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GRAIN PHYSICAL QUALITIES OF TWO SORGHUM (*Sorghum bicolor* (L.) Moench) VARIETIES AS AFFECTED BY COWDUNG AND INORGANIC NITROGEN IN NORTHERN GUINEA SAVANNA ECOLOGICAL ZONE, NIGERIA.

¹L. Goma, ¹H. Mani, ¹S.I Isa, ¹D.O Akinola and ²S.M Bature

¹Department of Agronomy, Faculty of Agriculture, Ahmadu Bello University, Zaria. ²College of Animal Science, Division of Agricultural Colleges, Ahmadu Bello University, Zaria.

Corresponding Author E-mail: lawal.goma@gmail.com

Abstract

Two sorghum varieties (SAMSORG-17, and SAMSORG-44) were grown at four rates of nitrogen fertilizer (0, 30, 60 and 90 kg Nha⁻¹) and cow dung (0, 5, 10 and 15 tons ha⁻¹). Treatments were laid out in a split plot design and replicated three times with nitrogen and cow dung rates assigned in the main plot while the varieties were assigned in the sub-plots. Grain physical quality characters such as hundred grains weight, density, volume, and grain size of the two sorghum varieties were significantly affected by application of cow dung and inorganic nitrogen fertilizer. Hundred grain weight and density were significantly enhanced at Samaru only. Increase of every 5 t ha⁻¹ of cow dung, significantly increased the parameters but the increase did not maintain a regular pattern as it was in the case of inorganic N fertilizer rate. SAMSORG-17 consistently performed better than SAMSORG-44 variety in all the grain physical quality characters studied in both years and locations. The sorghum varieties studied had grain size in the range of 1.99 - 3.69mm respectively. The grain physical quality parameters obtained exhibited differences among the varieties and some of the values found were within the acceptable limit of breweries even though none of the varieties fulfill all the quality requirements.

Keywords: variety, cow dung and nitrogen.

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is widely grown in the tropics and subtropics where it serves as a major staple food for humans and feed for livestock. Its tolerance to drought and diverse uses make it an important crop for improving the livelihoods of smallholder farmers in semi-arid regions (Rao *et al.*, 2009). The crop is regarded as one of the most important staple cereals in Africa, South Asia, and Central America, providing a major source of energy and dietary protein for millions of people (FAO, 2015).

In Nigeria and many parts of sub-Saharan Africa, sorghum grains are consumed in several forms, including boiled grain, popped grain, flour for thick porridge (tuwo), light porridge (akamu), composite bread, and snacks. The grain is also processed into traditional beverages such as non-

alcoholic *kunu* and alcoholic *burukutu*, while malted sorghum is used for sweet drinks and as a raw material in brewing industries, where it increasingly substitutes barley. Some sorghum varieties are also being evaluated for sugar production. Improved varieties with high malting quality released by the Institute for Agricultural Research have replaced barley in brewing; however, the influence of agronomic practices on their malting quality still requires further evaluation (Rao *et al.*, 2009; FAO, 2015).

Adequate fertilization using both organic and inorganic sources is important for achieving optimum sorghum yield and desirable grain physical quality. However, limited information exists in Nigeria on nitrogen uptake and its effects on grain quality when organic and inorganic fertilizers are combined. Popular malting and brewing sorghum varieties, SAMSORG-17 and SAMSORG-44 (short Kaura types), have not been adequately evaluated for their response to soil fertility management. Consequently, their nitrogen requirements from combined organic and inorganic sources, and the effects on growth, yield, and grain physical characteristics in the Northern Guinea Savanna, remain unclear.

This study was therefore conducted to: (i) compare the grain physical qualities of the two short Kaura varieties, (ii) evaluate the effect of cow dung on their grain physical qualities, and (iii) determine the influence of inorganic nitrogen fertilizer on the grain physical qualities of the two sorghum varieties.

Methodology

Grain physical quality of two sorghum varieties were determined in 2019 and 2020. The grain used were harvested and stored for seven years under ambient temperature conditions to determine their quality. The field experiments were conducted at the Research Farm of the Institute for Agricultural Research, Samaru (11°11'N, 7°38'E and 686 m above sea level,) and Kaduna State Agricultural Project, Maigana (11°39'N, 8°02'E and 500 m above sea level) to study the growth, yield and malting physical quality of two sorghum varieties as affected by cow dung and inorganic nitrogen fertilizer during the 2013 and 2014 rainy seasons in the Northern Guinea Savanna of Nigeria. The experiment consisted of two sorghum varieties (SAMSORG-17 and SAMSORG-44), four nitrogen rates (0, 30, 60 and 90 kg N ha⁻¹) and four cow dung rates (0, 5, 10 and 15 t ha⁻¹) arranged in a split-plot design with three replications. Nitrogen and cow dung were assigned to main plots, while varieties were allocated to sub-plots measuring 6.0 m × 4.5 m, with a net plot of 4.0 m × 1.5 m.

Well-rotted cow dung was crushed and incorporated along ridge crests two weeks before sowing. Urea, single super phosphate, and muriate of potash were applied two weeks after sowing to supply N, P, and K, respectively. Nitrogen was split at 2 and 6 weeks after sowing, while phosphorus and potassium were applied at 32 kg P₂O₅ and 30 kg K₂O ha⁻¹ by side dressing at 5 cm depth, about 8 cm away from plants

Grain Physical properties

The physical properties of sorghum grain measured included weight, volume, density and size of 100 grains randomly selected from each net plot, measured and recorded as follows:

Grain size (mm)

From each lot of 100 grains ten were randomly picked to measure their respective sizes. The two principal dimensions of the grain (length and breadth) of each variety were measured and average value were taken and recorded per each net plot using a Mitutoyo 500-196-20 Digital Vernier

Calliper 150mm / 6inch model (+0.01 mm) according to the modified method of (Suleman *et al.*, 2019).

100 grains weight (g)

The 100 grains were weighed using mettler Toledo electronic weighing balance P1210 and their weight was recorded in grammes (g).

100 grains volume (ml)

This was determined using water displacement method (Archimedes principle) as described by Karababa and Coşkuner (2013).

The 100 grains were poured in a known volume of water in a measuring cylinder and the displaced volume of water was measured to give volume of the 100 grains.

100 grains density (g ml⁻¹)

The density of the 100 grains was determined by its mass over volume according to Mohsenin (2020) as follows:

$$\text{Density} = \frac{Gw}{Gv} \text{ (g ml}^{-1}\text{)}$$

Where Gw referred to grain weight and Gv was the grain volume.

Results

Grain size (mm)

Grain size of the two sorghum varieties increased significantly with higher nitrogen and cow dung rates during the 2019 and 2020 wet seasons at both Samaru and Maigana (1a). Incremental application of 30 kg N ha⁻¹ and 5 t ha⁻¹ cow dung each resulted in significant improvements in grain size. When data were combined across years and locations, 15 t ha⁻¹ cow dung produced the highest grain size, although it was statistically similar to 10 t ha⁻¹, and both were superior to 0 and 5 t ha⁻¹, which recorded the lowest and comparable values.

SAMSORG-17 consistently produced significantly larger grains than SAMSORG-44 across locations and years. Significant interactions showed that increasing either nitrogen or cow dung while holding the other constant enhanced grain size. The combination of 90 kg N ha⁻¹ and 15 t ha⁻¹ cow dung produced the largest grains, while the control (0 kg N ha⁻¹ and 0 t ha⁻¹ cow dung) gave the smallest. Grain size increased progressively with each 30 kg N ha⁻¹ increment for both varieties, with SAMSORG-17 maintaining superior grain size over SAMSORG-44 (table 1b).

Table Ia. Effects of Nitrogen and Cow dung rates on grain size (mm) of two Sorghum Varieties at Samaru and Maigana in 2013, 2014 and combined rainy seasons.

Treatment	Grain size (mm)					
	Samaru			Maigana		
	2013	2014	Combined	2013	2014	Combined
Nitrogen (N) rate (kg ha⁻¹)						
0	2.18d	2.87d	2.53d	1.08d	1.55d	1.32d
30	2.63c	3.34c	2.99c	1.39c	1.97c	1.68c
60	2.93b	3.79b	3.36b	1.75b	2.48b	2.11b
90	3.53a	4.59a	4.06a	2.55a	3.54a	3.04a
SE±	0.011	0.014	0.079	0.010	0.014	0.065
Cowdung (C) rate (t ha⁻¹)						
0	2.60d	3.36d	2.98c	1.47d	2.09d	1.78c
5	2.74c	3.56c	3.15bc	1.62c	2.27c	1.05bc
10	2.89b	3.75b	3.32ab	1.75b	2.48b	2.12ab
15	3.04a	3.93a	3.48a	1.94a	2.68a	2.31a
SE±	0.011	0.014	0.079	0.010	0.014	0.065
Variety (V)						
SAMSORG-17	2.86a	3.69a	3.32a	1.73a	2.43a	2.68a
SAMSORG-44	2.78b	3.60b	3.15b	1.65b	2.34b	1.39b
SE±	0.008	0.009	0.056	0.007	0.010	0.046
Interaction						
N x V	ns	ns	ns	*	ns	ns
N x C	**	ns	ns	ns	ns	ns
C x V	ns	ns	ns	ns	ns	ns
N x C x V	ns	ns	ns	ns	ns	ns

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability, using Duncan Multiple Range Test (DMRT at $p \leq 0.05$)

ns: Not significant.

Table 1b. **Interaction between Nitrogen and cow dung rate at Samaru (2014) and Nitrogen and Variety on grain size (mm) of two sorghum varieties at Maigana 2013 rainy season.**

Treatment	Nitrogen (N) rate (kg ha ⁻¹)			
	0	30	60	90
2014				
Cowdung (C) (t ha⁻¹)				
0	2.49p	3.19l	3.62h	4.12d
5	2.89o	3.29k	3.71g	4.32c
10	2.99n	3.39j	3.84f	4.79b
15	3.09m	3.49i	3.98e	5.15a
SE±			0.027	
2013				
Variety (V)				
SAMSORG-17	1.12g	1.42e	1.77c	2.62a
SAMSORG-44	1.04h	1.37f	1.72d	2.48b
SE±			0.014	

Means followed by the same letter within a treatment group are not significantly different at 5 % level of probability, using Duncan Multiple Range Test (DMRT at $p \leq 0.05$)

100 grains weight (g)

The 100-grain weight of the two sorghum varieties increased significantly with higher nitrogen and cow dung rates at both Samaru and Maigana during the 2013 and 2014 wet seasons (table 2). Increasing nitrogen by each 30 kg N ha⁻¹ increased 100-grain weight up to 90 kg N ha⁻¹, although combined data showed comparable values between 0 and 30 kg N ha⁻¹, 30 and 60 kg N ha⁻¹, and no significant difference between 60 and 90 kg N ha⁻¹ at Samaru.

Similarly, each 5 t ha⁻¹ increase in cow dung significantly increased 100-grain weight. However, combined means at Samaru indicated that the difference in 100 grains weight was only between 10 to 15 t ha⁻¹ while at Maigana is between 0 and 15 t ha⁻¹ of the cow dung. The two sorghum varieties differed significantly, with SAMSORG-17 consistently producing heavier grains than SAMSORG-44 across locations and years. No significant interaction effects among treatments were observed for 100-grain weight.

Table 2. Effects of Nitrogen and Cow dung rates on 100 grains weight (g) of two Sorghum Varieties at Samaru and Maigana in 2013, 2014 and combined rainy seasons.

Treatment	100 grains weight (g)					
	Samaru			Maigana		
	2013	2014	Combined	2013	2014	Combined
Nitrogen (N) rate (kg ha⁻¹)						
0	2.57d	3.05d	2.81c	1.94d	2.56d	2.25c
30	2.66c	3.16c	2.91bc	2.11c	2.66c	2.39bc
60	2.76b	3.27b	3.02ab	2.20b	2.76b	2.48b
90	2.85a	3.38a	3.12a	2.44a	2.96a	2.70a
SE±	0.001	0.001	0.063	0.007	0.006	0.074
Cowdung (C) rate (t ha⁻¹)						
0	2.67d	3.16d	2.90b	2.10d	2.66d	2.38b
5	2.69c	3.19c	2.91b	2.14c	2.70c	2.42ab
10	2.73b	3.24b	2.92b	2.19b	2.76b	2.47ab
15	2.76a	3.26a	3.11a	2.27a	2.83a	2.55a
SE±	0.001	0.001	0.063	0.007	0.006	0.074
Variety (V)						
SAMSORG-17	2.72a	3.22a	2.99a	2.19a	2.76a	2.69a
SAMSORG-44	2.70b	3.21b	2.93b	2.15b	2.71b	2.23b
SE±	0.008	0.009	0.019	0.006	0.004	0.025
Interaction						
N x V	ns	ns	ns	ns	ns	ns
N x C	ns	ns	ns	ns	ns	ns
C x V	ns	ns	ns	ns	ns	ns
N x C x V	ns	ns	ns	ns	ns	ns

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability, using Duncan Multiple Range Test (DMRT at $p \leq 0.05$)
 ns: Not significant.

100 grains volume (ml)

Increasing nitrogen by 30 kg N ha⁻¹ and cow dung by 5 t ha⁻¹ (table 3), generally increased 100-grain volume of the two sorghum varieties at Samaru and Maigana in 2013 and 2014, although cow dung effects were not significant when years were combined. Higher and statistically similar values were obtained with 5–15 t ha⁻¹ at Samaru and 10–15 t ha⁻¹ at Maigana, while plots without cow dung produced the lowest grain volume. The variety SAMSORG-17 consistently recorded significantly greater 100-grain volume than SAMSORG-44 across locations and years, and no significant interactions among factors were observed.

100 grains density (g ml⁻¹)

Table IV shows that nitrogen application significantly increased 100-grain density of the two sorghum varieties at Samaru in both 2013 and 2014, and at Maigana only in 2013. At Samaru, combined data showed improvement in grain density up to 60 kg N ha⁻¹, with no further significant increase beyond this rate. At Maigana, significant increases occurred only between 0–30 kg N ha⁻¹ and 60–90 kg N ha⁻¹ in 2014 and in the combined data.

Table 3. Effects of Nitrogen and Cow dung rates on 100 grains volume (ml) of two Sorghum Varieties at Samaru and Maigana during 2013, 2014 and combined rainy seasons.

Treatment	100 grains volume (ml)					
	Samaru			Maigana		
	2013	2014	Combined	2013	2014	Combined
Nitrogen (N) rate (kg ha⁻¹)						
0	2.02d	2.39d	2.21d	1.93d	2.34d	2.04d
30	2.11c	2.54c	2.32c	2.24c	2.73c	2.28c
60	2.26b	2.88b	2.57b	2.32b	2.83b	2.78b
90	2.44a	3.41a	2.92a	2.73a	3.32a	3.12a
SE±	0.004	0.003	0.083	0.001	0.002	0.063
Cowdung (C) rate (t ha⁻¹)						
0	2.14d	2.61d	2.38b	2.18d	2.64d	2.41c
5	2.18c	2.75c	2.47ab	2.23c	2.71c	2.47bc
10	2.22b	2.87b	2.55ab	2.32b	2.82b	2.57ab
15	2.29a	2.99a	2.63a	2.50a	3.04a	2.77a
SE±	0.004	0.003	0.083	0.001	0.002	0.063
Variety (V)						
SAMSORG-17	2.22a	2.84a	2.78a	2.35a	2.86a	2.60a
SAMSORG-44	2.19b	2.77b	2.23b	2.26b	2.75b	2.51b
SE±	0.003	0.002	0.029	0.008	0.001	0.002
Interaction						
N x V	ns	ns	ns	ns	ns	ns
N x C	ns	ns	ns	ns	ns	ns
C x V	ns	ns	ns	ns	ns	ns
N x C x V	ns	ns	ns	ns	ns	ns

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability, using Duncan Multiple Range Test (DMRT at $p \leq 0.05$)

ns: Not significant.

Table 4. Effects of Nitrogen and Cow dung rates on 100 grains density (g ml^{-1}) of two Sorghum Varieties at Samaru and Maigana during 2013,2014 and combined rainy seasons.

Treatment	100 grains density (gml^{-1})					
	Samaru			Maigana		
	2013	2014	Combined	2013	2014	Combined
Nitrogen (N) rate (kg ha^{-1})						
0	1.17d	1.00d	1.09c	0.91d	0.94c	0.92c
30	1.22c	1.14c	1.18b	0.95c	0.99b	0.97b
60	1.26b	1.25b	1.26a	0.95b	0.99b	0.97b
90	1.27a	1.18a	1.28a	1.01a	1.12a	1.06a
SE \pm	0.003	0.009	0.015	0.009	0.005	0.013
Cowdung (C) rate (t ha^{-1})						
0	1.21d	1.12d	1.17c	0.92d	0.99c	0.95b
5	1.23c	1.15c	1.19bc	0.96c	1.00b	0.98a
10	1.24b	1.18b	1.21ab	0.97b	1.01a	0.99a
15	1.25a	1.22a	1.23a	0.97a	1.02a	0.99a
SE \pm	0.003	0.009	0.015	0.009	0.005	0.013
Variety (V)						
SAMSORG-17	1.23a	1.18a	1.27a	0.96a	1.01	0.98
SAMSORG-44	1.22b	1.16b	1.13b	0.94b	1.00	0.97
SE \pm	0.004	0.006	0.010	0.007	0.004	0.009
Interaction						
N x V	ns	ns	ns	ns	ns	ns
N x C	ns	ns	ns	ns	ns	ns
C x V	ns	ns	ns	ns	ns	ns
N x C x V	ns	ns	ns	ns	ns	ns

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability, using Duncan Multiple Range Test (DMRT at $p \leq 0.05$)

ns: Not significant.

Increasing cow dung by 5 t ha⁻¹ significantly improved 100-grain density at Samaru in 2013 and 2014 and at Maigana in 2013. Combined data showed that 10 and 15 t ha⁻¹ produced similarly higher values, comparable with 5 t ha⁻¹ at Samaru, while at Maigana all applied rates were statistically similar but higher than the control, which recorded the lowest density. The varieties differed significantly, with SAMSORG-44 giving higher grain density than SAMSORG-17 in individual years, whereas combined results showed SAMSORG-17 had higher water absorption efficiency. No significant interaction effects were observed.

Discussions

Effect of Nitrogen on Grain Physical Properties of Sorghum.

The primary quality criterion for selection of sorghum varieties for traditional beer production largely depends on desirable malting-related grain physical properties (Amadi *et al.*, 2022). In this study, the malting quality traits evaluated were hundred-grain weight, hundred-grain volume, and grain density. The observed increase in grain size with higher nitrogen application indicates that nitrogen influenced grain physical characteristics, particularly at 60 and 90 kg N ha⁻¹ across locations. Similar improvements in cereal grain quality with increased nitrogen supply have been reported, where nitrogen availability enhanced grain size, kernel weight, and overall malting performance (Barmeier *et al.*, 2021). Furthermore, the progressive increase in grain weight with each 30 kg N ha⁻¹ increment suggests that nitrogen played a major role in improving grain quality attributes, consistent with findings in malting barley where higher nitrogen rates increased 1000-kernel weight and related quality traits (Zhang *et al.*, 2024).

Effect of Cow Dung on Grain Physical Properties of Sorghum

Application of cow dung positively influenced sorghum grain quality, as reflected in improvements in grain weight, size, volume, and density parameters commonly used to assess malting quality. These increases can be attributed to the nutrients supplied by organic manure, which enhance photosynthetic capacity, assimilate production, and dry matter accumulation, thereby improving grain development. Similar findings have shown that organic fertilizer application improves soil nutrient availability and microbial activity, leading to enhanced sorghum productivity and grain quality traits (Nie *et al.*, 2024). The significant positive relationships observed among 100-grain weight, grain size, and density further indicate that improved nutrient supply from cow dung promoted assimilate partitioning to grains.

Although cow dung improved grain physical properties, its effects were less consistent than inorganic fertilizer due to the gradual nutrient release characteristic of organic manure. This slow mineralization pattern limits immediate nutrient availability compared with inorganic fertilizers, though it still contributes substantially to crop nutrition, particularly nitrogen, which plays a major role in determining grain physical attributes. Recent studies have confirmed that organic manure supplies essential nutrients, especially nitrogen, and improves grain yield and quality,

but its response is often slower compared with mineral fertilizers (Wang *et al.*, 2025; Nie *et al.*, 2024).

Varietal Response.

The poor physical quality observed in both sorghum varieties could be attributed to unfavorable storage conditions and prolonged storage duration before analysis. Storing grains under ordinary room temperature (about 30 °C) accelerates deterioration processes such as moisture fluctuation, respiration, and microbial activity, which reduce grain physical quality and viability (Gebremedhin *et al.*, 2025). This suggests that grains stored under typical farmer and merchant ambient conditions may exhibit reduced physical quality.

Grain storage is primarily aimed at preserving viability, purity, and germination capacity; however, high temperature and extended storage time can negatively affect these characteristics. Studies on cereal storage have shown that storage duration and temperature significantly influence grain physical properties and seed vigor, with better preservation achieved under controlled storage environments (Abdallah, 2024)

Conclusions

Physical grain qualities which included grain size, 100 grains weight, 100 grains volume and 100 grains density were significantly increased by the varying N rate used.

The response of the two sorghum varieties to the cow dung rates were also observed on grain physical qualities such as grain size, 100 grains weight, 100 grains volume and 100 grains density.

Grain physical quality characters such as 100 grains weight, density, volume and grain size of the two sorghum varieties were significantly increased by application of cow dung and inorganic nitrogen fertilizer. Every increase of 30 kg N ha⁻¹ and 5 t ha⁻¹ of cow dung significantly increased the parameters. The weight of 100 grains, volume and density at Samaru and Maigana were significantly affected by the increase in N from 30 to 60 kg ha⁻¹ in the combined years. Increase of every 5 t ha⁻¹ of cow dung, significantly increased the parameters but the increase did not maintain a common pattern as it was for inorganic N fertilizer rate. SAMSORG-17 was consistently superior to SAMSORG-44 variety with respect to the physical malting quality characters studied.

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