Original Research Article

**Effect of NPK fertilizer levels on yield and quality of beetroot (*Beta vulgaris* L.) in acidic soils**

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ABSTRACT

Beetroot (*Beta vulgaris* L.), also known as garden beet, is a widely cultivated root vegetable valued for its edible foliage and fleshy roots. Productivity is strongly influenced by soil fertility management. A field experiment was conducted during the Rabi season (September–December 2023) at the Woodhouse Horticultural Research Station, Ooty, to evaluate the effect of different mineral fertilizer levels on the growth, yield, and quality of beetroot cultivated in acidic soils. The study was laid out in a randomized block design with eight fertilizer treatments (T₁: N₀P₀K₀, T₂: N₁P₁K₂, T₃: N₁P₂K₂, T₄: N₂P₂K₀, T₅: N₂P₁K₁, T₆: N₃P₁K₁, T₇: N₂P₃K₂, T₈: N₃P₃K₂), each replicated three times. Data on root length, diameter, root‑to‑shoot ratio, fresh and dry root weight, yield per plot and per hectare, total soluble solids (TSS), and total sugars were recorded. Increasing nutrient levels significantly improved all measured parameters. Among the treatments, T₈ (N₃P₃K₂: 180 kg N ha-1, 240 kg P₂O₅ ha-1, 100 kg K₂O ha-1) produced the highest fresh root weight (135.5 g plant-1), dry weight (10 g plant-1), root diameter (21.97 cm), root yield (42.1 kg plot-1; 421.13 q ha-1), root‑to‑shoot ratio (3.98), TSS (19.96 °Brix), and total sugar (8.10%) all significantly superior (p < 0.05) to other treatments. . The control (T₁) consistently recorded the lowest values. These results demonstrate that balanced mineral fertilization, particularly T₈ and T₇, markedly enhances both yield and quality attributes of beetroot under temperate, acidic soil conditions.

Keywords: Beetroot (Beta vulgaris), mineral nutrients management, fertilizer treatments, yield performance, and quality attributes

1. INTRODUCTION

Beetroot (*Beta vulgaris* L.), belonging to the Chenopodiaceae family, is known for its vibrant deep red or crimson pigmentation. Commonly referred to as beet, chard, spinach beet, sea beet, or garden beet, it is highly beneficial to human health. Beets can be consumed raw, boiled, steamed, or roasted. Red beetroot is a rich source of essential minerals such as magnesium, manganese, sodium, potassium, iron and copper (Mathangi, 2019). Beetroot possesses a wide range of therapeutic properties, which contribute to the prevention of cardiovascular diseases and certain types of cancer (colon cancer) (Kavalcova et al., 2015). It contains numerous bioactive compounds, including glycine, betaine, saponins (De Zwart et al., 2003), betacyanins (Patkai et al., 1997), carotenoids (Dias et al., 2009), folates, betanins, polyphenols, and flavonoids (Vali et al., 2007), all of which offer significant health-promoting benefits. A food that has an alkaline pH of 7.5-8, beetroot is rich in vitamin C, B1, B2, niacin, B6, B12, and its leaves are a great source of vitamin A (Chauhan et al., 2020).

Across the country, beetroot is an important root vegetable crop, cultivated on approximately 645 hectares in Tamil Nadu, yielding around 15,480 metric tonnes annually, with an average productivity of 24 tonnes per hectare. Since the current yield levels are below the global average, it is essential to enhance production through the adoption of advanced cultivation techniques. The key beetroot-growing states in India include Haryana, Himachal Pradesh, West Bengal, Uttar Pradesh, Maharashtra, and Tamil Nadu. Nationwide, beetroot is grown on about 7,900 hectares, with Telangana accounting for 425 hectares and producing approximately 11,132 metric tonnes (Arulmani et al., 2024).

Fertilizer is one of the **costliest inputs** in agriculture, and applying the **appropriate dosage** is crucial for both **environmental sustainability** and **maximizing farm income.** The **excessive application** of **synthetic fertilizers** across different soil types has aggravated the **deficiency of secondary and micronutrients (Alnaass et al., 2021).** Furthermore, **inadequate plant nutrition** further intensifies the issue of **deteriorating soil health and fertility.** The present study focused on determining the influence of different rates of mineral nutrient application on the root development and quality traits of beetroot under acidic soil conditions.

2. matErialS and METHODS

**2.1 Experimental Site and Plant Material**

A field experiment was conducted from September to December 2023 at the Horticultural Research Station, Ooty, to investigate the effect of varying levels of mineral fertilizers on the growth, root yield, and quality of beetroot. The Improved Crystal Hybrid beetroot was used as the test crop.

**2.2 Soil description**

The initial soil nutrient status was: Soil pH at 4.21, alkaline KMnO₄-extractable nitrogen (N) at 385 kg ha-1, Bray's extractable phosphorus (P) at 192 kg ha-1 and NH₄OAc-extractable potassium (K) at 578 kg ha-1. Fertilizers P₂O₅ and K₂O were applied as a basal dose, while nitrogen (N) was split into two equal applications-one at sowing and the other 30 days after planting.

**2.3 Environmental Conditions**

The experiments were conducted with a mean maximum and minimum temperatures of 22.05 °C and 11.0 °C, respectively. Similarly, there were variations in the relative humidity between 80 and 85 percent, 275 mm of total rainfall, and 2 rainy days overall

**2.4 Experimental Design and Treatment Structure**

The experiment was laid out in a Randomized Block Design (RBD) with eight fertilizer treatments, each replicated three times.

**2.5 Spacing, Plot size and management practices**

The beetroot seeds were sown with a spacing of 20 x 10 cm and thinning was carried out 20 days after sowing to maintain the spacing. Each plot contains 10 square meters. Other management practices were followed as per the Crop Production Guide of Tamil Nadu Agricultural University. The details of the treatment structure are shown in Table 1.

**Table 1. Treatment structure and ferti** **lizer levels**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S.No** | **Treatment** | **N (Kg ha-1)** | **P2O5 (Kg ha-1)** | **K2O (Kg ha-1)** |
| 1 | T1 - N0P0K0 | 0 | 0 | 0 |
| 2 | T2 - N1P1K2 | 60 | 80 | 100 |
| 3 | T3 - N1P2K2 | 60 | 160 | 100 |
| 4 | T4 - N2P2K0 | 120 | 160 | 0 |
| 5 | T5 - N2P1K1 | 120 | 80 | 50 |
| 6 | T6 - N3P1K1 | 180 | 80 | 50 |
| 7 | T7 - N2P3K2 | 120 | 240 | 100 |
| 8 | T8 - N3P3K2 | 180 | 240 | 100 |

**2.6 Irrigation and Fertilizer Application Methods**

Phosphorus (P₂O₅) and potassium (K₂O) fertilizers were applied as a basal dose prior to sowing. Nitrogen (N) was applied in two equal splits, with half applied at sowing and the remaining half applied 30 days after planting to ensure sustained nutrient availability. Irrigation was provided through sprinkler irrigation at weekly regular intervals to maintain adequate soil moisture throughout the growing season.

2.7 **Weed management** was carried out manually as required.

**2.8 Harvesting**

When the roots reached their complete development and reached their maximum size and color, they were manually harvested (90-110 days after sowing).

**2.9 Growth and Yield Determinations**

Data on growth and yield were collected from five randomly selected plants in each treatment plot.

**2.9.1 Root length (cm)**

Measured using a ruler.

**2.9.2 Root diameter (cm)**

Measured using vernier calipers and averaged for each plot.

**2.9.3 Root to shoot ratio:** Calculated on a weight basis using the formula:

Root:shoot ratio= Root weight / Foliage weight

**2.9.4 Root yield per plot (kg plot**-1**)**

Determined by weighing harvested roots from each net plot.

**2.9.5 Root yield per hectare (t ha**-1**)**

Estimated by converting the plot yield to yield per hectare using the appropriate conversion factor.

**2.9.6 Beetroot fresh and dry weight**

Measured in grams using an electronic scale.

Roots were manually harvested once they reached full development, optimal size, and desired coloration.

**2.10 Quality Parameters Determination**

**2.10.1 Total soluble solids (°B) of** **Beetroot**

Determined using an Erma hand refractometer, with results expressed in degrees Brix (°B).

**2.10.2 Total sugars (%):**

Below the formula used for calculation of total sugar (%)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Total sugars (%) | = | 0.05 | ˟ | 250 | ˟ | 250 | ˟ | 100 |
| titre value | 25 | 25 |

3. results and discussion

**3.1 Fresh weight, Root diameter**

Table 3 indicated the impact of various nutrient doses on root fresh weight per plant, root dry weight per plant, root diameter, and root to shoot ratio. The addition of nutrients had a major impact on the root diameter. T8 (N3P3K2) had the largest root diameter (21.97) compared to T7 (19.50 cm) and T6 (18.50 cm), which was significantly better than any other treatment. T1 had the lowest root diameter measured (12.87). The largest fresh weight of root per plant (135.5 g) among the various fertilizer treatments was attained under treatment T8 (N3P3K2), which was noticeably better than the other treatments. In the treatment T1 (N0P0K0), a significantly lower minimum fresh weight of root per plant (22.9 g) was achieved.

When compared to the control, the nitrogen treatment greatly boosted the fresh weight and diameter of the roots. This outcome was consistent with the findings of El-Harriri and Mirvat (2001) as well as Nawar and Saleh (2003). He discovered that adding more nitrogen to the soil as fertilizer greatly increased the weight and diameter of the roots. Additionally, Nemeat Alla (2002) found that applying more nitrogen fertilizer to the soil resulted in a considerable increase in root diameter, fresh weight, and sugar yield. The increase in fertilizer doses caused an increase in root length and diameter (Turk., 2010).

**3.2 Dry weight, Root to shoot ratio**

The treatment T8 produced the highest dry weight of root per plant (10.0g), which was statistically considerably better than the other treatments. In treatment T1, the lowest dry weight of root per plant (2.5 g) was attained. T8 (N3P3K2) had the maximum root to shoot ratio (3.98), which was significantly higher than the other treatments; T1 (N0P0K0) had the lowest root to shoot ratio (2.72).

The treatment T8 produced the highest dry weight of root per plant (10.0g), which was statistically considerably better than the other treatments. In treatment T1, the lowest dry weight of root per plant (2.5 g) was attained. T8 (N3P3K2) had the maximum root to shoot ratio (3.98), which was significantly higher than the other treatments; T1 (N0P0K0) had the lowest root to shoot ratio (2.72). Sarhan and Ismail (2003) reported that root dry matter yield of fodder beet was significantly increased by increasing nitrogen fertilizer level. These results are consistent with the present results.

**3.3 Root yield (kg plot-1), Root yield (q ha-1)**

T8 had the maximum root yield (42.1 kg plot-1) compared to all other treatments, which indicated a considerable improvement. The lowest yield was recorded in control plot T1 (28.1 kg plot-1).

T8 had the greatest root production (421.13), which was much higher than any other treatment. T7 ranked in second (361.97). Plot T1, the control, had the lowest yield (281.13). The lowest yield was recorded in control plot T1 (281.13).

It's possible that greater cell division and rapid cell multiplication resulted in better plant growth in all aspects, while increased photosynthate translocation from leaves (source) to roots (sink) resulted in longer and wider roots. Similar results were found by Mali et al. (2018) in radish, Ingole et al. (2018) and Dlamini et al. (2020) in beetroot. According to Gwad et al. (2008), the application of fertilizers enhanced the mean root yield of fodder beet. The application of fertilization had a significant effect on root yield, especially N and P fertilization increased root yield (Turk., 2010). Root diameter increased with increasing N level (Moniruzzaman et al.,2013)

**Table 2: Effect of different fertilizer treatments on root fresh weight, dry weight, diameter, root‑to‑shoot ratio, and yield of beetroot (Improved Crystal Hybrid) grown at Ooty**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No** | **Treatment** | **Root fresh weight per plant (g)** | **Root dry weight per plant (g)** | **Root diameter**  **(cm)** | **Root to shoot ratio** | **Root yield (10 m2)**  **(kg plot-1)** | **Root yield**  **(q ha-1)** |
| 1 | T1 - N0P0K0 | 22.9 | 2.5 | 12.87 | 2.72 | 28.1 | 281.13 |
| 2 | T2 - N1P1K2 | 38.6 | 4.0 | 14.51 | 3.12 | 28.8 | 287.57 |
| 3 | T3 - N1P2K2 | 50.5 | 4.8 | 15.50 | 3.24 | 30.6 | 306.33 |
| 4 | T4 - N2P2K0 | 77.1 | 6.8 | 16.30 | 3.51 | 31.8 | 317.67 |
| 5 | T5 - N2P1K1 | 90.5 | 7.7 | 16.60 | 3.55 | 33.4 | 333.75 |
| 6 | T6 - N3P1K1 | 100.3 | 8.2 | 18.50 | 3.68 | 34.9 | 349.30 |
| 7 | T7 - N2P3K2 | 107.6 | 8.4 | 19.50 | 3.75 | 36.2 | 361.97 |
| 8 | T8 - N3P3K2 | 135.5 | 10.0 | 21.97 | 3.98 | 42.1 | 421.13 |
| **SEd** | | 4.14 | 0.03 | 2.19 | 0.03 | 2.51 | 19.42 |
| **CD (*P=*0.05%)** | | 8.89 | 0.08 | 4.71 | 0.06 | 5.40 | 41.65 |
| CD= critical difference at 5% significance, SEd = standard error of difference between means, q ha-1= quintals per hectare | | | | | | | |

**3.4 Total soluble solids, Total sugar**

T.S.S. levels varied between treatments. The highest T.S.S concentration (19.96 0B) was reported in T8, which is comparable to T7 and T6, and the lowest in T1 (12.59 0B). There was variation among the treatments in terms of total sugar. The highest total sugar level was reported (8.10%) in T8, which is comparable to T7 and T6, and the lowest in T1 (3.33%). T.S.S. is a key quality characteristic that quantifies the concentration of reducing sugars (fructose and glucose) and non-reducing sugars (sucrose), which are related to the root's sweet flavour. The T.S.S content of beetroot is advantageous because it can be used as a salad vegetable.

The nitrogen level has a substantial impact on the total soluble solids and sugar content of beets. Nitrogen application at 50 kg N ha-1 resulted in significantly higher total soluble solids and total sugar levels than the control (0 kg N ha-1). Increasing the nitrogen level of the fertilizers up to 150 kg N ha-1 enhanced the total soluble solids and total sugar of beetroot, but the tendency reversed at the highest level (200 kg N ha-1) (Rantao, 2013). The decline in TSS% caused by excessive nitrogen application can be attributed to its involvement in increasing root weight and diameter, tissue water content, and partitioning of more photosynthates to the tops rather than the roots of sugar beet plants, which may result in a lower TSS%. Abdelaal, and Tawfik (2015) and Ramadan et al., (2003) support this finding.

**Table 3. Effect of various inorganic nutrient dose on TSS, Total sugars of beetroot**

|  |  |  |  |
| --- | --- | --- | --- |
| **S.No** | **Treatment** | **TSS (0Brix)** | **Total sugar (%)** |
| 1 | T1 - N0P0K0 | 12.59 | 3.33 |
| 2 | T2 - N1P1K2 | 14.16 | 4.14 |
| 3 | T3 - N1P2K2 | 15.04 | 5.09 |
| 4 | T4 - N2P2K0 | 15.51 | 5.26 |
| 5 | T5 - N2P1K1 | 16.38 | 5.46 |
| 6 | T6 - N3P1K1 | 17.43 | 6.17 |
| 7 | T7 - N2P3K2 | 18.60 | 7.13 |
| 8 | T8 - N3P3K2 | 19.96 | 8.10 |
| **SEd** | | 1.64 | 1.16 |
| **CD (P=0.05%)** | | 3.52 | 2.50 |
| SEd = standard error of difference; CD = critical difference at p < 0.05; Total Soluble Sugar (T.S.S.); N- Nitrogen; P-Phosohorus; K-Potassium | | | |

**CONCLUSION**

The results of this study indicate that the application of T8 (N₃P₃K₂: 180 kg N ha-1, 240 kg P₂O₅ ha-1, 100 kg K₂O ha-1) produced the highest root yield, root dimensions, and quality attributes in the Improved Crystal Hybrid beetroot. Therefore, these fertilizer combinations are recommended for optimizing both yield and quality characteristics of beetroot under similar agro‑ecological conditions.

**DISCLAIMER (ARTIFIICIAL INTELLIGENCE)**

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1. ChatGPT

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

References

Kayalcova, P., Bystricka, J., Tomas, J., et al.,(2015). The content of total polyphenols and antioxidant activity in red beetroot. *Potravinarstvo*. 9(1),77-83.

De Zwart, F.J., Slow, S., Payne, R.J., et al. (2003) Glysine betaine and glycine betaine analogues in common foods. *Food Chem*, 83(2),197-204.

Patkai, G., Barta, J., & Varsanyi, I.(1997). Decomposition of anticarcinogen factors of the beetroot during juice and nectar production. *Cancer Lett*. 114,105-106.

Dias, M.G., Camoes, M.F.G.F.C., & Oliveira, L. (2009). Carotenoids in traditional Portuguese fruits and vegetables. *Food Chemistry*, 113, 808-815.

Vali, L., Stefanovits, B.E., Szentmihalyi, K., et al. (2007). Liver-protecting effects of table beet (Beta vulgaris var. Rubra) during ischemia-reperfusion. *Nutrition*. 23,172-178.

Chauhan, S., Chamoli, K., & Sharma, S. (2020). Beetroot- A Review Paper. *Journal of Pharmacognosy and Phytochemistry,*Sp9(2),424-427.

Arulmani, R., Sellamuthu, K.M., Maragatham, S., et al. (2024). Yield and quality of beetroot to soil test crop response (STCR) - integrated plant nutrient system (IPNS) based fertilizer prescription in Ultisols of Western Ghats of Tamil Nadu, India*. Plant science today*,11 (4), 91-97. <https://doi.org/10.14719/pst.4623>

Alnaass, N., Agil, H.K., & Ibrahim, H.K. (2021). Use of Fertilizers or Importance of Fertilizers in Agriculture. *International Journal of Advanced Academic Studies,*3(2),52-57

El-Harriri, D. M., & Gobarah Mirvat, E. (2001). Response of growth, yield and quality of sugar beet to nitrogen and potassium fertilizers under newly reclaimed sandy soil. *J. Agric. Sci. Mansoura Univ.,* 26(10), 5895-5907.

Nawar, F. R. R., & Saleh, S. A. (2003). Effect of plant spacing and nitrogen fertilizer levels on yield and yield components of sugar beet under calcareous soil condition. *J. Adv. Agric. Res.,* 8(1), 47–57.

Nemeat Alla, E. A. E., Mohamed, A. A. E., & Zalat, S. S.(2002). Effect of soil and foliar application of nitrogen fertilization on sugar beet. *J. Agric. Sci. Mansoura Univ.,* 27(3), 1343-1351.

Sarhan, G.M.A., & Smail, S.A. (2003). Response of fodder beet (Beta vulgaris L.) to different sources and levels of nitrogen under two levels of potassium fertilization. *Annals of Agric. Sci, Moshtohor,* 41(1), 461-473.

Mali, D.L., Virendra, S., Sarolia, D.K., et al. (2018). Effect of organic manures and biofertilizers on growth and yield of radish (Raphanus sativus L.) cv. Japanese white. *International Journal of Chemical Studies,* 6(2),1095-1098.

Ingole, V.S., Wagh, P.K., Nagre, P.K. et al. (2018). Effect of biofertilizer and organic manure on yield and yield contributing characters of beetroot (Beta vulgaris L.). *International Journal of Chemical Studies,* 6(5),1226-1228.

Dlamini, V.C., Kwanele, A.N., Michael, T. M., et al. (2020). Effects of Cattle Manure on the Growth, Yield, Quality and Shelf Life of Beetroot (Beta vulgaris L. cv. Detroit Dark Red). *Journal of Experimental Agriculture International,* 42(1), 93-104.

Abdel-Gwad, M. S. A., T. K. A. El-Aziz & M. A. A El-Galil. (2008). Effect of intercropping wheat with fodder beet under different levels of N-application on yield and quality. *Annals of Agricultural Science (Cairo).* 53 (2), 353-362.

Moniruzzaman, M., Akand, M.H., M. I. Hossain, M.I., at al. (2013). Effect of Nitrogen on the Growth and Yield of Carrot (Daucus carota L.), *The Agriculturists* 11(1), 76-81

M. Turk.2010. (2010).Effects of Fertilization on Root Yield and Quality of Fodder Beet (Beta Vulgaris Var. Crassa Mansf.). *Bulgarian Journal of Agricultural Science*, 16 ( 2) , 212-219

G. Rantao. (2013). Growth, Yield and Quality Response of Beet (Beta Vulgaris L.) to Nitrogen. M.Sc Thesis, University of The Free State, Bloemfontein.

Abdelaal, K.A.A., & Tawfik, S.F. (2015). Response of Sugar Beet Plant (Beta vulgaris L.) to Mineral Nitrogen Fertilization and Bio-Fertilizers, *Int.J.Curr.Microbiol.App.Sci*, 4(9), 677-688.

Ramadan, B.S.H., Hassan, H.R., & Fatma, A.A. (2003). Effect of mineral and biofertilizers on photosynthetic pigments, root quality, yield components and anatomical structure of sugar beet (Beta vulgaris L.) plants grown under reclaimed soils. *J. Agric. Sci. Mansoura Univ.*, 28(7), 5139-5160.