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Influence of NPK fertilizer on carrot (*Daucus carota* L.) growth, root yield, and selected soil physical properties in Katsina State, Nigeria

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Abstract
An experiment was carried out during the 2026 rainy season at the teaching and research farm of the College of Vocational Agriculture Tambu Daura Local Government Area of Katsina, Nigeria, which is located within the Sudan Savanna agro-ecological zone, to ascertain the impact of various rates of NPK fertiliser on growth, root yield, and specific soil properties. Four treatments were employed: 0 kg $N:P_2O_5:K_2O$ ha^{-1}, 20:10:10 kg $N:P_2O_5:K_2O$ ha^{-1}, 40:20:20 kg, and 60:30:30 kg $N:P_2O_5:K_2O$ ha^{-1}. A Randomised Complete Block Design (RCBD) with three replications was used to set up the experiment. Carrot seeds were directly sown on the prepared beds, at a rate of 8 kg/ha, spaced at 15 cm apart and inside rows. Based on the study's results, application of NPK 60:30:30 kg $N:P_2O_5:K_2O$ ha^{-1} significantly outperformed other treatments in terms of growth characteristics, such as plant height, number, length, and chlorophyll content of leaves, as well as yield characteristics, such as root diameter thickness and root weight of carrot per hectare. Furthermore, applying 60:30:30 kg $N:P_2O_5:K_2O$ ha^{-1} yielded 12,314 kg/ha, which is significantly more than other treatments. Nevertheless, the carrot's root length and biomass above ground were not significantly affected by any of the treatments. It is recommended that farmers in Daura local Government area and Sudan Savanna region should apply NPK 15:15:15 fertilizer at a rate of 60:30:30:kg/ha for optimal growth and yield of carrot varieties.

Keywords: NPK Fertilizer, Carrot, Growth, Root Yield, Soil physical properties

Introduction

As a member of Apiaceae family, Carrot (*Daucus carota* L.) is an important root vegetable crop which is known for its nutritional value and health benefits, Carrots are an excellent source of beta-carotene, which the body converts into vitamin A (Alara *et al*., 2022) [1]. It is widely cultivated across the world for its edible fleshy taproot. It is rich in beta-carotene, vitamins, minerals, and antioxidants, thereby contributing significantly to human nutrition and health (Rubatzky *et al*., 1999) [2]. Carrots also provide significant amounts of vitamin C, B vitamins like thiamine and riboflavin, and potassium, all contributing to overall health, strengthening the immune system, and supporting heart health (Leprince *et al*., 2021) [3]. In Nigeria, carrot production has increased considerably due to rising consumer demand, urbanization, and awareness of its nutritional value.

Carrot production in Northern Nigeria is constrained by poor soil fertility, low organic matter content, weak soil structure, and inadequate fertilizer management practices. Although inorganic fertilizers are widely used to improve crop productivity, information regarding their influence on both carrot yield and soil physical properties under Sudan Savanna conditions remains inadequate. The Sudan Savanna agroecological zone of Northern Nigeria possesses favorable climatic conditions for carrot production. However, the productivity of carrots in the region remains relatively low compared to global standards. One of the major factors responsible for low productivity is declining soil fertility resulting from continuous cultivation, nutrient depletion, low organic matter content, and inappropriate fertilizer management practices (Brady *et al.*, 2016) [4]

Essential nutrients like nitrogen, phosphorus, and potassium Carrots require for optimal root development, plant vigour and high yields of carrots. Carrots may show stunted growth, poor root development, and low yields without these nutrients. Fertilizers are often necessary to address these deficiencies (Olabode *et al*., 2023) [5]. Nitrogen, phosphorus, and potassium are essential macronutrients required for optimum crop growth and yield. Nitrogen promotes vegetative growth and chlorophyll formation, phosphorus enhances root development and energy transfer, while potassium improves water regulation, enzyme activation, and resistance to stress. The application of NPK fertilizer therefore plays a significant role in improving crop productivity (Marschner, 2012) [6]. Despite the importance of inorganic fertilizers in crop production, improper application rates may negatively affect soil physical conditions. Excessive use of mineral fertilizers

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may contribute to soil compaction, reduction in soil porosity, and poor water infiltration (Lal *et al.*, 2010) [7]. Soil physical properties such as bulk density, porosity, and moisture retention are particularly important for root crops like carrot because they directly influence root penetration, aeration, nutrient uptake, and water availability (Hillel, 2004) [8].

Sustainable crop production requires proper fertilizer management strategies that improve crop yield without degrading soil quality (FAO, 2022) [9]. However, limited information exists regarding the combined effects of NPK fertilizer application on carrot growth, root yield, and soil physical properties under Sudan Savanna conditions of Northern Nigeria. Declining soil fertility and poor nutrient management practices remain major constraints to sustainable vegetable production in Northern Nigeria (Brady *et al.*, 2016) [4]. Most farmers apply inorganic fertilizers indiscriminately without adequate knowledge of appropriate application rates for optimum crop performance and soil sustainability. In the Sudan Savanna agroecological zone, soils are generally characterized by low organic matter content, weak soil structure, low moisture retention capacity, and poor nutrient status (Esu *et al.*, 1991) [10]. These conditions negatively affect carrot growth and root development, resulting in low productivity.

Although NPK fertilizer is widely used to improve crop yield, excessive or inappropriate application may adversely affect soil physical properties such as bulk density, porosity, and moisture retention (Lal *et al.*, 2010) [7]. This may ultimately reduce soil productivity and long-term agricultural sustainability.

This study therefore aims to determine the optimum rate of NPK fertilizer that will improve carrot growth and yield while maintaining favorable soil physical conditions in the Sudan Savanna agroecological zone.

Materials and methods

Experimental site

The study was conducted during 2026 raining season at Teaching and research farm of College of Vocational Agriculture Tambu-Daura Daura Local Government Area, located in the northern part of Nigeria within the Sudan Savanna agro ecological zone. The area lies approximately between latitude 13.03° N and longitude 8.32° E, at an elevation of approximately 463–470 m above sea level. The area lies within the hot semi-arid Sudan Savanna zone of northwestern Nigeria.

Soil sampling and preparation

Soil samples were collected using a zigzag (*Z*-shaped) sampling pattern to ensure representativeness. Sampling was carried out at a depth of 0–30 cm, which corresponds to the active root zone and conducted at two stages: before planting and at harvest. At each stage, five soil samples were collected and combined to form a composite sample. The samples were air-dried under shade, gently crushed, and passed through a 2 mm sieve before laboratory analysis. The collected soil samples were analyzed using standard laboratory procedures as follows: Particle size distribution was determined using the hydrometer method (Bouyoucos, 1936) [11]. Bulk density was measured using the core method (Blake *et al.*, 1986) [12]. Particle density was determined using the pycnometer method. Total porosity was calculated using: $f = (1 - \frac{bulk\ density}{particle\ density}) \times 100$. Soil moisture retention was determined at different suction levels using a pressure plate apparatus (Klute, 1986) [13]. Available water holding capacity was calculated as the difference between field capacity (-33 kPa) and permanent wilting point (-1500 kPa).

Experimental design and treatments

The carrot variety used was Touchon which matured in 80-90 days, it was sourced from the International Institute of Tropical Agriculture Kano station. The NPK fertilizer was procured from the same institute. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. A total of four treatments were used as follows:

T_0: Control (0 kg N:P_2O_5:K_2O ha^{-1})
T_1: (20:10:10 kg N:P_2O_5:K_2O ha^{-1})
T_2: (40:20:20 kg N:P_2O_5:K_2O ha^{-1})
T_3: (60:30:30 kg N:P_2O_5:K_2O ha^{-1})

Each treatment was randomly assigned within each replication. The gross plot was measured 2.4 m × 2.4 m (5.76 m^2). A spacing of 1 m was maintained between adjacent plots, while 1.5 m spacing provided between replications. In addition, a border space of 1 m was allowed around the entire experimental field. A total number of 12 plots were established and the whole experimental area including pathways and borders was approximately 178.12 m^2. Net plot was demarcated within each gross plot to eliminate border effects, an outer row was excluded from

each side of the plot width, while 0.5 m was removed from both ends of the plot length. Thus, net plot size was 1.4 m × 1.4 m (1.96 m^2) which was used for yield assessment and other relevant measurements

Agronomic practices

The experimental site was manually cleared; debris were removed before land preparation. The land was manually prepared, and plots were properly demarcated. Carrot seeds were sown directly on the prepared beds at a spacing of 15 cm between rows and within rows at the rate of 8 kg/ha, three to four seeds were sown per hole. Thinning was carried out 10 days after planting to maintain one plant per stand. Fertilizer was applied two weeks after planting using the dibbling method about 5 cm away from the base of the plants, following the procedure described by Olufolaji & Oduwole (2022) [14]. Weeding was carried out manually using hoes at 3 and 7 weeks after planting and plant will be irrigated at interval of 3 to 5 days before rainfall fully established.

Data collection

Data was collected on plant height, number of leaves, length of leaves, chlorophyl content of leaves and root yield of carrot. Measurements were taken at 45, 60, 75, and 90 days after sowing (DAS). Four plants were randomly selected and tagged per plot for data collection.

Data analysis

The data collected from the experiment were subjected to statistical analysis using Analysis of Variance (ANOVA) to evaluate the effects of different NPK fertilizer rates on carrot growth, root yield, and selected physical properties. The analysis was carried out using GenStat statistical software (7th Edition). Treatment effects were considered significant at the 5% level of probability ($p \leq 0.05$). Significant differences were detected among treatment means, separation of means was performed using Tukey's Honestly Significant Difference (HSD) test

Results

Soil sampling and analysis

Table 1 presents Data on the physicochemical properties of soil in studied area. The result shows that the textural class of the soil at the experimental site is sandy loam. The total nitrogen and organic carbon were 0.194 and 1.90 % respectively, while available phosphorus was 13.50 mg kg^{-1}. The result showed that, proportion of clay as well as the percentages of organic carbon and total nitrogen were amended due to application of fertilizer. Similarly, there was increase in the levels of EC and available Phosphorus.

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Table 1. Physical and Chemical Properties of the Soil in the Experimental Site

Soil Properties	Soil Without Amendment	Soil with Amendment
Sand (%)	70.56	69.74
Silt (%)	19.44	19.06
Clay (%)	10	11.2
Textural Class	Sandy Loam	Sandy Loam
Organic Carbon (%)	1.9	2.3
EC (mS/cm)	98	98.25
Total Nitrogen (%)	0.194	0.197
Available Phosphorus (mg kg^{-1})	13.50	19.22

Plant height

The treatment on plant height was significant at 60, 45 and 90 days after sowing (DAS). At 60, 75 and 90 DAS application of NPK 60:30:30 was significantly higher ($p \leq 0.05$) than other treatments (Table 2).

Number of leaves

The treatments applied affected the number of carrot leaves at all measuring periods (Table 3). At 45 DAS, application of NPK 60:30:30 was significantly higher ($p \leq 0.05$) than other treatments. but at 60 DAS, applications of NPK 40:20:20 was significantly higher ($p \leq 0.05$) than other treatments. At 75 and 90 DAS applications of NPK 60:30:30 was significantly higher ($p \leq 0.05$) than other treatments.

Leaves length of carrot

Length of carrot leaves was significantly affected by treatments at 3 measuring periods (60, 75 and 90 DAS) as presented in table 4. At 60 DAS, applications of NPK 60:30:30, 40:20:20 and NPK 20:10:10 were statistically the same but significantly ($p \leq 0.05$) higher than control. At 75 DAS applying NPK 60:30:30 and NPK 40:20:20 were statistically the same but significantly ($p \leq 0.05$) higher than NPK 20:10:10 and the later one was significantly higher ($p \leq 0.05$) than control. But at 90 DAS applications of NPK 60:30:30 was significantly higher ($p \leq 0.05$) than other treatments.

Chlorophyll content of leave

Response of Chlorophyll Content of Leave to treatment is presented in table 5. The result showed significant at all measuring periods. At 45 DAS applications of NPK 60:30:30 and 20:10:10 were statistically the same but significantly higher ($p \leq 0.05$) than other treatments. At 60 DAS applications of NPK 60:30:30, NPK 40:20:20 and NPK 20:10:10 were statistically the same but significantly ($p \leq 0.05$) higher than control. The situations were different at 75 and 90 DAS, when applications of NPK 60:30:30 were significantly higher ($p \leq 0.05$) than other treatments.

Carrot root yield

Responses of root length, root diameter, root biomass and root weight per hectare to different levels of NPK fertilizers were presented in table 6. The treatments were not significant ($P > 0.05$) to root length and above ground biomass but significant ($p \leq 0.05$) on root diameter where applications of NPK 60:30:30 and NPK 40:20:20 were statistically the same but significantly ($p \leq 0.05$) higher than other treatments. When compared to other treatments, the weight of carrots per hectare increased significantly ($p \leq 0.05$) with application of NPK 60:30:30.

Table 2. Effect of NPK Fertilizer on Plant Height of Carrot (cm) at 45, 60, 75, ands 90 Days after Sowing

	Plant Height (cm)			
Treatment	45 DAS	60 DAS	75 DAS	90 DAS
Control	13.50	19.22^{d}	20.34^{d}	24.13^{d}
20:10:10:kg N:P_2O_5:K_2O h^{-1}	13.37	24.22^{c}	26.80^{c}	30.52^{c}
40:20:20:kg N:P_2O_5:K_2O h^{-1}	14.44	26.33^{b}	31.25^{b}	34.28^{b}
60:30:30:kg N:P_2O_5:K_2O h^{-1}	14.55	28.17^{a}	35.00^{a}	40.16^{a}
SED	0.699	0.162	0.152	0.191

Means in a column followed by the same letter(s) are not significantly different at 5% level of probability using TUKEY'S Test.

Table 3. Effect of NPK Fertilizer on Number of Leaves of Carrot at 45, 60, 75, ands 90 Days after Sowing

	Number of Leaves			
Treatment	45 DAS	60 DAS	75 DAS	90 DAS
Control	22.67^{d}	51.33^{d}	60.33^{c}	67.00^{d}
20:10:10:kg N:P_2O_5:K_2O h^{-1}	23.00^{c}	54.00^{c}	68.33^{b}	78.33^{c}
40:20:20:kg N:P_2O_5:K_2O h^{-1}	23.67^{b}	58.67^{a}	71.67^{a}	83.00^{b}
60:30:30:kg N:P_2O_5:K_2O h^{-1}	24.00^{a}	57.00^{b}	71.33^{a}	84.00^{a}
SED	0.272	0.385	0.471	0.236

Means in a column followed by the same letter(s) are not significantly different at 5% level of probability using TUKEY'S Test.

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Table 4. Effect of NPK Fertilizer on Leaves Length (cm) of Carrot at 45, 60, 75, ands 90 Days after Sowing

	Leave Length (cm)			
Treatment	45 DAS	60 DAS	75 DAS	90 DAS
Control	3.133	5.967^{b}	6.528^{c}	10.847^{c}
20:10:10:kg N:P_2O_5:K_2O h^{-1}	3.150	6.477^{a}	7.717^{b}	11.327^{bc}
40:20:20:kg N:P_2O_5:K_2O h^{-1}	3.543	6.688^{a}	9.241^{a}	11.870^{ab}
60:30:30:kg N:P_2O_5:K_2O h^{-1}	3.555	6.928^{a}	9.282^{a}	12.130^{a}
SED	0.0566	0.2111	0.3234	0.5940

Table 5. Effect of NPK Fertilizer on Chlorophyll Content of Leave (µmol m^{-2}) at 45, 60, 75, ands 90 Days after Sowing

	Chlorophyll content (µmol m^{-2})			
Treatment	45 DAS	60 DAS	75 DAS	90 DAS
Control	6.650^{c}	10.59^{b}	12.32^{d}	9.55^{d}
20:10:10:kg N:P_2O_5:K_2O h^{-1}	7.955^{a}	12.83^{a}	15.25^{c}	10.18^{c}
40:20:20:kg N:P_2O_5:K_2O h^{-1}	7.288^{b}	12.90^{a}	20.38^{b}	12.44^{b}
60:30:30:kg N:P_2O_5:K_2O h^{-1}	8.203^{a}	13.00^{a}	23.07^{a}	15.01^{a}
SED	0.274	0.175	0.299	0.243

Means in a column followed by the same letter(s) are not significantly different at 5% level of probability using TUKEY'S Test.

Table 6. Effect of NPK Fertilizer on Yield Root of Carrot

Treatment	Root length(cm)	Root diameter (mm)	Above ground biomass (kg/plot)	Root weight per hectare (kg/ha)
Control	13.55	29.12^{c}	0.624	6612^{d}
20:10:10:kg N:P_2O_5:K_2O h^{-1}	13.98	31.14^{b}	0.706	10008^{c}
40:20:20:kg N:P_2O_5:K_2O h^{-1}	14.01	33.21^{a}	0.876	11568^{b}
60:30:30:kg N:P_2O_5:K_2O h^{-1}	13.99	36.17^{a}	0.880	12626^{a}
SED	0.301	0.345	0.0892	751.3

Means in a column followed by the same letter(s) are not significantly different at 5% level of probability using TUKEY'S Test.

Discussion

The analysis of soil's physico-chemical properties before and after planting showed positive amendments in nitrogen, phosphorus, potassium organic carbon and cation exchange capacity, which suggested a positive response to fertilization. The result corroborates findings of Oluwatoyin & Akintoye (2017) [15] who reported changes in soil properties, including nitrogen, phosphorus, potassium and organic carbon levels due to fertilization

The result indicated that application of fertilizer resulted in significant performance in various growth parameters such plant height, number of leaves and leave length of carrot, this might be attributed to the fact that nitrogen builds strong leaves and stems, increased leaf area which capture sunlight and photosynthetic capacity. It also is in line with findings of Anthony *et al*. (2025) [16] who reported application of NPK fertilizer that resulted in tallest plants and highest number of carrot leaves.

Based on the result of the study, root diameter and root weight per hectare performed significantly higher with the highest performance on highest rate of treatment (NPK:60:30:30), this might be attributed to the fact that higher nutrients supplied probably enabled the plants to develop a larger and more active canopy, produce more photosynthates and efficiently translocate these assimilates to the developing storage roots. It is consistent with finding of Agbede *et al*., (2017) [17] who reported root diameter, root length, and fresh root yield in the NPK fertilizer treatments were improved compared to the control.

Nevertheless, the results demonstrated that the treatment had no significant effect on root length or biomass weight above the ground. This is likely because the fertiliser applied had a significant impact on the thickening and accumulation of fresh matter in the carrot storage root, but it did not produce enough change in root elongation or above-ground biomass to be statistically significant.

Conclusion

Based on the results of this study, application of NPK 60:30:30:kg demonstrated a highly significant performance in terms of plant height, number of leaves length of leaves and chlorophyll content of carrot. Furthermore, application of NPK 60:30:30:kg provided the thickest diameter of carrot as well as the highest yield of root weight of carrot (12626 kg /ha).

Recommendation

Based on the outcome of the study, it is recommended that farmers in Daura local Government area and sudan savanna region apply NPK 15:15:15 fertilizer at a rate of 60:30:30:kg/ha for optimal growth and yield of carrot varieties such as Touchon and similar variety.

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Conflicts of interest

The authors hereby declare no conflict of interest

References

1. Alara OO, Abdurahman NH, Ganiyu SO. Nutritional Properties and Health Benefits of Carrots (*Daucus carota*): A Review. Journal of Food Science and Technology. 2022;59(5):2239-2247.
2. Rubatzky VE, Quiros CF, Simon PW. Carrots and Related Vegetable, Umbelliferae. CAB International. 1999.
3. Leprince P, Robitaille A. The nutritional profile of carrots and their role in human health. Frontiers in Nutrition. 2021;8:1-9.
4. Brady NC, Weil RR. The nature and properties of soils (15th ed.). Pearson. 2016.
5. Olabode OF, Afolabi OS. Effect of NPK 15:15:15 on soil fertility and carrot growth in subhumid regions of Nigeria. Nigerian Journal of Soil Science. 2023;47(1):72-81.
6. Marschner P. Marschner's Mineral Nutrition of Higher Plants (3rd ed.). Academic Press. 2012.
7. Lal R, Stewart BA. Food Security and Soil Quality. CRC Press. 2010.
8. Hillel D. Introduction to environmental soil physics. Elsevier. 2004.
9. FAO. Fertilizer and Plant Nutrition Guide. Food and Agriculture Organization of the United Nations. 2022.
10. Esu IE, Moberg JP. Characteristics and composition of some savanna soils in Nigeria. Geoderma. 1991;48(1-2):113-129.
11. Bouyoucos GJ. Directions for making mechanical analysis of soils by the hydrometer method. Soil Science. 1936;42(3):225-230.
12. Blake GR, Hartge KH. Bulk density. In: Klute A, editor. Methods of Soil Analysis: Part 1—Physical and Mineralogical Methods (2nd ed.). Soil Science Society of America Book Series. 1986:363-375.
13. Klute A. Water retention: Laboratory methods. In: Klute A, editor. Methods of soil analysis: Part 1—Physical and mineralogical methods (2nd ed.). American Society of Agronomy & Soil Science Society of America. 1986:635-662.
14. Olufolaji AO, Oduwole OA. Effect of fertilizer application methods on growth and yield of vegetable crops in the humid tropics. Journal of Agricultural Science. 2022;57(4):24-35.
15. Oluwatoyin A, Akintoye A. Effects of NPK Fertilizer on Soil Physico-Chemical Properties and Yield of Carrot (*Daucus carota* L.) in Southwestern Nigeria. International Journal of Soil Science. 2017;12(1):10-1.
16. Anthony UO, Clifford U, Sunday EN, Okundaye OP. Effect of NPK 15: I5:15 Fertilizer on the Growth and Root Yield of Two Varieties of Carrot (*Daucus carota* L.) in a Humid Environment of Edo State, Nigeria. JERAMI Indonesian Journal of Crop Science. 2025;8(1):44-51.
17. Agbede TM, Adekiya AO, Eifediyi EK. Impact of Moultry manure and NPK Fertilizer on Soil physical properties and Growth and Yield of Carrot. Journal of Horticultural Research. 2017;25(1):81-88.

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