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Effects of Variety, Nitrogen Levels and Their Interactions on Some Growth Parameters and Fibre Fractions of Two Sorghum Varieties

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Target Audience: Animal Scientists, Ruminant Nutritionist, Pasture Specialist

Abstract

Sorghum (Sorghum bicolor L. Moench) is an important cereal and forage crop in Nigeria's semi-arid regions due to its drought tolerance and adaptability to low-fertility soils. Optimizing nitrogen fertilization for different sorghum varieties can improve growth and forage quality, addressing feed shortages for ruminant livestock. This study evaluated the effects of variety, nitrogen levels (0, 60, and 120 kg N/ha), and their interactions on growth parameters (stem diameter, leaf width, tiller number) and fibre fractions (acid detergent fibre (ADF), neutral detergent fibre (NDF), lignin (LIG) of two sorghum varieties (Sweet sorghum and SAMSORG-17). A split-plot design with three replications was conducted at the National Animal Production Research Institute (NAPRI), Shika, Nigeria, during the 2024 rainy season. Results showed significant ($p<0.05$) Variety and Nitrogen interactions for stem diameter and leaf width. Samsorgh-17 exhibited a pronounced increase in stem diameter (4.43 - 7.02 cm) and leaf width (4.70 - 5.19 cm) with nitrogen application, whereas sweet sorghum showed minimal morphological response. Tillering number was unaffected by variety or nitrogen. Sweet sorghum showed improved forage quality with nitrogen, as ADF (30.68 - 30.23%), NDF (70.30 - 68.42%), and lignin (8.23 - 6.98%) decreased progressively. Conversely, SAMSORG-17 showed negligible or negative responses, with ADF slightly increasing (31.20 - 32.12%) and NDF and lignin remaining unchanged. Fibre fractions also exhibited significant interactions. These findings indicate that nitrogen fertilization enhances forage quality in biomass-oriented varieties like sweet sorghum but provides limited benefits for grain-oriented varieties like SAMSORG-17. For optimal forage quality, sweet sorghum should be cultivated with 120 kg N/ha, while Samsorgh-17 performs best under moderate nitrogen inputs (60 kg N/ha) for stable forage and grain production. Variety-specific nitrogen management is recommended to maximize sorghum productivity, improve livestock feed quality, and enhance sustainable crop-livestock systems.

KEYWORDS: Variety, Nitrogen, Growth, Fibre and Fractions

Description of Problem

Sorghum (*Sorghum bicolor L. Moench*) is a vital forage crop for ruminant livestock production in Nigeria, particularly in semi-arid regions facing feed scarcity due to climate variability and population growth. With global demand for livestock products projected to rise by 70% by 2050, optimizing forage yield and quality is crucial for sustainable livestock systems (1). Sorghum's drought tolerance and adaptability make it a strategic crop for farmers in Nigeria's arid and semi-arid zones, where water scarcity limits the cultivation of other forage species (2).

Despite its potential, sorghum forage productivity remains suboptimal due to limited knowledge about varietal responses to nitrogen fertilization and their impact on growth and quality. Sweet Sorghum is valued for its high biomass and nutritional content, while SAMSORG-17 is bred for resilience and rapid growth (3). However, farmers lack evidence-based guidelines on how these varieties perform under different nitrogen levels and how these affect growth parameters (stem diameter, leaf width, tiller number) and fiber fractions (neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin). This study addresses these gaps by systematically evaluating the effects of variety, nitrogen levels, and their interactions on these parameters. By identifying optimal variety-nitrogen combinations, the findings will guide farmers in enhancing biomass yield and forage quality for livestock feed (4).

Materials and Methods

Study location: The study was conducted during the 2024 rainy season (May–October) at the Experimental Farm of the Feed and Nutrition Research Programme, National Animal Production Research Institute (NAPRI), Shika, located 22 km northwest of Zaria, Nigeria. The site lies in the Northern Guinea Savannah agroecological zone at Latitude 11°12'N, Longitude 7°33'E, and an elevation of 660 meters above sea level. The area has a tropical wet-and-dry climate with a distinct rainy season (April–October) and dry season (November–March). Long-term climatic data indicate annual rainfall of 1,100–1,580 mm, a mean maximum temperature of 30°C, and average relative humidity of 70% during the growing season.

Meteorological data of the experimental site

Weather observations at Shika during the experimental period in 2024 are presented in Table 1. The maximum and minimum air temperatures of 34.3 °C and 22.0°C, respectively, were recorded for the months of May to October during the rainy days. The total annual rainfall of 1,169.8 mm, with an average of 195.0 mm over a period of six months was recorded in 2024. The number of rainy days in Shika was 58. A mean relative humidity of 137.7% was observed during the rainy season (5).

Treatment and experimental design

The treatment consisted of two sorghum varieties (Sweet sorghum and SAMSORG-17) and three nitrogen levels (0, 60, and 120 Nkg/ha). They were factorially combined and laid down in a split-plot design and replicated three times on a 30 m × 14 m (0.042 ha) field at the feed and feeding experimental farm of the National Animal Production Research Institute, Shika, Zaria. The design included:

The varieties as sub-plots were:
V_1 = Sweet Sorghum
V_2 = SAMSORG-17
The nitrogen levels as sub-subplots were:
N_1 = 0 Nkg/ha
N_2 = 60 Nkg/ha
N_3 = 120 Nkg/ha

This resulted in six treatment combinations ($T_1 = V_1N_1$, $T_2 = V_1N_2$, $T_3 = V_1N_3$, $T_4 = V_2N_1$, $T_5 = V_2N_2$, $T_6 = V_2N_3$), replicated three times, totalling 18 experimental plots. The field was

Table 1: Weather observation at IAR during the experimental period

Months	Max. Air Temp (^{0}C)	Min. Air Temp (^{0}C)	Rainfall (mm)	Relative Humidity (%)
May	34.3	25.3	99.2(9)	113
June	30.9	23.5	149.5(8)	136.8
July	28.6	23.3	333.4(10)	151.5
August	27.4	23.4	228.6(12)	159.3
September	29.7	22.8	316.4(15)	144
October	30.9	22.0	42.7(4)	121.6
Total			1,169.8(58)	
Mean	30.3	19.5	195.0(10)	137.7

The number of rainy days is in parentheses
Source: IAR (2024)

prepared by ploughing, harrowing and ridging to provide a clean seed bed to enhance early plant germination. The experimental field was divided into 3 main blocks, each (24m x 4m) at 1m apart, and each block was subdivided into six (6) sub-plots (4m x 4m) at 1m apart. Each plot measured 4 m × 4 m, with 1 m spacing between plots to prevent cross-treatment interference.

Source of Experimental Materials

Seeds of Sweet Sorghum (V_1) and SAMSORG-17 (V_2) were obtained from the National Animal Production Research Institute (NAPRI), Shika, and the Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria, respectively. Urea (46% N) was used as the nitrogen fertiliser source, and it was sourced from local agricultural suppliers in Zaria.

Agronomic Management

Planting: Seeds were sown manually on ridges at a depth of 2 cm in June 2024, targeting a seed rate of 15 kg/ha to achieve a plant population of approximately 53,333 plants/ha.

Fertilisation: Nitrogen was applied as urea in two equal doses: 50% at 3 weeks after sowing (WAS) and 50% at 6 WAS to ensure optimal nutrient availability during vegetative and reproductive growth stages.

Weeding: Manual hoeing was performed at 3 and 6 WAS to control weeds and minimize competition for nutrients and water.

Parameters Measured

Growth Parameters: Data on crop phenology of the treatment combinations were measured at 6, 8, and 12 weeks after sowing. Five (5) plants were randomly selected and tagged per plot for the measurements of various agronomic parameters using the standard procedure as reported by (6). The following growth parameters were measured on the five randomly tagged plants per plot at 6, 8, and 12 weeks after sowing: Forage sampling was done at 8 and 12 weeks after sowing for chemical analysis.

Leaf Width (cm): Leaf width was determined by measuring the width of the leaf halfway or midpoint of the leaf length with the aid of a 30cm meter rule on the 5 randomly tagged plants per plot for all the leaves on the plants at 6, 8, and 12 weeks after sowing.

Stem Diameter (cm): Measured at the second internode by wrapping a cloth-sewing rope around the stem to determine its circumference, then placing the rope on a ruler to convert to centimetres.

Tiller Number: Tiller number was determined by counting the number of tillers of 5 of the randomly tagged plants per plot at 6,8, and 12 weeks after sowing

Chemical analysis

Forage samples harvested at 8 and 12 weeks, respectively, were analysed for Acid detergent fibre (ADF), neutral detergent fibre (NDF) and lignin using the standard procedure described by (7) at the Department of Animal Science Laboratory, Ahmadu Bello University, Zaria.

Statistical Analysis

Data were analysed using analysis of variance (ANOVA) in (8) to evaluate the effects of variety and nitrogen levels and their interactions on growth parameters, and fibre fractions. Significantly different means were compared using least significant differences (LSD) at 5% ($P \leq 0.05$) probability level of the SAS package.

The statistical model:

$Y_{ij} = \mu + V_i + N_j + (V \times N)_{ij} + E_{ij}$

Where:

Y_{ij} = observation

μ = population mean

V_i = effect of variety (V_1 = Sweet sorghum, V_2 = Samsorgh-17)

N_j = effect of nitrogen level (N_1 = 0 Nkg/ha, N_2 = 60 Nkg/ha, N_3 = 120 Nkg/ha)

$(V \times N)_{ij}$ = interaction effect of variety and nitrogen

E_{ij} = random error

Results and Discussion

Main Effects of Varieties and Nitrogen Levels on Growth Parameters of Sorghum

The main effects of two sorghum varieties and three nitrogen levels on the fibre fractions, are presented in Table 2.

Effect of Variety on Growth Parameters: The result showed there were no significant ($P > 0.05$) difference between the two varieties in terms of stem diameter and tiller number with samsorgh-17 sorghum variety having a numerically higher (5.90) stem diameter as compared to sweet sorghum variety while the sweet sorghum variety having a numerically higher (2.19) tiller number than samsorgh-17 sorghum variety. The result also showed a significant ($P < 0.05$) difference in leaf width between the two sorghum varieties. SAMSORG-17 exhibited a higher mean leaf width of 4.74 cm, which was significantly higher than the 3.48 cm recorded for sweet sorghum. The results showed that varietal differences significantly affected leaf width but not stem diameter or tiller number. This result agrees with the findings of (9), who reported that grain sorghum varieties like SAMSORG-17 have a higher leaf-to-stem ratio due to their breeding focus on grain and forage balance rather than extreme biomass accumulation.

Effect of Nitrogen Levels on Growth Parameters: The result showed there was no significant (P> 0.05) effect of nitrogen levels on all the parameters measured. The result also showed that stem diameter (SD) and leaf width (LW) experienced a progressive numerical increase with increasing nitrogen levels. Despite this trend, the differences among the nitrogen levels were not statistically significant (P > 0.05). SAMSORG-17 showed a pronounced increase in stem diameter and leaf width with higher nitrogen levels, while Sweet Sorghum maintained similar values across treatments. This suggests that SAMSORG-17 is more nitrogen-responsive in vegetative growth, consistent with (10), who found that moderate nitrogen application (60–120 kg N/ha) significantly enhanced morphological traits in SAMSORG-17 without excessive luxury growth. The lack of significant nitrogen effects on tillering agrees with (11), who noted that sorghum tillering is more genetically controlled and less influenced by nitrogen beyond a certain threshold. Sweet Sorghum's minimal nitrogen response could be due to its longer vegetative cycle, which prioritises stem elongation and sugar accumulation rather than rapid nitrogen uptake (12). Thus, while nitrogen enhances biomass in Samsorgh-17 by improving individual plant size (SD and LW), it does not affect tiller production in either variety.

Interaction Effects of Variety and Nitrogen Levels on Growth Parameters

The interaction effects of two sorghum varieties and three nitrogen levels are presented in Table 3.

Interaction Effects on Growth Parameters: There was a significant ($p<0.05$) Variety × Nitrogen interaction for stem diameter (SD) and leaf width (LW), indicating that the two sorghum varieties responded differently to nitrogen fertilisation. Samsorgh-17 showed a pronounced increase in SD (4.43 - 7.02 cm) and LW (4.70 - 5.19 cm) with higher nitrogen levels, while sweet sorghum maintained similar SD (4.24 - 4.42 cm) and only a modest increase in LW (2.86 - 3.83 cm). Tillering number (TN) was not significantly affected ($p>0.05$), indicating no varietal or nitrogen response. This interaction suggests that Samsorgh-17 is more nitrogen-responsive in vegetative growth, whereas sweet sorghum shows minimal response to nitrogen application. A significant Variety × Nitrogen interaction was observed for stem diameter (SD) and leaf width (LW), showing that the two sorghum varieties responded differently to nitrogen fertilisation. Specifically, SAMSORG-17 exhibited a marked increase in SD (4.43–7.02 cm) and LW (4.70–5.19 cm) with increasing nitrogen levels, whereas sweet sorghum showed minimal variation in SD (4.24–4.42 cm) and only a modest improvement in LW (2.86 – 3.83 cm) across nitrogen treatments.

This differential response can be attributed to the genetic growth habits of the two varieties. SAMSORG-17, being a dual-purpose grain-forage variety, has a shorter vegetative cycle and greater nutrient partitioning efficiency, allowing it to rapidly utilise moderate-to-high nitrogen for vegetative expansion (9). In contrast, sweet sorghum, which is bred primarily for biomass and sugar accumulation, inherently maintains a longer vegetative phase, resulting in slower nitrogen responsiveness under the same growth period (12).

These findings are consistent with (10), who reported that grain sorghum varieties like SAMSORG-17 show a linear increase in leaf width and stem diameter up to 120 kg N/ha, while Sweet Sorghum's growth was higher due to its delayed nitrogen uptake dynamics. Moreover, the minimal nitrogen-induced tillering response in both varieties suggests that tiller number is less nitrogen-dependent and more controlled by varietal genetics, as noted by (11).

Agronomically, this means: SAMSORG-17 benefits from nitrogen fertilisation for vegetative growth, making it ideal for moderate-intensity forage systems where rapid canopy development is needed. Sweet Sorghum requires a longer growth duration or higher cumulative nitrogen for full biomass expression, which aligns with its role in high-biomass silage or bioenergy systems.

Thus, the interaction implies that nitrogen management should be variety-specific, with SAMSORG-17 achieving optimal vegetative gains at 60 – 120 kg N/ha, while sweet sorghum may need higher nitrogen and/or extended growth periods to fully utilize additional fertilizer.

Table 2: Main Effect of Varieties and Nitrogen Levels on Growth Parameters

	SD	LW	TN
Varieties			
Sweet sorghum	4.33	3.48^{b}	2.19
SAMSORGH-17	5.90	4.74^{a}	2.15
SEM	0.88	0.60	0.80
LOS	NS	*	NS
Nitrogen level (Nkg/ha)			
0	4.38	3.78	2.11
60	5.34	4.09	2.00
120	5.63	4.47	2.39
SEM	1.32	0.90	1.21
LOS	NS	NS	NS

SEM = Standard Error of Mean; LOS = Level of Significance; NS = Not Significant; * = Significant at $P < 0.05$. Means within the same column for each factor with different superscripts (a, b) differ significantly ($P < 0.05$).

Table 3: Interaction Effects of Varieties and Nitrogen Levels on Growth Parameters

Varieties	Nitrogen Level (Nkg/ha)	SD	LW	TN
Sweet sorghum	0	4.32^{b}	2.86^{d}	2.33
	60	4.42^{b}	3.83^{c}	1.89
	120	4.24^{b}	3.74^{c}	2.33
Samsorgh-17	0	4.43^{b}	4.70^{ab}	1.89
	60	6.26^{a}	4.34^{bc}	2.11
	120	7.02^{a}	5.19^{a}	2.44
SEM		0.44	0.30	0.40
LOS		*	*	NS

SEM = Standard Error of Mean; LOS = Level of Significance; NS = Not Significant; * = Significant at $P < 0.05$. Means within the same column with different superscripts (a, b, c, d) differ significantly ($P < 0.05$).

Main Effects of Variety and Nitrogen Levels on Fibre Fractions

The main effects of two sorghum varieties and three nitrogen levels on the fibre fractions, are presented in Table 4.

Effect of Varieties on Fibre Fractions: The result showed there was no significant difference between the varieties ($P > 0.05$) on Acid Detergent Fibre (ADF), with samsorgh-17 having a higher (31.57) numerical value as compared to sweet sorghum (30.44). The result also showed a significant ($P<0.05$) difference between the varieties Neutral Detergent Fibre (NDF) and lignin. The Neutral Detergent Fibre (NDF) and lignin were statistically higher, 70.51 and 8.20, respectively, in the samsorgh-17 sorghum variety as compared to the sweet sorghum variety. For fibre composition, SAMSORG-17 had significantly higher NDF and lignin content compared to sweet sorghum, although ADF was not significantly different. This aligns with (13), who reported that grain sorghum varieties often accumulate more structural carbohydrates due to their higher stem density, leading to higher NDF and lignin.

Effect of Nitrogen Levels on Fibre Fractions: The result showed that nitrogen did not significantly ($P>0.05$) affect Acid Detergent Fibre (ADF), and it was numerically higher at 120 Nkg/ha. The result also showed there was a significant ($P<0.05$) effect of nitrogen levels on Neutral Detergent Fibre (NDF) and lignin. The Neutral Detergent Fibre (NDF) was statistically higher (70.35) at 0 Nkg/ha, and it was statistically similar at 60 Nkg/ha and 120 Nkg/ha. The lignin content was statistically higher (8.18) at 0 Nkg/ha, while statistically similar between 0 Nkg/ha and 60 Nkg/ha. The lignin content also showed that it was statistically similar between 60 Nkg/ha and 120 Nkg/ha. Nitrogen application significantly influenced NDF and lignin, where higher nitrogen reduced fibre fractions

Table 4: Main Effect of Varieties and Nitrogen Levels on the Fibre Fractions of Two Sorghum Varieties

	ADF	NDF	LIG
Variety			
Sweet sorghum	30.44	69.10^{b}	7.62^{b}
Samsorgh-17	31.57	70.51^{a}	8.20^{a}
SEM	0.62	0.29	0.25
LOS	NS	*	*
Nitrogen Level (Nkg/ha)			
0	30.94	70.35^{a}	8.18^{a}
60	30.91	69.52^{b}	8.01^{ab}
120	31.18	69.55^{b}	7.54^{b}
SEM	0.76	0.36	0.31

in sweet sorghum but had negligible effects on SAMSORG-17. Sweet sorghum showed a consistent reduction in ADF, NDF, and lignin with increasing nitrogen levels, indicating improved forage quality with fertilisation.

This observation agrees with (14), who demonstrated that nitrogen enhances leaf growth (which is lower in fibre) relative to stem tissue, thereby improving forage digestibility. However, at very high nitrogen rates, some studies (10) reported slight increases in lignin due to excessive vegetative growth, a trend partially observed in SAMSORG-17 at 120 N/ha.

Interaction Effects of Variety and Nitrogen Levels on Fibre Fractions of Sorghum

The interaction effects of two sorghum varieties and nitrogen levels are presented in Table 5.

There was a significant ($p<0.05$) Variety × Nitrogen interaction for all fibre fractions (ADF, NDF, and lignin). Sweet sorghum showed a consistent reduction in ADF (30.68 - 30.23%), NDF (70.30 to 68.42%), and lignin (8.23 to 6.98%) with increasing nitrogen levels, indicating improved forage quality. Conversely, Samsorgh-17 exhibited an opposite or negligible response, with ADF increasing (31.20 - 32.12%), while NDF (70.39 - 70.68%) and lignin (8.13 - 8.37%) remained unaffected by nitrogen. This crossover interaction suggests that nitrogen fertilisation enhances the nutritive value of sweet sorghum but not Samsorgh-17. Therefore, sweet sorghum at 120 kg N/ha provides the best fibre composition for high-quality forage. The Variety × Nitrogen interaction for fibre fractions is particularly important. Sweet sorghum benefited from higher nitrogen (120 kg N/ha), showing reduced lignin (6.98%) and NDF (68.42%), making it more digestible and suitable for ruminant feed. In contrast, SAMSORG-17 showed no quality improvement with nitrogen, indicating that it is better suited for moderate nitrogen conditions (60 kg N/ha), as also suggested by (9).

Table 5: Interaction Effects of Varieties and Nitrogen Levels on the Fibre Fractions of Two Sorghum Varieties

Variety	Nitrogen Levels (Nkg/ha)	ADF	NDF	LIG
Sweet sorghum	0	30.68^{b}	70.30^{a}	8.23^{a}
	60	30.41^{cd}	68.58^{b}	7.65^{b}
	120	30.23^{d}	68.42^{b}	6.98^{c}
Samsorgh-17	0	31.20^{bc}	70.39^{a}	8.13^{a}
	60	31.40^{ab}	70.45^{a}	8.37^{a}
	120	32.12^{a}	70.68^{a}	8.10^{a}
SEM		0.44	0.21	0.18
LOS		*	*	*

Conclusion and Application

This study demonstrated that sorghum varieties exhibit distinct responses to nitrogen fertilisation in both growth parameters and fibre fractions. Growth parameters (stem diameter and leaf width) of Samsorgh-17 was more responsive to nitrogen, showing significant increases at higher nitrogen rates, while sweet sorghum remained relatively unchanged. Tillering number was unaffected by variety or nitrogen. Fibre fractions (ADF, NDF, lignin) of sweet sorghum showed improved forage quality with increasing nitrogen, while Samsorgh-17 displayed negligible or negative responses.

Variety and nitrogen interactions were significant for both growth and fibre quality, confirming that nitrogen fertilisation should be variety-specific. Sweet sorghum at 120 kg N/ha is the best combination for high-quality forage production, whereas Samsorgh-17 performs best under moderate nitrogen inputs (60 kg N/ha) for stable forage quality. For livestock feed-focused production, farmers should adopt sweet sorghum with 120 kg N/ha to achieve optimal forage quality (lower fibre fractions and lignin) and for low-input systems or dual-purpose use (grain and fodder), Samsorgh-17 at 60 kg N/ha is recommended due to its stable fibre composition and better nitrogen use efficiency.

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