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Evaluation of Diverse Sorghum [*Sorghum bicolor* L. (Moench)] Genotypes for Drought Tolerance and Yield Performance in Nigeria

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Abstract

Sorghum is a staple cereal crop in Nigeria, particularly valued for its adaptability to harsh environments and its importance in food security. With increasing climate variability and recurrent drought episodes, identifying drought-tolerant genotypes for adaptation and climate-smart variety development, which forms the objective of this study, is critical. 192 diverse range of early, medium, and late-maturing sorghum lines, with varying degrees of drought tolerance sourced from sorghum-growing countries across Africa were evaluated, aimed at identifying high-yielding, drought-tolerant genotypes that could also serve as parental lines in crop improvement. The experiment was conducted using an alpha lattice design with two replications. Data were collected on agronomic, yield, and drought-tolerance traits and analyzed statistically. The collections were clustered, and correlation matrices, biplots, and scatterplots were used to determine trait contributions and classify genotypes. Four major clusters were identified at a Euclidean distance of 0.2. Correlation analysis revealed strong associations between grain yield and both panicle weight and panicle length (r = 0.96). Plant height showed a significant positive correlation with days to maturity (r=1), but a neutral association with yield—suggesting that taller plants require longer growth periods without necessarily improving productivity. Box plot and scatter plot analyses revealed a wide range of grain yield across maturity groups (<500 to ~2000 kg/ha), with medium-maturing genotypes achieving the highest median yield (1100 kg/ha) and the broadest yield range. Extra-early and early maturing genotypes had moderate but more uniform yields, indicating a relationship between earliness and productivity. In contrast, late-maturing genotypes exhibited very high yield variability. Variability was also observed in stay-green expression, a key drought-related trait. Notably, genotypes ICSV 246167, ICSV 246160, ICSV 246011, and ICSV 246145 were identified as promising parental lines for developing improved, drought-resilient sorghum varieties.

Keywords: Sorghum, Drought tolerance, Climate Smart, Genetic Diversity.

Introduction

Sorghum (*Sorghum bicolor* L. Moench) is a major staple crop in sub-Saharan Africa, especially in Nigeria, where it serves as both food and fodder, supporting livelihoods in semi-arid regions. It's adaptability to drought-prone and marginal soil makes it a preferred crop in dryland agriculture (Rosenow et al., 1983; House, 1985). However, increasing climate variability, recurrent droughts, and erratic rainfall patterns are posing significant challenges to sorghum production (Angarawai *et al*., 2019; Wortmann *et al*., 2006; Blum, 2004). These climate-related stresses underscore the need for increasing frequency of climate-related stresses highlights the urgent need for improved, climate-resilient varieties with enhanced drought tolerance and stable yields. The identification and exploitation of genetic variability within sorghum germplasm are essential for the development of drought-resilient varieties. Drought tolerance in sorghum is a complex trait, influenced by multiple physiological and morphological features such as stay-green, panicle structure, and root architecture (Blum, 2004; Borrell *et al*., 2000). The stay-green trait, for instance, enables sustained photosynthesis and grain filling under terminal drought stress (Borrell *et al*., 2000). Given the strategic importance of sorghum and the growing threats of climate change, this study was initiated to evaluate a wide array of sorghum genotypes collected across Africa. The primary objective was to identify promising lines with good yield potential and drought tolerance traits, which can serve both as directly adaptable varieties and as parental lines in breeding programs aimed at climate-smart agriculture.

Materials and Methods

Experimental Sites and Planting Design

The field trials were conducted in 2024 at two locations: Minjibir in Kano State (Lat. 12.08.45" Long 8.39.51" Alt. 429m) located in Sudan savanna agroecology and Gambawa of Jigawa State (Lat. 12.26.44" Long 9.26.15" Alt. 369m) situated in the Sahel agroecology of Nigeria. These regions experience early cessation of rain, providing ideal environments for evaluating end-of-season drought tolerance. The genotypes were planted on July 12 and July 17, 2024, at Minjibir and Gambawa, respectively. The experiment employed an alpha lattice design with two replications to control environmental variability and enhance the precision of treatment comparisons (Patterson & Williams, 1976).

Planting Materials

192 sorghum genotypes were sourced from various sorghum-growing regions in Africa, representing early, medium, and late-maturing types with known or suspected differences in drought tolerance traits.

Cultural Practices and Data Collection

The field was harrowed and ridged at 75cm inter raw spacing. 5–8 seeds were sown per hill at 30 cm intra-row spacing and later thinned to two plants per hill two weeks after sowing. Manual weeding was carried out with hoes. Insect pests, including armyworms and stem borers, were managed using Carbofuran and Cyper-Diforce. Data were collected on plant establishment, seedling vigor, phenological traits (days to 50% heading, flowering, and maturity), and morphological parameters such as plant height, panicle length, and number of panicles per plot. Yield and yield-related traits included panicle weight, grain weight per plot, grain yield (kg/ha), 100-grain weight, threshing percentage, and stalk weight. Additionally, the stay-green trait was visually scored post-anthesis as an indicator of drought resilience.

Data Analysis

Data were analyzed using JMP Pro 17 statistical software. Descriptive statistics, analysis of variance (ANOVA), correlation matrix, biplots, scatterplots, and cluster analysis were performed. Genotypes were grouped based on trait similarities using Euclidean distances and hierarchical clustering (SAS Institute, 2023; Gauch, 2006).

Results and Discussion

Descriptive statistics for phenotypic diversity in the evaluated genotypes, especially in grain yield, plant height, maturity, and drought-related traits (like stay-green) is presented in Table 1. Results from data analyzed revealed substantial genetic variability across the genotypes for drought-related and agronomic traits, enabling the classification of genotypes into four major clusters at a Euclidean distance of 0.2 this conforms to report by Angarawai *et al* 2021 (Fig 1.) This variability is consistent with prior studies that highlighted wide genetic diversity in African sorghum germplasm (Rosenow *et al*., 1983; House, 1985). Correlation analysis (Fig 2) showed strong associations between grain yield and panicle weight and length (r = 0.96), confirming earlier findings that panicle traits are robust indicators of yield performance (Wortmann *et al.,* 2006). Plant height correlated perfectly with days to maturity (r = 1.0), reflecting that taller plants tend to mature later. However, the lack of correlation between plant height and grain yield aligns with findings by Blum (2004), emphasizing that taller plants under drought do not necessarily produce higher yields.

Table 1. Summary statistics of diverse sorghum genotypes

Trait	**Mean**	**Min – Max**	**Std. Dev.**	**Notes**
Days to Heading	64.5 days	27 – 93	±23.3	Wide range in earliness
Days to Maturity	110.5 days	70 – 140	±23.4	Reflects variation across early, medium, and late types
Plant Height	160 cm	75 – 282 cm	±33.3	Substantial height variability
Panicle Length	26.1 cm	11.1 – 43.7 cm	±5.5	Moderate variability
Grain Yield	1005.2 kg/ha	63 – 3587	±645.2	High variation across genotypes
Panicle Yield	1514.2 kg/ha	87 – 4898	±892.1	Strongly correlated with grain yield
Stay-Green Score (SGS)	2.4 (out of 5)	0 – 5	±1.2	Indicates varying drought resilience
Anthocyanin Score (Antho_E_0to2)	2.7	0 – 5	±1.6	Some pigmentation diversity observed

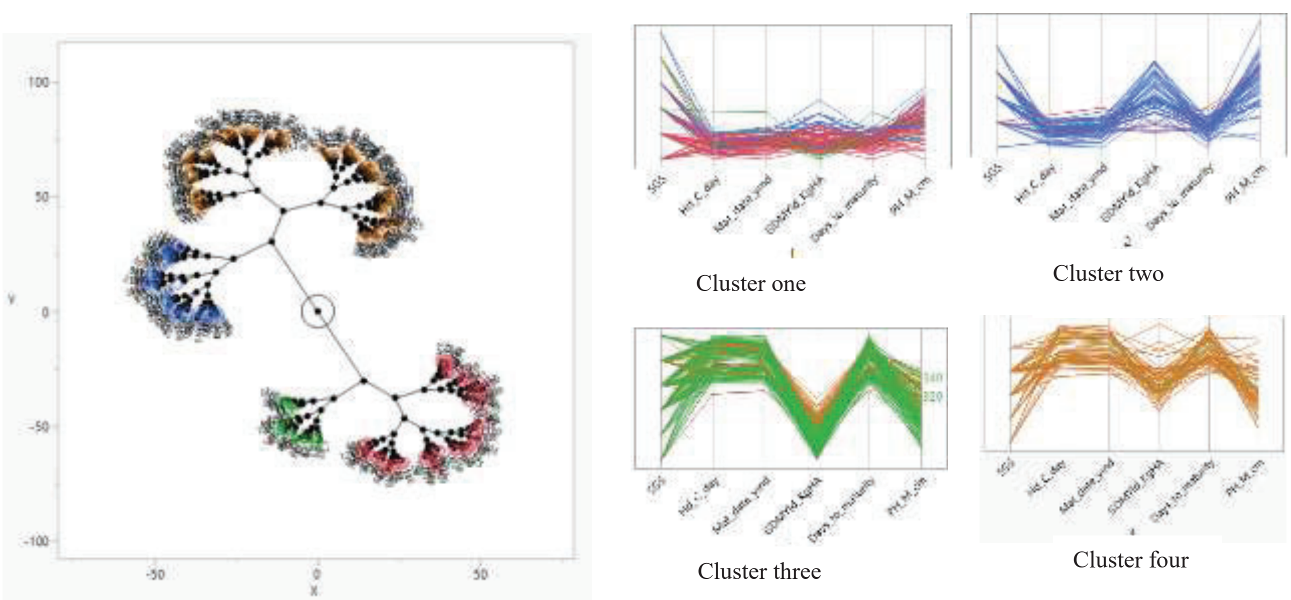


Figure 1. Constellation presentation of four distinct sorghum clusters

Box plot (Fig 3) and scatter plot analyses (Fig 4) revealed diverse grain yield performances across maturity groups. Medium-maturing genotypes showed the highest median yield (~1100 kg/ha) and the widest yield range, indicating broad adaptability. Early and extra-early maturing genotypes had more uniform, moderate yields, making them suitable for short growing seasons.

Late-maturing genotypes exhibited greater variability, which may indicate genotype × environment interactions (Gauch, 2006).

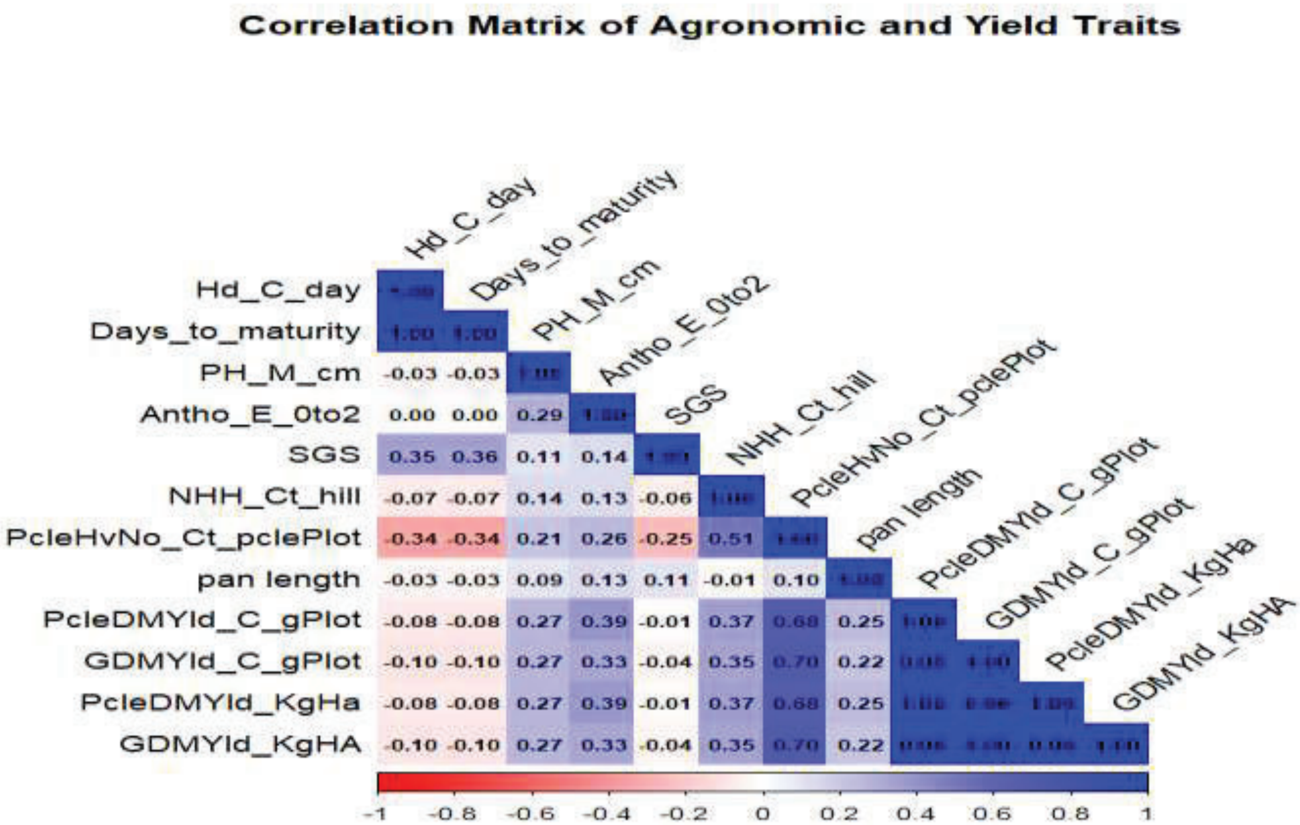
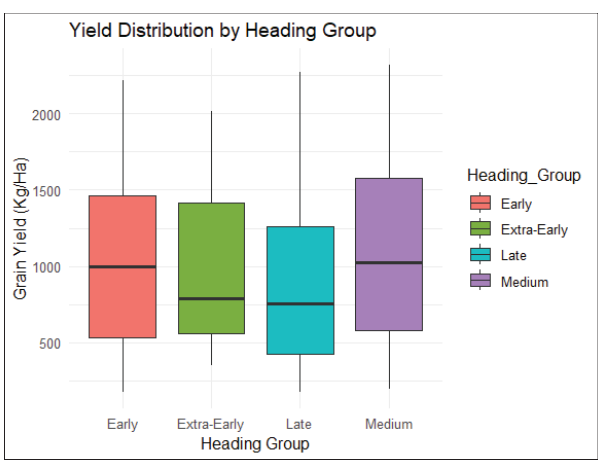
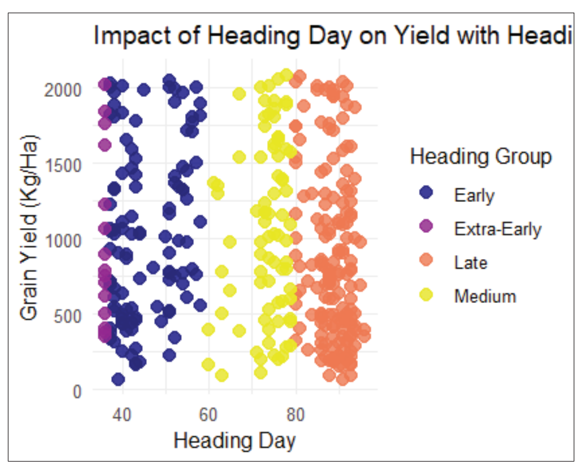


Figure 2: Scatterplot matrix of sorghum accessions showing correlation coefficient of different attributing characters for the sorghum accessions





Figures 3 and 4. Boxplot and scattered analysis of sorghum showing the distribution and maturity grouping.

Notably, variability in stay-green expression was observed, supporting its role as a reliable trait for post-flowering drought tolerance (Borrell *et al*., 2000). Genotypes ICSV 246167, ICSV 246160, ICSV 246011, and ICSV 246145 combined high yield with strong stay-green, making them excellent candidates for breeding drought-resilient cultivars.

Conclusion

This study identified significant phenotypic and agronomic diversity among 192 sorghum genotypes under end-of-season drought stress in two contrasting Nigerian ecologies. Medium-maturing genotypes demonstrated superior yield and adaptability. Key traits such as panicle weight, panicle length, and stay-green showed strong associations with yield under drought. Genotypes ICSV 246167, ICSV 246160, ICSV 246011, and ICSV 246145 stand out as potential parental materials for developing climate-resilient sorghum varieties.

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References

Angarawai, I. I., Leiser, W., Nebie, B., Mary, Y. Y., Daniel, A. A., Lawali, A., Ajeigbe, H. A., & Jerome, J. (2019). Morphological diversity assessment of Nigeria sorghum landraces for utilization in hybrid parent development. *Universal Journal of Agricultural Research, 7*(6), 221–227. https://doi.org/10.13189/ujar.2019.070604

Angarawai, I. I., Falalou, H., Aladele, S., Mary, Y., Aba, D. A., Ajeigbe, H., Ati, M., Afolayan, G., AbdulMalik, R., Jerome, J., Shinggu, C., Dawud, M. A., Gumel, J. U., Mutah, S., & Mohammed, M. I. (2021). Sorghum landrace germplasm: Genetic resources for demand-led product development and profiling in modern crop improvement. *Journal of Agricultural Biotechnology and Sustainable Development, 13*(2), 33–43. https://doi.org/10.5897/JABSD2020.0379

Blum, A. (2004). *Sorghum physiology*. In *Sorghum Improvement Conference of North America*. Lubbock, Texas.

Borrell, A. K., Hammer, G. L., & Douglas, A. C. L. (2000). Does maintaining green leaf area in sorghum improve yield under drought? II. Dry matter production and yield. *Crop Science, 40*(4), 1037–1048. https://doi.org/10.2135/cropsci2000.4041037x

Gauch, H. G. (2006). Statistical analysis of yield trials by AMMI and GGE. *Crop Science, 46*(4), 1488–1500. https://doi.org/10.2135/cropsci2005.07-0193

Hanumantharaju, T. H. (2017). Evaluation of sorghum genotypes under rainfed conditions for growth, yield and quality parameters. *International Journal of Pure & Applied Bioscience, 5*(5), 740–746.

House, L. R. (1985). *A guide to sorghum breeding*. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

Patterson, H. D., & Williams, E. R. (1976). A new class of resolvable incomplete block designs. *Biometrika, 63*(1), 83–92. https://doi.org/10.1093/biomet/63.1.83

Rosenow, D. T., Dahlberg, J. A., & Clark, L. E. (1983). Drought and lodging resistance for grain sorghum improvement. *Agronomy Abstracts*. ASA, Madison, WI.

SAS Institute Inc. (2023). *JMP® 17 fitting linear models*. Cary, NC: SAS Institute Inc.

Wortmann, C.S., Mamo, M., Mburu, C., Letayo, E., & Abebe, G. (2006). Drought tolerance of sorghum. Agricultural Systems, 89(2–3), 178–199.