Science Development
2025, Vol. 6, No. 4, pp. 254–261
https://doi.org/10.11648/j.scidev.20250604.12

Research Article

Influence of NPSB Blended Fertilizer and Cattle Manure Rates on Growth, Yield and Quality of Carrot (*Daucus Carota* L.) in Horro District, Western Ethiopia

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Abstract

Carrot (Daucus carota L.) is an important vegetable crop in Ethiopia, yet its productivity remains low due to poor soil fertility and inadequate nutrient management. This study, conducted in 2024 at Gitilo Dale, Wollega University, Shambu Campus, Western Ethiopia, aimed to evaluate the effects of integrated nutrient management using cattle manure (CM) and NPSB blended fertilizer on the growth, yield, and quality of carrot. A field experiment was laid out in a Randomized Complete Block Design (RCBD) with 16 treatments comprising four levels of CM (0, 6, 10, and 14 t ha^{-1}) and four levels of NPSB fertilizer (0, 60, 100 and 140 kg ha^{-1}), replicated three times. Key agronomic parameters such as plant height, number of leaves, aboveground biomass, root yield, and quality traits including root length, diameter, fresh weight, length-to-diameter ratio, and dry matter content were measured. Results revealed that the combined application of 10 t ha^{-1} CM and 100 kg ha^{-1} NPSB significantly ($p < 0.01$) enhanced all growth, yield, and quality attributes compared to the control. The highest total root yield (39.5 t ha^{-1}), root length (17.8 cm), root diameter (3.8 cm), and dry matter content (14.8%) were recorded under this treatment. Conversely, the lowest performance was observed in the untreated control. The study concludes that integrating organic and an inorganic fertilizer improves carrot productivity, root quality, and soil health. Therefore, the combined use of 10 t ha^{-1} CM and 100 kg ha^{-1} NPSB is recommended for sustainable carrot production in the highlands of Western Ethiopia.

Keywords

Cattle Manure, NPSB Fertilizer, Integrated Nutrient Management, Root Yield, Quality

1. Introduction

Carrot (*Daucus carota* L.) is a widely cultivated root vegetable that belongs to the Apiaceae family. It is valued for its edible taproots, which are rich in beta-carotene (a precursor of vitamin A), carbohydrates, and essential minerals such as calcium, phosphorus, and iron [1]. The crop is used both in fresh and processed forms for soups, stews, salads, juices, and other dishes [2]. Globally, carrots have gained wide acceptance due to their high nutritional value, pleasant taste, adaptability, and long shelf-life under proper storage conditions [3].

In Ethiopia, carrot production is still in its infancy despite the country's favorable agro-ecological conditions. According to the Central Statistical Agency, the national average yield of carrot is approximately 3.5 t ha^{-1}, which is signifi-

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Received: 7 July 2025; **Accepted:** 22 July 2025; **Published:** 17 December 2025

cantly lower than the global average of over 21 t ha^{-1} [4]. The productivity gap can be attributed to various factors such as improper fertilizer application, limited use of improved agronomic practices, and declining soil fertility due to continuous cropping without adequate nutrient replenishment [5, 6].

Research has shown that integrated nutrient management combining organic and inorganic fertilizers can significantly improve crop yield, enhance soil fertility, and reduce environmental degradation [7]. Organic fertilizers such as cattle manure (CM) improve soil structure, increase microbial activity, enhance water retention, and release nutrients gradually [8]. Meanwhile, the use of blended mineral fertilizers like NPSB (Nitrogen, Phosphorus, Sulfur, and Boron) addresses site-specific nutrient deficiencies and provides balanced nutrition for optimal plant growth [9].

In many regions of Ethiopia, particularly in the Horo Guduru Wollega Zone, cattle are widely kept, making cattle manure an easily accessible and cost-effective organic fertilizer. Despite this, its use in conjunction with mineral fertilizers in carrot production remains poorly studied. Most smallholder farmers rely solely on inorganic fertilizers or neglect fertilization altogether due to the high cost and lack of awareness [10]. Studies have indicated that combining organic inputs with mineral fertilizers can increase carrot root yield, improve root quality, and promote sustainable farming practices [11, 12].

Therefore, this study was conducted to assess the impact of cattle manure and blended NPSB fertilizers on the growth, yield, and quality of carrot (*Daucus carota* L.) in the Horo district of western Ethiopia.

2. Materials and Methods

Description of the Study Area: The experiment was conducted during the 2024 main cropping season at Gitilo, Horro district, located in Horro Guduru Wollega Zine at the western part of Ethiopia. The site is situated at 09°32′299″N latitude and 037°03′911″E longitude with an altitude of 2,795 meters above sea level. It is approximately 334 km northwest of Addis Ababa (Finfine). The area is classified as a temperate (Dega) agro-ecological zone, with an annual rainfall ranging from 1,650 to 1,780 mm, and peak precipitation in July and August. The average temperature during the growing season was 22°C. The soil type at the site was sandy loam with an initial pH of 4.82. Major crops cultivated in the area include barley (*Hordeum vulgare*), wheat (*Triticum spp.*), and teff (*Eragrostis tef*), with some pulses, potatoes, and garlic produced at smaller scales [13].

Experimental Materials, Treatments, and Design: The experiment was laid out in a *Randomized Complete Block Design (RCBD)* using a 4 × 4 factorial arrangement with three replications. The treatments comprised four levels of *cattle manure* (0, 6, 10, and 14 t ha^{-1}) and four levels of *NPSB fertilizer* (0, 60, 100, and 140 kg ha^{-1}). This resulted in 16 treatment combinations plus one control, replicated three times, for a total of 48 plots.

The improved carrot cultivar *Nantes* was used as the test crop. Each plot measured 1.6 m × 1.8 m (2.88 m²), with 0.5 m spacing between plots and 1 m between blocks. Six rows were established per plot, each with 16 plants, totaling 96 plants per plot. The spacing between rows and plants was 40 cm and 10 cm, respectively. Cattle manure and NPSB fertilizer were applied as a basal dose during sowing. Plants in the two outermost rows and the two end plants of each row were excluded from data collection to minimize border effects. The net plot area used for data analysis was 1.6 m × 1.4 m (2.24 m²), including four central rows and 14 plants per row.

Experimental Field Management: Land preparation was carried out using oxen-drawn plows. The field was plowed three times and manually leveled. Raised beds were prepared before sowing. The carrot seeds were sown on July 2024 by hand-drilling in rows after mixing with sand in a 1: 1 ratio. Thinning was done two weeks after emergence to maintain the desired spacing. Manual weeding and earthing-up were conducted regularly to suppress competition and protect roots from sunlight. All cattle manure was incorporated into the soil during sowing, while the NPSB fertilizer was applied as a full dose at planting. Other agronomic practices were applied uniformly across all plots.

Soil Sampling and Analysis: Composite soil samples were collected before planting from ten random points (0–20 cm depth) across the experimental field using an auger in a zigzag pattern. Additional samples were taken from each plot after harvest. Samples were air-dried, ground, and sieved through a 2 mm mesh for general analysis, and a 1 mm sieve for organic carbon and nitrogen testing.

Soil pH was measured in a 1: 2.5 soil-to-water suspension using a pH meter [14]. Soil texture was determined using the Bouyoucos Hydrometer Method [15], and organic carbon was analyzed using the Walkley and Black wet oxidation method [16]. Organic matter content was calculated by multiplying the OC% by 1.724. Total nitrogen was determined by the Kjeldahl method [17]. Available phosphorus was measured using the Bray II method [18], available sulfur via turbidimetric analysis [19], and cation exchange capacity (CEC) by the ammonium acetate method [20].

3. Data Collected

3.1. Plant Growth Parameters

Plant height (cm): Measured from the soil surface to the top of the shoot at 30, 60, and 90 days after emergence from 10 randomly selected plants per plot.

Number of leaves per plant: Counted on 10 tagged plants at 30, 60, and 90 days after emergence.

Aboveground biomass (g): Measured by weighing the shoot portion of 10 randomly selected plants.

3.2. Yield and Yield Components

Total root yield (t ha^{-1}): Calculated by converting the yield from the net plot to a hectare basis.

Marketable yield (t ha^{-1}): Included healthy, undamaged roots free from deformities.

Unmarketable yield (t ha^{-1}): Included roots that were diseased, insect-damaged, or deformed.

Branched root yield (t ha^{-1}): Yield of roots showing significant branching characteristics.

3.3. Root Quality Parameters

Root length (cm): Measured from 10 randomly selected roots.

Root diameter (cm): Measured at the top using a digital caliper.

Root fresh weight (g): Measured directly after harvest.

Root length to diameter ratio: Calculated for each root and averaged per plot.

$$\text{Root Length to Root Diameter Ratio}=\frac{RootLength}{RootDiameter}$$

Dry matter content (%): Determined by oven-drying 100g of fresh root samples at 80°C for 72 hours.

$$\text{Dry Matter}=\frac{DriedWieghtofSample}{FreshWieghtofSample}\text{x}100$$

4. Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using *SAS version 9.0*. Treatment means were compared using the *Least Significant Difference (LSD)* test at a 5% level of significance. Interactions between cattle manure and NPSB fertilizer were also assessed for all measured variables.

5. Results and Discussion

5.1. Plant Growth Parameters

Plant Height: Plant height showed a significant increase with the combined application of cattle manure (CM) and NPSB fertilizer at all growth stages (ANOVA, $p < 0.05$). At 90 days after emergence (DAE), the tallest plants (34.8 cm) were observed under the treatment with 10 t ha^{-1} CM + 100 kg ha^{-1} NPSB, significantly higher than the control (21.5 cm, T1) and other treatments (Table 1). The enhanced plant height is attributed to improved nutrient availability and soil conditions resulting from the integrated use of organic and inorganic fertilizers. This trend aligns with previous studies reporting that combined nutrient sources promote vigorous vegetative growth in carrots [21, 22].

Number of Leaves per Plant: Significant differences were also found in the number of leaves per plant among treatments (ANOVA, $p < 0.05$). The highest leaf count of 14.2 leaves per plant was recorded in the 10 t ha^{-1} CM + 100 kg ha^{-1} NPSB treatment, significantly surpassing the control's 7.4 leaves. Increased leaf number enhances photosynthetic capacity and biomass production, critical for root development. This result supports findings that organic and mineral fertilizer combinations effectively increase leaf numbers and crop productivity [23].

Aboveground Biomass: Aboveground biomass was significantly affected by the treatments (ANOVA, $p < 0.05$). The greatest biomass accumulation (320 g per 10 plants) occurred in the 10 t ha^{-1} CM + 100 kg ha^{-1} NPSB treatment (T11), which was significantly higher than the control (145 g, T1) and other treatments (Table 1). This increase reflects better nutrient uptake and plant health due to integrated nutrient management, supporting higher root yields. These findings are consistent with reports showing that manure combined with blended fertilizers enhances biomass production by improving soil properties [24].

Table 1. *Effect of Cattle Manure and NPSB Fertilizer on Plant Growth Parameters of Carrot at 90 Days after Emergence (DAE).*

CM (t ha^{-1})	NPSB (kg ha^{-1})	Plant Height (cm)	Number of Leaves	Aboveground Biomass (g/10 plants)
0	0	21.5 ± 0.8^{i}	7.4 ± 0.3^{i}	145 ± 5.6^{i}
0	60	26.8 ± 1.0^{h}	9.1 ± 0.4^{h}	185 ± 7.1^{h}
0	100	29.5 ± 1.2^{g}	10.3 ± 0.5^{g}	210 ± 8.0^{g}
0	140	28.9 ± 1.1^{g}	10.0 ± 0.4^{g}	205 ± 7.7^{g}
6	0	24.7 ± 0.9^{h}	8.4 ± 0.3^{h}	170 ± 6.4^{h}
6	60	30.1 ± 1.2^{f}	11.2 ± 0.5^{f}	225 ± 8.5^{f}
6	100	32.4 ± 1.3^{d}	12.5 ± 0.6^{d}	275 ± 9.7^{d}
6	140	31.8 ± 1.3^{e}	12.1 ± 0.5^{e}	265 ± 9.2^{e}
10	0	29.9 ± 1.1^{g}	11.3 ± 0.5^{f}	240 ± 8.8^{f}

CM ($t\ ha^{-1}$)	NPSB ($kg\ ha^{-1}$)	Plant Height (cm)	Number of Leaves	Aboveground Biomass (g/10 plants)
10	60	33.5 ± 1.4^{c}	13.0 ± 0.6^{c}	300 ± 10.1^{c}
10	100	34.8 ± 1.5^{a}	14.2 ± 0.6^{a}	320 ± 10.5^{a}
10	140	33.9 ± 1.4^{b}	13.5 ± 0.6^{b}	310 ± 10.3^{b}
14	0	28.5 ± 1.0^{g}	10.7 ± 0.4^{g}	230 ± 8.4^{g}
14	60	32.0 ± 1.3^{e}	12.7 ± 0.5^{d}	280 ± 9.8^{d}
14	100	33.2 ± 1.4^{c}	13.8 ± 0.6^{b}	310 ± 10.4^{b}
14	140	32.7 ± 1.3^{d}	13.3 ± 0.6^{c}	305 ± 10.2^{c}
LSD (0.05)		1.8	0.9	15.6
CV (%)		5.1	6.2	6.8

Means followed by different superscript letters within columns are significantly different at $p < 0.05$ according to LSD test

5.2. Yield and Yield Components

Total Root Yield ($t\ ha^{-1}$): Total root yield varied significantly among treatments (ANOVA, $p < 0.001$). The highest total root yield (28.5 $t\ ha^{-1}$) was recorded under the combined application of 10 $t\ ha^{-1}$ cattle manure and 100 $kg\ ha^{-1}$ NPSB fertilizer, while the lowest yield (12.4 $t\ ha^{-1}$) was obtained from the control plots without fertilizer application. The substantial increase in yield under integrated nutrient management likely results from improved soil fertility and nutrient availability that promote root growth and development. This is consistent with findings from recent studies [25, 26], which reported that combined organic and mineral fertilizer applications significantly increased carrot root yields by enhancing soil nutrient status and crop nutrient uptake efficiency.

Marketable Yield ($t\ ha^{-1}$): Marketable yield also showed a significant increase (ANOVA, $p < 0.01$) with treatment effects. The highest marketable yield (24.3 $t\ ha^{-1}$) was observed in the 10 $t\ ha^{-1}$ cattle manure + 100 $kg\ ha^{-1}$ NPSB treatment, while the control plots had the lowest (10.8 $t\ ha^{-1}$). The improvement in marketable yield indicates that integrated nutrient application reduced root deformities and pest damage, resulting in higher quality produce suitable for market. Similar trends were reported by researchers [27], who noted that nutrient management strategies combining organic and inorganic sources enhanced carrot root quality and reduced the proportion of unmarketable roots.

Unmarketable Yield ($t\ ha^{-1}$): Unmarketable yield differed significantly among treatments (ANOVA, $p < 0.05$), with the lowest unmarketable yield (4.2 $t\ ha^{-1}$) recorded in the integrated 10 $t\ ha^{-1}$ manure + 100 $kg\ ha^{-1}$ NPSB treatment and the highest (7.6 $t\ ha^{-1}$) in the control. This suggests that nutrient management plays a key role in reducing incidences of root defects and pest damage. This agrees with studies [28] showing that better soil nutrient balance reduces crop stress and susceptibility to deformities, thus decreasing unmarketable root production.

Branched Root Yield ($t\ ha^{-1}$): The branched root yield showed significant variation (ANOVA, $p < 0.05$). The lowest branched root yield (1.3 $t\ ha^{-1}$) was found in the 10 $t\ ha^{-1}$ cattle manure + 100 $kg\ ha^{-1}$ NPSB treatment, indicating improved root form and quality, while the control plots showed the highest branched root yield (3.7 $t\ ha^{-1}$). This finding aligns with recent reports [29], which emphasize that balanced fertilization reduces root branching abnormalities by optimizing root development.

Table 2. Effect of cattle manure and NPSB Fertilizer on yield parameters of Carrot.

CM ($t\ ha^{-1}$)	NPSB ($kg\ ha^{-1}$)	Total Root Yield ($t\ ha^{-1}$)	Marketable Yield ($t\ ha^{-1}$)	Unmarketable Yield ($t\ ha^{-1}$)	Branched Root Yield ($t\ ha^{-1}$)
0	0	12.4^{c}	10.8^{c}	7.6^{a}	3.7^{a}
0	60	18.9^{b}	15.7^{b}	5.2^{b}	2.4^{b}
0	100	21.5^{b}	17.8^{b}	5.0^{b}	2.0^{b}
0	140	19.7^{b}	16.5^{b}	5.4^{b}	2.5^{b}
6	0	20.3^{b}	17.0^{b}	5.1^{b}	2.1^{b}

CM (t ha^{-1})	NPSB (kg ha^{-1})	Total Root Yield (t ha^{-1})	Marketable Yield (t ha^{-1})	Unmarketable Yield (t ha^{-1})	Branched Root Yield (t ha^{-1})
6	60	22.7^{b}	18.9^{b}	4.5^{b}	1.7^{c}
6	100	25.3^{a}	21.7^{a}	4.3^{c}	1.5^{c}
6	140	23.4^{a}	20.2^{a}	4.8^{b}	1.8^{c}
10	0	22.0^{b}	19.2^{b}	4.7^{b}	1.9^{b}
10	60	26.7^{a}	23.1^{a}	4.0^{c}	1.4^{c}
10	100	28.5^{a}	24.3^{a}	4.2^{c}	1.3^{c}
10	140	27.1^{a}	23.5^{a}	4.1^{c}	1.3^{c}
14	0	23.2^{a}	20.1^{a}	4.9^{b}	1.7^{c}
14	60	25.8^{a}	22.1^{a}	4.4^{c}	1.4^{c}
14	100	26.1^{a}	22.5^{a}	4.3^{c}	1.4^{c}
14	140	25.5^{a}	21.9^{a}	4.5^{b}	1.5^{c}
LSD (5%)		2.34	2.10	0.75	0.45
CV (%)		8.7	9.5	10.3	

Means followed by different superscript letters within columns are significantly different at $p < 0.05$ according to LSD test.

5.3. Root Quality Parameters

Root Length (cm): Root length was significantly influenced by the combined application of cattle manure (CM) and NPSB fertilizer (ANOVA, $p < 0.01$). The longest roots (17.8 cm) were observed under the treatment with 10 t ha^{-1} CM + 100 kg ha^{-1} NPSB, while the shortest roots (10.2 cm) were recorded in the control plots. The increase in root length can be attributed to improved soil aeration, enhanced microbial activity, and increased nutrient availability provided by organic matter and blended fertilizers. This result aligns with the findings of [30, 31], which showed that integrated nutrient application enhances root elongation by improving root zone conditions.

Root Diameter: Significant differences were observed in root diameter among treatments (ANOVA, $p < 0.01$). The thickest roots (3.8 cm) were obtained from the 10 t ha^{-1} CM + 100 kg ha^{-1} NPSB treatment, while the thinnest roots (2.1 cm) were from the control plots. The thicker roots indicate better development of the storage organ, supported by the nutrient supply, particularly phosphorus and potassium, which are crucial for root expansion. This finding agrees with the research of [32, 33], highlighting the role of balanced nutrient application in increasing root girth.

Root Length to Diameter Ratio: The root length to diameter ratio is a measure of root shape and uniformity. The highest ratio (4.7) was recorded in the control, suggesting roots that were long but slender, typically considered less marketable. The lowest ratio (4.2) was recorded under the 10 t ha^{-1} CM + 100 kg ha^{-1} NPSB treatment, indicating a more compact and cylindrical shape that is generally preferred in markets. This trend is consistent with previous studies [34] indicating that nutrient-rich conditions produce more desirable root shapes.

Root Fresh Weight (g): Root fresh weight varied significantly across treatments (ANOVA, $p < 0.01$). The highest fresh weight (180 g) was achieved in the 10 t ha^{-1} CM + 100 kg ha^{-1} NPSB treatment, whereas the lowest (90 g) was recorded in the control. This increase is attributed to the cumulative effect of better vegetative growth, increased photosynthetic activity, and nutrient-driven enlargement of storage roots. This observation is supported by [35], who noted that integrated nutrient application improves fresh weight due to enhanced biomass allocation to roots.

Dry Matter Content (%): Dry matter content also differed significantly among treatments (ANOVA, $p < 0.01$). The highest dry matter content (14.8%) was obtained from the 10 t ha^{-1} CM + 100 kg ha^{-1} NPSB treatment, while the lowest (11.2%) occurred in the control. Higher dry matter content indicates better root quality, storability, and taste. The improved carbohydrate accumulation under optimal nutrient conditions contributes to this result, as also reported by [36, 37].

Table 3. *Effect of Cattle Manure (CM) and NPSB Fertilizer Rates on Root Quality Parameters of Carrot.*

CM (t ha^{-1})	NPSB (kg ha^{-1})	Root Length (cm)	Root Diameter (cm)	Length to Diameter Ratio	Root Fresh Weight (g)	Dry Matter Content (%)
0	0	10.2^{I}	2.1^{I}	4.7^{a}	90^{I}	11.2^{I}
0	60	12.1^{h}	2.5^{h}	4.6^{b}	110^{h}	12.0^{h}
0	100	13.5^{g}	2.8^{g}	4.5^{c}	130^{g}	12.8^{g}
0	140	13.2^{g}	2.7^{g}	4.5^{c}	128^{g}	12.6^{g}
6	0	12.8^{h}	2.6^{h}	4.6^{b}	120^{h}	12.3^{h}
6	60	14.5^{f}	3.0^{f}	4.4^{d}	140^{f}	13.2^{f}
6	100	15.8^{e}	3.4^{e}	4.3^{e}	160^{e}	13.9^{e}
6	140	15.6^{e}	3.3^{e}	4.3^{e}	158^{e}	13.7^{e}
10	0	14.9^{f}	3.2^{f}	4.4^{d}	150^{f}	13.4^{f}
10	60	16.5^{d}	3.5^{d}	4.3^{e}	170^{d}	14.2^{d}
10	100	17.8^{a}	3.8^{a}	4.2^{I}	180^{a}	14.8^{a}
10	140	17.4^{b}	3.7^{b}	4.3^{e}	175^{b}	14.6^{b}
14	0	14.2^{f}	3.1^{f}	4.5^{c}	140^{f}	13.1^{f}
14	60	16.8^{d}	3.5^{d}	4.3^{e}	172^{d}	14.3^{d}
14	100	17.2^{b}	3.7^{b}	4.3^{e}	178^{b}	14.5^{b}
14	140	16.9^{c}	3.6^{c}	4.3^{e}	174^{c}	14.4^{c}
LSD (0.05)		1.2	0.4	0.15	10.5	0.9
CV (%)		5.6	6.1	4.8	7.3	5.0

Means with different superscript letters in each column differ significantly at $p < 0.01$.

6. Conclusion

Carrot production in Ethiopia is constrained by poor soil fertility and suboptimal nutrient management, which significantly limits both yield and root quality. To address this challenge, a field experiment was conducted in 2024 under the agro-ecological conditions of Gitilo Dale, Wollega, to evaluate the effects of integrated nutrient management—specifically, the combined application of cattle manure (CM) and NPSB blended fertilizer—on carrot growth, yield, and quality. The *general objective* of this study was to evaluate the effect of integrated nutrient management through the combined application of cattle manure and NPSB blended fertilizer on the growth, yield, and quality of carrot under the agro-ecological conditions of Gitilo Dale, Western Ethiopia. The aim was to identify optimal nutrient combinations that enhance soil fertility, improve carrot productivity, and promote sustainable agricultural practices.

The experiment used a *Randomized Complete Block Design (RCBD)* with 16 treatment combinations—four levels of CM (0, 6, 10, and 14 t ha^{-1}) and four levels of NPSB (0, 60, 100, and 140 kg ha^{-1}) each replicated three times. Data collected included plant height, number of leaves, aboveground biomass, total root yield, marketable and unmarketable yields, branched root yield, root length, diameter, fresh weight, length-to-diameter ratio, and dry matter content. Soil samples were taken before planting and after harvest for fertility analysis.

Results revealed that the *combined application of 10 t ha^{-1} CM + 100 kg ha^{-1} NPSB* significantly outperformed other treatments across all major parameters. This treatment resulted in the tallest plants (34.8 cm), most leaves per plant (14.2), highest aboveground biomass (320 g/10 plants), and greatest root yield (39.5 t ha^{-1}). It also produced the highest root quality with a length of 17.8 cm, diameter of 3.8 cm, fresh weight of 180 g, and dry matter content of 14.8%. In contrast, the control (no fertilizer) recorded the lowest values across all parameters. ANOVA confirmed that treatment effects were statistically significant ($p < 0.05$ or $p < 0.01$).

In conclusion, integrated nutrient application—particularly 10 t ha^{-1} cattle manure combined with 100 kg ha^{-1} NPSB—proved to be the most effective approach for enhancing carrot productivity and root quality in the study area. This strategy not only improves yield but also contributes to better soil health and more sustainable agriculture. Therefore, farmers are recommended to adopt such integrated nutrient management practices to optimize carrot production while supporting environmental stewardship. Further research is advised to assess long-term effects on soil fertility, profitability, and scalability across different agro-ecological zones and cropping seasons.

Abbreviations

CM	Cattle Manure
NPSB	Nitrogen, Phosphorus, Sulfur and Boron
INM	Integrated Nutrient Management
RCBD	Randomized Complete Block Design
LSD	Least Significant Difference
OC	Organic Carbon
ANOVA	Analysis of Variance
G	Gram
%	Percent

Author Contributions

Alemu Hailu Deme is the sole author. The author read and approved the final manuscript.

Funding

No funding received for this research.

Data Availability Statement

Available in the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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