



GROWTH RESPONSE OF BEETROOT (*BETA VULGARIS* L.) TO SOWING METHODS, NUTRIENT REGIMES AND SEASONAL VARIABILITY IN NORTHERN GUINEA SAVANNA AGRO-ECOLOGICAL ZONE OF NIGERIA

¹Ibrahim, Iro, I., ²Fagam, A. S., ²Garba, A. A. and ²Sabo, M. U.

¹Department of Agricultural Technology, Federal College of Forestry Resources Management, Maiduguri, Borno State, Nigeria

²Department of Crop Production, Faculty of Agriculture and Agricultural Technology, Abubakar Tafawa Balewa University, Bauchi

Corresponding Author's Email: ibrahimiroibrahim@yahoo.com, **GSM:** 08065612959

ABSTRACT

Field experiments were conducted during rainy (May-August) and dry (November -February) seasons of 2024 and 2025 at the NVRI Research Farm, Vom, Jos South, Plateau State to evaluate growth response of beetroot (*Beta vulgaris* L) to sowing methods, nutrient regimes and seasonal variability. The treatments comprised of three sowing methods (drilling, broadcasting, transplanting) and four nutrient sources (control, NPK 80:60:60 kg ha⁻¹, poultry manure 10 t ha⁻¹, cow dung 10 t ha⁻¹). Factorially combined and laid out in a Randomized Complete Block Design with three replications across two seasons. The results showed a significant ($P < 0.05$) effects on morphological and physiological growth indices. The result further indicated that, drilling recorded highest plant height (42.15 cm), number of leaves (13.80), leaf area (345.60 cm²), leaf area ratio (125.40 cm² g⁻¹), net assimilation rate (0.045 g cm⁻² day⁻¹), crop growth rate (0.0085 g cm⁻² day⁻¹) and absolute growth rate (1.85 g plant⁻¹ day⁻¹), while broadcasting gave lowest values. Poultry manure at 10 t/ha significantly outperformed NPK, cow dung and control with 45.20 cm height, 14.60 leaves, 368.50 cm² leaf area and 132.50 cm² g⁻¹ LAR. Rainy season sowing (41.80 cm, 342.10 cm² leaf area) was superior to dry season (36.70 cm, 287.50 cm²). The non-significant interactions suggest these technologies can be scaled as independent packages for smallholder vegetable farmers in Jos metropolis who already face low soil fertility and seasonal water constraints.

Keywords: *Beta vulgaris*, Drilling, Poultry-manure, Seasonal, Variability

INTRODUCTION

Beetroot (*Beta vulgaris* L.) is a biennial root vegetable belonging to the Amaranthaceae family, cultivated for its fleshy taproot rich in betalains, dietary nitrates, flavonoids, minerals and vitamins (Mirmiran *et al.*, 2020). The crop has gained global importance as a functional food due to its antioxidant, anti-inflammatory, and cardio-metabolic regulatory properties. In Nigeria, beetroot is emerging as a high-value horticultural crop, especially in cool, high-altitude environments where temperate vegetables perform well. The Jos Plateau in north-central Nigeria, at about 1,200–1,829 m above sea level, offers a distinct agro-ecology. Its climate is near-temperate, with mean annual temperatures of 18–22°C and annual rainfall of 1,317 to 1,460 mm falling mainly between April and October (Akinwa, 2023). Rainfall peaks in July–August, followed by a long dry season from November to March. Soils are derived mainly from basalt, granite, and unconsolidated deposits and are classified largely as Inceptisols (Cambisols) and Alfisols (Lixisols). They are typically sandy loam to sandy clay loam, inherently low in nitrogen, available phosphorus, and exchangeable calcium (Akinwa, 2023).

Despite this comparative advantage, beetroot productivity in Plateau State remains low and variable. Two major constraints are sub-optimal sowing methods and inappropriate nutrient management. Sowing method affects plant stand, light interception, root shape, and how easily the crop can be managed. In *Beta vulgaris*, flat, ridge, and raised-bed systems have been tested with mixed results. Bed systems often support higher populations, while ridge systems tend to improve root aeration and development. Direct seeding is standard, but crusting and waterlogging can cause poor establishment and uneven stands. Nutrient management is equally critical for vegetative growth and root bulking. Beetroot needs substantial nitrogen, potassium, and boron for leaf expansion and for



translocating sucrose to the storage root. In Nigerian savanna soils, continuous cropping has depleted organic matter, making integrated nutrient management necessary. Work in Minna, in the southern Guinea Savanna, showed that 10 t ha⁻¹ poultry manure significantly improved leaf area index, plant vigour, and fresh leaf yield of beetroot compared to cow dung and goat droppings (Olorukooba et al., 2023). Similarly, 75% recommended dose of fertilizer (RDF) + 12.5% poultry manure + 12.5% vermicompost gave better growth and root yield than inorganic fertilizer alone (Hussain & Kerketta, 2023). Cattle manure at 40–60 t ha⁻¹ also improved vegetative growth, marketable yield, and postharvest quality of Detroit Dark Red beetroot (Dlamini *et al.*, 2020).

Seasonal variability further modulates growth response. Early rainy season sowing (April-May) coincides with moderate temperatures and increasing moisture, while late rainy season (August-September) exposes the crop to excessive soil moisture and foliar disease pressure, and dry season production (November-February) under irrigation exposes it to low night temperatures and high evapotranspiration. Understanding genotype × sowing method × nutrient × season interactions is essential for developing location-specific recommendations for Jos. This study therefore evaluated the growth response of beetroot to three sowing methods, four nutrient regimes, and two sowing seasons under Jos agro-ecological conditions.

MATERIALS AND METHODS

Experimental Site

The experiments were conducted during 2024 and 2025 rainy and dry seasons at the Research and Training Farm, National Veterinary Research Institute, Vom, Jos South LGA, Plateau State (Lat. 09° 43' N, long. 08° 47' E; elevation 1,263 m). The site falls within the northern Guinea savanna agro-ecological zone. Mean annual rainfall during the study period was 1,345 mm, with peak in July (242 mm). Mean minimum and maximum temperatures were 14.2°C and 27.8°C respectively in the rainy season and 11.5°C and 29.4°C in the dry season. Pre-cropping soil analysis (0-30 cm) revealed sandy loam texture (68% sand, 18% silt, 14% clay), pH 5.8, organic carbon 0.94%, total nitrogen 0.11%, available phosphorus 8.7 mg kg⁻¹ and exchangeable potassium 0.31 cmol kg⁻¹, consistent with previously reported low fertility status of Jos Plateau soils derived from granite (Akinwa, 2023). Two consecutive experiments were carried out: Rainy season (May - August 2024) and Dry season (November 2024 - February 2025) with irrigation.

Treatments and Experimental Design

The treatments comprised of three sowing methods (drilling, broadcasting, transplanting) and four nutrient sources (control, NPK 80:60:60 kg ha⁻¹, poultry manure 10 t ha⁻¹, cow dung 10 t ha⁻¹). Factorially combined and laid out in a Randomized Complete Block Design with three replications across two seasons. Detroit Dark Red beetroot cultivar was used. Seeds were soaked for 12 hours before sowing to improve germination. Organic manures were well decomposed, analyzed for NPK content, and incorporated two weeks before sowing. Half NPK was applied as basal, remaining half at 4 weeks after sowing (WAS). Thinning was done at 2 weeks after emergence to maintain one plant per stand for drilled and transplanted plots.

Data Collection and Analysis

Data were collected from five randomly tagged plants at 8 WAS on plant height (cm), number of leaves per plant, leaf length (cm), leaf breadth (cm), Net Assimilation Rate (NAR) (g cm⁻²day⁻¹), Crop Growth Rate (CGR) (g cm⁻²day⁻¹), Specific Leaf Weight (SLW) (g cm⁻²). All the data collected were subjected to analysis of variance (ANOVA) using GenStat. 17th edition. Significant means were separated using Duncan's Multiple Range Test (DMRT) at $p < 0.05$.

RESULTS

Morphological Growth Parameters (Plant Height (cm), Number of Leaves, Leaf Area (cm²), Specific Leaf Area (cm²), Specific Leaf Weight (cm²))

The result as presented in Table 1 showed that, drilling method recorded the highest growth performance across all five traits with plant height of 42.15 cm, number of leaves of 13.80, leaf area of 345.60 cm², specific leaf area of 245.30 cm² and specific leaf weight of 0.085 cm², and it was

significantly superior to transplanting and broadcasting. Transplanting was intermediate with 39.68 cm height, 12.10 leaves, 318.90 cm² leaf area, 232.80 cm² SLA and 0.079 cm² SLW, while broadcasting gave the lowest values of 35.42 cm, 10.25 leaves, 278.40 cm², 210.15 cm² and 0.072 cm².

The effect of Nutrient Sources indicated that, poultry manure at 10 t/ha significantly outperformed all other sources, recording 45.20 cm plant height, 14.60 leaves, 368.50 cm² leaf area, 258.40 cm² specific leaf area and 0.089 cm² specific leaf weight. This was followed by NPK fertilizer at 80 kg N/ha with 41.35 cm, 13.10 leaves, 332.70 cm², 238.90 cm² and 0.082 cm². Cow dung at 10 t/ha gave 38.90 cm, 11.80 leaves, 305.20 cm², 224.60 cm² and 0.076 cm², while the control gave the least values of 31.55 cm, 9.20 leaves, 252.80 cm², 195.30 cm² and 0.065 cm².

Seasonal effect on the other hand, rainy season sowing was significantly superior to dry season sowing across all traits. Rainy season recorded 41.80 cm height, 13.25 leaves, 342.10 cm² leaf area, 248.60 cm² SLA and 0.084 cm² SLW, while dry season recorded 36.70 cm, 11.10 leaves, 287.50 cm², 210.00 cm² and 0.072 cm².

Table 1: Morphological Growth Parameters of Beetroot as Influenced by Sowing Methods, Nutrient Sources and Season

Treatment	Plant Height (cm)	Number of Leaves	Leaf Area (cm ²)	Specific Leaf Area (cm ²)	Specific Leaf Weight (cm ²)
Sowing Method					
Drilling	42.15a	13.80a	345.60a	245.30a	0.085a
Broadcasting	35.42c	10.25c	278.40c	210.15c	0.072c
Transplanting	39.68b	12.10b	318.90b	232.80b	0.079b
SE±	1.24	0.38	8.45	5.22	0.002
P – value	0.0012	0.0008	0.0021	0.0034	0.0015
Nutrient Sources					
Poultry Manure (10 t/ha)	45.20a	14.60a	368.50a	258.40a	0.089a
Cow Dung (10 t/ha)	38.90c	11.80c	305.20c	224.60c	0.076c
NPK Fertilizer (80 kg N/ha)	41.35b	13.10b	332.70b	238.90b	0.082b
Control	31.55d	9.20d	252.80d	195.30d	0.065d
SE±	1.42	0.45	9.12	6.08	0.003
P – value	<0.0001	0.0002	<0.0001	0.0003	0.0001
Season					
Rainy	41.80a	13.25a	342.10a	248.60a	0.084a
Dry	36.70b	11.10b	287.50b	210.00b	0.072b
SE±	0.85	0.28	6.35	4.12	0.001
P - value	0.0025	0.0018	0.0011	0.0028	0.0019
Interaction					
SM * NS	0.452 NS	0.521 NS	0.638 NS	0.489 NS	0.712 NS
SM * S	0.385 NS	0.412 NS	0.558 NS	0.623 NS	0.601 NS
NS * S	0.478 NS	0.365 NS	0.429 NS	0.512 NS	0.548 NS
SM * NS * S	0.892 NS	0.745 NS	0.812 NS	0.768 NS	0.825 NS

Means within the same column having different letters are significant at 5% level of probability using Duncan Multiple Range Test (DMRT), SE = Standard Error, NS = Not Significant

Influence of Sowing Methods, Nutrient Sources and Season on Physiological Growth Indices

The result in Table 2 revealed that, drilling method consistently gave the highest physiological efficiency with leaf area ratio of 125.40 cm² g⁻¹, net assimilation rate of 0.045 g cm⁻² day⁻¹, crop growth rate of 0.0085 g cm⁻² day⁻¹ and absolute growth rate of 1.85 g plant⁻¹ day⁻¹. Transplanting followed with 112.80, 0.039, 0.0068 and 1.52, while broadcasting was lowest with 98.60, 0.032, 0.0052 and 1.24 (Table 2). Result on nutrient sources showed that, poultry manure at 10 t/ha recorded the highest values of 132.50 cm² g⁻¹ LAR, 0.048 g cm⁻² day⁻¹ NAR, 0.0092 g cm⁻² day⁻¹ CGR and 1.98 g plant⁻¹ day⁻¹

AGR, showing superior assimilate production and partitioning. NPK fertilizer at 80 kg N/ha was second with 118.40, 0.041, 0.0075 and 1.68. Cow dung at 10 t/ha gave 105.30, 0.036, 0.0061 and 1.42, and control gave 92.80, 0.028, 0.0045 and 1.05. Rainy season significantly increased all indices with 121.60 cm² g⁻¹ LAR, 0.043 NAR, 0.0081 CGR and 1.78 AGR compared to dry season with 102.90, 0.034, 0.0058 and 1.28. This reflects better moisture availability, lower temperature stress and higher radiation use efficiency in the rainy season.

Table 2: Physiological Growth Indices of Beetroot as Influenced by Sowing Methods, Nutrient Sources and Season

Treatment	Leaf Area Ratio (cm ² g ⁻¹)	Net Assimilation Rate (NAR) (g cm ⁻² day ⁻¹)	Crop Growth Rate (CGR) (g cm ⁻² day ⁻¹)	Absolute Growth Rate (g plant ⁻¹ day ⁻¹)
Sowing Method				
Drilling	125.40a	0.045a	0.0085a	1.85a
Broadcasting	98.60c	0.032c	0.0052c	1.24c
Transplanting	112.80b	0.039b	0.0068b	1.52b
SE±	3.45	0.001	0.0003	0.05
P – value	0.0015	0.0022	0.0018	0.0009
Nutrient Sources				
Poultry Manure (10 t/ha)	132.50a	0.048a	0.0092a	1.98a
Cow Dung (10 t/ha)	105.30c	0.036c	0.0061c	1.42c
NPK Fertilizer (80 kg N/ha)	118.40b	0.041b	0.0075b	1.68b
Control	92.80d	0.028d	0.0045d	1.05d
SE±	4.12	0.002	0.0004	0.06
P – value	<0.0001	0.0003	0.0001	<0.0001
Season				
Rainy	121.60a	0.043a	0.0081a	1.78a
Dry	102.90b	0.034b	0.0058b	1.28b
SE±	2.85	0.001	0.0002	0.04
P - value	0.0031	0.0025	0.0019	0.0022
Interaction				
SM * NS	0.562 NS	0.489 NS	0.524 NS	0.613 NS
SM * S	0.412 NS	0.538 NS	0.601 NS	0.445 NS
NS * S	0.389 NS	0.456 NS	0.478 NS	0.522 NS
SM * NS * S	0.834 NS	0.792 NS	0.856 NS	0.798 NS

Means within the same column having different letters are significant at 5% level of probability using Duncan Multiple Range Test (DMRT), SE = Standard Error, NS = Not Significant

DISCUSSION

The results of the present study demonstrated that sowing method, nutrient source and season are independent and significant determinants of vegetative and physiological growth of beetroot (*Beta vulgaris* L.) under the agro-ecological conditions of Jos, Plateau State. The superiority of drilling over broadcasting and transplanting in terms of plant height (42.15 cm), number of leaves (13.80), leaf area (345.60 cm²), leaf area ratio (125.40 cm² g⁻¹) and absolute growth rate (1.85 g plant⁻¹ day⁻¹) can be attributed to uniform depth placement, better seed-soil contact and reduced inter-plant competition at emergence. Drilling ensures precise intra-row spacing of 20 cm, which optimized light interception and reduced etiolation, unlike broadcasting which resulted in clumped emergence, mutual shading and lower net assimilation rate (0.032 g cm⁻² day⁻¹). Transplanting, though better than broadcasting, suffered transplanting shock and root deformation, leading to intermediate values (39.68 cm height, 112.80 cm² g⁻¹ LAR). This finding aligns with sugar beet studies which reported that flat and bed sowing methods differed significantly in plant population and yield attributes, with bed and ridge systems



influencing leaf growth through better nutrient utilization and maximum light interception. Similarly, the observed advantage of ridge and raised bed systems for root aeration is consistent with the principle that beetroot, as a storage root crop, requires loose, well-drained rooting medium to minimize mechanical impedance.

Nutrient regime was the most pronounced factor, with highly significant P-values from <0.0001 to 0.0003 . Poultry manure at 10 t/ha consistently gave the highest morphological and physiological values: 45.20 cm plant height, 14.60 leaves, 368.50 cm^2 leaf area, $132.50 \text{ cm}^2 \text{ g}^{-1}$ LAR, $0.048 \text{ g cm}^{-2} \text{ day}^{-1}$ NAR, and $0.0092 \text{ g cm}^{-2} \text{ day}^{-1}$ CGR. This agrees with Olorukooba *et al.* (2023), who worked at Gidan Kwanu, Minna, in the southern Guinea Savanna and found that 10 t ha^{-1} poultry manure performed better and produced higher fresh leaf yield than cow dung, goat droppings, and the control. The authors linked this to its higher nitrogen and phosphorus content and lower C:N ratio compared to other animal manures. Hussain and Kerketta (2023) in Prayagraj, India, during Rabi 2022, also reported that an integrated treatment of $75\% \text{ RDF} + 12.5\% \text{ poultry manure} + 12.5\% \text{ vermicompost}$ was best for beetroot growth and root yield, with sole organic sources, particularly goat and poultry manure, ranking next. In our work, the integrated equivalent (NPK) outperformed cow dung but was inferior to sole poultry manure. This is likely because Jos soils are inherently low in organic carbon (0.94%) and total nitrogen (0.11%), as described by Akinwa (2023) and Shrestha *et al.* (2021) for Inceptisols and Alfisols derived from granite and basalt on the Jos Plateau. In such soils, organic amendment improves effective cation exchange capacity, water-holding capacity, and microbial activity beyond what inorganic NPK alone can provide.

Dlamini *et al.* (2020), working with cv. Detroit Dark Red in Eswatini, also found that cattle manure at $40\text{--}60 \text{ t ha}^{-1}$ significantly increased vegetative growth, marketable yield, and quality attributes like aroma and flavour, while 20 t ha^{-1} cattle manure and the inorganic NPK control gave the lowest vegetative growth. That aligns with our observation: control plots recorded the lowest values at 31.55 cm height, 9.20 leaves, and $92.80 \text{ cm}^2 \text{ g}^{-1}$ LAR. The increase in specific leaf weight (0.089 cm^2 with poultry manure vs 0.065 cm^2 in the control) points to thicker, more photosynthetically efficient leaves under adequate nutrition, which translated directly into higher NAR and CGR (Kumar, 2023). Adequate nutrition also matters for betalain and nitrate accumulation, which underpins beetroot's status as a functional food with antioxidant and cardio-metabolic benefits (Mirmiran *et al.*, 2020). So integrated nutrient management improves both growth and nutritional quality.

Season also had a strong effect. Rainy season sowing recorded 41.80 cm height, 13.25 leaves, 342.10 cm^2 leaf area, $121.60 \text{ cm}^2 \text{ g}^{-1}$ LAR, and $1.78 \text{ g plant}^{-1} \text{ day}^{-1}$ AGR, compared to 36.70 cm , 11.10 leaves, 287.50 cm^2 , $102.90 \text{ cm}^2 \text{ g}^{-1}$, and $1.28 \text{ g plant}^{-1} \text{ day}^{-1}$ in the dry season.

The Jos Plateau has a near-temperate climate, with mean annual temperature of $18\text{--}22^\circ\text{C}$ and annual rainfall of 131.75 to 146 cm , and humidity exceeding 80% in July–August (Akinwa, 2023). Early rainy season offers optimal temperatures of $15\text{--}25^\circ\text{C}$, well-distributed moisture, and moderate vapour pressure deficit, all of which favour cell division, leaf expansion, and assimilate translocation. Dry season sowing, even with irrigation, is exposed to low night temperatures of $10\text{--}12^\circ\text{C}$ that limit meristematic activity, and to high evapotranspiration that induces moisture stress and reduces net assimilation rate from 0.043 to $0.034 \text{ g cm}^{-2} \text{ day}^{-1}$.

The seasonal effect on beetroot is critical because the crop is classified as a cool-season vegetable that performs best under cooler weather but can also be cultivated in hot areas of the tropics with appropriate management (Olorukooba *et al.*, 2023). The reduction in leaf area ratio in dry season indicates reduced investment in photosynthetic apparatus per unit biomass, a stress avoidance strategy.

CONCLUSION AND RECOMMENDATION

The major findings established that drilling method, application of 10 t/ha poultry manure, and targeting rainy season sowing maximizes morphological growth (plant height, leaf number, leaf area) and physiological efficiency (LAR, NAR, CGR, AGR). The non-significant interactions suggest these technologies can be scaled as independent packages for smallholder vegetable farmers in Jos metropolis who already face low soil fertility and seasonal water constraints.



REFERENCES

- Akinwa, A. O. (2023). *Agricultural potentials of soils derived from selected parent materials on the Jos Plateau, Nigeria* (Doctoral dissertation, University of Ibadan).
- Dlamini, V. C., Nxumalo, K. A., Masarirambi, M. T., Wahome, P. K., & Oseni, T. O. (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.
- Hussain, S., & Kerketta, A. (2023). Effect of organic manure and inorganic fertilizer on growth and root yield of beetroot (*Beta vulgaris* L.). *International Journal of Environment and Climate Change*, **13**(8): 1866–1870. <https://doi.org/10.9734/ijecc/2023/v13i82141>
- Kumar, S. (2023). Impact of organic and inorganic fertilizers on the growth and yield of beetroot (*Beta vulgaris* L.) in the hilly region of Nepal. *Journal of Agricultural Sciences*, **29**(2), 45-54.
- Mirmiran, P., Houshialsadat, Z., Gaeini, Z., Bahadoran, Z., & Azizi, F. (2020). Functional properties of beetroot (*Beta vulgaris*) in management of cardio-metabolic diseases. *Nutrition & Metabolism*, **17**: 3. <https://doi.org/10.1186/s12986-019-0421-0>
- Olorukooba, M. M., Suleiman, R. T., Mohammed, R., Adedapo, J. O., Adeogun, T. T. A., & Essien, J. E. (2023). Growth and yield of beetroot (*Beta vulgaris*) as affected by the application of different sources and varying rates of nutrients of animal origin in Gidan Kwanu, Minna, Niger State of Nigeria. *Russian Journal of Agricultural and Socio-Economic Sciences*, **4**(136): 170–175.
- Shrestha, D., Srivastava, A., Shakya, S. M., Khadka, R. B., & Acharya, B. S. (2021). Effect of organic and inorganic sources of nitrogen on growth, yield, and quality of beetroot varieties in Nepal. *Agronomy*, **11**(9): 1765. <https://doi.org/10.3390/agronomy11091765>