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Research Article

Growth and Yield Responses of Coleus Potato (*Coleus rotundifolius*) to Accession and Plant Population Density in the Northern Guinea Savanna of Nigeria

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Abstract

Field experiments were conducted during the 2023 and 2024 rainy seasons at the Teaching and Research Farm of the Federal University of Agriculture, Zuru, Nigeria, to evaluate the growth and yield response of two coleus potato (Coleus rotundifolius P.A. Chev. & Perrot) s to varying plant population densities. The treatments consisted of two s (Ex-Zuru Black and Ex-Zuru Brown) and four plant population densities (22,222; 29,629; 44,444; and 88,888 plants ha⁻¹), arranged in a split-plot design with three replications. Results revealed significant ($P \leq 0.05$) differences in all growth and yield parameters measured. Ex-Zuru Black consistently outperformed Ex-Zuru Brown, exhibiting greater plant height, higher leaf number, greater leaf area index and higher shoot dry weight. Consequently, Ex-Zuru Black produced significantly higher fresh tuber yield. Plant population density significantly influenced all parameters, with the lowest density (22,222 plants ha⁻¹) producing the highest growth indices and tuber yield, while the highest density (88,888 plants ha⁻¹) resulted in the poorest performance due to intensified intra-specific competition. The interaction between and plant population density was not significant for most yield parameters, indicating consistent responses across densities. It is concluded that Ex-Zuru Black possesses superior genetic potential for coleus potato production, and a plant population density of 22,222 plants ha⁻¹ is optimal for maximizing growth and tuber yield under rain-fed conditions in the Northern Guinea Savanna ecological zone.

Keywords: *Coleus Potato, Plant Population Density, Performance, Tuber Yield, Intra-Specific Competition.*

INTRODUCTION

Coleus potato (*Coleus rotundifolius* Chev & Perrot), also known as Hausa potato or Tumuku, is an indigenous tropical root and tuber crop belonging to the family Lamiaceae. Although previously classified under the genus *Solenostemon*, recent taxonomic revision has reinstated it within *Coleus* (Paton et al., 2019). The crop is native to tropical Africa and remains an important minor tuber crop valued for its distinctive flavour, unique aroma, and considerable nutritional and medicinal properties (Namena *et al.,* 2009). Despite its significance, coleus potato has received limited research attention compared with major tuber crops such as cassava, yam, and sweet potato.

In Nigeria, coleus potato cultivation is predominantly practiced by smallholder farmers, particularly women, in rural communities across Plateau, Kaduna, Borno, and Adamawa states (Aniedu & Agugo, 2010). The crop contributes substantially to household food security, dietary diversity, and income generation in these areas. However, productivity remains low, with average yields of 3–5 t ha⁻¹ compared with 10–19 t ha⁻¹ reported in Ghana and South Africa (Ogedegbe et al., 2015). This yield gap has been attributed to several factors, including the use of unimproved s, suboptimal agronomic practices, and lack of scientifically validated recommendations for crop management.

One of the critical agronomic factors influencing coleus potato productivity is plant population density. Optimal plant spacing determines the degree of intra-specific competition for light, water, nutrients, and space, which in turn affects canopy development, photosynthetic efficiency, biomass accumulation, and ultimately tuber yield. Excessively high plant

densities intensify competition, leading to etiolated growth, reduced branching, lower leaf area development, and diminished assimilate partitioning to tubers (Pavani Rani et al., 2023). Conversely, very low densities may result in inefficient land utilization and reduced yield per unit area despite superior individual plant performance.

Selection is equally fundamental to crop improvement, as genetic differences among s determine inherent yield potential, adaptability to environmental conditions, and response to management practices. In coleus potato, characteristics such as growth habit, maturity duration, leaf area development, and harvest index significantly influence productivity (Muhammad et al., 2016). Despite the existence of distinct s maintained by farmers, comparative evaluation of their agronomic performance under defined management conditions remains limited.

In the Northern Guinea Savanna zone of Nigeria, characterized by a mono-modal rainfall pattern and sandy loam soils, coleus potato production faces additional challenges including short growing seasons, low soil fertility, and high temperatures. Identifying well-adapted, high-yielding s and determining appropriate plant population densities are essential steps toward sustainable intensification of coleus potato production in this agro-ecology.

This study was therefore conducted to: (i) evaluate the growth and yield performance of two coleus potato s (Ex-Zuru Black and Ex-Zuru Brown) under field conditions, and (ii) determine the optimum plant population density for maximizing growth and tuber yield in the Northern Guinea Savanna of Nigeria.

MATERIALS AND METHODS

Experimental Site

Field experiments were conducted during the 2023 and 2024 rainy seasons at the Teaching and Research Farm of the Federal University of Agriculture, Zuru (Latitude 11°35′N; Longitude 4°45′E; 394 m above sea level), located in the Northern Guinea Savanna ecological zone of Nigeria. The area receives annual rainfall ranging from 690 to 885 mm, distributed over 4–6 months (April to October). Minimum temperatures range from 18 to 29°C, while maximum temperatures range from 30 to 38°C. Relative humidity varies from 26 to 39% during the dry period and 55 to 85% during the rainy season. The soil at the experimental site is sandy loam in texture, slightly acidic (pH 5.6–6.3), with moderate organic carbon content, low available phosphorus, and moderate cation exchange capacity.

Treatments and Experimental Design

The experiment consisted of two factors: coleus potato s (Ex-Zuru Black and Ex-Zuru Brown) and four plant population densities (22,222; 29,629; 44,444; and 88,888 plants ha^{-1}, corresponding to intra-row spacings of 60, 45, 30, and 15 cm, respectively, on ridges spaced 75 cm apart). The treatments were arranged in a split-plot design with three replications, with plant population density assigned to main plots and to subplots. Gross plot size was 6 m × 4.5 m (27 m^2), and net plot size was 6 m × 2.5 m (15 m^2).

Description of Accession

Ex-Zuru Black was obtained from farming communities in the Dongo area of Zuru, Kebbi State. It is characterized by dark-skinned tubers and a late-maturing growth habit, requiring 120–145 days to reach physiological maturity. Ex-Zuru Brown was sourced from Ribah town, Kebbi State, and is distinguished by its brown-skinned tubers and early maturity (110–125 days).

Cultural Practices

Land was prepared by spraying glyphosate herbicide at 20 ml L^{-1} water three weeks before ploughing. The field was ploughed and ridged using oxen. Ridges were constructed manually at 75 cm inter-row spacing and approximately 40 cm height. Healthy, disease-free seed tubers were selected, dressed with dithiocarbamate fungicide at 2.0 g kg^{-1} seed, and planted at approximately 5 cm depth according to treatment spacings. Basal application of NPK 15:15:15 fertilizer was applied uniformly at 300 kg ha^{-1} in two equal split doses at planting and at 6 weeks after planting (WAP). Weeds were controlled manually at 5, 9, and 13 WAP. Plants were earthed up at 3 WAP to prevent tuber greening. Insect pests were controlled by spraying lambda-cyhalothrin at 4 ml L^{-1} water as needed.

Data Collection

Data were collected on plant height (cm), number of leaves per plant, leaf area index (LAI), and shoot dry weight (g $plant^{-1}$) at 7, 9, and 11 WAP from ten randomly selected and tagged plants per net plot. Leaf area was estimated using the leaf disc-dry matter method described by Clovis and Jackson (2013). LAI was calculated as the ratio of total leaf area per plant to ground area occupied per plant. Shoot dry weight was determined by oven-drying shoot samples at 70°C to constant weight. At harvest maturity, all tubers within each net plot were harvested, cleaned, and weighed to determine fresh tuber yield, which was then extrapolated to tonnes per hectare (t ha^{-1}).

Data Analysis

All data were subjected to analysis of variance (ANOVA) using the Statistical Analysis System (SAS, 2003) package. Treatment means were separated using Duncan's Multiple Range Test (DMRT) at 5% probability level.

RESULTS

Plant Height

Plant height was significantly ($P \leq 0.05$) affected by and plant population density at all sampling dates in both seasons and the combined analysis. Ex-Zuru Black produced significantly taller plants than Ex-Zuru Brown at 9 and 11 WAP in the 2024 season and combined data. At 9 WAP combined, Ex-Zuru Black recorded a plant height of 15.58 cm compared with 14.67 cm for Ex-Zuru Brown.

Table 1: Plant height (cm) of two Coleus potato as Influenced by Plant population density and NPK rates at 7, 9 and 11WAP in 2023, 2024 Rainy Seasons and the Combined data at Zuru

Treatments	Rainy Seasons								
	7WAP			9WAP			11WAP		
	2023	2024	Combined	2023	2024	Combined	2023	2024	Combined
Ex-Zuru Black	7.14	8.86	11.65	8.74	16.27^{a}	15.58^{a}	11.05^{a}	20.98^{a}	32.24
Ex-Zuru Brown	7.02	8.78	11.36	8.36	15.53^{b}	14.67^{b}	10.75^{b}	20.43^{b}	32.21
SE±	**0.065**	**0.069**	**0.129**	**0.065**	**0.055**	**0.174**	**0.081**	**0.082**	**0.608**
Plant population density (plants ha^{-1})									
22,222	7.70^{a}	9.05^{a}	13.34^{a}	9.32^{a}	18.83^{a}	9.32^{a}	11.90^{a}	24.49^{a}	40.41^{a}
29,629	7.51^{ab}	8.91^{ab}	12.37^{b}	8.70^{b}	17.22^{b}	8.70^{b}	11.08^{a}	22.43^{b}	33.58^{b}
44,444	7.15^{b}	8.74^{b}	11.36^{c}	8.35^{b}	15.58^{c}	8.35^{b}	10.44^{ab}	20.45^{c}	27.05^{c}
88,888	5.96^{c}	8.56^{c}	8.90^{d}	7.84^{c}	11.83^{d}	7.84^{c}	10.17^{c}	15.45^{d}	23.80^{d}
SE±	**0.103**	**0.138**	**0.259**	**0.130**	**0.111**	**0.130**	**0.163**	**0.165**	**1.217**
D x V	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) are not significantly different ($p \leq 0.05$) using DMRT. SE± are shown. NS= not significant. WAP= Weeks after planting

The lowest density of 22,222 plants ha^{-1} consistently produced the tallest plants, with combined means of 13.34, 9.32, and 40.41 cm at 7, 9, and 11 WAP, respectively. Plant height decreased progressively with increasing density, with the highest density (88,888 plants ha^{-1}) producing the shortest plants across all sampling dates.

Number of Leaves

Leaf production was significantly ($P \leq 0.05$) influenced by and plant population density at 7, 9, and 11 WAP in both seasons and the combined analysis. Ex-Zuru Black consistently produced significantly more leaves than Ex-Zuru Brown at all growth stages. At 9 WAP combined, Ex-Zuru Black produced 61.07 leaves per plant compared with 56.29 leaves for Ex-Zuru Brown.

Table 2: Number of leaves of two Coleus potato as Influenced by Plant population density and NPK rates at 7, 9, and 11WAP in 2023,2024 Rainy Seasons and the Combined data at Zuru

Treatments	Rainy Seasons								
	7WAP			9WAP			11WAP		
	2023	2024	Combined	2023	2024	Combined	2023	2024	Combined
Ex-Zuru Black	39.83^{a}	53.72^{a}	49.26^{a}	53.72^{a}	58.68^{a}	61.07^{a}	58.68^{a}	68.41^{a}	63.59^{a}
Ex-Zuru Brown	37.00^{b}	20.24^{b}	45.68^{b}	49.37^{b}	54.37^{b}	56.29^{b}	54.39^{b}	63.28^{b}	58.84^{b}
SE±	**0.145**	**0.151**	**0.245**	**0.151**	**0.166**	**0.204**	**0.165**	**0.222**	**0.552**
Plant population density (Plants ha^{-1})									
22,222	51.70^{a}	68.91^{a}	62.81^{a}	67.71^{a}	73.91^{a}	76.20^{a}	73.91^{a}	83.50^{a}	78.71^{a}
29,629	42.00^{b}	56.08^{b}	51.56^{b}	55.10^{b}	61.12^{b}	63.43^{b}	61.12^{b}	70.83^{b}	65.98^{b}
44,444	31.91^{c}	43.66^{c}	40.31^{c}	43.66^{c}	48.70^{c}	50.85^{c}	48.70^{c}	58.00^{c}	53.35^{c}
88,888	28.04^{d}	37.54^{d}	35.20^{d}	35.54^{d}	42.37^{d}	44.22^{d}	42.41^{d}	50.91^{d}	46.66^{d}
SE±	**0.290**	**0.303**	**0.491**	**0.301**	**0.333**	**0.408**	**0.331**	**0.445**	**0.390**
D x V	NS	NS	NS	NS	NS	NS	NS	NS	NS
F x V	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) are not significantly different ($p \leq 0.05$) using DMRT. SE± and $LSD_{0.05}$ are shown NS= not significant. WAP= Weeks after planting.

Plant population density significantly affected leaf number, with the lowest density (22,222 plants ha^{-1}) producing the highest leaf count (62.81, 76.20, and 78.71 at 7, 9, and 11 WAP combined, respectively). Leaf number decreased progressively with increasing plant density, reaching minimum values at 88,888 plants ha^{-1}.

Leaf Area Index

Leaf area index (LAI) was significantly ($P \leq 0.05$) influenced by and plant population density throughout the growing period. Ex-Zuru Black maintained significantly higher LAI than Ex-Zuru Brown at 9 and 11 WAP in the combined analysis, with values of 1.67 vs. 1.62 and 1.70 vs. 1.65, respectively.

Table 3: Leaf area index (LAI) per plant of two coleus potato as Influenced by Plant population density and NPK rates at 7, 9 and 11 WAP in 2023, 2024 rainy seasons and the Combined data at Zuru

Treatments	Rainy Seasons								
	7WAP			9WAP			11WAP		
	2023	2024	Combined	2023	2024	Combined	2023	2024	Combined
Ex-Zuru Black	1.57	1.60	1.61	1.60	1.66	1.67^{a}	1.66^{a}	1.75^{a}	1.70^{a}
Ex-Zuru Brown	1.55	1.59	1.59	1.59	1.64	1.62^{b}	1.64^{b}	1.65^{b}	1.65^{b}
SE±	**0.006**	**0.005**	**0.005**	**0.005**	**0.006**	**0.007**	**0.006**	**0.005**	**0.007**
Plant population density ((Plants ha^{-1})									
22,222	1.67^{a}	1.74^{a}	1.71^{a}	1.71^{a}	1.74^{a}	1.77^{a}	1.74^{a}	1.83^{a}	1.79^{a}
29,629	1.64^{a}	1.67^{b}	1.69^{b}	1.67^{a}	1.73^{a}	1.71^{b}	1.73^{a}	1.74^{a}	1.68^{b}
44,444	1.49^{c}	1.53^{c}	1.43^{c}	1.53^{b}	1.58^{b}	1.59^{c}	1.58^{b}	1.64^{b}	1.59^{c}
88,888	1.42^{d}	1.47^{d}	1.53^{d}	1.47^{c}	1.55^{b}	1.53^{d}	1.55^{b}	1.58^{c}	1.49^{d}
SE±	**0.011**	**0.012**	**0.011**	**0.011**	**0.012**	**0.014**	**0.012**	**0.011**	**0.014**
D x V	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) are not significantly different ($p \leq 0.05$) using DMRT. SE± are shown not significant. WAP= Weeks after planting.

Plant population density significantly affected LAI, with 22,222 plants ha^{-1} producing the highest LAI values (1.71, 1.77, and 1.79 at 7, 9, and 11 WAP combined, respectively). The highest density (88,888 plants ha^{-1}) consistently produced the lowest LAI across all growth stages.

Shoot Dry Weight

Shoot dry matter accumulation was significantly ($P \leq 0.05$) influenced by and plant population density. Ex-Zuru Black produced significantly greater shoot dry weight than Ex-Zuru Brown at all sampling dates in both seasons and the combined analysis. At 9 WAP combined, shoot dry weights were 19.67 and 17.89 g plant^{-1} for Ex-Zuru Black and Ex-Zuru Brown, respectively.

Table 4: Shoot dry weight (g) of two coleus potato varieties as Influenced by Plant population density and NPK rates on at 7 WAP in 2023, 2024 rainy seasons and the Combined data at Zuru

Treatments	Rainy Seasons								
	2023	2024	Combined	2023	2024	Combined	2023	2024	Combined
Variety									
Ex-Zuru Black	19.81a	19.45a	19.63a	19.67a	19.67a	19.67a	21.83a	22.65a	22.24a
Ex-Zuru Brown	18.25b	17.85b	18.05b	17.59b	18.18b	17.89	24.29	20.77b	20.53b
SE±	**0.098**	**0.097**	**0.091**	**0.134**	**0.100**	**0.113**	**0.098**	**0.117**	**0.103**
Plant population density (Plants ha^{-1})									
22,222	23.13a	23.13a	23.23a	23.38a	23.13a	23.36a	25.62a	26.14a	25.88a
29,629	19.74b	19.89b	19.93b	17.31c	16.75c	17.03c	22.40b	23.41b	22.91b
44,444	16.83c	16.75c	17.07c	20.01b	19.89b	19.95b	19.17c	20.17c	19.67c
88,888	14.84d	14.83d	14.90d	15.43d	14.83d	15.13d	17.05d	17.12d	17.09d
SE±	**0.197**	**0.200**	**0.226**	**0.268**	**0.197**	**0.182**	**0.197**	**0.233**	**0.204**
D x V	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) are not significantly different ($p \leq 0.05$) using DMRT. SE± and $LSD_{0.05}$ are shown. NS= not significant. WAP= Weeks after planting

The lowest density (22,222 plants ha^{-1}) produced the highest shoot dry weight values (23.23, 23.36, and 25.88 g plant^{-1} at 7, 9, and 11 WAP combined, respectively). Shoot dry weight decreased with increasing plant density, reaching minimum values at 88,888 plants ha^{-1}.

Yield components

Tuber Weight per Stand (g)

Tuber weight per stand was significantly influenced ($p<0.05$) by accession and plant population density during both growing seasons and in the combined analysis. Across all environments, Ex-Zuru Black consistently produced significantly heavier tubers per stand compared to Ex-Zuru Brown. Plant population density exerted a pronounced effect, with the lowest density (22,222 plants ha^{-1}) resulting in the highest tuber weight per stand, which was statistically similar to the densities of 29,629 and 44,444 plants ha^{-1}. Conversely, the highest density (88,888 plants ha^{-1}) produced the lowest tuber weight per stand in both seasons and the combined mean.

Mean Tuber Weight (g)

The main effects of accession and plant population density significantly affected mean tuber weight. A clear accession effect was observed, with Ex-Zuru Black producing significantly heavier individual tubers than Ex-Zuru Brown in 2023, 2024, and the combined analysis. Population density significantly influenced mean tuber weight; the lowest density of 22,222 plants ha^{-1} recorded the highest mean tuber weight, which was significantly greater than the intermediate densities of 29,629 and 44,444 plants ha^{-1}. In contrast, the highest density of 88,888 plants ha^{-1} produced the lowest mean tuber weight across all trials.

Fresh Tuber Yield (t ha^{-1})

Fresh tuber yield was significantly influenced by accession and plant population density in both seasons and the combined analysis. A significant accession difference was observed, with Ex-Zuru Black producing higher fresh tuber yields than Ex-Zuru Brown across all environments. Plant population density significantly affected fresh tuber yield; the lowest density of 22,222 plants ha^{-1} produced a higher yield than the intermediate densities of 29,629 and 44,444 plants ha^{-1}. Conversely, the highest density of 88,888 plants ha^{-1} resulted in the lowest fresh tuber yield in both seasons and the combined data.

Table 5: Tuber weight per stand (g), Mean tuber weight (g) and fresh tuber yield; of two Coleus Potato Varieties as Influenced by Plant population density and NPK rates in 2023,2024 rainy seasons and the Combined data at Zuru

Treatments	Rainy seasons								
	2023	2024	Combined	2023	2024	Combined	2023	2024	Combined
Variety									
Ex-Zuru Black	51.12a	56.41a	53.77a	2.47a	4.01a	3.24a	1.90a	1.96a	1.93a
Ex-Zuru Brown	49.20b	51.55b	50.38b	2.33b	3.63b	2.98b	1.64b	1.85b	1.74b
SE±	**0.541**	**0.501**	**0.500**	**0.018**	**0.005**	**0.024**	**0.009**	**0.002**	**0.010**
Plants ha^{-1}									
22,222	60.61a	62.16a	61.38a	2.66a	4.42a	3.54a	2.44a	2.57a	2.50a
29,629	55.85b	55.18b	55.51b	2.59a	4.23b	3.41b	1.90b	2.06b	1.98b
44,444	42.76c	51.75c	47.26c	2.27b	3.72c	3.00c	1.43c	1.59c	1.51c
88,888	41.42d	46.89d	44.15d	2.07c	2.89d	2.48d	1.33d	1.39d	1.36d
SE±	**1.083**	**1.013**	**1.00**	**0.036**	**0.011**	**0.048**	**0.009**	**0.005**	**0.020**
D x V	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) are not significantly different ($p \leq 0.05$) using DMRT. SE± are shown. NS= not significant. WAP= Weeks after planting

DISCUSSION

The consistent superiority of Ex-Zuru Black over Ex-Zuru Brown across all growth and yield parameters demonstrates the importance of genetic factors in determining coleus potato productivity. Ex-Zuru Black exhibited enhanced vegetative vigour, as evidenced by greater plant height, higher leaf number, larger leaf area index, and greater shoot dry matter accumulation. These traits are indicative of superior canopy development and photosynthetic capacity, which provide the assimilate supply necessary for tuber initiation and bulking. The enhanced vegetative growth of Ex-Zuru Black translated into significantly higher fresh tuber yield, confirming that s with robust canopy development and greater biomass production possess higher yield potential. This finding aligns with previous reports indicating that differences in growth habit, leaf area duration, and dry matter partitioning significantly influence tuber yield in coleus potato (Muhammad et al., 2016; Namo et al., 2022). The superior performance of Ex-Zuru Black may be attributed to its later maturity (120–145 days) compared with Ex-Zuru Brown (110–125 days). Longer maturity duration allows extended periods of canopy photosynthesis and assimilates production, providing a prolonged tuber bulking phase. This

characteristic is particularly advantageous under Northern Guinea Savanna conditions, where the growing season extends from May to October.

Effect of Plant Population Density

The inverse relationship between plant population density and individual plant performance observed in this study is consistent with established principles of plant competition. At low densities (22,222 plants ha^{-1}), reduced inter-plant competition enabled unrestricted canopy development, greater leaf area expansion, and higher photosynthetic rates per plant. These conditions favoured enhanced assimilate production and partitioning to tubers, resulting in superior tuber yield. Conversely, increasing plant density to 88,888 plants ha^{-1} intensified competition for light, water, and nutrients. The resulting stress manifested as reduced plant height, fewer leaves, lower leaf area index, and diminished shoot dry matter accumulation. Under high-density conditions, plants allocate more resources to vertical growth (etiolation) at the expense of lateral branching and leaf production, reducing overall photosynthetic capacity (Pavani Rani et al., 2023). The yield reduction at high densities indicates that the negative effects of intensified competition on individual plant productivity outweighed any potential advantage of increased plant numbers per unit area. This finding supports previous reports in potato and other tuber crops (Bussan et al., 2007; Bayorbor & Gumarh, 2007).

CONCLUSION

This study demonstrated that coleus potato s differs significantly in their growth and yield potential under Northern Guinea Savanna conditions. Ex-Zuru Black exhibited superior vegetative growth and produced significantly higher fresh tuber yield compared with Ex-Zuru Brown, confirming its potential for improved coleus potato production in the study area. Plant population density is a critical determinant of coleus potato productivity, with lower densities promoting enhanced individual plant growth and higher tuber yield. A plant population density of 22,222 plants ha^{-1} (60 cm × 75 cm spacing) is optimal for maximizing tuber yield under rain-fed conditions. It is recommended that farmers in the Northern Guinea Savanna adopt Ex-Zuru Black and maintain plant populations of approximately 22,222 plants ha^{-1} for enhanced coleus potato productivity.

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