



**EVALUATION OF MORPHOLOGICAL TRAITS OF BARLEY (*Hordeum vulgare* L.)
VARIETIES IN DIFFERENT INTER-ROW SPACINGS AND
NITROGEN RATES UNDER IRRIGATION**

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ABSTRACT

A field experiment was conducted over two consecutive cropping seasons, 2021/2022 and 2022/2023, at the National Root Crop Research Institute's station in Vom, located in the Jos South Local Government Area of Plateau State (Longitude 8°53' E, Latitude 9°56' N) at an altitude of 1,217 meters above sea level. The aim of the study was to evaluate how different barley genotypes, inter-row spacing, and nitrogen application rates affect barley production. The experimental setup included three barley genotypes (Traveler, Zhana, and Arupo's'), four nitrogen levels (0, 80, 100, and 120 kg N ha⁻¹), and three inter-row spacing configurations (20, 30, and 40 cm), organized in a split-split plot design with three replications. The findings indicated that the control treatment resulted in significantly fewer days to heading, with 49.00 days recorded in the 2021/2022 season and 49.30 days in 2022/2023 at a nitrogen application of 80 kg/ha⁻¹. In contrast, the 120 kg N/ha treatment led to delayed heading in both years. However, both the control and the 120 kg N/ha⁻¹ treatment resulted in significantly earlier flowering days at a 40 cm inter-row spacing during both seasons. The genotype Arupo's achieved the highest grain yields, reaching 1251.0 kg/ha in 2021/22 and 1876.4 kg/ha in 2022/23 at a 20 cm inter-row spacing, with the application of 120 kg N/ha⁻¹. The study found significant interactions among the number of days to heading, flowering, physiological maturity, and grain yield concerning nitrogen levels, row spacing, and variety. In conclusion, the genotype Arupo's was the earliest to reach heading, flowering, and maturity, while also yielding the highest grain production in the 20 cm inter-row spacing with a nitrogen level of 120 kg/ha. It is recommended that farmers utilize the Arupo's genotype with a 20 cm inter-row spacing and 120 kg N/ha for optimal barley production.

Keywords: Barley, Nitrogen, Spacing, Irrigation

INTRODUCTION

Barley (*Hordeum vulgare* L.) is an important cereal crop belonging to the grass family Poaceae. It is the fourth most widely cultivated cereal after wheat, rice, and corn (FAO, 2017 and Anon. 2018). Barley has been domesticated for over 10,000 years and is now grown in various regions around the world, including Europe, North America, Asia, and Africa (Shewry and Hey, 2016). Globally, the Russian Federation is the highest producer of barley in the world, accounting to 21.85% of the world's barley production. The top 5 countries (Russia, Australia, Canada, Turkey, and Ukraine) account for 61.98% of it. The world's total barley production was estimated at 94,289 metric tons in 2020 (Anon., 2020). Ethiopia is the first largest producer of barley 2,350 in Africa followed by Algeria, 1,845 metric tons, etc. accounting for about 16.17% of total barley production in the continent (Anon., 2020). Enhancing barley production can contribute to Nigeria's food security by increasing the availability of a versatile crop that can be used in various food products, including bread, porridge, and snacks (Aremu *et al.* 2017). Barley is a versatile crop with multiple uses. Its primary use is in the production of malt for the brewing industry, as well as for distilling and the production of alcoholic beverages. Additionally, barley is used as animal feed, human food, and as a raw material in the pharmaceutical industry (Mulugeta *et al.* 2018; Dhillon and Uppal. 2019); Anon., 2020); Akinseye *et al.* 2020) and Aremu *et al.* (2020). In recent years, there has been a growing interest in the nutritional benefits of barley. It is a good source of dietary fiber, protein, and essential



minerals presence of beta-glucan (an anti-cholesterol substance), acetylcholine (a substance which nourishes our nervous system and recovers memory loss), easy digestibility (due to low gluten contents) and high lysine, thiamin, and riboflavin (Khalid, 2017). Barley also contains various bioactive compounds. Such as phenolic acids, flavonoids, and tocopherols, which have potential health benefits, including antioxidant and anti-inflammatory properties (Al-Qahtani *et al.* 2020). Proper agronomic practices, such as optimizing inter-row spacing in barley production. Inter-row spacing and nitrogen levels, are crucial for achieving high yield and quality in barley production. Inter-row spacing affects plant population density, light interception, and nutrient uptake, while nitrogen is an essential nutrient for plant growth and grain protein content (Akinseye *et al.* 2020).

Despite its importance, barley production faces several challenges, such as climate change, pests, and disease, which can limit its yield and quality. Furthermore, barley production is limited in some regions due to various factors, including low adoption rates, limited research, and inadequate infrastructure (Ajeigbe *et al.* 2017). Barley is a versatile and valuable crop with diverse applications in the food, feed, and industrial sectors. Efforts to improve its production utilization can contribute to food security, economic development, and human health. Barley is one of the important food crops grown in Borno state and in Nigeria as a whole, grown mainly by small farmers, the Boko Haram insurgency activities have forced many of the areas and local barley production has declined over the years (Tijani and Tijani, 2019, and Dambazau *et al.* 2021). Understanding the effects of agronomic practices, such as inter-row spacing and nitrogen levels management, can help optimize barley production and maximize its potential benefits.

MATERIALS AND METHODS

Field experiments were conducted at the National Root Crop Research Institute outpost, located in Vom, Jos South Local Government Area in Plateau State (Longitude 8°53' E, and Latitude 9°56' N) at an altitude of 1,217 meters above sea level during the dry seasons of 2020/21 and 2021/22. The mean temperature ranged from 20.4°C to 29.6°C, with a relative humidity of 29.5% in December (coolest month) and April (hottest month) (Eziashi, 2007). The rainfall pattern is unimodal, ranging from 700 to 1250 mm and is characterized by distinct dry seasons (October – March) and rainy seasons (April – September) (Mustapha *et al.* 2010). The experiment consisted of three barley varieties (Traveler, Zhana, and Arupo's local), four nitrogen levels (0, 80, 100, 120 kg N ha⁻¹), and three inter-row spacing's (20, 30, 40 cm). These factors were combined factorially and laid out in a Split-Split Plot Design (SSPD) with three replications. The main plot contained nitrogen fertilization rates, the sub-plot contained inter-row spacing, and the sub-sub plots contained the barley varieties. The gross plot size was 2 m x 3 m (6 m²) and contained a different number of rows at different inter-row spacing's. The net plot size was 2.4 x 1.8 m (4.32 m²) with varying row numbers at different inter-row spacing's. The space between plots and between blocks measured 0.5 m and 1.0 m respectively. The experimental site was previously planted with sorghum. The field was cleared, plowed, and harrowed twice with a tractor to a fine tilt at the onset of the irrigation season. The experimental plots received basal application fertilizer (NPK 15:15:15) incorporated before sowing, while nitrogen fertilizer treatments were applied in two split doses; half at jointing and the second half at booting stages. Data on various parameters such as plant height, leaf area, total dry matter, Crop Growth Rate (CGR), tiller count, and grain yield were collected. All data collected were subjected to analysis of variance (ANOVA) using statistical software, Statistic 8.0. The treatment means were compared using the Least Significant Difference Test (LSD) at a 5% level of probability when F-values were significant to compare treatment means (Gomez and Gomez, 1994).

Table 1: Physiochemical Characteristics of Soil of the Experimental Site during the 2021/2023 and 2021/22 Dry Seasons at NRCRI, Vom

Soil composition			
Particle size (g/kg)		2021/2022	2022/2023
Sand (%)		51.70	59.20
Silt (%)		32.50	25.90
Clay (%)		15.80	15.80
Textural class		Sandy loam	Sandy loam
Chemical characteristics			
P ^H (H ₂ O)		6.87	6.86
Nitrogen (N)		0.24	0.55
Organic matter (O.M)		2.76	1.79
Organic carbon (O.C)		1.60	3.09
Carbon-Nitrogen (C:N)		6.67	3.25
Phosphorous (P)		12.60	17.50
Exchangeable bases			
Calcium (Ca ²⁺)		4.60	6.80
Magnesium (Mg ²⁺)		4.20	13.00
Potassium (K ⁺)		8.58	11.14
Sodium (Na ⁺)		0.07	0.14
Carbon Exchange Capacity (C.E.C)		17.45	31.08
Percentage Base Saturation (%Base Salt)		98.31	98.1

Soil samples as analyzed by Soil Science Department, Faculty of Agriculture, University of Maiduguri

RESULTS AND DISCUSSION

Effects of Nitrogen Levels and Inter-row Spacing on Growth Parameters

Table 2 Presents the effects of nitrogen levels and inter-row spacing on various growth parameters recorded during the irrigated seasons of 2021/2022 and 2022/2023. The results reveal a statistically significant ($P \leq 0.05$) difference among the three barley genotypes in both years. The genotype Traveler took the longest to reach 50% heading (55.63 days in 2021/2022 and 54.06 days in 2022/2023) and 50% flowering (61.75 days and 69.11 days, respectively), whereas Arupo's' was the fastest, requiring only 48.67 days and 45.39 days in both seasons. This variation in time to heading and flowering may stem from genetic differences as well as environmental influences (Miriam *et al.* 2021). Moreover, increased competition for resources such as light, water, and nutrients might have played a role (Smith *et al.*, 2019), along with alterations in apical dominance and plant structure as shown in Table 2. The effect of inter-row spacing on days to heading varied from 47.47 to 51.61 days in the 2021/2022 season and 50.11 to 51.61 days in 2022/2023. For flowering, the days ranged from 53.19 to 58.22 days in 2021/2022 and from 59.44 to 60.08 days in 2022/2023. This indicates that a spacing of 40 cm generally led to earlier heading and flowering throughout the seasons, although in 2022/2023, the earliest flowering occurred at a spacing of 20 cm (Johnson *et al.* 2020; Eman and Mohammed, 2023). The response of genotypes to nitrogen levels markedly affected the days to heading and flowering, with average times ranging from 49.00 to 50.04 days in 2021/2022 and from 49.30 to 51.67 days in 2022/2023. For days to flowering, the range remained consistent at 59.30 to 61.07 days across both seasons. Notably, the control treatment resulted in the earliest heading at 49.00 days in 2021/2022 and 49.30 days with 80 kg N/ha⁻¹ in 2022/2023. In contrast, 120 kg N/ha⁻¹ led to delays in heading across both years, although early flowering was associated with both the control treatment and 120 kg N/ha⁻¹ in their respective seasons (Swamy *et al.* 2020; Zhiwei *et al.* 2022). Additionally, significant interactions were noted between nitrogen \times spacing, nitrogen \times variety, and spacing \times variety throughout the two seasons

Table 2: Influence of Nitrogen Rates and Inter-row Spacing on Days to 50% Heading and Days to 50% Flowering at Vom, 2021/2022, 2022/2023 and combined

Treatment	Days to 50% heading		Days to 50% flowering	
	2021/2022	2022/2023	2021/2022	2022/2023
Genotypes (G)				
Traveler	55.63 ^a	54.06 ^a	61.75 ^a	69.11 ^a
Zhana	44.19 ^b	52.47 ^b	57.00 ^b	58.22 ^b
Arupo 's'	48.67 ^c	45.39 ^c	47.64 ^c	52.19 ^c
SE±	0.121	0.069	0.191	0.061
Space(S)				
20 cm	47.47 ^c	51.64 ^a	53.19 ^c	59.44 ^b
30 cm	49.42 ^b	50.11 ^b	54.97 ^b	60.08 ^a
40 cm	51.61 ^a	50.17 ^b	58.22 ^a	60.00 ^a
SE±	0.108	0.071	0.205	0.063
Nitrogen (kg ha⁻¹)				
Control	49.00 ^c	50.96 ^b	56.15 ^a	59.30 ^c
80	49.56 ^b	49.30 ^d	56.07 ^a	59.44 ^{bc}
100	49.41 ^b	50.63 ^c	54.59 ^b	61.07 ^a
120	50.04 ^a	51.67 ^a	55.04 ^b	59.52 ^b
SE±	0.078	0.056	0.204	0.065
Interaction				
N x S	*	**	*	**
N x V	**	**	**	**
S x V	**	**	*	**
N x S x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 3: Interaction of Nitrogen and Spacing on Days to 50% Heading of Barley

Spacing	0 kg ha ⁻¹	80 kg ha ⁻¹	100 kg ha ⁻¹	120 kg ha ⁻¹
	2021/2022			
20 cm	46.89 ^d	46.44 ^g	47.00 ^{fg}	47.89 ^{ef}
30 cm	49.22 ^{fg}	50.33 ^{cd}	49.11 ^{de}	49.11 ^{de}
40 cm	50.89 ^{bc}	51.67 ^{ab}	52.00 ^{ab}	52.67 ^a
SE±	0.450			
2022/2023				
20 cm	54.67 ^a	48.67 ^g	50.89 ^d	52.33 ^b
30 cm	49.33 ^f	48.67 ^g	50.67 ^{de}	51.78 ^c
40 cm	48.89 ^{fg}	50.56 ^{dc}	50.33 ^e	50.89 ^d
SE±	0.187			
Combined				
20 cm	51.11 ^{ab}	49.67 ^b	50.56 ^{ab}	51.33 ^a
30 cm	50.04 ^{ab}	50.11 ^{ab}	50.67 ^{ab}	51.33 ^a
40 cm	50.04 ^{ab}	51.63 ^{ab}	51.33 ^a	51.33 ^a
SE±				

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 4: Interaction of Nitrogen and Variety on Days to 50% Heading of Barley

	0 kg ha ⁻¹	80 kg ha ⁻¹	100 kg ha ⁻¹	120 kg ha ⁻¹
Spacing	2021/2022			
20 cm	54.56 ^b	55.89 ^a	56.33 ^a	55.78 ^{ab}
30 cm	48.11 ^c	48.56 ^c	48.11 ^c	49.11 ^c
40 cm	44.33 ^d	44.00 ^d	43.67 ^d	44.78 ^d
SE±	0.450			
	2022/2023			
20 cm	55.56 ^b	49.67 ^g	53.33 ^d	51.33 ^f
30 cm	51.78 ^{ef}	52.22 ^c	54.56 ^c	57.67 ^a
40 cm	45.56 ^h	46.00 ^h	44.00 ⁱ	46.00 ^h
SE±	0.187			
	Combined			
20 cm	55.04 ^{ab}	54.15 ^{bc}	56.11 ^a	55.48 ^{ab}
30 cm	51.07 ^e	51.82 ^{dc}	51.74 ^{de}	53.04 ^{cd}
40 cm	45.07 ^f	45.44 ^f	44.70 ^f	45.48 ^f
SE±	0.585			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 5: Interaction of Spacing and Variety on Days to 50% Heading of Barley

	Traveler	Zhana	Arupo 's'
Spacing	2021/2022		
20 cm	52.42 ^c	54.50 ^b	60.00 ^a
30 cm	47.58 ^c	48.92 ^d	48.92 ^d
40 cm	41.17 ^g	44.92 ^f	46.50 ^e
SE±	0.390		
	2022/2023		
20 cm	54.75 ^a	51.33 ^d	51.33 ^d
30 cm	54.33 ^{ab}	53.83 ^c	54.00 ^{bc}
40 cm	45.83 ^e	45.17 ^f	45.17 ^f
SE±	0.162		
	Combined		
20 cm	54.83 ^b	54.47 ^b	56.28 ^a
30 cm	52.69 ^c	51.69 ^c	51.36 ^c
40 cm	44.47 ^d	45.44 ^d	45.61 ^d
SE±	0.506		

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Physiological Maturity and Grain Yield

Table 6 Presents the significant effects of nitrogen rates and inter-row spacing on the days required for barley to reach physiological maturity during the irrigated seasons of 2021/22 and 2022/23. The 'Traveler' genotype exhibited notably longer maturation times, taking 92.36 days and 101.28 days in the respective years. Across the sampling periods, the spacing between rows significantly influenced the maturity of various barley varieties. Specifically, 20 cm spacing led to the quickest physiological maturity, while spacings of 30 to 40 cm caused delays in both years. This delay is likely due to the increased spacing among the barley genotypes or the inherent genetic traits of the varieties (Smith *et al.* 2019; Johnson *et al.* 2020). Moreover, excessive nitrogen applications are known to promote vegetative growth, which can delay the transition to reproductive growth and thus extend the time to maturity (Gupta *et al.* 2020). In terms of grain yield, distinct differences were found among barley varieties, primarily resultant from their unique characteristics and performance. The 'Arupo' variety achieved the highest grain yield, recording outputs of 1251.0 kg ha⁻¹ and 1876.4 kg ha⁻¹, surpassing other varieties in both years. Consistently, the 20 cm inter-row spacing produced the highest grain yields compared to wider spacings. Wider spacing can contribute to better yields by



improving air circulation, minimizing disease risk, and enhancing nutrient absorption (Swamy *et al.* 2020; Singh *et al.*, 2020; Gupta *et al.*, 2020). Additionally, the application of nitrogen significantly influenced grain yield, with 120 kg N ha⁻¹ leading to substantial increases compared to the control. This increase in yield is likely linked to the beneficial effects of nitrogen and spacing on yield-related attributes, such as effective tillers, which directly correlate with grain yield (Singh *et al.* 2020; Singh *et al.* 2022; Shrijana *et al.* 2022). However, it's crucial to optimize nitrogen application to reduce the risk of delaying maturity while maximizing yields, as excessive nitrogen can lead to overgrowth and postponed maturity. Significant interactions were observed between days to physiological maturity and grain yield concerning nitrogen x spacing, nitrogen x variety, and spacing x variety throughout the seasons.

Table 7: Influence of Nitrogen Rates and Inter-row Spacing on Physiological Maturity and Grain Yield kg ha⁻¹ of Barley

treatment	Physiological maturity		Grain yield (kg ha ⁻¹)	
	2021/2022	2022/2023	2021/2022	2022/2023
Genotypes (G)				
Traveler	92.36 ^a	101.28 ^a	1103.5 ^c	1651.2 ^b
Zhana	84.39 ^b	83.69 ^b	1171.0 ^b	1664.8 ^b
Arupo 's'	77.92 ^c	74.72 ^c	1251.0 ^a	1876.4 ^a
SE±	0.166	0.063	9.479	5.481
Space(S)				
20 cm	83.11 ^c	86.19 ^c	1190.7 ^a	1938.8 ^a
30 cm	84.97 ^b	86.94 ^a	1140.3 ^b	1731.4 ^b
40 cm	86.58 ^a	86.56 ^b	1194.5 ^a	1522.3 ^c
SE±	0.159	0.057	8.701	7.035
Nitrogen (kg ha⁻¹)				
Control	75.74 ^c	85.89 ^b	863.8 ^d	1478.9 ^d
80	88.26 ^a	86.11 ^b	1138.0 ^c	1789.1 ^b
100	88.03 ^{ab}	88.19 ^a	1265.9 ^b	1697.7 ^c
120	87.52 ^b	86.07 ^b	1432.9 ^a	1957.7 ^a
SE±	0.151	0.065	8.3069	5.580
Interaction				
N x S	**	**	**	**
N x V	**	**	**	**
S x V	**	**	**	**
N x S x V	NS	NS	NS	NS
			NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant

Table 8: Interaction of Nitrogen and Spacing on Days to 50% Flowering of Barley

		0 kg ha ⁻¹	80 kg ha ⁻¹	100 kg ha ⁻¹	120 kg ha ⁻¹
Spacing		2021/2022			
20 cm		53.67 ^{ef}	53.00 ^f	53.00 ^f	53.11 ^f
30 cm		55.67 ^{cd}	55.33 ^d	54.22 ^c	54.67 ^{de}
40 cm		59.11 ^a	59.89 ^a	56.56 ^{bc}	57.33 ^b
	SE±	0.389			
		2022/2023			
20 cm		58.67 ^f	58.56 ^f	61.56 ^a	59.00 ^{ef}
30 cm		60.00 ^c	59.22 ^{de}	61.11 ^a	60.00 ^c
40 cm		59.22 ^{de}	60.56 ^b	60.56 ^b	59.67 ^{cd}
	SE±	0.184			
		Combined			
20 cm		57.93 ^b	58.19 ^b	59.19 ^{ab}	58.15 ^b
30 cm		59.37 ^{ab}	59.30 ^{ab}	59.15 ^{ab}	58.70 ^{ab}
40 cm		60.22 ^{ab}	61.00 ^a	59.74 ^{ab}	59.52 ^{ab}
	SE±	0.910			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 9: Interaction of Nitrogen and Variety on Days to 50% Flowering of Barley

		0 kg ha ⁻¹	80 kg ha ⁻¹	100 kg ha ⁻¹	120 kg ha ⁻¹
Spacing		2021/2022			
20 cm		61.11 ^b	63.33 ^a	61.22 ^b	61.33 ^b
30 cm		59.00 ^c	58.33 ^c	54.78 ^e	55.89 ^d
40 cm		48.33 ^f	46.56 ^g	47.78 ^f	47.89 ^f
	SE±	0.389			
		2022/2023			
20 cm		57.78 ^g	56.44 ^h	60.33 ^c	58.33 ^f
30 cm		68.44 ^c	69.22 ^b	71.56 ^a	67.22 ^d
40 cm		51.67 ^j	52.67 ⁱ	51.33 ^j	53.11 ⁱ
	SE±	0.184			
		Combined			
20 cm		61.78 ^b	62.30 ^{ab}	63.33 ^{ab}	62.26 ^{ab}
30 cm		63.44 ^{ab}	64.59 ^a	62.93 ^{ab}	61.85 ^b
40 cm		52.30 ^c	51.59 ^c	51.82 ^c	52.26 ^c
	SE±	0.910			

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

Table 10: Interaction of Spacing and Variety on Days to 50% Flowering of Barley

Spacing	Traveler 2021/2022	Zhana	Arupo 's'
20 cm	58.58 ^d	61.58 ^b	65.08 ^a
30 cm	55.17 ^e	55.92 ^c	59.92 ^c
40 cm	45.83 ^h	47.42 ^g	49.67 ^f
SE±	0.337		
	2022/2023		
20 cm	57.58 ^d	58.50 ^c	58.58 ^c
30 cm	68.58 ^b	69.33 ^a	69.42 ^a
40 cm	52.17 ^e	52.42 ^e	52.00 ^e
SE±	0.160		
	Combined		
20 cm	61.06 ^b	62.56 ^{ab}	63.64 ^a
30 cm	62.75 ^{ab}	62.94 ^{ab}	63.92 ^a
40 cm	51.28 ^c	51.89 ^c	52.81 ^c
SE±	0.788		

Means followed by the same letter are not significantly different at 5% level of probability using DMRT

CONCLUSION AND RECOMMENDATION

It can be concluded that all the three factors (barley varieties, inter-row spacing, and nitrogen rates) have a significant influence in determining performance of the barley in the Vom, area of Nigeria. Among the genotypes Arupo's' was the best performing variety in 20 cm inter-row spacing, and nitrogen rate 120 kg N ha⁻¹ enhanced good grain yield and this can be recommended for farmers in the -area study.

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