Trends in BIOSCIENCES RESEARCH
Website: https://trendbioresearch.com
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ISSN: 3080-7719 (Print) 3080-7727 (Online)

ASSESSING THE INTEGRATED EFFECT OF ORGANIC MANURE AND MINERAL FERTILIZERS ON CARROT GROWTH AND YIELD

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Abstract

An experiment was conducted at the Research Farm, Arid Zone Research Center, DI Khan, to appraise the response of poultry manure, an organic manure, in amalgamation with mineral fertilizers on the development, produce, and quality of carrot. The highest gross yield (29.70 t ha^{-1}) of carrot was attained from the T7 treatment [recommended dose of mineral fertilizers (RDIF) + poultry manure (RDP)], while the subsequent lowest gross yield (16.04 t ha^{-1}) was documented in the poultry manure treated plots (RDP). T7 treated carrot plants exhibited the uppermost values for root fresh weight (64.08 g), vendible yield (16.27 t ha^{-1}), length of shoot (76.01 cm), root diameter (11.48 mm), and N content (2.56%). Bearing in mind the major nutrients and biochemical physiognomies of carrot, the findings suggest that poultry manure is not adequate to maximize yield, but it positively impact when applied in combination with mineral fertilizers. The study also discovered that poultry manure had no noteworthy contribution to increasing N, P, K, and S content in soils.

Article History

Received:
January 10, 2024

Revised:
February 15, 2024

Accepted:
March 22, 2024

Available Online:
June 30, 2024

Keywords: “Organic Amendments”, “Carrot Growth”, “Inorganic Fertilizers”, “Poultry Manure”, “Yield Performance”, “Soil Nutrients”.

INTRODUCTION

Both organic and mineral fertilizers play a crucial role in enhancing crop progression. However, the undiscerning use of mineral fertilizers can lead to hostile effects on soil health by altering its physicochemical and biological indices, ultimately depleting soil fertility. In Pakistan, soil organic matter content is alarmingly low, with approximately 90% of cultivable land containing less than 1% organic matter, compared to the ideal minimum of 3% (Liang X,). Declining soil fertility has become a significant constraint to agricultural productivity, with crop yields diminishing in certain soils (Agegnehu G). Therefore, maintaining soil fertility is indispensable for ensuring maintainable agricultural production, and organic droppings play a dynamic role in this regard.

Organic manures are derived from the putrefaction of life based materials, provided that the raw materials are free from contaminants. Despite the potential benefits of organic fertilizers, large-scale production and utilization remain limited in Pakistan. Recycling crop remains and organic litters through composting is a crucial approach to producing organic fertilizers (Rashid MI). However, the rapid accumulation of metropolitan and agricultural waste has become a stern environmental concern, necessitating sustainable waste management solutions.

Recently, various companies have begun producing organic fertilizers using urban and agricultural waste. Poultry manure is among the commonly used organic amendments, known for its potential to mend soil fertility and crop productivity. The adoption of organic composts can contribute to environmental sustainability, reduce dependence on chemical fertilizers, and save substantial foreign exchange. However, before recommending its widespread use, it is crucial to assess the quality and effectiveness of poultry manure through scientific research across different agro-ecological zones (AEZs) of Pakistan.

Given these considerations, the present study was commenced to appraise the effects of poultry manure in comparison with inorganic fertilizers on the progression and quality of carrot, as well as their influence on post-harvest soil nutrient status. The findings of this research will deliver valued insights into the efficacy of poultry manure as a commercially viable organic fertilizer for sustainable crop production.

MATERIALS AND METHODS

Site, Design and Experiment Duration

The experiment was conducted at the Arid Zone Research Center, Dera Ismail Khan, Pakistan, from November 2023 to February 2024 to evaluate the effects of poultry manure in amalgamation with mineral fertilizers on the progression and quality of carrot (*Daucus carota* L.). The experimental soil was silt loam, and the field had previously been cultivated with rice before the commencement of the study.

The trial was thrice replicated in a randomized complete block design (RCBD). Each experimental plot measured 4 m × 2.5 m, with a total of 24 plots assigned to eight treatments as follows:

- T_0 (Control): No fertilizer application
- T_1 (Recommended Dose of Inorganic Fertilizers - RDIF): 150 kg ha^{-1} urea, 100 kg ha^{-1} triple superphosphate (TSP), 90 kg ha^{-1} muriate of potash (MOP), and 100 kg ha^{-1} gypsum

- T_2 (Recommended Dose of Poultry Manure - RDP): 10 t ha⁻¹ poultry manure
- T_3 (½ RDIF + ½ RDP)
- T_4 (RDIF + ½ RDP)
- T_5 (¼ RDIF + RDP)
- T_6 (½ RDIF + RDP)
- T_7 (RDIF + RDP)

The full concentrations of chief nutrients in poultry manure are presented in Table 1.

Table 1. Major Nutrient Status of used Poultry Manure

N (%)	P (ppm)	K (cmol kg^{-1})	S (ppm)
0.54	0.23	0.19	0.13

Fertilizer Application and Crop Management

All TSP, gypsum, and poultry manure were combined into the soil through land opeartions as per the treatment schedule. Urea and MOP were applied in three (at sowing, 15 and 35 days after seeding) equal splits:

Standard agronomic practices were followed to ensure optimal crop growth. Thinning was conceded after ample seed germination to maintain even plant spacing. Routine intercultural operations, including irrigation, weeding, and pest control, were performed as necessary.

Data Collection and Parameters Measured

Data were noted on various progression and quality factors, including:

- Vegetative growth parameters: Plant height, shoot length, and root length
- Root characteristics: Root diameter, fresh and dry masses of root
- Shoot characteristics: Fresh and dry masses of shoot
- Yield parameters: Gross yield, marketable yield
- Root defects: Percentage of branched and cracked roots

Soil Analysis

Soil samples were collected before sowing and after harvest to determine chemical properties and nutrient content. The following parameters were analyzed: organic carbon, nitrogen (N), phosphorus (P), potassium (K) and sulfur (S).

Statistical Analysis

The recorded data were imperiled to analysis of variance (ANOVA). The least significant difference (LSD) test was applied to compare treatment means and determine significant differences among them at a 5% level of significance.

RESULTS

Root Fresh Weight

Root fresh weight exhibited significant variation among treatments (Figure 1). The lowermost value was recorded in the control (T0) at approximately 15 g. All treatments contributed to substantial increases, with T1, T2, T3, and T4 ranging between 40 and 54 g. The maximum root fresh weight was observed in T6 (65 g) and T7 (66 g), representing a 4.3-fold increase over the control. Statistical analysis confirmed that T6 and T7 were suggestively dissimilar from the other treatments ($p < 0.05$), highlighting their strong influence on root biomass accumulation.

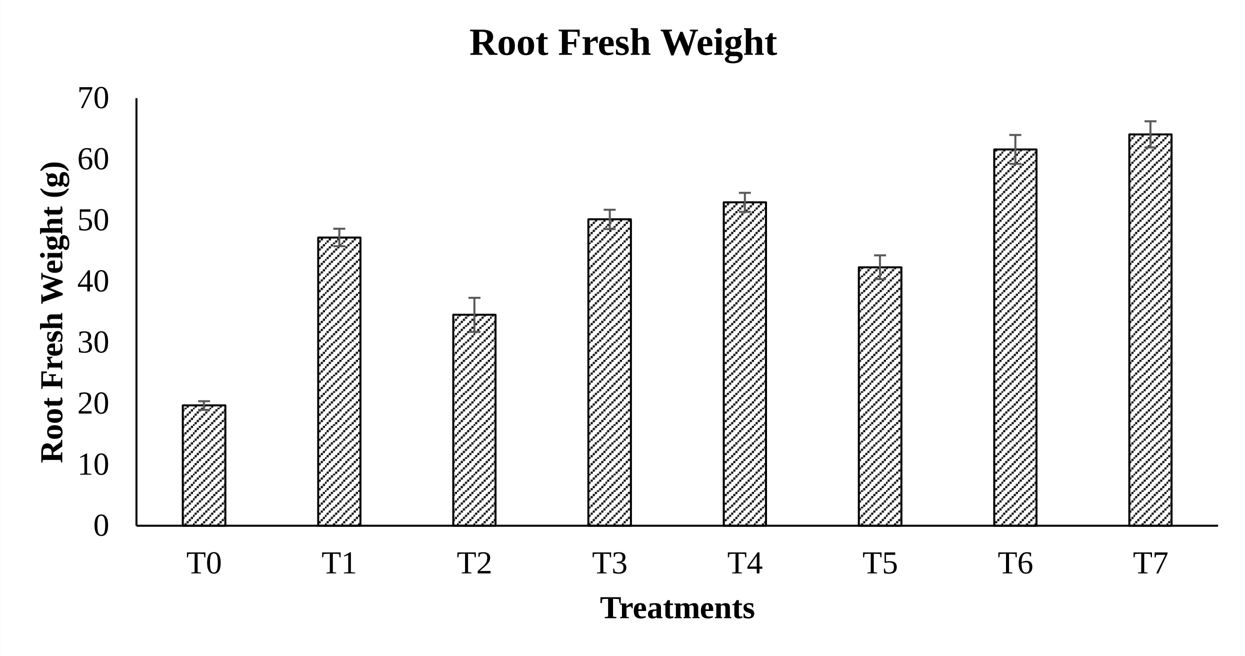

Figure 1. Variation in fresh weight of carrot root under organic and mineral fertilizer combinations

Root Dry Weight

The bottommost root dry weight was experiential in T0 (3.5 g) (Figure 2). With the application of treatments, this parameter increased significantly. T1, T2, T3, and T4 recorded values between 6.5 g and 10 g, while T6 (12.5 g) and T7 (12.8 g) exhibited the highest values, leading to a 3.5-fold increase over the control. Statistical comparisons confirmed that T6 and T7 were significantly superior ($p < 0.05$), demonstrating their effectiveness in enhancing root dry matter content.

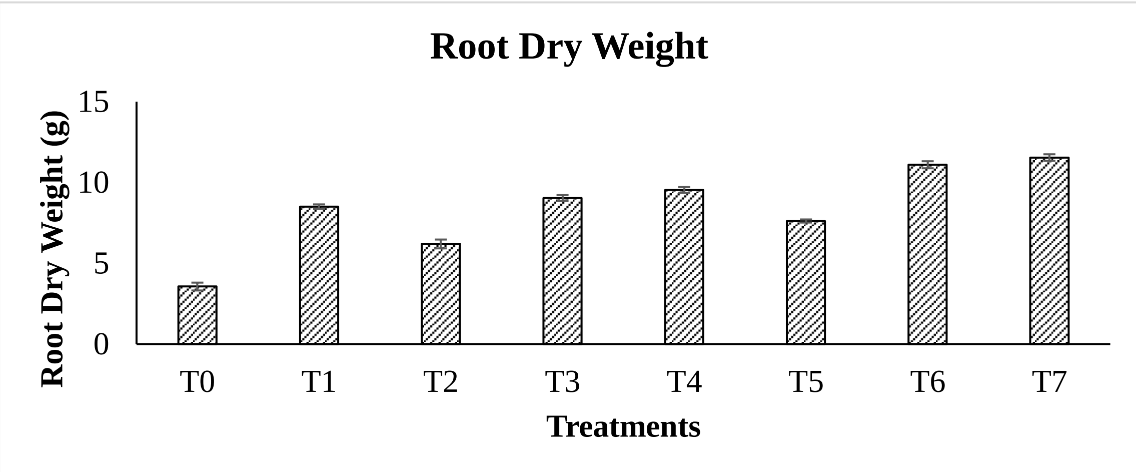

Figure 2. Variation in dry weight of carrot root under organic and mineral fertilizer combinations

Shoot Fresh Weight

Shoot fresh weight was the lowest in the control (T0) at 10 g (Figure 3). All treatments contributed to significant improvements, with T1 (28 g), T2 (20 g), T3 (30 g), and T4 (31 g) showing noticeable increases. The maximum shoot fresh weight was noted in T6 (35 g) and T7 (36 g), which resulted in a 3.6-fold increase over the control. Statistical analysis confirmed a highly significant effect (**p < 0.01**), indicating that these treatments had the most pronounced impact on shoot biomass.

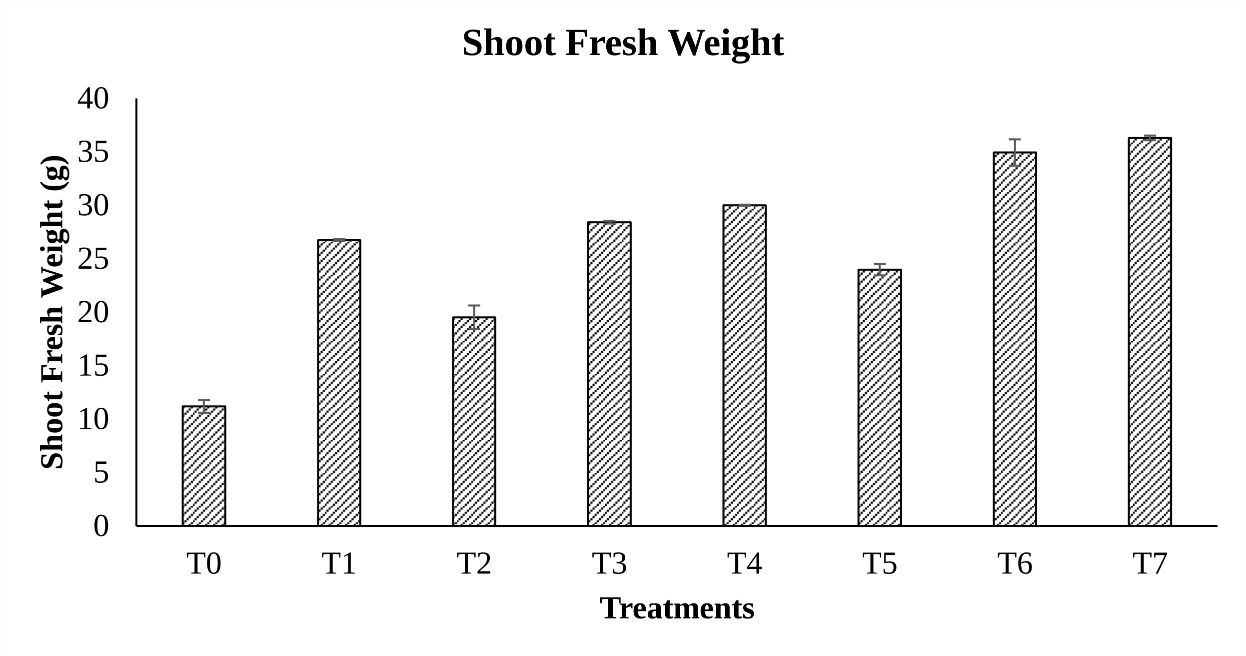

Figure 3. Variation in fresh weight of carrot shoot under organic and mineral fertilizer combinations

Shoot Dry Weight

The shoot dry weight showed significant variation among treatments (Figure 4). The lowermost shoot dry weight was documented in the control (T0) at approximately 1.2 g. Application of treatments led to a noticeable increase, with T1 and T2 reaching around 3.0 g and 2.5 g, respectively. T3 and T4 exhibited further increments at approximately 3.2 g and 3.4 g. T5 resulted in a slightly lower shoot dry weight (around 2.9 g) than T4. The supreme shoot dry weight was observed in T6 and T7, reaching approximately 4.2 g and 4.3 g, respectively. The statistical differences indicate that T6 and T7 were pointedly superior ($p < 0.05$) compared to other treatments, whereas T0 showed the lowest shoot biomass accumulation.

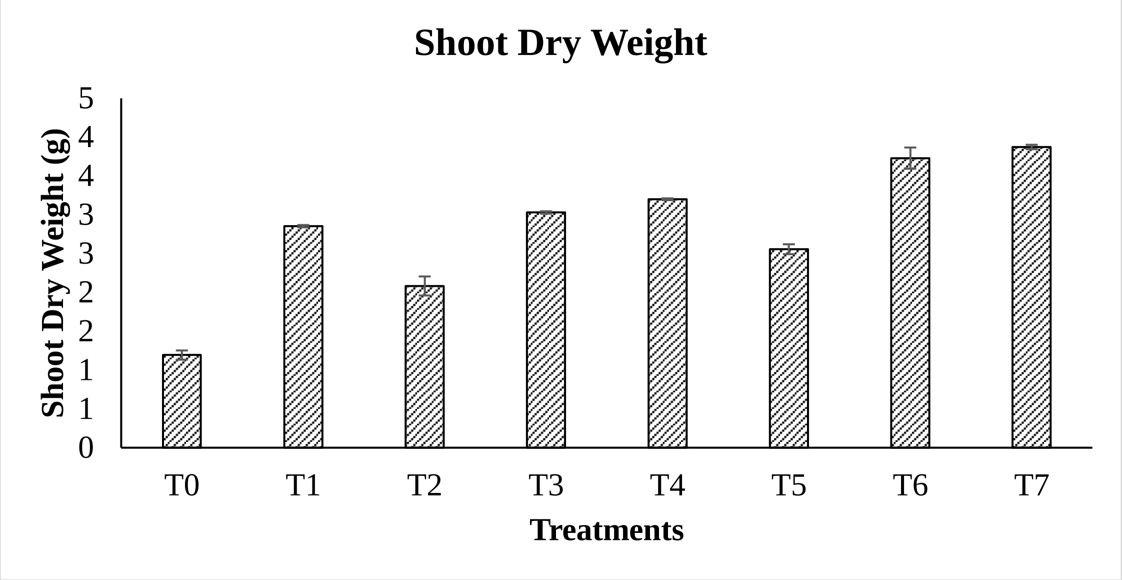

Figure 4. Variation in dry weight of carrot shoot under organic and mineral fertilizer combinations

Shoot Length

The shortest shoot length was recorded in T0 (25 cm), whereas the treated plants exhibited substantial elongation (Figure 5). T1, T2, T3, and T4 produced plants with shoot lengths between 45 cm and 62 cm. The tallest plants were observed in T6 (75 cm) and T7 (78 cm), which resulted in more than a threefold increase over the control. Statistical analysis indicated substantial differences ($p < 0.05$) among treatments, confirming the beneficial effects of T6 and T7 in promoting shoot elongation.

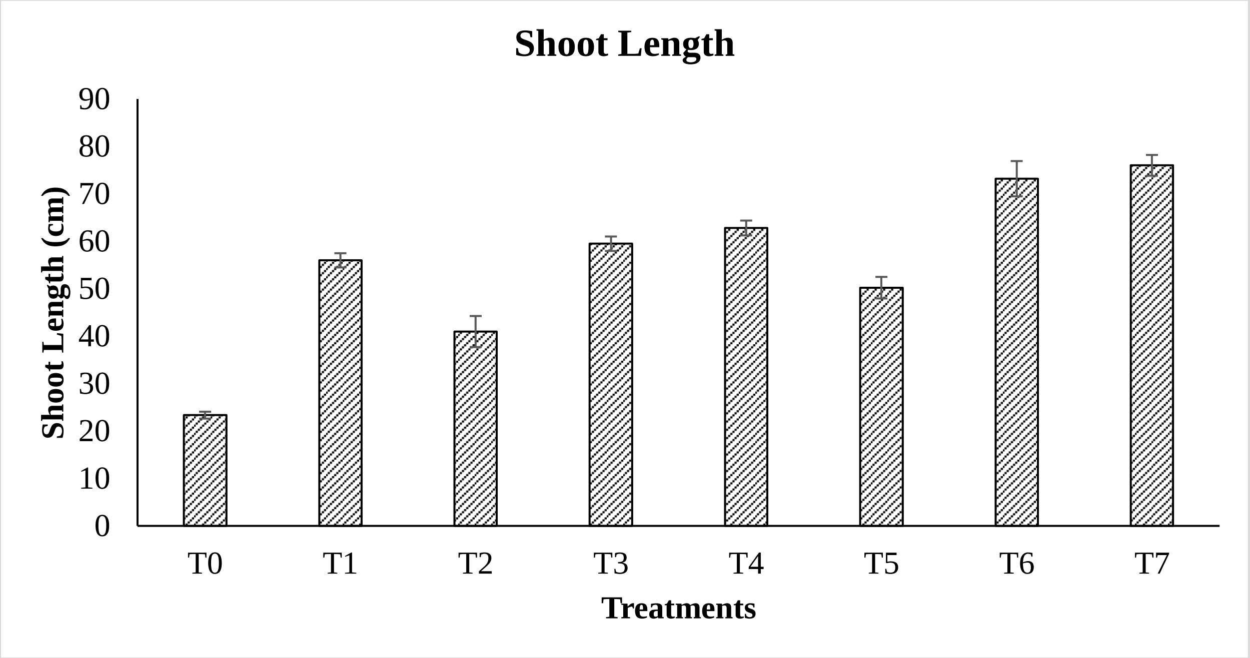

Figure 5. Variation in shoot length of carrot under organic and mineral fertilizer combinations

Root Length

Root length varied significantly across treatments (Figure 6). The control (T0) exhibited the shortest roots at 8 cm, while T1, T2, T3, and T4 ranged between 12 cm and 17 cm. The longest roots were recorded in T6 (20 cm) and T7 (21 cm). Statistical analysis confirmed that T6 and T7 significantly outperformed the other treatments ($p < 0.05$), indicating their effectiveness in promoting root elongation.

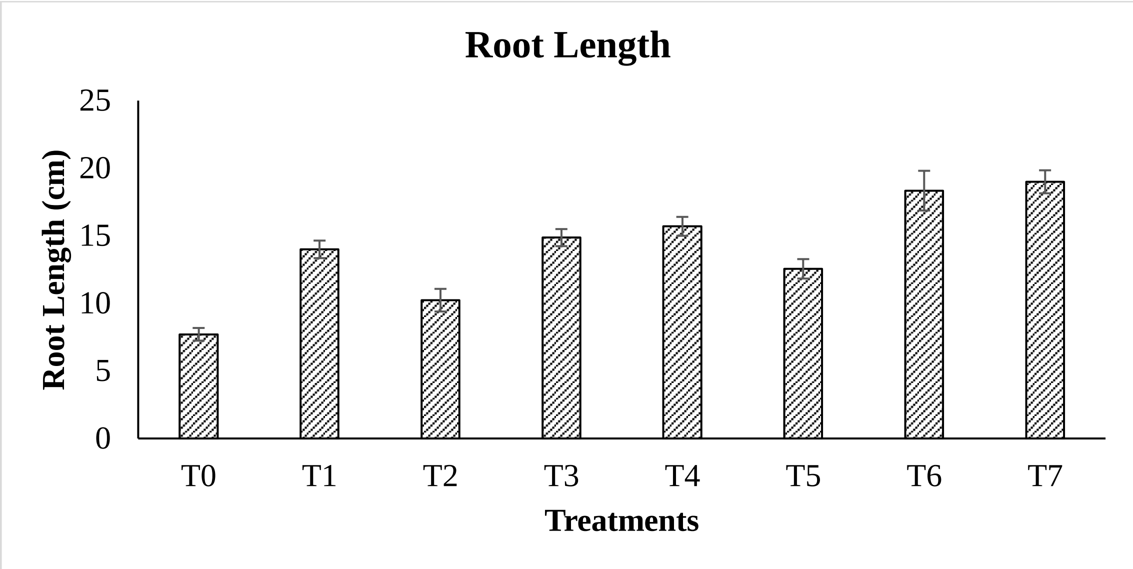

Figure 6. Variation in root length of carrot under organic and mineral fertilizer combinations

Root Diameter

The smallest root diameter was recorded in T0 (4 cm) (Figure 7). With the application of treatments, root diameter increased significantly. T1, T2, T3, and T4 ranged from 6.5 cm to 9.5 cm, while the highest values were observed in T6 (12 cm) and T7 (12.5 cm). Statistical analysis confirmed that T6 and T7 were suggestively dissimilar from the other treatments ($p < 0.05$), demonstrating their ability to enhance root girth.

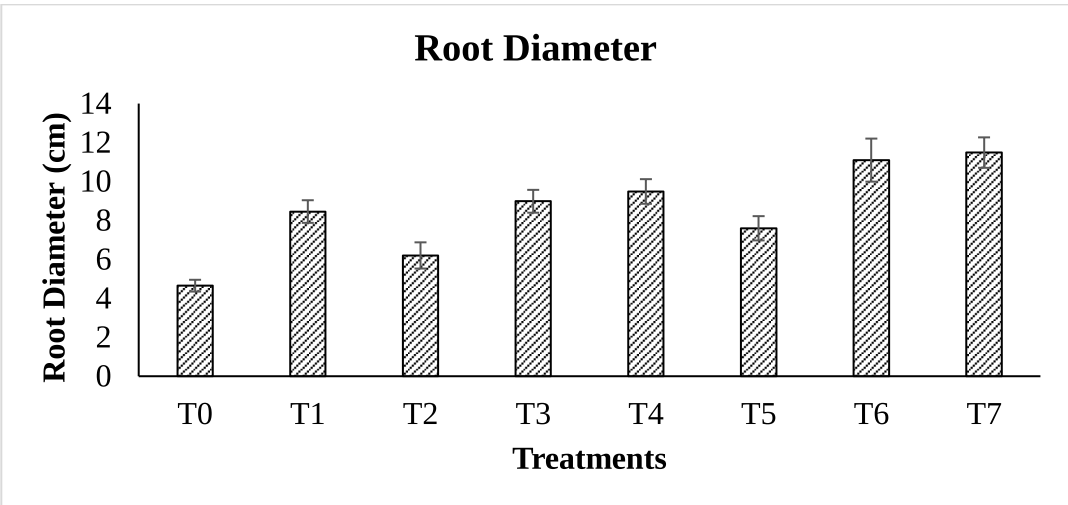

Figure 7. Variation in root diameter of carrot under organic and mineral fertilizer combinations

Root Gross Yield

Root gross yield exhibited considerable variation among treatments (Figure 8). The control (T0) resulted in the lowest yield (10 t ha⁻¹), while all other treatments showed noticeable improvements. T1, T2, T3, and T4 recorded yields between 17 t ha⁻¹ and 25 t ha⁻¹. The highest values were observed in T6 (30 t ha⁻¹) and T7 (31 t ha⁻¹), reflecting a threefold increase compared to the control. Statistical analysis confirmed highly significant differences ($p < 0.01$), with T6 and T7 demonstrating the greatest potential for enhancing root gross yield.

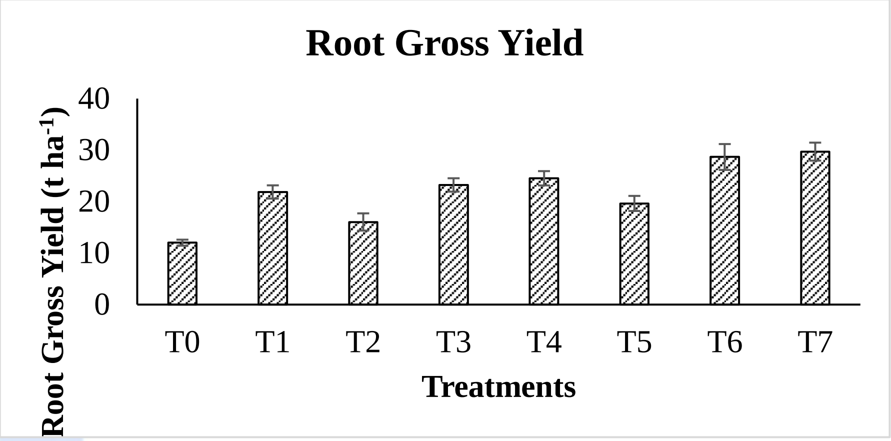

Figure 9. Variation in root gross yield of carrot under organic and mineral fertilizer combinations

Root Marketable Yield

The root marketable yield followed a trend similar to shoot dry weight, with significant statistical differences among treatments (Figure 9). T0 exhibited the lowest yield at approximately 6 t ha⁻¹. T1 and T2 demonstrated moderate improvements, reaching about 12 t ha⁻¹ and 9 t ha⁻¹, respectively. T3 and T4 exhibited further increments at around 13 t ha⁻¹ and 14 t ha⁻¹. T5 showed a slight reduction to approximately 11 t ha⁻¹. The peak root marketable yield was recorded in T6 and T7, with values of roughly 16 t ha⁻¹ and 17 t ha⁻¹, respectively. Statistical analysis showed that T6 and T7 were expressively higher ($p < 0.05$) than all other treatments, whereas T0 had the lowest yield.

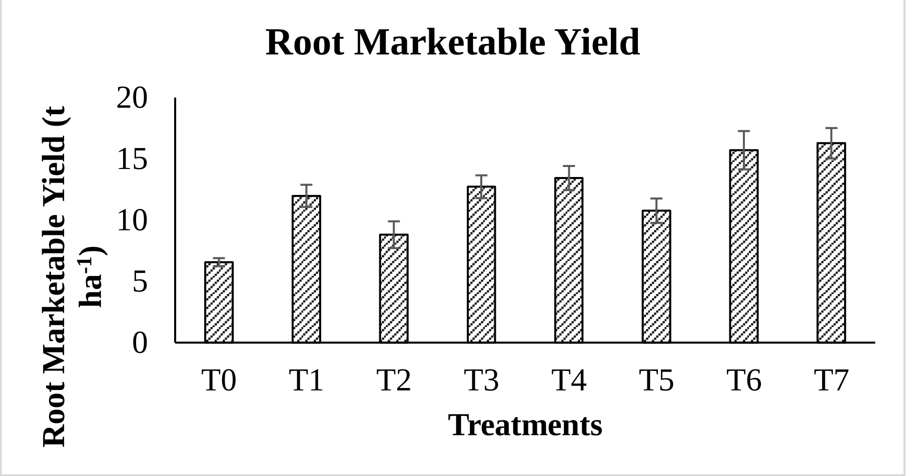

Figure 9. Variation in root marketable yield of carrot under organic and mineral fertilizer combinations

Carrot Nutrient Status

The nutrient composition of carrot plants was significantly influenced by treatments (Figure 10). Nitrogen (N) content increased progressively across treatments, with T0 showing the lowest value (0.6%), while T7 exhibited the highest (2.8%). Phosphorus (P) remained relatively stable across treatments but showed a gradual increase from 0.25% in T0 to 1.1% in T7. Potassium (K) concentrations enhanced gradually, ranging from 0.5% in T0 to 1.2% in T7. The levels of Sulfur (S) also improved significantly, with the lowest value (0.7%) recorded in T0 and the highest (1.35%) in T7. The statistical analysis designated significant differences ($p < 0.05$) amongst T6/T7 and other treatments, suggesting that these treatments were most effective in augmenting the nutrient content of carrot plants. The amplified nutrient accumulation in T6 and T7 suggests better nutrient uptake efficiency, likely due to better soil fertility and microbial activity.

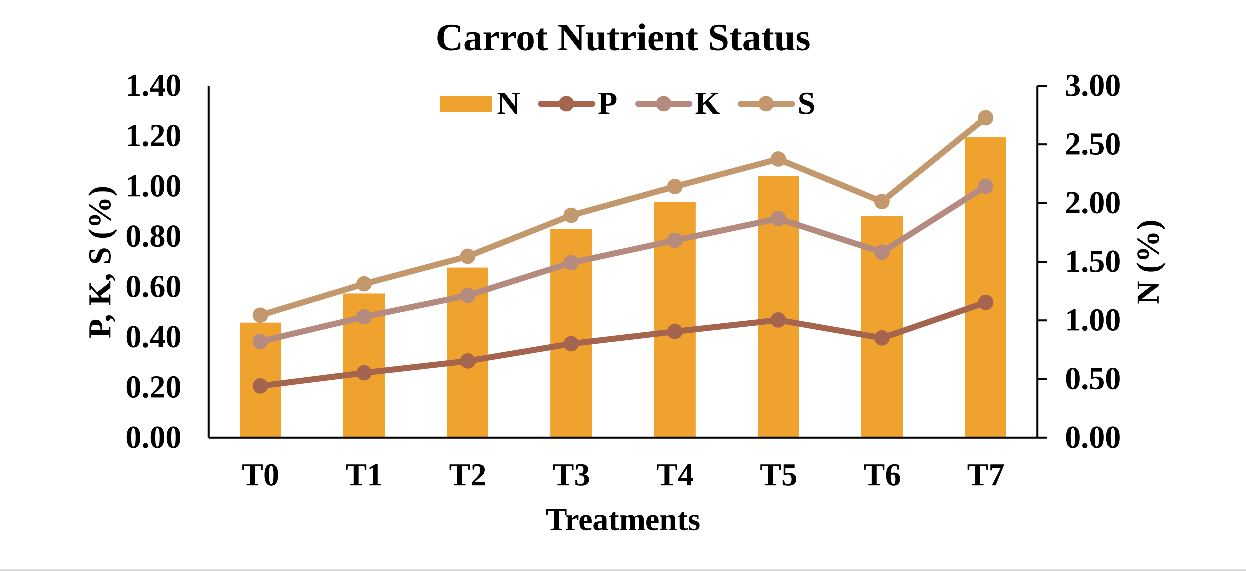

Figure 10. Variation in nutrient uptake by carrot under organic and mineral fertilizer combinations

Soil Nutrient Status

Soil nutrient status varied suggestively among treatments, with noticeable improvements in nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) levels (Figure 11). The nitrogen content was lowermost in T0 (0.4%) and progressively increased to 1.5% in T7. Phosphorus content remained comparatively stable but amplified slightly from 0.2% in T0 to 0.6% in T7. Potassium concentrations demonstrated a gradual increase from 0.3% in T0 to 0.9% in T7, indicating improved soil fertility. Sulfur showed the most noticeable increase, with levels rising from 0.4% in T0 to 1.4% in T7. Statistical analysis discovered weighty variances ($p < 0.05$) among treatments, with T6 and T7 demonstrating the highest nutrient availability. The improvement in soil nutrient status in T6 and T7 advocates that these treatments improved soil microbial activity, nutrient mineralization, and total soil health.

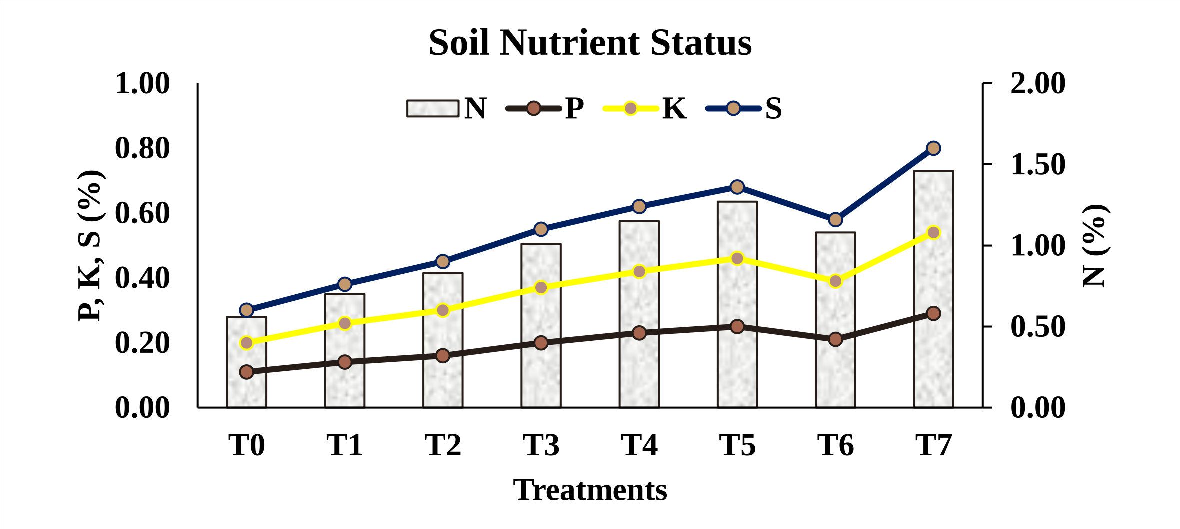

Figure 11. Variation in soil nutrient status under organic and mineral fertilizer combinations

DISCUSSION

The results of this study validate that different treatments significantly influenced shoot dry weight, root marketable yield, and nutrient status in carrot plants and soil. The cumulative trend in shoot dry weight and root marketable yield across treatments advocates the beneficial effects of nutrient supplementation and soil fertility enhancements. The highest shoot dry weight (4.3 g) and root marketable yield (17 t ha^{-1}) were noted in T7, which can be attributed to improved nutrient availability and uptake efficiency. These findings align with earlier studies demonstrating that balanced nutrient management enhances plant growth and productivity (Singh A,), (Zhang Y).

The augmentation in carrot nutrient status under T6 and T7 treatments suggests a straight correlation between soil nutrient availability and plant uptake. Nitrogen content enlarged from 0.6% in T0 to 2.8% in T7, while phosphorus, potassium, and sulfur also showed significant improvements. Adequate nitrogen supply is critical for vegetative growth and biomass accumulation, as reported by Li et al. (Li J,). Potassium and sulfur play essential roles in root development and enzymatic activities, which could explain the increased marketable root yield under higher nutrient treatments (Kumar R,).

Soil nutrient status exhibited a similar trend, with T7 showing the highest levels of nitrogen (1.5%), phosphorus (0.6%), potassium (0.9%), and sulfur (1.4%). The gradual improvement in soil nutrient content across treatments suggests that microbial activity and organic matter mineralization played a significant role in nutrient release and uptake (Sharma V,). Similar studies have shown that integrated nutrient management enhances soil fertility, ensuring sustained nutrient supply for plant uptake (Rahman S).

The statistical analysis confirmed that T6 and T7 treatments were significantly superior ($p < 0.05$) in improving plant and soil nutrient status. This climaxes the importance of optimizing nutrient combinations to maximize yield and maintain soil health. These findings support former research emphasizing the role of integrated nutrient management in sustainable crop production (Patel M,).

CONCLUSION

The outcomes of this study highlight the significant impact of nutrient management on carrot growth, yield, and soil fertility. Treatments T6 and T7 verified the highest shoot dry weight (4.3 g) and root marketable yield (17 t ha^{-1}), emphasizing the significance of balanced nutrient application for ideal crop performance. The improved nutrient status of carrots under these treatments, with nitrogen content reaching 2.8%, along with amplified phosphorus, potassium, and sulfur levels, indicates enhanced nutrient uptake efficiency. Additionally, soil nutrient status improved noticeably in T7, with nitrogen, phosphorus, potassium, and sulfur levels reaching 1.5%, 0.6%, 0.9%, and 1.4%, respectively, signifying sustained soil fertility. These results strengthen the role of integrated nutrient management in sustainable agricultural practices, ensuring both productivity and long-term soil health. Future research should explore the long-term effects of these treatments on microbial activity and soil nutrient cycling to find a more sustainable approach to crop production. Implementing balanced nutrient management strategies can boost carrot yield and quality while maintaining soil fertility, subsidiary environmentally sustainable farming systems.

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