



Effects of Organic and Inorganic Fertilizers on the Performance of Sorghum (*Sorghum Bicolor* (L. Moench) Varieties in Two Agro-Ecological Zones of Taraba State, Nigeria

¹*Tebe E. Enang, ¹Chukudi G. Michael, ²Temitope G. Adelalu and ²Idris Umar

¹Department of Agronomy, Taraba State University, Jalingo, Nigeria

²Department of Geography, Taraba State University, Jalingo, Nigeria

*Corresponding Author: tebeenang1@gmail.com/08062921582

ARTICLE HISTORY

Received: 04/06/2025

Accepted: 27/07/2025

Article Type:

Research Paper

Volume: 13

Issue: 1

Pp: 162 – 182

ABSTRACT

The study investigated the effects of organic and inorganic fertilizers on the performance of Sorghum (*Sorghum bicolor* (L.) Moench) varieties in two agro-ecological zones of Taraba State Nigeria, to identify the sorghum varieties that perform best in terms of total biomass yield across two agro-ecological zones of Taraba State, to evaluate the effects of different fertilizer regimes (organic, inorganic, and mixed) on the growth and yield performance of sorghum and to recommend suitable variety (fertilizer combinations) that can enhance total biomass production for farmers and herders in Jalingo and Bali. The experiment was a split-plot design replicated three times. Four fertilizer regimes (Organic fertilizer (cow-dung) at 20 t/ha, inorganic fertilizer (NPK 20:10:10) at 300 kg/ha, mixed fertilizer at 10 t/ha cow-dung + 150 kg/ha NPK 20:10:10 and control at 0 kg/ha served as the main treatment while the twelve Sorghum varieties Samsorg 3, Samsorg 16, Samsorg 40, Samsorg 43, Samsorg 44, Samsorg 45, Samsorg 46, Samsorg 49, Samsorg 50sw, CSR 01, Jalingo and Kaduna local varieties were assigned as the sub-treatments giving 48 treatment combinations. Planting spacing for each plot was 60cm x 20cm. Data collected includes, plant height, number of leaves, Leaf area, stem girth, days to 50% tasseling and yield per ha⁻¹. Collected data were subjected to analysis of variance and the means separated using DMRT at 5% probability level. Results showed that total plant biomass of V2, V3, V11 and V12 in the order 3.75 t/ha > 3.37 t/ha < 3.94 t/ha > 3.43 t/ha respectively were the higher performing varieties across the locations while fertilizer (Mixture) resulted in higher total biomass. The study recommends V2 in Jalingo and V2/V3 in Bali, combined with mixed or organic fertilizers, for herders and farmers aiming to maximize total plant biomass in the respective locations.

Keywords: Fertilizer, Sorghum, Varieties, fertilizer Mixture, Herders

INTRODUCTION

Global demand for sorghum is increasing, with projections showing a further 59–98% rise by 2050 (Elferink & Schierhorn, 2019). However, yield gaps remain a challenge, likely caused by extreme weather, pest and disease pressure, input levels, crop diversification, and farm management practices (Rabbinge *et al.*, 1997). Sorghum

(*Sorghum bicolor* (L.) Moench), a monocot grain crop from the family Gramineae, serves as food, animal feed, and a source of bioethanol. It is a zero-waste crop, as every part of the plant has uses in food, feed, and industry (Suarni, 2016). Globally, sorghum ranks as the fifth most important cereal after maize, rice, wheat, and barley (FAOSTAT,

2024; FAO, 2025), with Nigeria being the world's second-largest producer (FAO, 2019). More so, the utilization of Sorghum is generally obtained from the main products such as stems, seeds, leaves and by-products like dregs/bagasse (Ndampamuri *et al.*, 2020). Sorghum is a viable food grain for many parts of the world, mostly for food insecure people who live in marginal area with poor and erratic rains and often poor soils (AATF, 2011).

Soil fertility decline remains a major constraint to agricultural production across Africa, particularly in Nigeria, where it poses a significant challenge to achieving sustainable soil productivity (Essiet, 2024). This decline is often attributed to the inherently low fertility of many agricultural soils in the region, which are unable to sustain optimal crop yields over extended periods without the application of fertilizers (Saidu *et al.*, 2011). Farmers apply less than half of the 150 kg N ha⁻¹ recommended for Sorghum in North-East region due to the problem of high cost of inorganic fertilizer (Tyagi *et al.*, 2016). Over the years, a lot of constraints have surrounded the multipurpose Sorghum crop (*Sorghum bicolor*) which has limited its ability to produce the expected leaves used for feeding livestock and high grain yields for other industrial usage. In spite of the importance of the crop, farmers in the region grow local cultivars which are low yielding and susceptible to disease with the frequent and cyclical occurrence of drought and erratic rainfall. Sorghum could be an insurance crop to the small-scale resource-poor farmers constituting the majority of the rural farming community in Nigeria (Ajeigbe *et al.* 2018). Sorghum yield is partly determined by the varieties of cultivars and the cultural practices of the region. When increased production is desired, farmers often extend into marginal lands as opposed to intensive production of the existing acreage. Besides food, Sorghum is used as livestock feed; house thatching, raw materials for biofuel industries (Gain, 2020) and also in the beverage and baking industries in Nigeria (Baiyegunhi and Fraser, 2009). In Nigeria, sorghum is cultivated more extensively than many other crops, reflecting

its potential for profitability and commercial viability (Baiyegunhi and Fraser, 2009; Aduba *et al.*, 2013).

Production is negatively affected by climate challenges and institutionally-induced price volatility (Odozi, 2015). This is further exacerbated by recurring militant insurrections which continue to affect Sorghum production in the dominant cultivation region of North-Eastern, including Taraba state, Nigeria (FAO, 2017). Among the constraints to Sorghum production are subsistence farmers who do not invest much in fertilizer and improved varieties. This increases the price risk that Sorghum producers face; hence, their reluctance to invest in commercial Sorghum production has lingered over the years. Also, the choice of the fertilizer types, sole organic, sole inorganic or mixture or combination that will effectively promote grain and biomass yield is yet to be adequately invested in the study area. Therefore, the objective of this research is to evaluate the response of ten improved and two local varieties of sorghum to four fertilizer regimes in two locations.

MATERIALS AND METHODS

The Study Area

The study was conducted in two locations representing distinct agro-ecological zones in Taraba State, Nigeria (Jalingo and Bali Local Government Areas), at Taraba State University Teaching and Research Farm Jalingo and Federal Polytechnic Research Farm Bali (Figure 1). Jalingo, the capital city of Taraba State, is located at approximately latitude 8.89° N and longitude 11.36° E (Figure 2). Jalingo is characterized by a tropical wet and dry climate, with an annual rainfall ranging from 1,000 to 1,500 mm and temperatures between 24°C and 38°C. The soil type is typically sandy loam to loamy, moderately fertile, and well-drained. Bali is situated in the southern part of Taraba State, with approximate coordinates 7.85° N latitude and 10.96° E longitude (Figure 3). It also falls within the Southern Guinea Savannah ecological zone. Bali receives slightly higher rainfall than Jalingo, typically between 1,200 and 1,800 mm annually, and has a humid tropical climate.

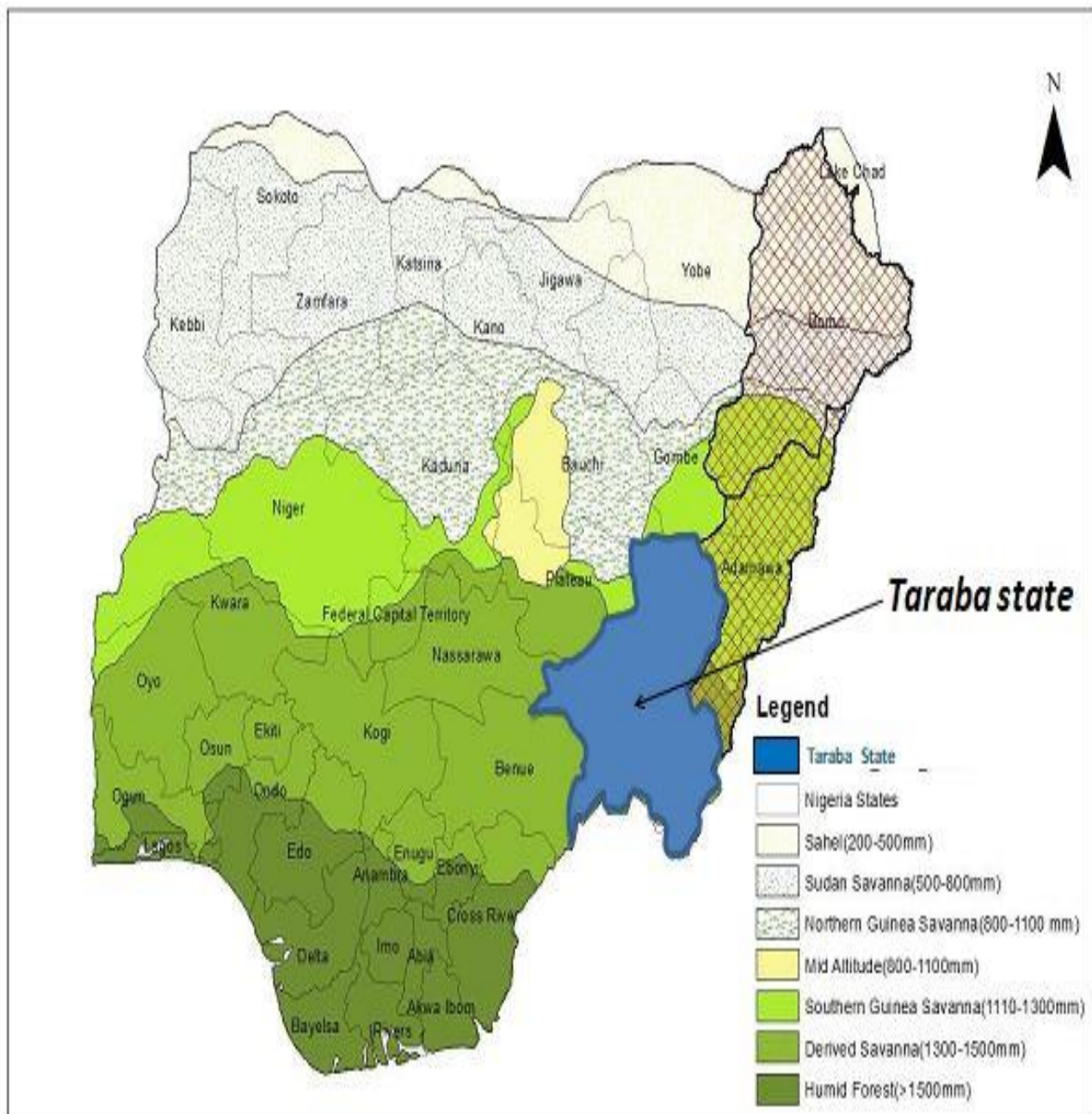


Figure 1: Agro-ecological zones of Nigeria showing Taraba State
Source: Alamu et al. (2013)

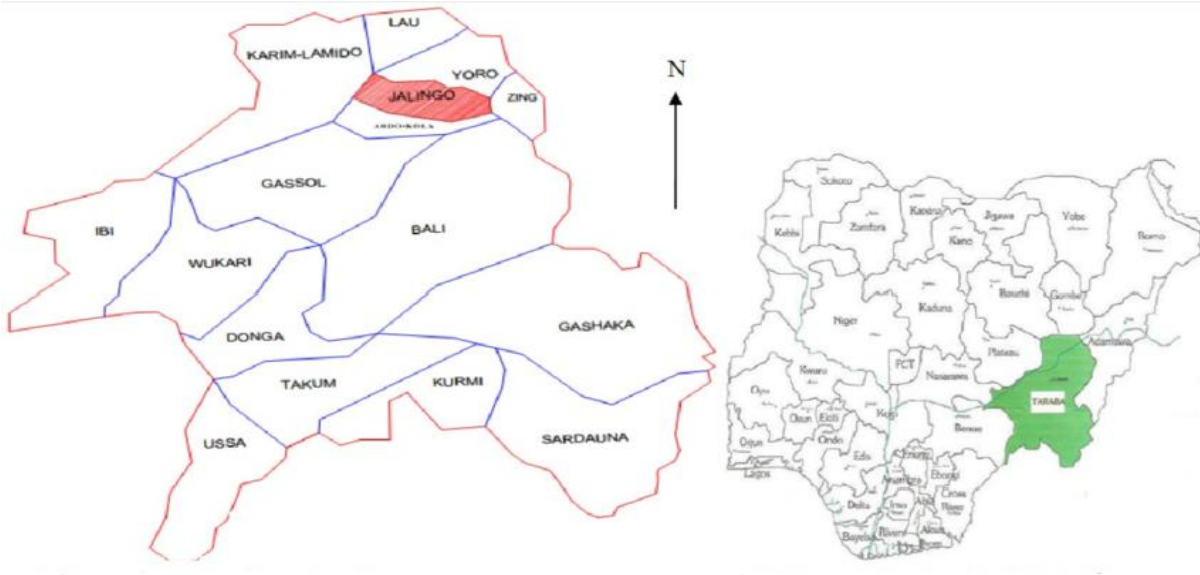


Figure 2: Map of Nigeria showing Taraba and Jalingo

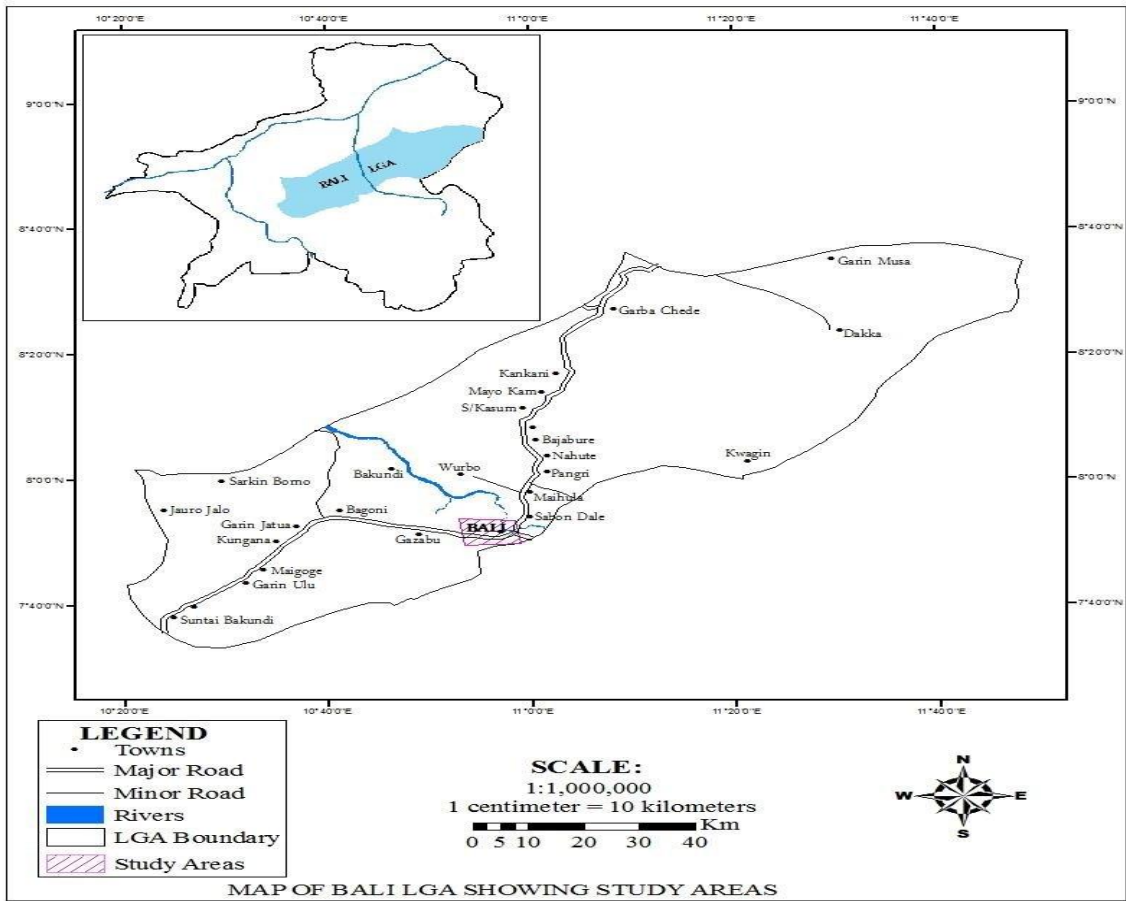


Figure 3: Map of Bali LGA, Taraba State

The soils in Bali are generally deep, loamy, and well-suited for cereal crop production. Both locations are major agricultural zones in the state and are representative of sorghum-producing areas. The choice of these sites provided a good basis for evaluating varietal response to fertilizer regimes under varying ecological and edaphic conditions.

In addition to climatic variability, the edaphic (soil-related) conditions of the two sites also differ, influencing crop performance. Soils at the Jalingo site are generally sandy-loam with moderate organic matter content but low in essential nutrients such as nitrogen and phosphorus. The Bali site, on the other hand, has relatively heavier loamy soils with slightly higher fertility and better moisture retention capacity. These variations in edaphic factors are crucial in determining the suitability of the locations for different cropping systems and in interpreting the outcomes of agronomic trials conducted therein (Taraba State Ministry of Agriculture and Natural Resources, 2019).

Taraba State is bordered with different neighboring states, to the East by Adamawa State, to the North by Gombe, Bauchi and Plateau States, to the West by Nassarawa and South by Benue State and Republic of Cameroon. The State lies largely within the middle of Nigeria and consists of undulating landscape with few mountainous features. The Mambilla Plateau with an Altitude of 1,800 meters (6000 ft) above sea level has a temperate climate all year round (Jonathan *et al.*, 2018) which makes the environment very advantageous for growth of agricultural crops and tourism. Mean annual rainfall in Jalingo is 800mm while that of Bali is over 200mm. Mean annual temperature in Jalingo is 30.31°C while that of Bali ranges from 25-30°C. The percentage of rainfall in Taraba state is 40.3% with 54.98% relative humidity. The state is usually very warm in March with 40.44°C, and an average wind of 8.84km/h.

Experimental Design

Twelve varieties of Sorghum cultivars (*Sorghum bicolor*) were used for this study. Ten improved varieties of Sorghum were sourced from Institute of Agricultural Research (IAR), Samaru, Zaria, Kaduna State, Nigeria while two local varieties (Jalingo

dawa and Kaduna kaura) were purchased from open market. The Cow-dung used as organic manure was obtained from cattle farms within the study areas (Jalingo and Bali) respectively while the NPK inorganic fertilizer was sourced from Taraba State Agricultural Development Programme (TADP), Jalingo, Taraba State.

The experiment was Split-Plot Design (SPD), replicated three times. Four fertilizer regimes (Organic fertilizer (cow-dung) at the rate of 20 t/ha (org), inorganic fertilizer (NPK 20:10:10) at the rate of 300 kg/ha or (180 g/plot) (ino), mixed fertilizer at the rate of 10 t/ha cow-dung + 150 kg/ha of NPK 20:10:10 (mix) and control at 0 kg/ha (ctr) served as the main treatment while the twelve Sorghum varieties (V1, V2, V3, V4, V5, V6, V7, V8, V9, V10, V11, V12) were the sub-treatments giving a total of 48 treatment combinations.

The size of each experimental plot was 2m x 3m (6m² per plot). The inter-row and intra-row planting spaces was 60 cm and 20 cm respectively and the cow dung organic manure was applied in it completely dried form. The total experimental area was 55.5 m x 25 m (i. e. 1,387.5 m²). The Sorghum heads were manually harvested using harvesting sickle at 18 Weeks After Planting (WAP) and were dried there after processed by heating with stick to remove grains which were sieved by blowing to separate grains from chaff.

Data Collection

Data were collected from five selected plants, exempting the boarder plants on the following parameters;

- i. **Plant heights (cm):** The height of each Sorghum plant was measured from ground level to the tip of the plant using measuring tape.
- ii. **Number of leaves:** The number of leaves was obtained by counting the total number of leaves for each of the selected tag plants and figures obtained were recorded.
- iii. **Leaf Area:** This was obtained by using the formula, Leaf Area = Length x Breadth x Number of leaf x constant (0.82) (Easlon and Bloom, 2015).

- iv. **Stem girth (cm):** Stem girths of five tagged plants were measured using twine and measuring tape.
- v. **1000 seed weight (g):** This was obtained by counting 1000 seed (after threshing, cleaning and sun drying) for each individual tagged plant in each plot and then weighed with the help of a digital weighing balance machine.
- vi. **Grain yield:** Grain yield was obtained by weighing the total seed yield per treatment after threshing, cleaning and sun drying using a weighing balance.
- vii. **Total plant biomass at harvest:** The sampled plants of fresh Sorghum plant using an electronic digital scale machine. The five tagged plants of sorghum were uprooted; root shaken to remove soil particles, bundled together and the fresh weight taken with top loading scale machine to obtain the total plant biomass.
- viii. **Days to 50% Tasseling:** This was recorded from daily visible observation covering the period of tested emergence up to 50% of the plant population (i.e half of total number of plants 65 in a plot). The number of days from planting date till when half of the plant tassels was recorded for each treatment.

Data Analysis

Plant height, Number of leaves, leaf Area, stem girth, 1000 seed weight, grain yield, total plant biomass at harvest and days to 50% tasseling data collected were subjected to Analysis of Variance (ANOVA) using a Statistical Analysis System software (SAS 9.0v) and treatment means were separated using Duncan's Multiple Range Test (DMRT) at 5% probability level.

RESULTS AND DISCUSSION

Number of Leaves

The number of leaves in sorghum was significantly influenced by both variety and fertilizer treatments at different growth stages (3, 6, 9, and 18 WAP) and locations (Jalingo and Bali) during the 2023 wet season (Table 1). Significant varietal differences were observed in number of leaves at several growth stages. At 3 WAP, although no

significant differences were found at Jalingo location, Bali and the combined analysis showed that V11 (Jalingo local variety) produced the highest number of leaves (6.95), followed closely by V4 (SAMSORG 43) and V2 (SAMSORG 16), while V5 (SAMSORG 44) and V3 (SAMSORG 40) recorded lower number of leaves. This suggests that local landraces may exhibit early vegetative vigor under certain agro-ecological conditions (Aliyu et al., 2020).

By 6 WAP, significant differences were evident at Jalingo, where V12 (Kaduna local) and V3 had the highest number of leaves (9.95 and 9.63 respectively), while V7 (SAMSORG 46) and V6 (SAMSORG 45) recorded lower values. In Bali, V2 and V11 stood out with higher leaf production, contributing to significant variation in the combined data. These findings align with the report by ICRISAT (2019) which noted that improved sorghum varieties often show diverse vegetative performance depending on genetic makeup and site-specific conditions. At 9 WAP, varietal differences were again notable, particularly in Jalingo where V2 recorded the highest number of leaves (9.05), while V7 and V6 had significantly fewer. In Bali, V11 recorded significantly more leaves than V7 and V8. The overall combined data indicated a range of 7.81 (V7) to 10.75 (V11), highlighting the robustness of local varieties at mid-vegetative stages. This corroborates findings by Ezeaku et al. (2018), who emphasized the adaptive advantages of local germplasm in nutrient-poor or stress-prone environments. By 18 WAP (harvest stage), varietal differences diminished at both locations and in the combined analysis, indicating convergence in leaf shedding or senescence across genotypes toward physiological maturity.

Fertilizer application significantly influenced the number of leaves across all stages, especially in Bali. The Mixed fertilizer treatment (Mix) produced the highest number of leaves across most stages and locations, notably at 3 WAP (7.80 leaves combined) and 6 WAP (10.43 leaves combined).

Table 1: Effects of variety and Fertilizer on Number of Leaves (cm) of Sorghum at Jalingo and Bali During 2023 Wet Season

	3WAP			6WAP			9WAP			18WAP		
	Jalingo	Bali	Combined	Jalingo	Bali	Combined	Jalingo	Bali	Combined	Jalingo	Bali	Combined
Variety												
V1	4.50a	7.70b	6.10b	7.95gh	9.15cd	8.55bc	6.23efg	11.69ab	8.96ab	3.65ab	14.97a	9.31a
V2	4.53a	8.03ab	6.28ab	8.85cde	11.95a	10.40a	9.05a	12.28ab	10.66a	4.28a	12.17a	8.23a
V3	4.45a	6.33c	5.39abc	9.63ab	10.03bcd	9.83ab	7.77cd	11.42ab	9.59ab	4.33a	12.48a	8.40a
V4	4.53a	8.78ab	6.67ab	8.80cdef	10.80abc	9.80ab	8.22bc	11.71ab	9.97ab	4.00a	9.78a	6.89a
V5	4.22a	6.70c	5.46bc	9.50abc	10.95abc	10.23a	8.83ab	11.90ab	10.37a	3.70ab	10.37a	7.03a
V6	4.73a	7.63b	6.18c	8.10fgh	8.48d	8.29c	5.82fg	12.37ab	9.09ab	3.37ab	10.57a	6.97a
V7	4.52a	7.10b	5.81abc	7.50h	10.88abc	9.19abc	5.50g	10.12b	7.81b	3.38ab	10.08a	6.73a
V8	4.50a	6.75c	5.63abc	8.68def	9.78bcd	9.23abc	6.47ef	10.55b	8.51ab	2.65b	9.60a	6.13a
V9	4.67a	6.75ab	5.71abc	9.10bcd	8.90d	9.00abc	6.47ef	11.20ab	8.84ab	2.65b	10.07a	6.36a
V10	4.48a	7.58b	6.03b	9.23abcd	10.80abc	10.01a	7.00de	11.71ab	9.36ab	3.90a	9.60a	6.75a
V11	4.17a	9.73a	6.95a	8.35efg	11.13ab	9.74ab	7.90c	13.60a	10.75a	4.20a	9.66a	6.93a
V12	4.65a	6.60d	5.63abc	9.95a	10.88abc	10.42a	7.90c	12.71ab	10.30a	4.02a	9.43a	6.72a
Fertilizer												
Mix	4.48a	11.12a	7.80a	9.68a	11.17a	10.43a	8.22a	13.06a	10.64a	4.07a	11.48a	7.78a
Ino	4.58a	10.88ab	7.73a	10.07a	10.88ab	10.48a	7.87a	11.50b	9.68ab	3.72a	11.59a	7.66a
Org	4.52a	10.08b	7.30b	8.70b	10.09b	9.40b	6.94b	11.92ab	9.43b	3.46a	10.64a	7.05a
Ctl	4.41a	9.11c	6.76c	6.76c	9.11c	7.94c	6.03c	10.41b	8.22c	3.45a	9.56a	6.51a
V x F	Ns	***	ns	***	ns	ns	***	ns	ns	ns	ns	ns

Means with the same letter are not significantly different using DMRT at 5% probability

V₁ = SAMSORG 3, V₂ = SAMSORG 16, V₃ = SAMSORG 40, V₄ = SAMSORG 43, V₅ = SAMSORG 44, V₆ = SAMSORG 45, V₇ = SAMSORG 46, V₈ = SAMSORG 49, V₉ = SAMSORG 50sw, V₁₀ = CSR 01, V₁₁ = Jalingo local variety (Dawa), V₁₂ = Kaduna local variety (Kaura)

This was followed by Inorganic (Ino) and Organic (Org) treatments, while the Control (Ctl) consistently recorded the lowest number of leaves. At 9 WAP, the mixed fertilizer continued to show superiority (10.64 leaves combined) when compared with other treated plots, indicating its positive role in promoting vegetative growth through balanced nutrient availability. The control treatment, with only 8.22 leaves, highlighted the limitations of relying solely on inherent soil fertility. These findings are consistent with those of Adediran *et al.* (2021), who demonstrated that integrated fertilizer application enhances leaf production and plant vigour in cereals. Interestingly, while the Variety $\times$ Fertilizer ($V \times F$) interaction was significant only at 6 WAP ($p < 0.001$), it was not significant at later stages, implying that while early vegetative growth is sensitive to specific variety–nutrient combinations, this effect diminishes as plants mature. The results indicate that V11 (Jalingo local variety) and V2 (SAMSORG 16) performed consistently well in leaf production, especially at later growth stages, suggesting their suitability for biomass-focused production. The use of mixed fertilizer was most effective across growth stages and locations, underscoring the benefit of integrated nutrient management. Future trials should explore long-term soil effects and grain yield correlations.

The interaction between sorghum variety and fertilizer type significantly influenced the number of leaves at 6 WAP at Jalingo during the 2023 wet season (Table 2). The highest number of leaves (11.66) was recorded in variety V8 (SAMSORG 49) under inorganic fertilizer, which was statistically similar to V11 (Jalingo local), V5 (SAMSORG 44), V12 (Kaduna local), and V9 (SAMSORG 50sw) under inorganic or organic fertilization, showing values above 11 leaves. Conversely, the lowest number of leaves (5.13) was observed in V1 (SAMSORG 3) under the control treatment (no fertilizer), which was significantly lower than all fertilized treatments. Across most varieties, plants treated with inorganic or mixed fertilizers consistently recorded higher leaf numbers than those under organic or control conditions. This

trend aligns with findings by Olowe *et al.* (2020), who reported that mineral fertilizers rapidly supply nutrients that promote early vegetative growth, such as leaf expansion and tillering. For instance, varieties such as V10 (CSR 01) and V12 performed exceptionally under both inorganic and mixed fertilizer conditions, reflecting their adaptability and potential for high vegetative vigor when nutrient supply is adequate.

According to Table 2, organic fertilizer treatments, though generally lower than inorganic in performance, still outperformed the control in most cases. For example, V12 under organic fertilizer (11.40) was statistically comparable to the best inorganic treatments, suggesting its compatibility with low-input systems and potential in sustainable agriculture. This supports previous studies that highlighted the gradual nutrient release from organic materials, which can sustain growth over time (Agbede, 2010). Control treatments across all varieties consistently recorded the least number of leaves, reflecting the nutrient limitations of the unfertilized plots. This underscores the importance of external nutrient inputs for optimizing leaf production, a crucial determinant of photosynthetic capacity and biomass accumulation in sorghum (Ibrahim *et al.*, 2015). At 9 WAP, significant interaction effects were also observed. The highest number of leaves (12.20) was recorded in V5 (SAMSORG 44) under mixed fertilizer, followed by V4 (SAMSORG 43) and V11 (Jalingo local) under inorganic fertilization, all producing over 10 leaves per plant. In contrast, the lowest leaf numbers (4.80) were noted in V1 under the control, highlighting again the poor vegetative performance in nutrient-deficient conditions. Mixed fertilizer treatments (combining organic and inorganic inputs) were particularly effective in enhancing leaf production in V5 and V4, possibly due to the synergistic effects of immediate nutrient availability from the inorganic component and sustained release from the organic component. This supports the integrated nutrient management strategy recommended by FAO (2006) and Palm *et al.* (2001), emphasizing the combined use of nutrient sources to

optimize growth and sustainability. Some local varieties, such as V12 (Kaura), also responded well to mixed and organic fertilization, maintaining competitive leaf production (10.67) under organic input alone. This resilience suggests their potential role in low-input farming systems common in rural Nigerian communities.

Interestingly, some varieties like V7 (SAMSORG 46) and V6 (SAMSORG 45) showed minimal response across treatments, with consistently low leaf counts, suggesting possible genetic limitations in early vegetative vigour or nutrient use efficiency. Overall, sorghum vegetative development at both 6 and 9 WAP was significantly influenced by the interaction between variety and fertilizer type. Inorganic and mixed fertilizer treatments generally enhanced leaf development, especially in improved varieties like SAMSORG 44, 43, and local types such as Jalingo local (Dawa) (Table 2). This indicates the importance of matching appropriate fertilizer types with specific varieties for optimal growth performance. These findings are consistent with earlier reports by Adamu *et al.* (2018) and Ezeaku and Mohammed (2006), which emphasize varietal differences in nutrient uptake and growth response.

Stem Girth (cm)

Stem girth is a key agronomic trait reflecting the plant's structural strength and potential to support grain production (Ibrahim *et al.*, 2015). Table 3 shows that variety and fertilizer regimes significantly influenced stem girth at different growth stages across the two locations (Jalingo and Bali). At 3 WAP, no significant differences were observed among the varieties in the combined analysis. However, the stem girth values were generally higher in Bali than in Jalingo, indicating location-specific influence. Variety V9 (SAMSORG 50sw), V5 (SAMSORG 44), and V11 (Jalingo local) recorded the highest stem girth values in Bali (6.75 cm, 5.70 cm, and 6.73 cm respectively), suggesting favorable early growth conditions at the Bali site. Although fertilizer effect was not significant at this stage, plants treated with mixed and inorganic fertilizers showed slightly higher stem girth (in Bali) than those under organic

and control treatments, consistent with findings by Agbede (2010) on the influence of nutrient availability in early growth. At 6 WAP, a significant interaction was observed between variety and fertilizer ($p < 0.05$).

The combined mean stem girth ranged from 7.16 cm to 9.08 cm. V5, V12 (Kaura), and V11 showed superior stem girth (8.20–8.68 cm), especially in Bali. Among fertilizer types, inorganic (8.18 cm) and mixed (7.94 cm) treatments were most effective, though not statistically significant. These results affirm that sufficient and balanced nutrient supply boosts vegetative development during critical stages (FAO, 2006).

By 9 WAP, stem girth continued to increase, with the highest combined values recorded in V12 (10.11 cm), V2 (10.43 cm), and V3 (10.06 cm). Again, inorganic and mixed fertilizers produced thicker stems compared to organic and control plots.

This is consistent with the report of Olayiwola *et al.* (2018), who highlighted the role of NPK fertilizer in increasing plant girth and structural integrity. At harvest, stem girth narrowed slightly across treatments, yet notable differences were still observed. The highest values were observed in V11 (9.26 cm), V3 (9.08 cm), and V12 (9.03 cm), while varieties under mixed (8.99 cm) and inorganic (7.59 cm) fertilizers remained bigger. Organic and control treatments recorded lower girths, reflecting the long-term advantage of timely and adequate nutrient availability. These findings support the integrated nutrient management approach advocated by Palm *et al.* (2001).

Stem Girth (cm)

Stem girth is a key agronomic trait reflecting the plant's structural strength and potential to support grain production (Ibrahim *et al.*, 2015). Table 3 shows that variety and fertilizer regimes significantly influenced stem girth at different growth stages across the two locations (Jalingo and Bali). At 3 WAP, no significant differences were observed among the varieties in the combined analysis. However, the stem girth values were generally higher in Bali than in Jalingo, indicating location-specific influence. Variety V9 (SAMSORG 50sw), V5 (SAMSORG 44), and

V11 (Jalingo local) recorded the highest stem girth values in Bali (6.75 cm, 5.70 cm, and

6.73 cm respectively), suggesting favorable early growth conditions at the Bali site.

Table 2: Effects of Interaction of Variety and Fertilizer on Number of Sorghum Leaves at 6 and 9 WAP During 2023 Wet Season at Jalingo

	Mix	Ino	Org	Ctl
6 WAP				
Variety				
V1	8.06k-r	10.86a-f	7.73m-r	5.13u
V2	9.46e-k	9.53e-k	8.46i-p	7.93k-r
V3	9.06g-o	10.46a-g	9.33f-m	9.66d-j
V4	10.00b-I	9.86c-i	9.40e-l	5.93s-u
V5	11.53ab	10.33a-g	9.46e-k	6.66r-u
V6	9.13g-o	8.66h-p	7.60o-r	7.00q-s
V7	6.80r-t	7.66n-r	8.40i-q	7.06p-s
V8	11.00a-e	11.66a	6.66r-u	5.40tu
V9	11.33a-c	9.93b-I	9.26f-n	5.86s-u
V10	10.20a-h	11.13a-d	8.86g-o	6.73r-t
V11	8.13k-r	11.68a	7.80l-r	5.80s-u
V12	11.46a-c	9.00g-o	11.40a-c	7.93k-r
9 WAP				
V1	7.33i-p	6.13n-r	6.67l-r	4.80r
V2	8.80d-k	9.27c-h	9.80b-e	8.33d-l
V3	7.67g-n	9.67c-e	8.07e-m	5.67o-r
V4	11.40a	9.40c-g	6.07n-r	6.00n-r
V5	12.20a	9.53c-f	7.67g-n	5.93n-r
V6	6.33n-r	6.13n-r	5.40p-r	5.60p-r
V7	5.33qr	5.93n-r	5.33qr	5.40p-r
V8	7.07j-q	7.73f-n	5.67o-r	5.40p-r
V9	6.13n-r	6.80l-q	6.13n-r	7.00k-q
V10	7.53g-n	8.87c-j	5.53p-r	6.07n-r
V11	10.07b-d	9.60c-e	6.33l-r	5.60p-r
V12	8.93c-i	5.40p-r	10.67a-c	6.60l-r

Means with the same letter are not significantly different using DMRT at 5% probability

V₁ = SAMSORG 3, V₂ = SAMSORG 16, V₃ = SAMSORG 40, V₄ = SAMSORG 43, V₅ = SAMSORG 44, V₆ = SAMSORG 45, V₇ = SAMSORG 46, V₈ = SAMSORG 49, V₉ = SAMSORG 50sw, V₁₀ = CSR 01, V₁₁ = Jalingo local variety (Dawa), V₁₂ = Kaduna local variety (Kaura)

Although fertilizer effect was not significant at this stage, plants treated with mixed and inorganic fertilizers showed slightly higher stem girth (in Bali) than those under organic and control treatments, consistent with findings by Agbede (2010) on the influence of nutrient availability in early growth. At 6 WAP, a significant interaction was observed between variety and fertilizer ($p < 0.05$). The combined mean stem girth ranged from 7.16 cm to 9.08 cm. V5, V12 (Kaura), and V11 showed superior stem girth (8.20–8.68 cm), especially in Bali. Among fertilizer types, inorganic (8.18 cm) and mixed (7.94 cm) treatments were most effective, though not statistically significant. These results affirm

that sufficient and balanced nutrient supply boosts vegetative development during critical stages (FAO, 2006).

By 9 WAP, stem girth continued to increase, with the highest combined values recorded in V12 (10.11 cm), V2 (10.43 cm), and V3 (10.06 cm). Again, inorganic and mixed fertilizers produced thicker stems compared to organic and control plots. This is consistent with the report of Olayiwola *et al.* (2018), who highlighted the role of NPK fertilizer in increasing plant girth and structural integrity.

Table 3: Effects of Variety and Fertilizer on Stem Girth (cm) of Sorghum at Jalingo and Bali in 2023 Wet Season

	3WAP			6WAP			9WAP			18WAP		
	Jalingo	Bali	Combine	Jalingo	Bali	Combine	Jalingo	Bali	Combine	Jalingo	Bali	Combine
Variety												
V1	2.80a	4.70b	3.75ab	8.38ab	6.33a	7.35bc	6.63bc	11.69ab	9.16ab	6.55abc	9.08a	7.81a
V2	2.92a	4.03ef	3.48ab	8.03b	6.26a	7.16a	8.58ab	12.28ab	10.43a	7.83a	9.54a	8.68a
V3	3.18a	4.33cd	3.71ab	8.83ab	6.90a	7.87ab	8.71ab	11.42ab	10.06ab	7.48a	9.81a	9.08a
V4	3.08a	4.78e	3.58ab	8.46ab	6.26a	7.36ab	7.25bc	10.51a	8.88ab	7.63a	10.54a	6.89a
V5	3.23a	5.70c	4.46ab	8.93ab	7.48a	8.20a	8.09ab	11.90ab	9.99a	6.60abc	9.30a	7.95a
V6	3.01a	5.63b	4.32ab	9.23a	6.67a	7.95c	6.64bc	12.37ab	9.50ab	6.40abc	10.40a	8.40a
V7	2.95a	4.10b	3.53ab	9.28a	8.77a	9.02abc	5.50g	11.12a	8.31b	4.93c	11.14a	8.03a
V8	3.13a	4.75e	3.94ab	9.18ab	7.46a	8.32abc	6.70bc	10.55b	8.62ab	5.45bc	10.20a	7.82a
V9	3.18a	6.75a	4.97ab	8.71ab	7.37a	8.04abc	6.66bc	11.20ab	8.93ab	6.33abc	10.30a	8.31a
V10	3.27a	4.58b	3.93ab	8.98ab	6.67a	7.82a	7.00de	11.71ab	9.35ab	6.73abc	9.55a	8.14a
V11	3.25a	6.73f	4.99ab	9.16ab	8.21a	8.68ab	7.86ab	10.69a	9.27a	7.83a	10.69a	9.26a
V12	3.08a	5.60d	4.34ab	8.93ab	7.21a	8.07a	9.32a	10.91a	10.11a	7.16ab	10.90a	9.03a
Fertilizer												
Mix	3.18a	7.19a	5.18a	8.63a	7.26a	7.94a	8.50a	10.15a	9.32a	8.02a	9.96a	8.99a
Ino	3.11a	7.89a	5.50a	8.92a	7.44a	8.18a	8.05a	9.99a	8.93ab	6.90b	8.29b	7.59a
Org	3.89a	6.41b	5.15a	8.88a	6.44a	7.66a	6.60b	10.63a	9.02b	6.00b	7.59b	6.79a
Ctl	3.00a	6.07c	4.53a	8.93a	7.10a	8.01a	6.40b	9.75a	8.07c	6.04b	8.33b	7.16a
V x F	Ns	***	ns	***	ns	ns	***	ns	ns	ns	ns	ns

Means with the same letter are not significantly different using DMRT at 5% probability

V₁ = SAMSORG 3, V₂ = SAMSORG 16, V₃ = SAMSORG 40, V₄ = SAMSORG 43, V₅ = SAMSORG 44, V₆ = SAMSORG 45, V₇ = SAMSORG 46, V₈ = SAMSORG 49, V₉ = SAMSORG 50sw, V₁₀ = CSR 01, V₁₁ = Jalingo local variety (Dawa), V₁₂ = Kaduna local variety (Kaura)

At harvest, stem girth narrowed slightly across treatments, yet notable differences were still observed. The highest values were observed in V11 (9.26 cm), V3 (9.08 cm), and V12 (9.03 cm), while varieties under mixed (8.99 cm) and inorganic (7.59 cm) fertilizers remained bigger. Organic and control treatments recorded lower girths, reflecting the long-term advantage of timely and adequate nutrient availability. These findings support the integrated nutrient management approach advocated by Palm *et al.* (2001).

Table 4 presents the interaction effects of variety and fertilizer on stem girth of sorghum at 6 and 9 WAP in Jalingo. Significant interactions ($p < 0.05$) were observed at both stages. At 6 WAP, stem girth ranged from 4.47 cm to 13.13 cm. V12 (Kaura) under the control treatment produced the highest stem girth (13.13 cm), which was significantly greater than all other treatments. This unexpected result highlights the potential of local genotypes to perform well under minimal input, possibly due to local adaptation. V5 (SAMSORG 44) under mixed fertilizer (11.57 cm) and V3 (SAMSORG 40) under inorganic fertilizer (10.53 cm) also recorded significantly high values. These results align with Adamu *et al.* (2018), who found that nutrient availability at early stages enhances vegetative growth and plant robustness. Conversely, the lowest values were observed in V7 (SAMSORG 46) under control and organic treatments, suggesting lower responsiveness or poor nutrient use efficiency. The superiority of mixed fertilizer indicates the benefits of combining organic and inorganic inputs, which improves nutrient availability and uptake efficiency (Palm *et al.*, 2001).

At 9 WAP, stem girth generally declined or stabilized, ranging from 3.53 cm to 10.07 cm. V11 (Jalingo local) under inorganic fertilizer produced the highest girth (10.07 cm), followed by V5 and V3 under mixed fertilizer (9.53 cm and 9.33 cm respectively). These values suggest that

continued access to nutrients supports structural development well into mid-growth stages. In contrast, the lowest stem girths were observed in V7 and V8 under organic and control treatments, further affirming that sole organic amendments may be insufficient for optimal growth in sorghum, especially during peak vegetative demand (Ibrahim *et al.*, 2015). Local varieties such as V11 and V12 (Kaura) demonstrated consistent performance across fertilizer treatments, making them suitable for both intensive and low-input farming systems. The combined effects of variety and nutrient source observed in this study are in agreement with Ezeaku and Mohammed (2006), who emphasized the importance of genotype $\times$ environment $\times$ management interactions in crop improvement programs.

The study revealed that both fertilizer type and varietal selection significantly influenced stem girth at different growth stages (Table 3). Mixed and inorganic fertilizers consistently enhanced stem development, especially in improved varieties such as SAMSORG 44, SAMSORG 40, and CSR 01. Local varieties (Jalingo local and Kaura) also showed strong adaptability and competitive performance under both high and low input conditions. This highlights the importance of integrated nutrient management and varietal adaptation in improving sorghum production in diverse agro-ecological zones of Nigeria.

At 3 weeks after planting (WAP), the interaction between variety and fertilizer type had a significant effect on stem girth in Bali (Table 6). Stem girth at this early stage is critical as it determines the plant's initial structural stability and vigour, which influences later biomass accumulation and lodging resistance (Ibrahim *et al.*, 2015). The highest stem girth (12.06 cm) was observed in V5 (SAMSORG 44) under mixed fertilizer, followed closely by V1 (SAMSORG 3) with 12.00 cm and V2 (SAMSORG 16)

with 11.40 cm under the same treatment. This confirms the superior effect of mixed fertilizer application on early stem development. The results are consistent with findings by Palm *et al.* (2001) and Adamu *et al.* (2018), who reported that combining organic and inorganic nutrients provides both quick and sustained nutrient availability for early vegetative growth. V4 (SAMSORG 43) and V9 (SAMSORG 50sw) also responded well under mixed fertilizers, recording stem girths above 10 cm. Conversely, some varieties such as V12 (Kaduna local) under organic fertilizer (5.53 cm) and V2 under organic and inorganic treatments (6.13 cm and 6.60 cm respectively) recorded significantly lower girth values, indicating either a genetic limitation or poor nutrient use efficiency at this early stage. Overall, varieties under mixed fertilizer consistently exhibited the bigger stem girths, suggesting that integrated nutrient management enhances early plant vigour more effectively than single nutrient sources. The control treatments, although not significantly different in some varieties (e. g. V1 and V5), generally recorded lower stem girths than mixed treatments. This trend supports previous research that nutrient limitations under control conditions can suppress early stem development (FAO, 2006; Olayiwola *et al.*, 2018). Interestingly, the local variety V11 (Jalingo local) had a notable stem girth (10.60 cm) under the control treatment, outperforming several improved varieties under fertilized conditions. This suggests a strong genetic adaptation of local varieties to the prevailing agro-ecological conditions in Bali, a finding

also supported by Ezeaku and Mohammed (2006). These findings underscore the importance of integrated soil fertility management and genotype-specific nutrient responsiveness in optimizing early-stage sorghum development, which is critical for achieving high yield potential under varying environmental conditions.

Days to 50% Tasseling (DT50%T) and Total Fresh Plant Biomass

The number of days to 50% tasseling differed significantly ($p \leq 0.05$) across varieties, fertilizer treatments, and locations (Table 6). Tasseling is a critical phenological stage in sorghum, marking the onset of reproductive growth and often correlating with grain yield and maturity phase (Ibrahim *et al.*, 2015; Olayiwola *et al.*, 2018). The earliest tasseling was recorded in V6 (SAMSORG 45) with 68.67 days in Jalingo and 75.3 days in Bali (average: 71.96 days), indicating its suitability for short-season environments or areas prone to terminal drought. Other early-tasseling varieties included V9 (SAMSORG 50sw), V10 (CSR 01), and V1 (SAMSORG 3), all maturing between 70 and 77 days across both sites.

In contrast, the late tasseling varieties were V12 (Kaduna local) and V11 (Jalingo local), with combined mean values of 107.38 and 101.75 days, respectively. These local varieties appear to be long-duration types, likely adapted to regions with extended growing periods. This wide range in tasseling time suggests significant genetic variability among varieties, a useful trait for breeding programs targeting both early and late maturity (Ezeaku and Mohammed, 2006).

Table 4: Effects of interaction of variety and fertilizer on stem girth (cm) of Sorghum at 6 and 9WAP during 2023 wet season in Jalingo

	Mix	Ino	Org	Ctl
6 WAP				
Variety				
V1	8.47b-I	6.33c-I	6.80c-I	4.80h-i
V2	9.00b-I	9.40a-g	7.27b-I	8.67b-i
V3	9.85a-e	10.53a-c	8.27b-I	6.20c-I
V4	7.94b-I	9.67a-f	5.07g-I	6.33c-i
V5	11.57ab	9.27a-h	6.47c-I	5.07g-i
V6	7.17b-i	8.47b-i	5.73d-i	5.20f-i
V7	7.17b-i	5.20f-i	5.53e-i	4.47i
V8	7.13b-i	7.20b-i	7.07c-i	5.40e-i
V9	7.00c-i	6.87c-i	6.20c-i	6.60c-i
V10	7.47b-i	8.00b-i	5.33f-I	5.67d-i
V11	10.20a-d	9.60a-g	6.60c-i	5.07g-i
V12	9.07a-h	6.13c-i	8.73a-i	13.13a
9WAP at Harvest				
V1	8.60a-f	5.80b-h	7.20a-h	4.60fgh
V2	8.53a-e	8.40a-f	5.00e-h	9.20a-d
V3	9.33abc	8.40a-f	4.27gh	7.93a-f
V4	8.40a-f	8.67a-e	5.67b-h	7.80a-f
V5	9.53ab	5.07e-h	6.93a-h	4.87e-h
V6	7.00a-f	7.67a-f	5.47c-h	5.47e-h
V7	6.27a-h	5.20d-h	3.53h	4.73e-h
V8	6.93a-h	3.53h	6.73a-h	4.60fgh
V9	6.80a-h	6.20a-h	6.67a-h	5.67a-h
V10	6.60a-h	7.67a-f	6.53a-h	6.13a-h
V11	9.53ab	10.07a	6.20a-h	5.53b-h
V12	8.73a-e	6.13a-h	7.80a-f	6.00b-h

Means with the same letter are not significantly different using DMRT at 5% probability

V₁ = SAMSORG 3, V₂ = SAMSORG 16, V₃ = SAMSORG 40, V₄ = SAMSORG 43, V₅ = SAMSORG 44, V₆ = SAMSORG 45, V₇ = SAMSORG 46, V₈ = SAMSORG 49, V₉ = SAMSORG 50sw, V₁₀ = CSR 01, V₁₁ = Jalingo local variety (Dawa), V₁₂ = Kaduna local variety (Kaura).

Table 5: Effects of Interaction of Variety and Fertilizer on Stem Girth (cm) at 3WAP during 2023 Wet Season in Bali

Variety	Mix	Ino	Org	Ctr
V1	12.00a	8.20b-h	9.13a-g	8.86a-h
V2	11.40ab	6.60f-h	6.13gh	6.60f-h
V3	10.26a-e	7.73c-h	8.33b-h	6.53f-h
V4	11.26a-c	7.13d-h	7.46d-h	8.00b-h
V5	12.06a	7.93b-h	7.80c-h	9.20a-g
V6	8.73a-h	8.46b-h	8.46b-h	8.73a-h
V7	9.06a-h	8.40b-h	9.46a-g	7.80c-h
V8	9.13a-g	8.86a-h	6.53f-h	9.60a-g
V9	9.93a-f	10.06a-f	8.06b-h	6.93e-h
V10	7.73c-h	8.73a-h	6.73e-h	9.60a-g
V11	8.86a-h	8.20b-h	7.40d-h	10.60a-d
V12	9.06a-h	9.20a-g	5.53h	7.53d-h

Means with the same letter are not significantly different using DMRT at 5% probability

V₁ = SAMSORG 3, V₂ = SAMSORG 16, V₃ = SAMSORG 40, V₄ = SAMSORG 43, V₅ = SAMSORG 44, V₆ = SAMSORG 45, V₇ = SAMSORG 46, V₈ = SAMSORG 49, V₉ = SAMSORG 50sw, V₁₀ = CSR 01, V₁₁ = Jalingo local variety (Dawa), V₁₂ = Kaduna local variety (K. Kaura).

Across fertilizer types, plants in the control (no fertilizer) took the longest time to tassel (92.83 days on average), significantly more than those under mixed fertilizer (84.14 days), inorganic (80.25 days), and organic (78.75 days). These

findings align with those of FAO (2006) and Palm *et al.* (2001), which emphasized that improved soil fertility accelerates physiological development in cereal crops. Total fresh plant biomass was significantly affected by variety and fertilizer type at both locations ($p \leq 0.05$), though the interaction effect (Variety $\times$ Fertilizer) was not significant for the combined data (Table 7). Highest biomass yields were observed in: V11 (Jalingo local) (3.94 t/ha), V2 (SAMSORG 16) (3.75 t/ha), V3 (SAMSORG 40) (3.37 t/ha), V12 (Kaduna local) (3.43 t/ha). These varieties demonstrated superior vegetative growth and resource use efficiency, possibly due to their longer growth durations, as supported by Adamu *et al.* (2018). The long vegetative phase in local varieties likely enabled more biomass accumulation compared to earlier maturing genotypes like V6 and V8, which recorded lower biomass values of 2.27 and 1.83 t/ha, respectively.

Fertilizer type significantly influenced biomass accumulation. Mixed fertilizer resulted in the highest biomass (3.21 t/ha), followed closely by inorganic (2.90 t/ha) and organic fertilizer (2.84 t/ha). The control treatment produced the lowest biomass (2.26 t/ha), a pattern consistent with the role of balanced nutrient supply in promoting vigorous vegetative growth (Palm *et al.*, 2001; Olayiwola *et al.*, 2018). Although the interaction between variety and fertilizer was not statistically significant for combined biomass, trends showed that improved varieties such as V2 and V3 responded strongly to fertilizer, especially mixed types. On the other hand, local varieties like V11 maintained relatively high biomass even under sub-optimal conditions, reinforcing their potential in low-input systems (Ezeaku and Mohammed, 2006). The experiment revealed clear varietal and fertilizer effects on days to 50% tasseling and fresh plant biomass in sorghum. Early maturing improved varieties like SAMSORG 45 and SAMSORG 3 are suited for areas with

shorter rainy seasons, while local varieties such as Jalingo and Kaduna locals may be ideal for regions with longer growing windows and biomass-focused utilization. Mixed fertilizer application was consistently superior in promoting early tasseling and high biomass production, confirming the importance of integrated soil fertility management for optimal sorghum performance.

Table 7 shows the interaction effects of variety and fertilizer on days to 50% tasseling and total fresh biomass of Sorghum in Jalingo and Bali (2023 Wet Season). The interaction between sorghum variety and fertilizer type significantly influenced the number of days to 50% tasseling in both Jalingo and Bali. Tasseling time is a critical phenological stage that directly relates to flowering, pollination, and eventual grain set, and is influenced by both genetic and nutritional factors (Ibrahim *et al.*, 2015; FAO, 2006). In Jalingo, the earliest tasseling (55.00 days) was recorded by SAMSORG 45 (V6) under organic fertilizer, while the latest (108.00 days) was observed in Kaduna local (V12) under control treatment. Similarly, Bali followed the same pattern, where the earliest tasseling (63.0 days) was also found in V6 under inorganic fertilizer, and the latest (117.0 days) in V12 under control. This shows that local varieties tended to tassel later than improved varieties, particularly under nutrient-deficient (control) conditions.

Improved varieties such as SAMSORG 3 (V1), SAMSORG 43 (V4), and SAMSORG 50sw (V9) tasseled earlier across fertilizer types, especially under inorganic and mixed fertilizers (Table 6). Early tasseling in these improved varieties indicates their responsiveness to nutrient application and their suitability for areas with short rainy seasons (Adamu *et al.*, 2018; Olayiwola *et al.*, 2018). Notably, local varieties (V11 and V12) maintained their characteristically long vegetative phases, especially under low-nutrient conditions. This delayed tasseling can be

advantageous for biomass accumulation but may reduce grain filling time if the rainy season ends early (Ezeaku and Mohammed, 2006).

The variety $\times$ fertilizer interaction also had a significant effect on total fresh biomass yield in both locations (Table 6) which conforms to the findings of (Ajeigbe *et al.*, 2015). In Jalingo, SAMSORG 16 (V2) under organic fertilizer produced the highest biomass (3.33 t/ha), followed by V3 and V4 under mixed and inorganic fertilizer treatments. V7 (SAMSORG 46) under control recorded the lowest biomass (0.93 t/ha), highlighting the importance of nutrient input for vegetative growth which is in-line with (Vanlauwe *et al.*, 2010) findings.

In Bali, the highest biomass yield (6.40 t/ha) was also obtained from V2 under organic fertilizer (Table 7), indicating a strong nutrient-use efficiency of SAMSORG 16 for above-ground growth. Other high performers included V11 (Jalingo local) and V12 (Kaduna local)

under mixed and inorganic fertilizers, yielding above 5.0 t/ha (table 7). This aligns with findings by Palm *et al.*, (2001), who emphasized that organic sources improve biomass by enhancing soil structure and microbial activity over time. Interestingly, some improved varieties such as V8 (SAMSORG 49) and V7 (SAMSORG 46) recorded consistently low biomass yields under all treatments in both locations (Table 6). This may indicate a poor adaptation or low response to the fertilizer regimes tested and suggests a need for further evaluation or breeding improvement. The control treatments in both sites consistently resulted in lower biomass yields across varieties, reaffirming the necessity of fertilization, especially integrated use of organic and inorganic fertilizers, which consistently enhanced biomass production. This is supported by previous studies that showed nutrient synergy improves crop vigor and yield sustainability (Palm *et al.*, 2001; Olayiwola *et al.*, 2018).

Table 6: Effects of Variety and Fertilizer on Days to 50% Tasseling and Total Fresh Plant Biomass of Sorghum at Jalingo and Bali in 2023 Wet Season

	DT50%T (days)		Total Plant Biomass (t/ha)			
	Jalingo	Bali	Combined	Jalingo	Bali	Combine
Variety						
V1	73.50e	80.3i	76.88ef	1.58cd	2.88de	2.20d
V2	85.08c	92.3d	88.67c	2.73a	5.00a	3.75ab
V3	84.42c	92.8c	88.58c	2.28b	4.47ab	3.37ab
V4	78.50d	83.5g	81.00d	2.18b	4.06bc	3.08bc
V5	80.08d	85.5f	82.79d	1.79c	3.52cd	2.60cd
V6	68.67f	75.3j	71.96g	1.56cd	2.99de	2.27d
V7	73.33e	80.3i	76.79ef	1.23e	2.71de	1.88d
V8	73.08e	87.3e	80.17de	1.22de	2.51e	1.83d
V9	70.17ef	81.3h	75.71f	1.66c	3.27ced	2.39cd
V10	71.25ef	81.3h	76.25f	2.15b	3.97bc	3.05bc
V11	99.50b	104.0b	101.75b	2.73a	5.26a	3.94a
V12	103.50a	111.3a	107.38a	2.39ab	4.56ab	3.43ab
Fertilizer						
Mix	81.03b	87.25b	84.14b	2.22a	4.22a	3.21a
Ino	76.08c	84.42c	80.25c	2.03ab	3.92ab	2.90a
Org	75.33c	82.17d	78.75c	1.95b	3.78b	2.84a
Ctr	87.92a	97.74a	92.83a	1.60c	3.04c	2.26b
V x F	***	***	***	*	***	ns

Means with the same letter are not significantly different using DMRT at 5% probability

V₁ = SAMSORG 3, V₂ = SAMSORG 16, V₃ = SAMSORG 40, V₄ = SAMSORG 43, V₅ = SAMSORG 44, V₆ = SAMSORG 45, V₇ = SAMSORG 46, V₈ = SAMSORG 49, V₉ = SAMSORG 50sw, V₁₀ = CSR 01, V₁₁ = Jalingo local variety (Dawa), V₁₂ = Kaduna local variety (Kaura)

Table 7: Effects of Interaction of Variety and Fertilizer on Days to 50% Tasseling (DT50%T) and Total Fresh Plant Biomass of Sorghum during 2023 Wet Season in Jalingo and Bali

	Mix	Ino	Org	Ctr	Mix	Ino	Org	Ctr
	Days to 50% tasseling							
	Jalingo				Bali			
V1	74.00j-p	65.00r	67.00pqr	88.00ef	75.0v	74.0w	75.0v	97.0h
V2	86.33fg	80.00g-k	79.00h-k	95.00cd	90.0k	88.0m	87.0n	104.0e
V3	82.66f-l	81.00f-g	76.00i-n	98.00bcd	87.0n	89.0l	88.0m	107.0d
V4	79.00h-l	74.00j-p	76.00i-n	85.00fgh	84.0p	82.0q	74.0w	94.0i
V5	84.33fgh	72.00l-r	71.00m-r	93.00ed	89.0l	76.0u	79.0r	98.0g
V6	74.66j-o	57.00s	55.00s	88.00ef	77.0t	63.0v	64.0x	97.0h
V7	74.33j-p	68.00o-r	68.00o-r	83.00f-i	78.0s	76.0u	76.0u	91.0j
V8	73.33j-p	68.00qr	71.00m-r	81.00f-g	79.0r	79.0r	79.0r	112.0b
V9	69.66m-r	69.00n-r	69.00n-r	73.00l-q	86.0o	87.0n	78.0s	74.0w
V10	73.00k-q	77.00i-m	70.00m-r	65.00r	86.0o	87.0n	78.0s	74.0w
V11	98.00bcd	101.00bc	101.00bc	98.00bcd	108.0c	100.0f	100.0f	108.0
V12	102.00abc	103.00ab	101.00bc	108.00a	108.0c	112.0b	108.0a	117.0a
	Fresh biomass yield (t/ha)							
V1	1.73f-m	1.76f-m	1.86e-k	0.93m	2.90h-m	3.45e-m	3.30e-m	2.06lm
V2	3.16ab	2.90abc	3.33a	1.50h-m	5.37a-d	4.70a-h	6.40a	2.65i-m
V3	2.66a-e	1.96d-j	2.56a-f	1.93d-j	5.00a-e	4.03b-k	4.80a-g	4.03b-k
V4	2.66a-e	2.00d-j	1.93d-j	2.13c-i	4.83a-f	4.00b-k	3.73d-m	3.50e-m
V5	1.93d-j	1.90d-j	2.03d-j	1.30i-m	3.56d-m	4.30b-j	3.86c-l	1.93m
V6	1.63g-m	1.90d-j	1.46i-m	1.23j-m	3.23e-m	3.60d-m	2.73i-m	2.40klm
V7	1.16j-m	0.93m	1.43i-m	0.96lm	3.06f-m	2.50j-m	2.50j-m	2.70i-m
V8	1.43i-m	1.23j-m	1.16j-m	1.03klm	2.70i-m	2.63i-m	2.46j-m	2.10lm
V9	1.93d-j	1.50h-m	1.60g-m	1.60g-m	4.13b-k	2.70i-m	3.13f-m	2.75i-m
V10	2.53a-f	2.50a-f	1.80f-l	1.76f-m	5.00a-e	4.37b-l	3.53d-m	2.97g-m
V11	3.00ab	3.00ab	2.43b-g	2.50a-f	5.80ab	5.57abc	4.83a-f	4.65a-h
V12	2.73a-d	2.73a-d	1.76f-m	2.33b-h	5.06a-e	4.80a-g	3.56d-m	4.90a-f

Means with the same letter are not significantly different using DMRT at 5% probability

V₁ = SAMSORG 3, V₂ = SAMSORG 16, V₃ = SAMSORG 40, V₄ = SAMSORG 43, V₅ = SAMSORG 44, V₆ = SAMSORG 45, V₇ = SAMSORG 46, V₈ = SAMSORG 49, V₉ = SAMSORG 50sw, V₁₀ = CSR 01, V₁₁ = Jalingo local variety (Dawa), V₁₂ = Kaduna local variety (Kaura).

CONCLUSION

This study investigated the interactive effects of different sorghum varieties and fertilizer regimes (organic, inorganic, and their mixtures) on growth and yield parameters, including number of leaves, days to 50% flowering, and grain yield per hectare in Jalingo and Bali locations. The results revealed significant varietal responses, with Samsorg 16 (V₂) outperforming other varieties in terms of number of leaves with an effect attributed to its superior genetic potential and enhanced nutrient uptake, especially under high inorganic fertilizer application.

Organic fertilizer consistently produced the highest yields across both locations and in the combined analysis. In terms of total plant biomass, varieties V₁₁, V₂, V₁₂, and V₃ were the top performers, with respective yields of 3.94 t/ha, 3.75 t/ha, 3.43 t/ha, and 3.37 t/ha across locations. Among the fertilizer treatments, the mixture of organic and inorganic fertilizers resulted in the highest total biomass production. Based on these findings, if the goal is to maximize total biomass particularly for herders, then variety V₂ (in Jalingo) and varieties V₂ and V₃ (in Bali) when combined with either organic or mixture fertilizer treatments are

recommended as suitable options for farmers and herders in the study areas.

Furthermore, the interaction between organic and inorganic fertilizer treatments significantly improved grain yield compared to untreated plots, with the mixture treatment producing the highest yields in Bali, likely due to improved nutrient synchronization and varietal adaptability across sampling points. In Jalingo, the combined application of fertilizers also showed clear superiority over other treatments except for the mixture and organic-only treatments, which were statistically comparable. These findings confirm that both genetic potential of the sorghum varieties and the type of fertilizer input significantly affect growth and yield. Conclusively, combining organic and inorganic fertilizer sources offers a promising strategy for optimizing sorghum productivity, especially when matched with well-adapted varieties across agro-ecological zones with good biomass output.

REFERENCES

- AATF (African Agricultural Technology Foundation) (2011). Feasibility study on Striga Control in Sorghum Nairobi, *African Agricultural Technology*. ISBN 9966-775-12-19.
- Adediran, J., A., Banjoko, V., A. (2003). Comparative effectiveness of some compost fertilizer formations for maize in Nigeria. *Nigerian Journal of soil science*, 13:24-49.
- Aduba, J. J., Mignouna, D. B., Manyong, V., & Abdoulaye, T. (2013). Determinants of market participation among sorghum farmers in Nigeria. *Journal of Economics and Sustainable Development*, 4(6), 62–68.
- Ajeigbe, H. A., Akinseye, F. M., Angarawai, I. I., Umma, S. A., Inuwa, A. H., Adinoyi, A., & Abdulazeez, T. (2017). *Enhancing farmers' access to technology and market for increased sorghum productivity in the selected Staple Crop Processing Zones*. In 51st Annual Conference of the Agricultural Society of Nigeria (ASN), October 23–27, 2017, Agricultural Research Council of Nigeria, Abuja, Nigeria (pp. 1068–1072). <http://oar.icrisat.org/10373/>
- Ajeigbe, H. A., Akinseye, F. M., Jonah, J., & Kuniha, A. (2018). Sorghum yield and water use under phosphorus fertilization applications in the Sudan savanna of Nigeria. *Global Advanced Research Journal of Agricultural Science*, 7(8), 245–257.
- Ajeigbe, H. A., Akinseye, F. M., Tukur, A., Inuwa, A. H., & Whitbread, A. M. (2024). Response of sorghum varieties to organic and inorganic fertilizer strategies in Sudan savanna of Nigeria: Productivity, nitrogen, and water use efficiencies. *Journal of Agronomy Research*, 5(3).
- Ajeigbe, H. A., Kamara, A. Y., & Yusuf, A. B. (2015). *Fertilizer effects on the performance of sorghum varieties under different agroecologies in Nigeria*. *African Journal of Agricultural Research*, 10(12), 1410–1417.
- Akanbi, W., B., Togun, a., O., Adediran, J., A., Ilupeju, e., A., O. (2010). Growth, dry matter and mineral nitrogen fertilizer for tomato production *J. of veg. science*, 11 (1):57-65.
- Akinfasoye, J. A., Olufolaji, A. O., Tauru, F. M., & Adenowoola, R. A. (1997). Effect of different phosphorus levels on the yield of four tomato cultivars (*Lycopersicon esculentum*). In Proceedings of the 15th Annual Conference of the Horticultural Society of Nigeria. NIHORT, Ibadan, Nigeria.
- Alamu, O. T., Amao, A. O., Nwokedi, C. I., Oke, O. A., & Lawa, I. O. (2013). Diversity and nutritional status of edible insects in Nigeria: a review. *International Journal of*

- Biodiversity and Conservation*. 5(4): 215-222.
- Ayub, M., Nadeem, M. A., Tanveer, A., & Husnain, A. (2002). Effect of different levels of nitrogen and harvesting times on the growth, yield and quality of sorghum fodder. *Asian Journal of Plant Sciences*, 1(4), 304–307.
- Baiyegunhi, L. J. S., & Fraser, G. C. G. (2009). Profitability in sorghum production in three villages of Kaduna State, Nigeria. *Journal of Applied Sciences Research*, 5(10), 1685–1691.
- Blum, A. (2011). *Plant breeding for water-limited environments*. New York, NY: Springer. <https://doi.org/10.1007/978-1-4419-7491-4>
- Dademal, A. A., Dangale, J. H., & Mhaskar, N. V. (2004). Effect of manures and fertilizers on content and uptake of nutrients by okra on lateritic soil of Konkan. *Journal of Soils and Crops*, 14(2), 262–268.
- Easlon, H. M., Carlisle, E., McKay, J. K., & Bloom, A. J. (2015). Does low stomatal conductance or photosynthetic capacity enhance growth at elevated CO₂ in *Arabidopsis thaliana*? *Plant Physiology*, 167(3), 793–799. <https://doi.org/10.1104/pp.114.245241>
- Elferink, M. & Schierhorn, F. *Global Demand for Food Is Rising. Can We Meet It*; Harvard Business Review: Boston, MA, USA, 2016; Available online: <https://hbr.org/2016/04/global-demand-for-food-is-rising-canwe-meet-it> (accessed on 16 March 2019).
- Emeberi, C. O., Akinrinde, E. A., & Ojeniyi, S. O. (1992). *Effects of poultry manure on soil fertility and crop yield in southwestern Nigeria*. *Nigerian Journal of Soil Science*, 5, 28–36.
- Essiet, D. (2024, May 8). Addressing declining soil fertility in Africa amid population surge. *FARA Africa*, pp. 1–3. <https://faraafrica.org/>
- Ezeaku, I. E., Uguru, M. I., & Akinwale, M. G. (2018). Evaluation of indigenous sorghum genotypes for drought tolerance. *Journal of Agronomy and Crop Science*, 204(1), 12–21.
- Ezeaku, P. I., & Mohammed, I. B. (2006). Characterization of drought tolerance in diverse cowpea genotypes in the Sudan savannah of Nigeria. *Agricultural Journal*, 1(4), 252–259.
- FAO. Lake Chad Basin Crises: Response Strategy (2017–2019): Mitigating the Impact of the Crisis and Strengthening the Resilience and Food Security of Conflict-Affected Communities; FAO: Rome, Italy, 2017; pp. 1–12.
- FAOSTAT. 2024. Database of agricultural production. Rome: Food and Agriculture Organization of the United Nations. Available at <http://faostat.fao.org/default.aspx> accessed November 2015.
- Food and Agriculture Organization of the United Nations. (2006). *Plant nutrition for food security: A guide for integrated nutrient management* (Fertilizer and Plant Nutrition Bulletin No. 16). Rome: Author. [openknowledge.fao.org+14fao.org+14scirp.org+14](https://openknowledge.fao.org/14fao.org+14scirp.org+14).
- GAIN. 2020. Grain and Feed Update – Nigeria. Report by Global Agricultural Research Network (GAIN), Foreign Agriculture Acta Agriculturae Scandinavica, Section B — Soil & Plant Science 671 Service, United State Department for Agriculture. <https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReport>.

- Gungula, D. T., Kling, J. G., & Togun, A. O. (2005). *The influence of nitrogen and phosphorus on growth and yield of sorghum (Sorghum bicolor (L.) Moench) in a savanna agro-ecology of Nigeria*. Nigerian Journal of Soil Research, 6, 35–43.
- Gungula, D. T., Kling, J. G., & Togun, A. O. (2014). Influence of nitrogen fertilization on genotype differences in sorghum: effects on chlorophyll, leaf number, flowering and grain yield. *Agronomy Journal*, 106(3), 987–994.
- Ibrahim, U., Usman, B. A., & Kureh, I. (2002). Effects of poultry manure and inorganic fertilizer on the performance of sorghum (*Sorghum bicolor* L.) in the northern Guinea savanna of Nigeria. *Nigerian Journal of Soil Science*, 13, 22–29.
- Ibrahim, U., Yusuf, A. A., & Lado, A. (2015). Response of sorghum (*Sorghum bicolor* L.) to NPK fertilizer in a savannah region of Nigeria. *Nigerian Journal of Basic and Applied Sciences*, 23(2), 99–104.
- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). (2019). *Sorghum improvement: Annual report*. ICRISAT.
- Ndapamuri, M. H., Herawati, M. M., & Meitiniarti, V. I. (2020). Production of sugar from sweet sorghum stems with hydrolysis method using *Trichoderma viride*. *Biosaintifika: Journal of Biology & Biological Education*, 13(1).
- Ndukwe, O. O., Okondor, P. I., Uko, I., Obidiebube, E. A., Okolie, H., Apalowo, O. A., & Orji, C. M. (2023). Agronomic performance of five sorghum varieties in a humid tropical zone as influenced by fertilizer rates. *International Journal of Agriculture, Environment and Bioresearch*, 8(2), 103–114. <https://doi.org/10.35410/IJAEB.2023.582>
- Obilana, A. T. (2004). *Sorghum improvement in Nigeria: Opportunities, constraints, and strategies*. In L. S. K. Twumasi-Afriyie, H. O. Mochiah, & A. Menkir (Eds.), *Proceedings of the Workshop on Sorghum and Millet Improvement in West and Central Africa* (pp. 17–24).
- Odozi, J. C. (2015). Cross-border trade in grain between Nigeria and neighbouring Niger: Risk management assessment along Sokoto Illela-Konni border land. *Cogent Economics & Finance*, 3(1). <https://doi.org/10.1080/23322039.2015.1025055>
- Odozi, J.C. *Cross Border Trade in Grain between Nigeria and Neighbouring Niger: Risk Management Assessment Along Sokoto Illela-Konni Border Land*. Cogent Econ. Financ. 2015, 3, 1029250.
- Olayiwola, M. O., Olaniyan, A. B., & Ojeniyi, S. O. (2018). Growth and yield response of sorghum (*Sorghum bicolor* L.) to organic and inorganic fertilizer on an Alfisol in southwestern Nigeria. *International Journal of Agriculture and Biology*, 20(3), 489–494.
- Olowe, V. I. O., Ojo, D. K., & Akanbi, W. B. (2020). Influence of nutrient sources on growth and yield of cereal crops under savanna conditions. *Nigerian Journal of Soil Science*, 30(1), 111–120.
- Palm, C. A., Myers, R. J. K., & Nandwa, S. M. (2001). Organic-inorganic nutrient interactions in soil fertility replenishment. In R. J. Buresh, P. A. Sanchez, & F. Calhoun (Eds.), *Replenishing soil fertility in Africa* (pp. 193–218). Soil Science Society of America.
- Premsekhar, M. & Rajashree, V. (2009). Performance of hybrid tomato as influenced by foliar feeding of water

- soluble fertilizers. *American-Eurasian Journal of Sustainable Agriculture*, 3(1), 33–36.
- Rabbinge, R., & van Oijen, M. (1997). *Scenario studies for future agriculture and crop protection*. *European Journal of Plant Pathology*, 103(3), 197–201.
- Saidu, A., Bello, L. Y., Tsado, E. K., & Ibrahim, F. K. (2011). Effect of cow dung on the performance of tomato. *International Journal of Applied Biological Research*, 17, 169–176.
- Shuaibu, Y. M., Bala, R. A., Kawure, S., & Shuaibu, Z. (2018). *Effect of organic and inorganic fertilizer on the growth and yield of sorghum (Sorghum bicolor L. Moench) in Bauchi state, Nigeria*. *GSC Biological and Pharmaceutical Sciences*, 2(1), 25–31.
- Suarni, S. (2016). *The Role of Sorghum's Physicochemical Properties in Food and Industrial Diversification and Its Development Prospects*. *Journal of Agricultural Research and Development*, 35(3), 99–110.
- Taraba State Ministry of Agriculture and Natural Resources. (2019). *Soil and land resource survey report of Taraba State*. Jalingo, Nigeria: Department of Agricultural Services and Land Use Planning.
- Taruvinga, A., Mashingaidze, A. B., & Manyangarirwa, W. (2021). Genotype-by-environment interaction effects on growth and physiological traits of sorghum (*Sorghum bicolor* L. Moench) in semi-arid environments. *South African Journal of Plant and Soil*, 38(1), 65–72. <https://doi.org/10.1080/02571862.2020.1799877>
- Tyagi, P. K., Puniya, R., Yadav, R. K., & Sahu, R. K. (2014). Effect of integrated nutrient management on yield and nutrient uptake in sorghum (*Sorghum bicolor* L.). *Indian Journal of Agronomy*, 59(1), 139–142.
- Vanlauwe, B., Bationo, A., Chianu, J., Giller, K. E., Merckx, R., Mkwunye, U., Ohiokpehai, O., Pypers, P., Tabo, R., Shepherd, K. D., Smaling, E. M. A., Woomer, P. L. and Sanginga, N. (2020). Integrated soil fertility management Operational definition and consequences for implementation and dissemination. *Outlook on Agriculture*. 39(1): 17–24.