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Effect of Variety, Nitrogen Levels and their Interactions on Proximate and Mineral Composition of Sorghum

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Abstract

This study was conducted to evaluate the effects of variety and nitrogen fertilization on the proximate and mineral composition of sorghum forage. Two sorghum varieties (Sweet Sorghum and SAMSORG-17) were cultivated under three nitrogen levels (0, 60, and 120 kg N/ha) in a split-plot design with three replications during the 2024 rainy season at the National Animal Production Research Institute (NAPRI), Shika, Zaria, Nigeria. Forage samples harvested at 8 and 12 weeks after sowing were analyzed for proximate (dry matter, crude protein, crude fiber, ether extract, ash, and nitrogen-free extract) and mineral (calcium, magnesium, potassium, and phosphorus) composition using standard procedures. The results revealed that both variety and nitrogen levels significantly (P<0.05) influenced most proximate parameters. Sweet sorghum recorded higher values of dry matter (97.26%), crude protein (7.94%), and nitrogen-free extract (61.47%), indicating superior forage quality. In contrast, SAMSORG-17 exhibited significantly higher crude fiber (30.46%), ash content (7.93%), and potassium concentration (1.85%), reflecting its grain-oriented genetic makeup. Nitrogen application significantly improved crude protein content, with the highest value (7.92%) obtained at 60 kg N/ha, while dry matter and NFE were highest at 120 kg N/ha. Crude fiber decreased progressively with increasing nitrogen, suggesting enhanced digestibility at higher nitrogen levels. However, ether extract and most mineral components, except potassium, were not significantly influenced by variety or nitrogen level. Significant interaction effects (P<0.05) between variety and nitrogen level were observed for all proximate traits and for calcium and potassium among the minerals. Sweet sorghum responded positively to nitrogen fertilization, particularly at 60 kg N/ha, showing notable improvements in crude protein and energy composition. In contrast, SAMSORG-17 showed minimal nutritional response to increasing nitrogen rates. The study concludes that Sweet Sorghum fertilized at 60 kg N/ha is best suited for forage production due to its favorable nutritional profile and efficient nitrogen response. The findings emphasize the need for variety-specific nutrient management strategies to optimize sorghum forage quality, improve livestock productivity, and enhance sustainable agricultural practices in Northern Guinea Savannah regions.

Keywords: Sorghum, Variety, Nitrogen, Proximate and Mineral

Description of Problem

Sorghum residues are becoming important feed sources for livestock raised by resource-poor smallholders in southern Asia and sub-Saharan Africa (1). However, attributes relating to crop residue improvement have been largely ignored, with emphasis being placed on grain yield. Forage sorghum plays a vital role in the agricultural economy of developing countries by providing production systems with cheap sources of feed for livestock due to its drought and disease resistance (2; 3). It is an important source of nourishment for ruminants in many countries due to their high forage characteristics (4). 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 (5). Forage shortage during the scarcity period can be reduced by the introduction of the high-yielding cultivars (6). Different sorghum cultivars vary in both fodder yield and quality (7; 8; 6). The introduction of high-yielding crop varieties is the most suitable option to fulfil forage shortage (8).

Even though less research has been done on the effect of variety and nitrogen level and their interactions on the proximate and mineral composition of sorghum itself in the area of animal nutrition, at the moment, there is information on the proximate and mineral composition of sorghum. There is also limited research on the effect of variety and nitrogen level and their interactions on proximate and mineral composition of sorghum as animal feed in this region. Thus, the present study aims to analyze the proximate and mineral composition, as well as their interactions, in sorghum and its feasibility for use as animal feed, with the economic benefit of farmers in mind.

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 (9).

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

Table 1: Weather observation at IAR during the experimental period

Months	Max. Air Temp (^0C)	Min. Air Temp (^0C)	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)

mean relative humidity of 137.7% was observed during the rainy season.

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 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.

Chemical Analysis

Forage samples harvested at 8 and 12 weeks after sowing, respectively, were analysed for dry matter (DM), Ash, crude fibre (CF), crude protein (CP), ether extract (EE) and nitrogen-free extract (NFE) using the standard procedure as described by (10). Mineral contents such as Sodium (Na), Calcium (Ca), Potassium (K), Magnesium (Mg), and Phosphorus (P) were determined by (10) methods using the Atomic Absorption Spectrophotometer at the Department of Animal Science laboratory, Ahmadu Bello University, Zaria.

Statistical Analysis

Data were analysed using analysis of variance (ANOVA) in (11) to evaluate the effects of variety and nitrogen levels and their interactions on proximate and mineral composition of sorghum. 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 Proximate Composition of Sorghum: The effect of variety and nitrogen levels on the proximate composition of sweet sorghum and samsorgh-17 sorghum varieties forages is presented in Table 2.

Effect of variety: The dry matter contents (DM), crude protein, crude fibre, ash, and nitrogen-free extracts (NFE) were significantly different ($P<0.05$), as influenced by variety. The dry matter contents (97.26%), crude protein (7.94%), and nitrogen free extract (61.47%) were highest in the sweet sorghum variety, while the crude fibre (30.46%) and Ash (7.93%) were highest in the samsorgh-17 sorghum variety. The data showed that sweet sorghum significantly outperformed SAMSORG-17 in terms of dry matter (DM), crude protein (CP), and nitrogen-free extract (NFE). This aligns with the report of (12), who noted that sweet sorghum generally contains higher sugar and protein content, particularly in the leaf and stem tissues. The high NFE in sweet sorghum is indicative of its superior energy value, making it suitable for

Table 2: Main effect of varieties and nitrogen levels on the proximate composition of sorghum

	DM	CP	CF	EE	ASH	NFE
Variety						
Sweet sorghum	97.26^{a}_{b}	7.94^{a}_{b}	24.33^{b}	0.38	5.94^{b}	61.47^{a}_{b}
Samsorgh-17	95.98	6.72	30.46^{a}	0.35	7.93^{a}	54.56
SEM	0.32	0.03	0.00	0.07	0.03	0.51
LOS	*	*	*	NS	*	*
Nitrogen Level (Nkg/ha)						
0	96.22^{b}	7.17^{b}	29.03^{a}	0.37	7.09^{a}	56.36^{b}
60	96.24^{b}	7.92^{a}	27.00^{b}	0.41	7.13^{a}	57.58^{b}
120	97.40^{a}	6.91^{c}	26.16^{c}	0.32	6.58^{b}	60.12^{a}
SEM	0.39	0.04	0.10	0.08	0.04	0.63
LOS	*	*	*	NS	*	*

[abc]Means with different superscripts along the same row are significantly ($P<0.05$) different, SEM: standard error of means, LOS: levels of significance, *: Significant, NS: Not significant

livestock feeding and biofuel applications. In contrast, SAMSORG-17 recorded significantly higher crude fiber (CF) and ash content, which supports the assertion by (13) that this variety is primarily cultivated for its grain, and hence may contain more fibrous structural material. High fiber content, while important for roughage, is often associated with lower digestibility and may not be desirable in high-energy animal feed formulations. Nonetheless, such traits might be advantageous in extensive grazing systems where the feed quantity is more important than nutrient density or quality.

Effect of nitrogen level: The dry matter content (DM), crude protein, crude fibre, ash, and nitrogen-free extracts (NFE) were significantly different ($P<0.05$), as influenced by nitrogen level. The dry matter (97.40%) and nitrogen-free extract (60.12%) were highest at 120Nkg/ha, while the crude protein (7.92%) and crude fibre (29.03%) were highest at 60Nkg/ha and 0Nkg/ha, respectively. The dry matter, ash, and nitrogen-free extract were statistically similar at 0Nkg/ha and 60Nkg/ha, respectively. The dry matter (DM) and nitrogen-free extract (NFE) increase as the nitrogen level is increased, while the crude fibre decreases as the nitrogen level is increased. Nitrogen application had a clear effect on the chemical composition of both varieties. Nitrogen fertilization significantly increased dry matter content and crude protein, particularly at 60 kg N/ha, while it decreased crude fiber content. These results are in line with findings by (14) and (15), who emphasized that nitrogen plays a critical role in amino acid and protein synthesis in forage crops. The increase in CP with nitrogen is also supported by (16) and (17), who noted that sweet sorghum responds positively to nitrogen up to moderate levels, beyond which the benefits may decline.

The highest CP was recorded at 60 kg N/ha, and not at 120 kg N/ha. This suggests that sweet sorghum and SAMSORG-17 may not benefit from excessive nitrogen input in terms of protein quality, and excessive nitrogen could lead to nutrient imbalance or environmental leaching. This agrees with (18), who reported diminishing returns and environmental risks with nitrogen levels above 120 kg/ha. For crude fiber, a decreasing trend was observed with increasing nitrogen levels. This supports the view that nitrogen can stimulate the development of more tender, less lignified tissues, which improves digestibility (19). Conversely, ash content and ether extract (EE) did not show significant trends across nitrogen treatments, suggesting that some nutrient traits are less responsive to nitrogen fertilization and may be more dependent on inherent varietal genetics or environmental interactions.

Interaction Effects of Variety and Nitrogen Levels on Proximate Composition of Sorghum

Table 3 shows how the combined effect of variety and nitrogen levels influences the proximate composition of sorghum.

There was a significant ($p<0.05$) interaction between sorghum variety and nitrogen level for all proximate parameters, indicating that the response to nitrogen varied between varieties. Sweet sorghum showed improved crude protein and nitrogen-free extract at moderate nitrogen (60–120 kg N), while Samsorgh-17 showed minimal response and even increased crude fibre with higher nitrogen. Thus, nitrogen fertilisation should be optimised for each variety, with sweet sorghum benefiting more from moderate nitrogen levels compared to Samsorgh-17. The interaction between variety and nitrogen level was significant for all proximate parameters. Sweet sorghum showed the most marked improvement in CP and NFE at moderate nitrogen levels (60 kg/ha), while SAMSORG-17 responded poorly to nitrogen, particularly at higher doses. This differential response mirrors the findings of (20), who reported that certain sweet sorghum genotypes are more efficient at utilizing applied nitrogen to boost quality traits. SAMSORG-17, being a grain-dominant type, may partition nitrogen more toward reproductive growth and grain filling than toward vegetative tissues, thereby limiting its forage quality improvements.

Table 3: Interaction effects of varieties and nitrogen levels on the proximate composition of sorghum

Variety	NL	DM	CP	CF	EE	ASH	NFE
Sweet sorghum	0	96.39^{c}	7.68^{b}	28.32^{c}	0.38^{ab}	5.61^{e}	58.03^{c}
	60	97.96^{a}	8.79^{a}	23.58^{d}	0.43^{a}	6.62^{d}	60.60^{b}
	120	97.44^{b}	7.35^{c}	21.09^{e}	0.33^{b}	5.58^{c}	65.78^{a}
Samsorgh-17	0	96.05^{C}	6.67^{e}	29.73^{b}	0.36^{ab}	8.57^{a}	54.68^{d}
	60	94.51^{d}	7.04^{d}	30.43^{b}	0.38^{ab}	7.64^{b}	54.55^{d}
	120	97.37^{b}	6.46^{f}	31.23^{a}	0.30^{b}	7.58^{c}	54.45^{d}
SEM		0.22	0.02	0.40	0.05	0.02	0.36
LOS		*	*	*	*	*	*

abcdef Means with different superscripts along the same row are significantly ($P<0.05$) different, SEM: standard error of means, LOS: levels of significance, NL: Nitrogen Level*: Significant, NS: Not significant.

Main Effects of Variety and Nitrogen Levels on Mineral Composition of Sorghum

The effect of variety and nitrogen level on mineral composition of *Sorghum bicolor* forages is presented in Table 4.

Effect of variety: The results show that potassium (K) differed significantly ($P<0.05$) among varieties, with the highest (1.85 %) obtained in the samsorgh-17 sorghum variety. SAMSORG-17 recorded significantly higher potassium content than sweet sorghum, which is consistent with findings by (21), who reported that varietal genetics significantly influence mineral uptake and accumulation in sorghum tissues. Though other minerals like calcium (Ca) and magnesium (Mg) were not statistically different across varieties, SAMSORG-17 showed numerically higher values, suggesting potential varietal capacity for higher mineral retention under certain soil or climatic conditions.

Interaction Effects of Variety and Nitrogen Levels on Mineral Composition of Sorghum

There was a significant ($p<0.05$) interaction between variety and nitrogen levels for calcium and potassium, indicating that the two varieties responded differently to nitrogen fertilization for these minerals. Samsorgh-17 showed a progressive increase in calcium with nitrogen, while sweet sorghum remained relatively stable. Potassium content in samsorgh-17 peaked (1.15) at 60 kg N, whereas sweet sorghum increased gradually with nitrogen. In contrast, magnesium and phosphorus did not show significant interaction, suggesting a uniform response across varieties. Thus, variety-specific nitrogen management is necessary for optimizing calcium and potassium composition in sorghum. In terms of mineral interaction, potassium and calcium showed significant variety-by-nitrogen interactions. SAMSORG-17 exhibited a linear increase in calcium content with nitrogen application, while sweet sorghum remained stable. Potassium levels in SAMSORG-17 peaked at 60 kg N/ha, while sweet sorghum showed a gradual increase across nitrogen levels. These findings reinforce the view by (22) that mineral uptake under nitrogen influence is highly genotype-

Table 4: Main effect of varieties and nitrogen levels on the mineral composition of sorghum

	Ca	Mg	K	P
Variety				
Sweet sorghum	0.11	0.14	1.08[b]	0.12
Samsorgh_17	0.17	0.16	1.85[a]	0.11
SEM	0.05	0.07	0.14	0.11
LOS	NS	NS	*	NS
Nitrogen Level (Nkg/ha)				
0	0.13	0.15	1.30	0.10
60	0.14	0.15	1.65	0.10
120	0.14	0.14	1.45	0.14
SEM	0.06	0.08	0.42	0.22
LOS	NS	NS	NS	NS

[ab]Means with different superscripts along the same row are significantly ($P<0.05$) different, SEM: standard error of means, LOS: levels of significance, *: Significant, NS: Not significant.

Table 5: Interaction effects of varieties and nitrogen levels on the miner al composition of sorghum

Variety	Nitrogen Levels (Nkg/ha)	Ca	Mg	K	P
Sweet sorghum	0	0.12^{b}	0.14	0.90^{b}	0.10
	60	0.12^{b}	0.13	1.15^{b}	0.09
	120	0.10^{b}	0.14	1.20^{b}	0.16
Samsorgh-17	0	0.15^{ab}	0.16	1.70^{a}	0.11
	60	0.17^{ab}	0.17	2.15^{a}	0.11
	120	0.19^{a}	0.14	1.70^{a}	0.12
SEM		0.03	0.05	0.24	0.13
LOS		*	NS	*	NS

[ab]Means with different superscripts along the same row are significantly (P<0.05) different, SEM: standard error of means, LOS: levels of significance, *: Significant, NS: Not significant.

specific and requires tailored management practices to optimize nutritional outcomes.

Conclusion and Application

This study concludes that both sorghum variety and nitrogen level significantly influence the nutritional quality of sorghum forage. Sweet sorghum emerged as the superior variety in terms of protein content and energy availability, which are key determinants of forage quality. The findings reveal that moderate nitrogen fertilization (60 kg N/ha) enhances the nutritive value of sorghum, especially in sweet sorghum, by increasing crude protein and nitrogen-free extract while reducing crude fiber. In contrast, SAMSORG-17, although higher in fiber and potassium content, showed limited response to nitrogen in terms of forage quality improvement, reflecting its grain-focused breeding background. These outcomes underscore the importance of integrating varietal selection with site-specific nitrogen management to achieve both agronomic efficiency and nutritional targets in sorghum production systems. Based on the findings of this study, sweet Sorghum is encouraged for forage production, especially in regions where protein-rich animal feed is in demand. Its superior nutritional profile and positive response to nitrogen application make it ideal for livestock systems. Nitrogen fertilization at 60 kg N/ha is recommended for optimum crude protein enhancement and overall feed quality, balancing both economic and environmental sustainability. SAMSORG-17 may be best utilized where higher fiber or potassium is required in feed formulations. However, its limited response to nitrogen suggests that higher rates may not be cost-effective.

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