



Influence of Climate-Resilient Cropping Systems on Vegetative and Yield Parameters of Cassava (*Manihot esculenta* Crantz) Maize (*Zea mays* L.) Intercrops under Herbicide and Hand-Weeding Management in Taraba State, Nigeria

^{1*}Tsoken M. D., ²Micheal C. G., ³Angyu D., ⁴Wabuji B. B. and ⁵Gargea N. G.

¹Department of Crop Science, Federal University of Agriculture Zuru, Kebbi State, Nigeria

²Department of Crop Science, Taraba State University, Jalingo, Nigeria

³Department of Soil Science and Land Resources Management, Federal University Wukari, Taraba State, Nigeria

⁴Department of Biological Science, College of Education Zing, Taraba State, Nigeria

⁵Department of Crop Production and Protection, Federal University Wukari, Taraba State, Nigeria

*Corresponding Authors: tsokenmaigidad@gmail.com

ARTICLE HISTORY

Received: 05/06/2026

Accepted: 20/07/2026

Article Type:

Research Paper

Volume: 14

Issue: 1

Pp: 233 –245

This study evaluated the influence of cassava variety and weed management practices on the vegetative growth and yield performance of Cassava (*Manihot esculenta* Crantz) Maize (*Zea mays* L.) intercrops in Taraba State, Nigeria. The experiment was conducted during the 2024 cropping season at two agroecological locations: Taraba State University Teaching and Research Farm, Jalingo, and Federal University Wukari Teaching and Research Farm. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Treatments consisted of two cassava varieties (Farmers Pride and Game Changer) and three weed management practices: Atrazine herbicide application, recommended hand-weeding, and unweeded control. Data were collected on crop establishment, vegetative growth, weed suppression, biomass production, and yield parameters, and were subjected to analysis of variance using SAS software. The study revealed significant effects of cassava variety, weed management, and location on crop performance. Atrazine application provided superior weed suppression and enhanced crop growth compared with hand-weeding and unweeded control. Farmers Pride consistently outperformed Game Changer, recording the highest fresh biomass yield of 12.5 t ha⁻¹ under Atrazine treatment compared with 10.8 t ha⁻¹ for Game Changer. The novelty of this study lies in demonstrating the interactive influence of improved cassava variety selection and integrated weed management for enhancing climate resilience of cassava maize systems under semi-arid conditions of Taraba State. The study concludes that combining Farmers Pride cassava variety with effective weed management, particularly Atrazine-based weed control, offers a promising strategy for improving productivity and sustainability of cassava maize intercropping systems in Nigeria.

Keywords: Climate-resilient agriculture, Intercropping, Atrazine, Hand-weeding, Weed management, Semi-arid agriculture.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) and maize (*Zea mays* L.) are among the most important food crops cultivated in tropical Africa, contributing significantly to food security, income generation, and livelihood improvement among smallholder farmers. Cassava is widely appreciated for its

adaptability to marginal environments, drought tolerance, and ability to produce reasonable yields under low-input production systems, while maize remains an important cereal crop for human consumption, livestock feed, and industrial purposes (El-Sharkawy, 2004; FAO, 2021). Increasing climate variability, declining

soil fertility, and limited agricultural resources have created the need for sustainable and climate-resilient cropping systems. Intercropping, particularly cassava maize association, improves resource-use efficiency through complementary utilization of sunlight, soil moisture, and nutrients. The differences in canopy structure, rooting pattern, and growth duration between cassava and maize enhance land productivity and yield stability compared with sole cropping systems (Vandermeer, 1992; Tsubo and Walker, 2003; Lithourgidis *et al.*, 2011).

Cassava maize intercropping is widely practiced by smallholder farmers because it provides diversified harvests, reduces production risks, and improves food security under uncertain climatic conditions. Cassava's deep root system enables access to soil moisture from deeper layers, while maize efficiently utilizes available radiation during its early growth period, resulting in complementary resource utilization (Tsubo and Walker, 2003). However, weed interference remains one of the major constraints affecting productivity of cassava maize systems. Weeds compete with crops for essential resources including water, nutrients, light, and space, leading to reduced crop growth and yield. The impact of weed competition is more severe in semi-arid environments where limited moisture availability increases competition between crops and weeds (Oerke, 2006; Chauhan and Johnson, 2010).

Effective weed management is therefore critical for improving crop establishment, vegetative growth, and yield performance. Atrazine is a commonly used selective pre-emergence herbicide in maize-based production systems because of its effectiveness in suppressing broadleaf weeds and some grass species during early crop development (Heap, 2020). Similarly, timely hand-weeding remains an important weed control practice among smallholder farmers, although it is labour-intensive and may become less effective when delayed beyond the critical weed competition period (Ngouajio and Mutch, 2004).

In addition to weed management, cassava varieties differ in their ability to withstand

environmental stress and competition due to variations in growth habit, canopy development, and resource acquisition efficiency. Selecting suitable varieties with appropriate management practices is therefore essential for improving productivity and resilience of cassava-based systems (Adewolu *et al.*, 2010). Although cassava maize intercropping is extensively practiced in Nigeria, limited information exists on the interaction between cassava variety, weed management strategy, and agroecological conditions, particularly under semi-arid environments of Taraba State. Understanding these interactions is necessary for developing location-specific recommendations that improve crop productivity and sustainability.

Therefore, this study aimed to (i) evaluate the effect of Atrazine and hand-weeding on cassava establishment, growth, and biomass production; (ii) determine varietal differences between Farmers Pride and Game Changer; and (iii) assess the influence of agroecological location on cassava maize intercrop performance under semi-arid conditions of Taraba State.

MATERIALS AND METHODS

Study Area

The experiment was conducted during the 2024 cropping season at two locations representing different agroecological zones of Taraba State, Nigeria. The locations were selected to evaluate the response of cassava maize climate-resilient intercropping systems under contrasting environmental conditions.

The Jalingo experimental site is located within the Northern Guinea Savanna ecological zone of Nigeria at approximately 08°05'2N and 11°02'2E, with an elevation of about 349 m above sea level. The area experiences a tropical wet-and-dry climate characterized by a unimodal rainfall pattern occurring mainly between April and October. Annual rainfall ranges from 800 to 1,063 mm, followed by a relatively long dry season extending from November to March (Adeola *et al.*, 2023). The mean annual temperature ranges between 25 and 35°C, while relative humidity varies between wet and dry seasons. The vegetation

is predominantly Northern Guinea Savanna, characterized by scattered trees, grasses, and shrubs adapted to seasonal moisture availability (Ayoade, 2004; Thierry *et al.*, 2026).

The Wukari experimental site is located within the Southern Guinea Savanna ecological zone of Taraba State at approximately 07°50'37N and 09°46'31E (Figure 1), with an elevation of about 187 m above sea level. The area experiences a tropical savanna climate with a

relatively longer growing season compared with Jalingo (Ofoezie *et al.*, 2022). Annual rainfall ranges between 1,000 and 1,300 mm, distributed mainly from April to October. Mean temperature ranges from 24 to 34°C, while relative humidity remains higher during the rainy season due to increased vegetation cover and moisture availability, this area features a mix of trees and tall grasses (Markus *et al.*, 2022; Thierry *et al.*, 2026).

LOCATION MAP OF JALINGO AND WUKARI AGROECOLOGICAL ZONES IN TARABA STATE, NIGERIA

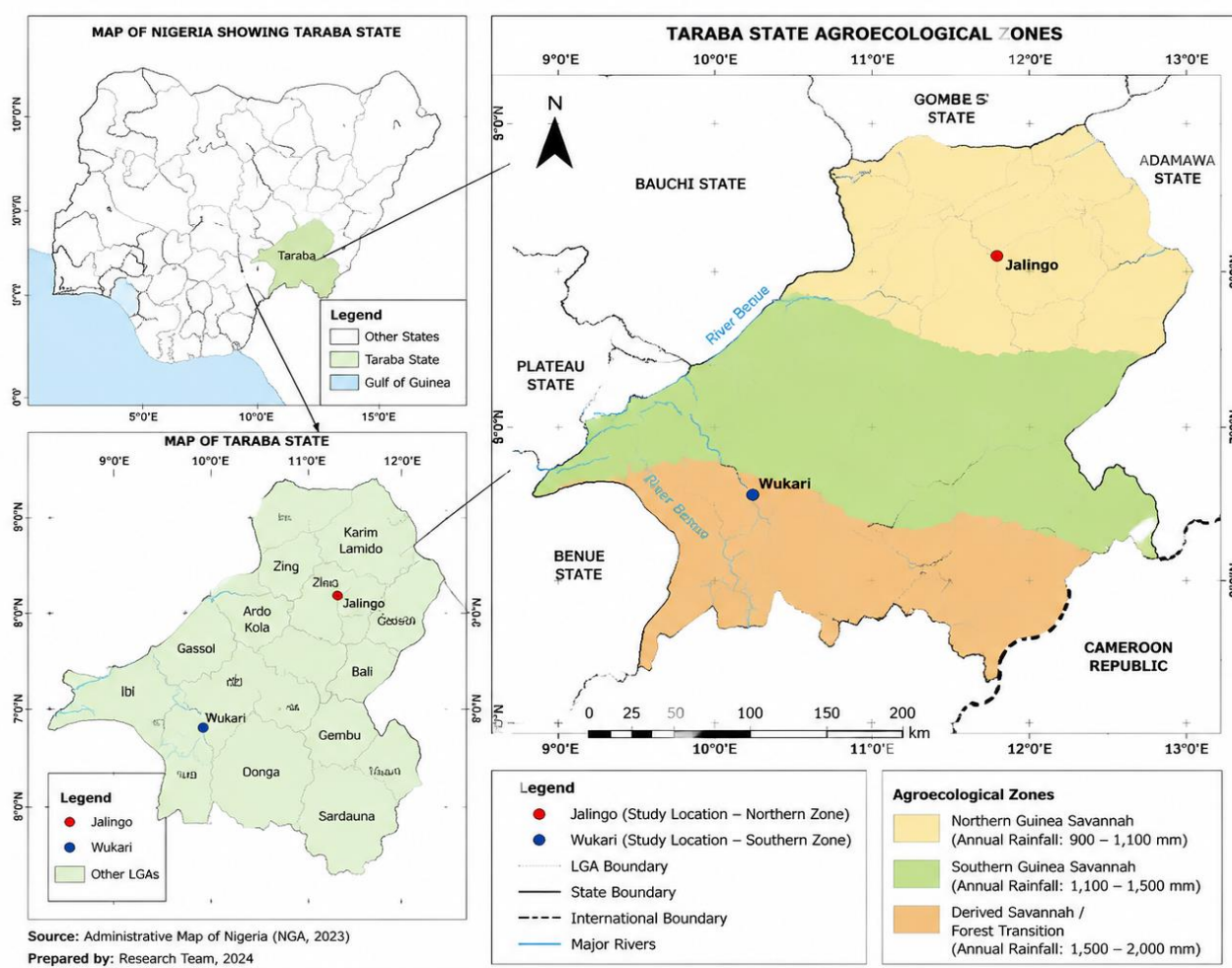


Figure 1: Map of Jalingo and Wukari Agro-Ecological Zones of Taraba State
Source: Nationsonline.org (2026)

Soil Sampling and Laboratory Procedures

Before the establishment of the experiment, soil samples were collected from each experimental location to determine the initial physical and chemical properties of the soils. Composite soil samples were collected randomly from different points within each experimental site using a soil auger at a depth of 0-15 cm.

The collected soil samples were bulked together, air-dried, gently crushed using a mortar and pestle to break soil aggregates, and passed through a 2 mm sieve to remove plant residues, stones, and other unwanted materials before laboratory analysis.

Routine soil analyses were carried out at the Department of Soil Science Laboratory, Federal University Wukari, to determine soil physical and chemical characteristics. Soil pH was determined using standard procedures described by McLean (1982), organic carbon and organic matter were determined following Nelson and Sommers (1982; 2016), total nitrogen was determined using the Kjeldahl method described by Bremner and Mulvaney (1982) and Bremner (2018), available phosphorus was determined using the Bray and Kurtz method (Bray and Kurtz, 1945), while particle size distribution was determined using the hydrometer method of Gee and Bauder (1986). Exchangeable cations were determined following Thomas (1982).

Cropping System and Study Design

The study evaluated a cassava maize intercropping system under different weed management strategies. Two cassava varieties used were Farmers Pride (FP) and Game Changer (GC). Maize was planted as an intercrop with both cassava varieties. The weed management treatments evaluated were (1) atrazine herbicide (H), applied as a pre-emergence herbicide at the recommended rate. (2) recommended hand-weeding (RHW) manual weed removal

carried out at 6 weeks after planting and (3) unweeded control (UWC), plots allowed to grow naturally without weed removal.

Experimental Design and Sampling Techniques

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications at each location. Each treatment was randomly assigned within each block to minimize experimental error. Each experimental plot measured 5 m × 5 m (25 m²), with 1 m spacing between plots and 2 m between replications. Cassava was planted at 1 m × 1 m spacing, while maize was planted at 25 cm × 1 m spacing. Standard agronomic practices, including fertilizer application and pest management, were uniformly applied across all treatments.

Data Collection and Analysis

Data were collected on crop establishment, vegetative growth, weed suppression, and yield performance.

Crop growth parameters

Crop establishment was assessed at three weeks after planting (WAP) by determining the germination (emergence) percentage of both Cassava and maize, calculated as:

$$\text{Germination Percentage} = \frac{\text{Number of Germinated Seeds}}{\text{Total Seeds Planted}} \times 100 \quad 1$$

Vegetative growth parameters were measured periodically at 4, 8, and 12 WAP. Plant height was measured from the soil surface to the terminal leaf apex using a graduated meter rule, while stem girth was measured and recorded using a rope and later placed on a standard ruler as adopted by Yaroson *et al.* (2024). Non-destructively estimate leaf area (LA), individual leaf length (L) and maximum leaf width (W) were measured in centimeter, and leaf area was calculated using the empirical adjustment model adopted by Niu *et al.* (2023) and Vasileva (2026).

$$L A = L \times W \times 0.75 \quad 2$$

Where 0.75 represents the shape correction coefficient widely adopted for cereal and broadleaf crops.

Yield and yield components

At physiological maturity, crop harvest was conducted within the designated net plot area to determine the total biomass production and yield performance following the methods adopted by Yaroson *et al.* (2024). Cassava and maize plant samples were separated into above-ground components (stems, leaves, and crop residues) and below-ground components. Above-ground fresh biomass was weighed immediately post-harvest using a digital balance and converted to tonnes per hectare (t ha⁻¹). Below-ground biomass, consisting of fresh cassava storage roots, was carefully excavated, cleaned of adhering soil particles, and weighed to record fresh root yield. Total fresh biomass was computed as the sum of above-ground and below-ground fresh biomass. Final economic yield for cassava was extrapolated from the net plot fresh root weight and expressed in tonnes per hectare (t ha⁻¹).

Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) using SAS statistical software (SAS Institute, 2018). Treatment means were separated using Least Significant Difference (LSD) at 5% probability level ($p \leq 0.05$).

RESULTS AND DISCUSSION

Soil Physico-Chemical Properties of the Experimental Locations

The initial soil properties of the two experimental locations are presented in Table 1. The soils of both locations were generally suitable for cassava and maize production, although variations existed between Wukari and Jalingo. Wukari recorded higher values of soil pH, organic carbon, organic matter, total nitrogen, available phosphorus, exchangeable bases, and cation exchange capacity compared with Jalingo. The soil analysis revealed differences in fertility status between Wukari and Jalingo locations. Wukari recorded higher values of organic carbon, organic matter, total nitrogen, available phosphorus, exchangeable cations, and cation exchange capacity compared with Jalingo. These improved soil conditions provided a more favourable environment for crop growth and may have contributed to the better performance of cassava maize intercrops at Wukari. Soil organic matter improves nutrient availability, soil structure, and water retention capacity, which are important under semi-arid production conditions (Nelson and Sommers, 2016). Both locations had slightly acidic soils suitable for cassava production (Howeler, 2002).

Table 1: Average Soil Physico-Chemical Properties of the Experimental Locations

Parameter	Unit of Measurement	Wukari	Jalingo
Organic Carbon (OC)	%	1.12	0.42
Organic Matter (OM)	%	1.93	0.72
Total Nitrogen (N)	%	0.10	0.06
Available Phosphorus (P)	mg kg ⁻¹	7.6	3.9
Exchangeable Potassium (K)	cmol kg ⁻¹	0.18	0.12
Exchangeable Calcium (Ca)	cmol kg ⁻¹	4.15	2.70
Exchangeable Magnesium (Mg)	cmol kg ⁻¹	1.08	0.81
Cation Exchange Capacity (CEC)	cmol kg ⁻¹	11.7	7.8
Electrical Conductivity (EC)	dS m ⁻¹	0.14	0.09
Bulk Density	g cm ⁻³	1.41	1.46
Soil Texture	Textural class	Sandy clay loam	Sandy loam

Source: Laboratory soil analysis (2024).

Effects of Weed Management and Cassava Variety on Germination Percentage

Germination percentage of cassava was significantly influenced by weed management practices and cassava variety (Table 2). Atrazine-treated plots recorded the highest germination percentage, followed by recommended hand-weeding, while the unweeded control recorded the lowest values. Atrazine increased cassava establishment by reducing early weed competition during the critical emergence period. Farmers Pride recorded higher germination percentage (85%) compared with Game Changer (78%) under Atrazine application, indicating possible genetic differences in establishment ability and early growth vigour. The lower germination recorded under unweeded conditions may be associated with early competition between

cassava plants and weeds for soil moisture, nutrients, and available space. Early weed interference can negatively affect crop establishment and reduce subsequent growth potential (Chauhan and Johnson, 2010). The superiority of Farmers Pride suggests that this variety may possess better adaptation characteristics, including stronger sprouting ability and improved tolerance to early environmental stress. Similar varietal differences in cassava establishment and growth response have been reported by Adewolu, Olorunfemi, and Adetimirin (2010). The improved performance under Atrazine agrees with findings of Aktar, Sengupta, and Chowdhury (2009), who reported that effective early weed suppression enhances crop establishment by reducing competition during early growth stages.

Table 2: Effects of Weed Management on Germination Percentage of Cassava

Variety	Atrazine (%)	Recommended Weeding (%)	Hand-Weeding (%)	Unweeded Control (%)
Farmers Pride	85a	82b		70c
Game Changer	78a	75b		65c

Key: Means followed by different letters within rows are significantly different at $p \leq 0.05$.

Effects of Weed Management on Cassava Plant Height, Leaf Area and Stem Girth

Plant height, leaf area and stem girth was significantly affected by weed management treatments and cassava varieties (Table 3). Atrazine-treated plots produced the tallest plants, followed by recommended hand-weeding, while the unweeded plots recorded the shortest plants. Cassava growth parameters, including plant height, leaf area, and stem girth, were significantly influenced by cassava variety and weed management practices. The superior growth performance observed under Atrazine treatment can be attributed to effective early-season weed suppression, which reduced competition for critical growth resources such as soil moisture, mineral nutrients, and solar radiation. Under reduced weed pressure, cassava plants were able to maintain higher rates of photosynthesis, resulting in increased assimilate production and improved vegetative development.

The increase in plant height under Atrazine management indicates improved cell division, cell elongation, and biomass accumulation resulting from better availability of water and nutrients. Adequate nitrogen and phosphorus supply enhances chlorophyll formation, leaf expansion, and photosynthetic enzyme activity, thereby promoting vigorous shoot development and canopy formation. In contrast, prolonged weed competition in the unweeded control reduced resource availability, limiting metabolic activities required for stem elongation and overall plant growth (Gardner, Pearce, and Mitchell, 1985; Zimdahl, 2018).

The higher leaf area recorded under effective weed management as shown on Table 3 reflects improved canopy establishment and greater light interception capacity. Leaf area is a major determinant of photosynthetic efficiency because a larger photosynthetic surface allows greater

capture of solar radiation and increased carbon assimilation. The additional assimilates produced through enhanced photosynthetic activity are subsequently allocated towards vegetative growth and storage root development. Therefore, the larger leaf area observed in Farmers Pride under Atrazine treatment suggests improved canopy architecture and greater physiological efficiency compared with Game Changer (El-Sharkawy, 2004).

Stem girth is closely associated with plant vigour, carbohydrate storage capacity, and assimilate transport efficiency in cassava. The increased stem diameter observed under Atrazine treatment indicates improved accumulation of structural carbohydrates and greater source strength of the crop. A well-developed stem provides stronger vascular capacity for transporting photosynthates from leaves to developing storage roots, which can contribute to increased biomass and yield formation. The consistent superiority of Farmers Pride across plant height, leaf area, and stem girth suggests genetic differences in physiological efficiency, including better root establishment, nutrient uptake capacity, canopy development, and assimilate partitioning. Cassava varieties differ in their ability to regulate growth under environmental stress, and varieties with rapid canopy development can achieve earlier ground cover, reduce weed establishment and improve resource capture (Howeler, 2002).

The reduced vegetative growth observed under the unweeded treatment resulted from continuous crop weed competition during critical growth stages. Weeds reduce crop physiological performance by decreasing leaf expansion, lowering photosynthetic activity, and restricting biomass accumulation through competition for water, nutrients, and light. Under semi-arid conditions, this effect becomes more

pronounced because limited soil moisture intensifies competition between cassava and weeds (Chauhan and Johnson, 2010). The results demonstrate that effective weed management enhances cassava physiological processes by improving resource availability, canopy development, photosynthetic efficiency, and assimilate

production. The superior response of Farmers Pride under Atrazine management indicates that combining genetically improved varieties with appropriate weed control strategies provides a sustainable approach for improving cassava productivity and climate resilience in semi-arid production environments.

Table 3: Effects of Weed Management on Cassava Plant Height, Leaf Area and Stem Girth

Cassava Variety	Weed Management	Plant Height (cm)	Leaf Area (cm ²)	Stem Girth (cm)
Farmers Pride	Atrazine	135.0a	42.0a	3.1a
Farmers Pride	Hand-weeding	130.0b	40.0b	3.0b
Farmers Pride	Unweeded control	110.0c	28.0c	2.2c
Game Changer	Atrazine	128.0a	38.0a	2.8a
Game Changer	Hand-weeding	125.0b	36.0b	2.7b
Game Changer	Unweeded control	105.0c	25.0c	2.0c

Key: Means followed by different letters within each parameter are significantly different at $p \leq 0.05$.

Effects of Cassava Variety and Weed Management on Biomass Production

Fresh biomass production represents the combined effect of crop establishment, vegetative development, and resource utilization. The effect of variety and weed management on above-ground biomass, below-ground biomass, and total fresh biomass is presented in Table 3.

Fresh above-ground biomass, below-ground biomass, and total plant biomass were significantly influenced by cassava variety and weed management practices. The trend observed for all biomass components showed that Atrazine-treated plots produced the highest biomass accumulation, followed by hand-weeding, while the unweeded control recorded the lowest values.

Farmers Pride under Atrazine produced the highest above-ground biomass (5.8 t ha⁻¹), below-ground biomass (6.7 t ha⁻¹), and total fresh biomass (12.5 t ha⁻¹). This was followed by Farmers Pride under hand-weeding, which recorded 5.4 t ha⁻¹, 6.4 t ha⁻¹, and 11.8 t ha⁻¹ for above-ground biomass, below-ground biomass, and total biomass, respectively.

Game Changer under Atrazine produced 5.0 t ha⁻¹ above-ground biomass, 5.8 t ha⁻¹ below-ground biomass, and 10.8 t ha⁻¹ total biomass, indicating that although both varieties

responded positively to improved weed management, Farmers Pride had greater biomass accumulation potential. The higher biomass production observed under Atrazine treatment can be attributed to effective early-season weed suppression, which reduced competition for water, nutrients, and solar radiation. Improved access to growth resources promotes leaf expansion, stem development, photosynthetic activity, and greater dry matter accumulation (Gardner, Pearce, and Mitchell, 1985). The higher below-ground biomass recorded by Farmers Pride under Atrazine (6.7 t ha⁻¹) indicates better assimilate partitioning towards storage root development. Cassava productivity depends on the ability of the plant to efficiently convert photosynthates produced by the canopy into storage roots, a process enhanced when competition stress is minimized (El-Sharkawy, 2004).

The unweeded treatments recorded the lowest biomass accumulation. Game Changer under unweeded conditions produced 8.0 t ha⁻¹ total biomass, while Farmers Pride recorded 7.2 t ha⁻¹. Although Game Changer showed slightly higher biomass under severe weed competition, Farmers Pride demonstrated greater productivity when adequate weed control was provided. This suggests that Farmers Pride possesses higher yield potential

under favourable management conditions, while Game Changer may exhibit some tolerance to high competition stress.

The reduction in biomass under unweeded conditions was associated with prolonged weed interference, which restricted crop access to essential resources and reduced canopy development. Similar findings have shown that uncontrolled weed competition reduces

cassava growth, root bulking, and final yield through reduced resource availability (Chauhan and Johnson, 2010; Zimdahl, 2018). The results demonstrate that combining Farmers Pride cassava variety with effective weed management, particularly Atrazine application, enhanced biomass production and improved productivity of cassava-based climate-resilient cropping systems.

Table 4: Effects of Cassava Variety and Weed Management on Biomass Production

Cassava Variety	Weed Management	Above-ground Biomass (t ha ⁻¹)	Below-ground biomass (t ha ⁻¹)	Total plant biomass (t ha ⁻¹)
Farmers Pride	Atrazine	5.8a	6.7a	12.5a
Farmers Pride	Hand-weeding	5.4a	6.4b	11.8b
Farmers Pride	Unweeded control	3.3c	3.9c	7.2c
Game Changer	Atrazine	5.0b	5.8a	10.8a
Game Changer	Hand-weeding	4.7b	5.3b	10.0b
Game Changer	Unweeded control	3.8c	4.2c	8.0c

Key: Means followed by different letters within rows are significantly different at $p \leq 0.05$.

Location Effects on Cassava-Maize Climate-Resilient Intercropping System

The performance of cassava maize intercrops was influenced by environmental conditions associated with the two experimental locations. Differences in soil fertility status, rainfall distribution, temperature, and ecological characteristics between Wukari and Jalingo contributed to variations in crop growth and productivity.

The Wukari location generally recorded higher crop performance compared with Jalingo, which may be attributed to its relatively favourable soil fertility status, higher organic carbon content, greater nutrient availability, and longer growing season (Table 1). The higher organic matter (1.93%), total nitrogen (0.10%), available phosphorus (7.60 mg kg⁻¹), and cation exchange capacity (11.70 cmol kg⁻¹) recorded at Wukari provided a better nutrient environment for crop development compared with Jalingo. Soil fertility is an important determinant of crop productivity because nutrient availability regulates leaf expansion, photosynthetic activity, biomass accumulation, and yield formation. Organic matter improves soil structure, water retention capacity, and

nutrient release, which are particularly important under semi-arid conditions where moisture stress can limit crop growth (Nelson and Sommers, 2016). The favourable performance of crops at Wukari may also be associated with climatic differences between the two locations. Wukari, located within the Southern Guinea Savanna zone, experiences relatively higher rainfall and longer moisture availability compared with Jalingo. Adequate moisture availability supports cassava root development and maize biomass production by reducing water stress during critical growth stages.

Effects of Experimental Location on Cassava Growth and Biomass Performance

The performance of cassava maize intercrops varied significantly between Wukari and Jalingo locations (Table 5). Wukari recorded higher values for crop establishment, vegetative growth, and biomass production compared with Jalingo. The performance of cassava-maize intercrops differed significantly between Wukari and Jalingo locations. Wukari recorded higher germination percentage (84.5%), plant height (132.4 cm), leaf area (40.5 cm²), stem diameter (3.0 cm), and fresh biomass yield (12.1 t ha⁻¹) compared

with Jalingo. The superior performance at Wukari was associated with more favourable soil fertility conditions, including higher organic matter, nitrogen, phosphorus, and cation exchange capacity. Improved soil fertility enhances nutrient availability, leaf

expansion, photosynthetic efficiency, and biomass accumulation (Nelson and Sommers, 2016). Higher rainfall availability and longer moisture duration at Wukari likely reduced water stress during critical crop growth stages, improving crop development and productivity.

Table 5: Effects of Experimental Location on Cassava Growth and Biomass Performance

Parameter	Wukari	Jalingo
Germination percentage (%)	84.5	78.2
Plant height (cm)	132.4	118.6
Leaf area (cm ²)	40.5	32.8
Stem diameter (cm)	3.0	2.4
Fresh biomass yield (t ha ⁻¹)	12.1	9.3

CONCLUSION

This study demonstrated that cassava variety, weed management, and location significantly influenced the productivity of cassava maize intercropping systems in Taraba State, Nigeria. Atrazine application provided effective weed suppression and enhanced crop establishment, vegetative growth, and biomass accumulation compared with hand-weeding and unweeded control. Farmers Pride consistently showed superior performance compared with Game Changer, producing higher growth parameters and biomass yield. The highest productivity was achieved under Farmers Pride combined with Atrazine management, indicating the importance of integrating improved varieties with effective weed control strategies. Wukari recorded better crop performance than Jalingo due to more favourable soil fertility and environmental conditions. The study provides location-specific evidence that combining improved cassava varieties with sustainable weed management practices can enhance productivity and climate resilience of cassava maize systems under semi-arid conditions.

RECOMMENDATIONS

Based on the findings, the following recommendations are made:

- i. Farmers Pride is recommended for cultivation in cassava maize intercropping systems because of its superior growth and yield performance.
- ii. Farmers should adopt effective weed management practices, particularly Atrazine application or timely hand-weeding, to minimize weed competition and improve productivity.
- iii. Soil fertility management should also be promoted, especially in areas with low soil nutrient status.
- iv. Furthermore, future studies should evaluate the long-term environmental effects of Atrazine, conduct economic analyses of weed management options, and assess additional cassava varieties under different agroecological conditions.
- v. Long-term effects of Atrazine application on soil biological properties.
- vi. Economic analysis of herbicide versus manual weed management.
- vii. Performance of additional cassava varieties under different climate scenarios.
- viii. Integration of legumes as companion crops in cassava maize climate-resilient systems.

REFERENCES

- Adeola, R., Akinrinola, T., & Fagbola, O. (2023). Performances of maize and soybean as influenced by intercropping and fertilizer sources in the Northern Guinea Savanna agro-ecology of Nigeria. *Journal of Central European Agriculture*, 24(3), 667-680. <https://doi.org/10.5513/jcea01/24.3.3753>
- Adewolu, M. A., Olorunfemi, O. T., & Adetimirin, V. O. (2010). Genetic variability and growth performance of cassava genotypes under different environmental conditions. *African Journal of Agricultural Research*, 5(20), 2781-2787.
- Aktar, M. W., Sengupta, D., & Chowdhury, A. (2009). Impact of pesticides use in agriculture: Their benefits and hazards. *Interdisciplinary Toxicology*, 2(1), 112. <https://doi.org/10.2478/v10102-009-0001-7>
- Bray, R. H., & Kurtz, L. T. (1945). Determination of total, organic, and available forms of phosphorus in soils. *Soil Science*, 59, 3945.
- Bremner, J. M. (2018). Nitrogen-total. In D. L. Sparks (Ed.), *Methods of Soil Analysis, Part 3: Chemical Methods*. *Soil Science Society of America*. 1085 - 1121.
- Bremner, J. M., & Mulvaney, C. S. (1982). Nitrogen-total. In A. L. Page, R. H. Miller, & D. R. Keeney (Eds.), *Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties*. American Society of Agronomy. 595-624.
- Chauhan, B. S., & Johnson, D. E. (2010). The role of weed ecology and management in tropical cropping systems. *Field Crops Research*, 117(23), 171-177. <https://doi.org/10.1016/j.fcr.2010.03.010>
- El-Sharkawy, M. A. (2004). Cassava biology and physiology. *Plant Molecular Biology*, 56, 481-501. <https://doi.org/10.1007/s11103-005-2270-7>
- Food and Agriculture Organization. (2011). *Save and grow: A new paradigm of agriculture*. FAO, Rome, Italy. Pp 1-102.
- Food and Agriculture Organization. (2021). *FAOSTAT: Agricultural production statistics*. Available at <https://www.fao.org/faostat/en/>. Accessed on February 12, 2025.
- Gardner, F. P., Pearce, R. B., & Mitchell, R. L. (1985). *Physiology of Crop Plants*. Iowa State University Press, Ames, Iowa. 31-36
- Gee, G. W., & Bauder, J. W. (1986). Particle-size analysis. In A. Klute (Ed.), *Methods of Soil Analysis: Part 1 Physical and Mineralogical Methods* (2nd ed.). American Society of Agronomy. pp. 383-411.
- Heap, I. (2020). *The International Survey of Herbicide Resistant Weeds*. Available from: www.weedscience.org. Accessed on February 12, 2025.
- Howeler, R. H. (2002). Cassava mineral nutrition and fertilization. In R. J. Hillocks, J. M. Thresh, & A. C. Bellotti (Eds.), *Cassava: Biology, Production and Utilization*. 115-147).

- Lithourgidis, A. S., Dordas, C. A., Damalas, C. A., & Vlachostergios, D. N. (2011). Annual intercrops: An alternative pathway for sustainable agriculture. *Australian Journal of Crop Science*, 5(4), 396-410.
- Markus, U. M., Ilori, O. P., Wada, I. M., Musa, S. T., & Peter, J. E. (2022). Hydrogeochemical evaluation and geospatial distribution modeling of the major ion chemistry of groundwater and their suitability for drinking and irrigation in Lagelu, Southwestern Nigeria. *Applied Water Science*, 12(7), Article 168. <https://doi.org/10.1007/s13201-022-01680-w>.
- McClean, E.O. (1982). Soil pH and Lime Requirement. In *Methods of Soil Analysis*, A.L. Page (Ed.). <https://doi.org/10.2134/agronmonogr9.2.2ed.c12>. Accessed on February 12, 2025.
- Nationsonline.org (2026). Administrative Map of Nigeria. Available at <https://www.nationsonline.org/one-world/map/nigeria-administrative-map>. Accessed on January 22, 2026.
- Nelson, D. W., & Sommers, L. E. (1982). Total carbon, organic carbon, and organic matter. In A. L. Page, R. H. Miller, & D. R. Keeney (Eds.), *Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties*. *American Society of Agronomy*. 539-579.
- Nelson, D. W., & Sommers, L. E. (2016). Total carbon, organic carbon, and organic matter. In D. L. Sparks (Ed.), *Methods of Soil Analysis: Part 3 Chemical Methods*. *Soil Science Society of America*. 961-1010.
- Niu, L., Qin, W., You, Y., Mo, Q., Pan, J., Tian, L., Xu, G., Chen, C., & Li, Z. (2023). Effects of precipitation variability and conservation tillage on soil moisture, yield and quality of silage maize. *Frontiers in Sustainable Food Systems*, 7, Article 1198649. <https://doi.org/10.3389/fsufs.2023.1198649>.
- Odu, C. T. I., Babalola, O., Udo, E. J., Ogunkunle, A. O., Bakare, T. A., & Adeoye, G. O. (2015). *Laboratory Manual for Agronomic and Soil Analysis*. Soil Science Society of Nigeria.
- Oerke, E. C. (2006). Crop losses to pests. *Journal of Agricultural Science*, 144(1), 31-43. <https://doi.org/10.1017/S0021859605005708>.
- Ofoezie, E. I., Eludoyin, A. O., Udeh, E. B., Onanuga, M. Y., Salami, O. O., & Adebayo, A. A. (2022). Climate, urbanization and environmental pollution in West Africa. *Sustainability*, 14(23), 15602. <https://doi.org/10.3390/su142315602>.
- Thierry, E. A. A., Ossamulu, I. F., Bala, I. A., Eustace, D., Muhammad, H. K., Shnada, A. H., Salubuyi, S. B., Shingu, J.P., Muhammad, H. L., Justin, E.N.J. and Makun, H. A. (2025). Mycotoxins contamination of maize (*Zea mays* L) from different agroecological zones in Nigeria: A systematic review. *Journal of Food Composition and Analysis*, 146 (2025) 107991. <https://doi.org/10.1016/j.jfca.2025.107991>.
- Thomas, G. W. (1982). Exchangeable cations. In A. L. Page, R. H. Miller, & D. R. Keeney (Eds.), *Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties*.

- American Society of Agronomy. 159-165.
- Tsubo, M., & Walker, S. (2003). A model of radiation interception and use by a maize bean intercrop canopy. *Agricultural and Forest Meteorology*, 119(12), 41-53.
- Vandermeer, J. (1992). *The Ecology of Intercropping*. Cambridge University Press. Pp 1-231.
- Vasileva, V. (2026). Pea–oat cover crops improve ear leaf area, grain yield and nitrogen use efficiency of rainfed maize under residual nitrogen fertilization. *Preprints.org*, 2026071008.
<https://doi.org/10.20944/preprints202607.1008.v1>
- Yaroson, A. Y., Audu, E. B., & Umar, A. (2024). Performance of cassava (*Manihot esculenta* Crantz) as influenced by poultry droppings and NPK fertilizer in Jos, Plateau State, Nigeria. *ADAN Journal of Agriculture*, 5(1), 120–132.
- Zimdahl, R. L. (2018). *Fundamentals of Weed Science* (5th ed.). Academic Press. Pp 1- 758.