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Research Article

Evaluation of Barley (*Hordeum Vulgare* L.) Varieties Under Different Nitrogen Fertilizer Rates in The Sudan Savanna of Nigeria

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Abstract

*Barley (Hordeum vulgare L.) is an important cereal crop with diverse uses, yet its production in Nigeria is constrained by poor soil fertility and inadequate nitrogen management. This study evaluated the response of barley varieties to different nitrogen rates in the Sudan Savanna zone of Kebbi State, Nigeria. Field experiments were conducted during the 2023/2024 and 2024/2025 dry seasons at Jega, Kebbi State (12°12.99' N, 4°21.90' E; 197 m a.s.l.). Four barley varieties (Arupos, Focus, LCRI-207, LCRI-211) and four nitrogen rates (0, 60, 120, 180 kg N ha^{-1}) were evaluated in a randomized complete block design with three replications. Data were collected on establishment count, plant height, leaf length, leaf area index (LAI), crop growth rate (CGR), tiller count, days to 50% heading, productive tillers, spikelets per spike, 1000-grain weight, and grain yield. Nitrogen application significantly ($p<0.05$) improved all growth and yield parameters. The highest grain yield (5.40 t ha^{-1}) was obtained at 120 kg N ha^{-1}, representing a 231% increase over the control (1.63 t ha^{-1}). The variety Focus consistently outperformed others, producing the highest grain yield (5.54 t ha^{-1}). Significant variety × nitrogen interactions were observed for most traits, with Focus at 120 kg N ha^{-1} producing the highest grain yield (5.64 t ha^{-1}). Correlation analysis revealed strong positive relationships between grain yield and spikelets per spike (r=0.894**),** 1000-grain weight (r=0.858), and LAI (r=0.591**). The combination of Focus variety and 120 kg N ha^{-1} is recommended for optimum barley production in the Sudan Savanna zone of Nigeria.*

Keywords: *Barley, Nitrogen rates, growth parameters, yield components, Sudan Savanna.*

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the world's oldest cultivated cereal crops and an important member of the Poaceae family. Owing to its adaptability to diverse agroecological conditions and wide range of uses in human nutrition, livestock feed, and the malting and brewing industries, barley remains a crop of significant economic importance worldwide (Saisho & Purugganan, 2007). Global production reached approximately 150 million metric tonnes in 2022; however, production in Nigeria remains relatively low despite the favourable conditions for cultivation in the northern Sudan Savanna region (FAO, 2022).

Nitrogen is the most important nutrient influencing barley growth, development, and grain yield because of its essential role in chlorophyll formation, photosynthesis, protein synthesis, and biomass accumulation (Lemaire et al., 2008). Nevertheless, barley varieties differ in their nitrogen-use efficiency, resulting in varying responses to nitrogen fertilizer application under different environmental conditions (Xu et al., 2012). Both inadequate and excessive nitrogen application can reduce productivity and fertilizer-use efficiency, highlighting the need to determine optimum nitrogen rates for specific barley varieties and production environments (Fageria & Baligar, 2008). In the Sudan Savanna agroecological zone of Nigeria, information on the optimum nitrogen fertilizer requirements of improved barley varieties is limited. Consequently, farmers often apply nitrogen fertilizer without location-specific recommendations, leading to suboptimal yields and increased production costs. Identifying suitable variety–nitrogen combinations is therefore essential for improving barley productivity and promoting sustainable fertilizer management in the region. This study was conducted to evaluate the response of four barley varieties to different nitrogen fertilizer rates under the Sudan Savanna conditions of Jega, Kebbi State, Nigeria, with the aim of identifying the optimum nitrogen level and the most productive variety for enhanced growth and grain yield.

MATERIALS AND METHODS

Field experiments were conducted during the 2023/2024 and 2024/2025 dry seasons at the Fadama Teaching and Research Farm of Abdullahi Fodiyo University of Science and Technology, Aliero, located in Jega, Kebbi State, Nigeria (12°12.99′ N, 4°21.90′ E; 197 m above sea level). The experimental site is situated within the Sudan Savanna agroecological zone, which is characterized by a prolonged dry season with cool Harmattan conditions from November to February followed by hot and dry weather between March and May, making it suitable for irrigated crop production. Prior to land preparation, composite soil samples were collected from a depth of 0–30 cm and analyzed using standard laboratory procedures described by Black (1965). The soil was classified as sandy loam, comprising 72.5% sand, 15.3% silt, and 12.2% clay, with a slightly acidic pH (6.2), low organic carbon (4.8 g kg^{-1}), total nitrogen (0.52 g kg^{-1}), available phosphorus (8.6 mg kg^{-1}), and cation exchange capacity (5.86 cmol kg^{-1}), indicating generally low inherent fertility. The experiment consisted of four barley (Hordeum vulgare L.) varieties (Arupos, Focus, LCRI-207, and LCRI-211) and four nitrogen fertilizer rates (0, 60, 120, and 180 kg N ha^{-1}) arranged in a randomized complete block design (RCBD) with three replications. Each experimental plot measured 2.0 × 1.8 m (3.6 m^2), with 1.0 m spacing between blocks and 0.5 m between adjacent plots. Certified seeds were obtained from the Lake Chad Research Institute (LCRI), Maiduguri, Nigeria. Land preparation involved ploughing and harrowing to obtain a fine seedbed before sowing by drilling at 25 cm inter-row spacing. Irrigation water was supplied from a tube well at intervals of 3–5 days throughout the growing period. Nitrogen fertilizer was applied as urea (46% N) in three equal split applications at 2, 5, and 8 weeks after planting (WAP). Crop protection was achieved using Deltamethrin (0.01 L ha^{-1}) for insect control and Spirotetramat + Flubendiamide (Tihan) at 0.02 L ha^{-1}, while weeds were controlled manually as required. At physiological maturity, the crop was harvested manually, threshed, cleaned, and prepared for yield determination.

Data were collected on establishment count, plant height, leaf length, leaf area index (LAI), crop growth rate (CGR), tiller count, days to 50% heading, productive tillers, spikelets per spike, 1000-grain weight, and grain yield. Leaf area was estimated using the leaf disc dry matter method described by Clovis and Jackson (2013), while LAI was calculated as the ratio of total leaf area to the corresponding ground area following the procedure of Brown (1984). Crop growth rate was determined according to the method of Radford (1967). Data obtained from the two experimental seasons were subjected to analysis of variance (ANOVA) using SAS software (SAS Institute, 2003). Treatment means were separated using Duncan's Multiple Range Test (DMRT) at the 5% probability level, and Pearson's correlation analysis was performed to determine relationships among the measured growth, yield, and yield-related traits.

Results and Discussion

Nitrogen application significantly ($p < 0.05$) improved all growth, yield, and yield component traits of barley (Table 1). Growth parameters, including establishment count, plant height, leaf area index (LAI), crop growth rate (CGR), and tiller number, increased progressively with nitrogen application up to 120 kg N ha^{-1}, after which no further improvement was observed. The highest values for plant height (70.25 cm), LAI (3.69), CGR (6.40 g m^{-2} $week^{-1}$), and tiller count (7.79 $plant^{-1}$) were obtained at 120 kg N ha^{-1}. These improvements reflect the vital role of nitrogen in enhancing chlorophyll synthesis, photosynthetic efficiency, canopy development, and biomass accumulation, consistent with the findings of Vahamidis et al. (2023) and Abebe et al. (2024).

Table 1. Effect of Nitrogen Rates on Growth, Yield Components, and Grain Yield of Barley (Combined Analysis)

Nitrogen Rate (kg N ha^{-1})	Establishment (%)	Plant Height (cm) 11 WAP	LAI 11 WAP	CGR 11 WAP (g m^{-2} wk^{-1})	Tiller Count 11 WAP	Productive Tillers (%)	Spikelets per Spike	1000-Grain Weight (g)	Grain Yield (t ha^{-1})
0	63.16d	39.38d	2.06c	3.51c	3.11c	45.51d	19.00d	28.49d	1.63d
60	71.69c	52.64c	2.70b	4.84b	5.41b	63.83c	22.83c	32.30c	3.36c
120	83.35b	70.25a	3.69a	6.40a	7.79a	95.88a	30.58a	47.21a	5.40a
180	90.70a	61.36b	3.37a	5.63a	6.25b	85.86b	27.25b	36.99b	4.55b
SE±	**4.017**	**3.305**	**0.889**	**0.931**	**0.642**	**3.241**	**1.112**	**3.107**	**0.347**

Means followed by the same letter(s) within a column are not significantly different at p<0.05 using DMRT. WAP = Weeks after planting

Nitrogen also significantly enhanced reproductive traits and grain yield. Productive tillers, spikelets per spike, and 1000-grain weight increased markedly with nitrogen application, while days to 50% heading decreased, indicating improved crop development. Grain yield increased from 1.63 t ha^{-1} in the control to 5.40 t ha^{-1} at 120 kg N ha^{-1}, representing a 231% increase. However, grain yield declined at 180 kg N ha^{-1}, suggesting that excessive nitrogen promoted vegetative growth at the expense of grain production. Similar responses have been reported by Cammarano et al. (2024) and Mittermayer et al. (2025).

Significant varietal differences were observed for all measured parameters (Table 2). Focus consistently produced superior growth and yield, recording the highest grain yield (5.54 t ha^{-1}), while Arupos produced the lowest (2.89 t ha^{-1}). The superior performance of Focus indicates greater genetic potential, better nitrogen-use efficiency, and enhanced assimilate production and partitioning, resulting in higher productivity under the experimental conditions.

Table 2. Effect of Variety on Growth, Yield Components, and Grain Yield of Barley (Combined Analysis)

Variety	Establishment (%)	Plant Height (cm) 11 WAP	LAI 11 WAP	CGR 11 WAP (g m^{-2} wk^{-1})	Tiller Count 11 WAP	Productive Tillers (%)	Spikelets per Spike	1000-Grain Weight (g)	Grain Yield (t ha^{-1})
Arupos	80.93a	57.46b	2.45b	3.75b	3.28c	67.45c	21.75c	28.96c	2.89c
Focus	81.08a	68.37a	3.59a	6.02a	7.18a	96.67a	30.69a	45.07a	5.54a
LCRI-207	71.50c	58.12b	2.59b	3.77b	4.53b	72.84b	27.67b	38.97b	3.33b
LCRI-211	77.91b	47.37c	2.40b	3.66b	4.75b	73.61b	28.17b	38.42b	3.22b
SE±	**4.227**	**3.752**	**0.861**	**0.922**	**0.658**	**3.241**	**1.112**	**3.271**	**0.355**

Means followed by the same letter(s) within a column are not significantly different at $p<0.05$ using DMRT. WAP = Weeks after planting

The variety × nitrogen interaction significantly influenced several growth traits and grain yield (Table 3). The combination of Focus and 120 kg N ha^{-1} produced the highest grain yield (5.64 t ha^{-1}), demonstrating that varietal response to nitrogen differs among genotypes. The superior response of Focus suggests greater efficiency in nitrogen uptake and utilization, emphasizing the importance of combining appropriate nitrogen management with high-performing varieties to maximize barley productivity.

Table 3. Variety x Nitrogen Interaction Effect on Grain Yield (Combined Analysis, t ha^{-1})

Variety	0 kg N ha^{-1}	60 kg N ha^{-1}	120 kg N ha^{-1}	180 kg N ha^{-1}
Arupos	1.98g	3.63e	4.06c	3.97d
Focus	2.60f	4.78b	5.64a	4.90b
LCRI-207	2.21fg	3.88de	4.73b	4.16bc
LCRI-211	2.93f	3.91d	4.71b	3.99d
SE±		0.347		

Means followed by the same letter(s) within the table are not significantly different at $p<0.05$ using DMRT

Correlation analysis showed that grain yield was positively associated with all growth and yield traits (Table 4), with the strongest correlations observed for spikelets per spike (r = 0.894) and 1000-grain weight (r = 0.858). Positive relationships with LAI, plant height, CGR, and tiller number further indicate that vigorous vegetative growth supports greater assimilate production and grain filling. These findings identify spikelets per spike and 1000-grain weight as important selection criteria for improving barley yield under different nitrogen management regimes.

Table 4. Correlation Matrix between Growth and Yield Attributes of Barley (Combined Data)

Variable	YLD	PH11	LL11	LAI11	CGR11	TC11	SPS	1000G
YLD	1.00							
PH11	0.523**	1.00						
LL11	0.314**	0.676**	1.00					
LAI11	0.591**	0.257*	0.347**	1.00				
CGR11	0.398**	0.228*	0.135ns	0.349**	1.00			
TC11	0.357**	0.265*	0.119ns	0.567**	0.489**	1.00		
SPS	0.894**	0.576**	0.368**	0.356**	0.231*	0.592**	1.00	
1000G	0.858**	0.546**	0.359**	0.486**	0.348**	0.164ns	0.399**	1.00

YLD = Grain yield, PH = Plant height, LL = Leaf length, LAI = Leaf area index, CGR = Crop growth rate, TC = Tiller count, SPS = Spikelets per spike, 1000G = 1000-grain weight. ** = $p<0.01$, * = $p<0.05$, ns = Not significant

CONCLUSION

Nitrogen application and varietal differences significantly influenced the growth and yield of barley under the Sudan Savanna conditions of Nigeria. Applying 120 kg N ha^{-1} produced the highest grain yield and optimized growth and yield components, while higher nitrogen application reduced yield. Among the varieties evaluated, Focus consistently outperformed the others and showed the greatest response to nitrogen application. Therefore, the combination of the Focus variety and 120 kg N ha^{-1} is recommended for achieving optimum barley productivity in the Sudan Savanna agroecological zone of Nigeria.

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