | 63.92 | 73.13 | 63.06 | 63.56 | 68.84 | 73.02 |
| T3=100% Vermicompost | 53.61 | 62.13 | 30.75 | 34.79 | 48.35 | 48.02 | 64.15 | 70.23 | 57.70 | 64.10 | 74.08 | 75.72 |
| T4=75% FYM + 25% Vermicompost | 51.30 | 57.12 | 41.81 | 44.64 | 44.28 | 44.83 | 50.78 | 76.32 | 53.46 | 56.83 | 64.02 | 72.76 |
| T5=50% FYM + 50% Vermicompost | 49.75 | 61.53 | 42.59 | 46.76 | 38.09 | 40.15 | 62.68 | 66.37 | 56.62 | 54.48 | 62.63 | 68.02 |
| T6=25% FYM + 75% Vermicompost | 52.15 | 54.68 | 41.41 | 42.69 | 43.38 | 44.78 | 59.52 | 75.50 | 59.86 | 64.04 | 64.86 | 73.63 |
| T7=50% FYM + 50 % RDF | 64.75 | 70.52 | 40.68 | 47.67 | 39.30 | 46.87 | 74.65 | 76.58 | 61.05 | 63.45 | 78.08 | 78.72 |
| T8=50% Vermicompost + 50% RDF | 57.35 | 64.26 | 43.66 | 46.44 | 45.51 | 48.95 | 68.32 | 74.17 | 58.20 | 59.64 | 64.64 | 65.43 |
| T9=Control | 32.84 | 32.84 | 32.84 | 32.84 | 27.62 | 27.62 | 55.77 | 55.77 | 57.79 | 57.79 | 57.73 | 57.73 |
| Mean | 49.30 | 55.44 | 37.27 | 39.97 | 40.67 | 43.42 | 62.67 | 70.46 | 58.09 | 60.22 | 67.50 | 70.38 |
| **CD at 5%** |  | | | | | |  | | | | | |
| T | 5.16 | | 1.84 | | NS | | 3.31 | | NS | | NS | |
| N | 10.96 | | 7.44 | | 8.67 | | 7.02 | | 5.39 | | 7.19 | |

**Table 7 Effect of *Trichoderma*, manureand fertilizers on post-harvest parameters in rose var. Top Secret.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment**  ***Trichoderma***  **Nutrients** | **Weight loss (%)** | | | | | | **Malondialdehyde content (****nmol/g FW)** | | | | | |
| **1st Flush** | | **2nd Flush** | | **3rd Flush** | | **1st Flush** | | **2nd Flush** | | **3rd Flush** | |
| **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** |
| T1=100% RDF | 7.37 | 8.45 | 6.68 | 6.76 | 5.63 | 5.48 | 5.70 | 5.79 | 4.58 | 4.59 | 5.06 | 5.67 |
| T2=100% FYM | 6.86 | 7.26 | 5.01 | 5.51 | 7.17 | 5.66 | 6.46 | 7.04 | 5.23 | 5.42 | 6.51 | 6.54 |
| T3=100% Vermicompost | 6.04 | 6.49 | 5.42 | 5.85 | 6.29 | 6.18 | 5.80 | 7.32 | 5.60 | 6.71 | 6.80 | 6.91 |
| T4=75% FYM + 25% Vermicompost | 6.46 | 7.09 | 5.62 | 6.63 | 7.08 | 6.77 | 6.70 | 7.67 | 5.40 | 5.48 | 6.47 | 7.31 |
| T5=50% FYM + 50% Vermicompost | 6.57 | 7.05 | 5.40 | 6.62 | 6.72 | 6.44 | 6.89 | 6.80 | 5.44 | 5.60 | 5.76 | 6.43 |
| T6=25% FYM + 75% Vermicompost | 7.17 | 8.03 | 5.35 | 7.49 | 7.37 | 7.65 | 6.81 | 6.57 | 6.05 | 6.58 | 6.02 | 6.21 |
| T7=50% FYM + 50 % RDF | 5.45 | 5.52 | 5.02 | 5.12 | 5.39 | 6.84 | 7.06 | 8.08 | 5.93 | 6.91 | 7.51 | 7.54 |
| T8=50% Vermicompost + 50% RDF | 5.77 | 5.91 | 7.74 | 7.84 | 7.70 | 6.78 | 7.30 | 7.90 | 5.45 | 6.44 | 7.13 | 7.20 |
| T9=Control | 7.59 | 7.59 | 7.11 | 7.11 | 6.92 | 6.92 | 7.37 | 7.37 | 5.97 | 5.97 | 5.79 | 5.79 |
| Mean | 6.59 | 7.04 | 5.93 | 6.55 | 6.70 | 6.52 | 6.67 | 7.22 | 5.52 | 5.97 | 6.33 | 6.65 |
| **CD at 5%** |  | | | | | |  | | | | | |
| T | 0.38 | | 0.31 | | 0.22 | | 0.53 | | 0.17 | | NS | |
| N | 0.82 | | 0.91 | | 0.75 | | 0.13 | | 0.96 | | 0.79 | |

**Table 8 Effect of *Trichoderma*, manureand fertilizers on post-harvest parameters in rose in cv. Top Secret**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatment**  ***Trichoderma***  **Nutrients** | **Water uptake (ml)** | | | | | |
| **1st Flush** | | **2nd Flush** | | **3rd Flush** | |
| **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** | **Un inoculated** | **Inoculated** |
| T1= 100% RDF | 36.06 | 35.62 | 21.26 | 32.62 | 33.74 | 29.40 |
| T2=100% FYM | 30.71 | 32.27 | 24.31 | 30.27 | 31.07 | 30.81 |
| T3=100% Vermicompost | 28.03 | 30.90 | 30.03 | 38.10 | 31.79 | 31.89 |
| T4=75% FYM + 25% Vermicompost | 27.63 | 32.33 | 26.63 | 29.33 | 25.03 | 32.28 |
| T5=50% FYM + 50% Vermicompost | 24.29 | 23.14 | 30.09 | 23.42 | 27.87 | 25.23 |
| T6=25% FYM + 75% Vermicompost | 20.10 | 31.64 | 24.30 | 28.24 | 23.40 | 27.45 |
| T7=50% FYM + 50 % RDF | 33.26 | 41.83 | 25.06 | 28.03 | 23.75 | 33.43 |
| T8=50% Vermicompost+ 50% RDF | 26.84 | 34.52 | 23.24 | 27.72 | 25.49 | 28.73 |
| T9=Control | 19.07 | 19.07 | 17.87 | 17.87 | 18.23 | 18.23 |
| Mean | 27.33 | 35.62 | 24.75 | 28.40 | 26.70 | 28.60 |
| **CD at 5%** |  | | | | | |
| T | 3.44 | | 2.76 | | NS | |
| N | 7.31 | | 5.86 | | 6.21 | |

**Conclusion**

The current research indicates that the combination of organic and inorganic nutrient sources, especially when paired with *Trichoderma* inoculation, significantly improves both the growth and quality metrics of rose plants. Among all the treatments, T7 (50% FYM + 50% RDF with *Trichoderma*) and T8 (50% Vermicompost + 50% RDF with *Trichoderma*) consistently excelled in key growth parameters including plant spread, leaf area, early flowering, flower diameter, stem length, petal count, improved leaf mass, earlier blooming, thicker stems, prolonged flower longevity and greater water uptake. Furthermore, these treatments enhanced postharvest characteristics, leading to reduced weight loss and improved oxidative stress management, as evidenced by lower MDA levels. These results demonstrate that a combination of organic and inorganic fertilizer with beneficial microbes like *Trichoderma* is a reliable and eco-friendly strategy for optimizing rose production and quality in polyhouse environments.

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