

**Original Article**

# Growth and Yield Performance of Selected Varieties of Cassava (*Manihot Esculenta*) Grown at Varying Spacing Under Rain Fed Condition in Bali, Taraba State-Nigeria

<sup>1</sup>Y.S. RAJAB, <sup>2</sup>DR. A.A. BASHIR, <sup>3</sup>I.N. AUWAL

<sup>1,2,3</sup>Department of Crop Production Technology, Federal Polytechnic, Bali, Indonesia.

**ABSTRACT:** *With the current trend of escalation in the price of foodstuffs in Nigeria, it becomes pertinent for researchers in food production to embark on research to come out with cheaper alternatives that will ensure a sustainable food supply to the growing populace. Cassava is identified as one of the staple foods consumed in the Sub-Saharan tropics. This experiment is carried out in the Teaching and Research Farm of the School of Agricultural Technology, Federal Polytechnic, Bali, to determine the Growth and Yield Performance of selected varieties of Cassava (*Manihot esculenta*) Grown at Varying Spacing (1 m x 0.9 m, 1 m x 0.7 m and 1 m x 0.5 m) in the Bali area. A Complete Randomized Block Design (CRBD) is adopted and replicated three times. A zig-zag sampling method with 25% representative samples is used for data collection. Parameters assessed include Plant height at 3, 6 and 9 Months After Planting (MAP); stem girth, number of tubers per plant, thickness of the tuber and tuber weight at harvest. Data collected are subjected to Analysis of Variance (ANOVA) with the help of the SPSS statistical package. Means are separated using Tukey Honestly Significant Difference (HSD). The results show significant differences among the improved cassava varieties as well as between the varieties and the local cultivar. A significant interaction is also observed between the two factors at  $p = 0.05$ .*

**KEYWORDS:** *Variety, Cassava, Spacing, Tuber, Stem.*

## 1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a perennial woody shrub which belongs to the Euphorbiaceae family, and it is primarily cultivated for its starchy roots [1]. It is believed to have originated from South America, but it is now an important source of food security for more than 800 million people in the tropics and subtropics. It is one of the primary food sources in sub-Saharan Africa, providing an important source of calories, crucial to food security [20]. Cassava, described as the “golden crop of Africa”, plays a significant role in the supply of food and hunger eradication [16]. Besides its role as a food crop, cassava is increasingly becoming an important industrial commodity for animal feed, starch, bioethanol, and value-added products. In Nigeria, production of the crop is essential and serves as a major caloric intake source [20]. The root crop is processed into food such as “gari”, “fufu” as staples directly consumed at homes and restaurants, while it is also used in industrial production of high-quality flour, starch, ethanol and animal feed [16]; [18]. Reference [1] estimated that Africa contributed more than 65% of the world's cassava output. However, global production exceeds 300 million metric tonnes annually, with Nigeria, Thailand, Ghana, and Brazil as leading producers.

Despite its importance, the yields of the crop are very low. The yields of Nigeria and the other top African cassava producers are 37 to 64% below the global yield levels [18]. These yields were 8, 14 and 14.7 t/ha in the Democratic Republic of Congo, Nigeria and Cameroon, respectively. The average farmer's yield in Nigeria of 10-15 tons per hectare is low compared to countries like Brazil, India and Thailand, which were highly successful in commercial production, obtaining yields of between 25 and 40 tons per hectare [5]. The low cassava yields prevailing in Nigeria are caused by the use of inadequate agronomic practices such as incorrect spacing or the use of non-improved varieties [18], [11]. The current cassava yield levels can be increased by a factor of five by emphasizing that farmers adopt a “basket” of improved agronomic practices, such as the use of improved variety, correct fertilizing and spacing [11]; [12].

Cassava varieties show significant genetic diversity in traits such as drought tolerance, canopy architecture, harvest index, root dry matter content, disease resistance, and post-harvest physiological deterioration. These characteristics directly influence how a plant captures resources (light, water, nutrients) and converts them into economic yield. Therefore, this study is carried out to determine the best-performing variety (among the varieties in question) suitable for the farmers in Bali, as well as the suitable spacing distance to be adopted for the cultivation of the varieties.

**Effect of Variety on Cassava Growth and Yield** - The genetic makeup of a cassava variety primarily dictates its phenology, growth pattern, and yield capacity. Recent breeding practices focused on developing varieties with specific adaptation to abiotic and biotic stresses, coupled with maintaining or improving yield potential.

**Growth Habit and Canopy Patterns** - Varieties differ in canopy duration, leaf area index (LAI), and branching patterns. Erect, early-branching varieties with moderate leaf area index (LAI) show better weed suppression and higher light interception. Reference [2] reported that canopy development traits are very much heritable and highly correlated with resulting root yield. Late-branching or compact canopy varieties may conserve moisture better in drought-stricken areas, but could lead to the accumulation of less total biomass. Reference [10] stressed that canopy efficiency in light interception is the primary determinant of biomass accumulation and is greatly influenced by planting density. Reference [21] found that, irrespective of planting distance, cassava yield is variety-specific and that recommendations should be focused on the growth habit of the improved variety in question.

**Dry Matter Content (DMC) and Root Yield** - The fundamental yield component is fresh root weight, but DMC (25-40%) is an important quality trait for food and industry. High-yielding varieties may not always have the highest DMC. Reference [9] elucidated the genetic independence and trade-offs between these traits, stressing the need for targeted breeding. Modern genomic tools are now being used to identify quantitative trait loci (QTLs) for these complex traits, accelerating breeding cycles.

**Harvest Index (HI)** - HI quantifies the proportion of total biological dry matter apportioned to the storage roots. Improved varieties mostly have a HI of 0.5-0.6, significantly higher than traditional cultivars (0.3-0.4). Reference [14] observed that high-HI varieties proved better in converting nutrients into harvestable product, which is good for fertiliser use efficiency. Reference [15] reported that varieties with a longer and extended bulking period could reciprocate for lower plant numbers per unit area by producing larger individual root size.

**Tolerance to stress** - The choice of variety is a crucial adaptation strategy. Drought-tolerant varieties (e.g., TMEB 693) maintain root bulking under water stress, while provitamin "A" bio-fortified varieties (e.g., UMUCASS 38) address malnutrition. Resistance to cassava mosaic disease (CMD) and cassava brown streak disease (CBSD) is more important in East and Central Africa, where these viruses are problematic. Findings showed that increasing soil fertility and plant spacing decrease the severity of CMD, and an intra-spacing of 0.8 m yielded the best results [19]. However, [15] opined that the adoption of disease-resistant varieties exclusively can multiply yields when compared to susceptible varieties, irrespective of fertilizer input.

**Maturity Period** - Short-cycle varieties (8-10 months) mostly have a unvarying growth pattern and could require higher densities to optimize ground cover quickly, while long-cycle varieties (12-18 months) have extensive time to develop wider canopies and large roots, with the ability to perform well across a wider range of spacing. Effect of Spacing on Growth and Yield - Planting spacing is the determinant of plant population density, which directly regulates the competition for abiotic resources and modulates the crop microenvironment.

**Competition for Resources** - Water and Nutrients: Higher densities increase total water and nutrient uptake, potentially reducing soil moisture and nutrients more rapidly, particularly in rain-fed or low-fertility systems. Wider spacing allows for a larger root rhizosphere per plant. However, in terms of light interception, reference [6] used light interception modelling to prove that spacing that achieves 90-95% light interception by 4-5 months after planting (MAP) mostly produces optimum yield, but this target depends on varietal canopy characteristics.

**Agronomic and Physiological Implications** - Correct spacing leads to firm stem development, reduces lodging, and improves air circulation within the canopy, which can reduce humidity and potentially reduce the incidence of diseases like leaf blight. Findings also showed that increasing plant spacing decreases the severity of CMD, and an intra-spacing of 0.8 m yielded the best results [19]. Furthermore, it influences the possibility of intercropping and mechanized operations (planting, weeding, harvesting). The system of skip-row or double-row planting patterns, studied by [17], aimed at balancing high population density with increased light penetration and ease of access for machinery.

**Population Density and Yield Components** - There is a well-established inverse relationship between plant population per hectare and yield per plant. Reference [3] showed that as plant density increases, individual plant yield, root number and size usually decrease due to increased competition. However, the aim is to find the population density at which the increase in plant number supersedes the decrease in individual plant output, optimizing total yield. This maximum density varies with variety and environment.

**Interaction Between Variety and Spacing** - Cassava does not exhibit a definite spacing for yield optimization because spacing is variety-specific, as it depends on the variety's growth pattern. Variety with a wide and vigorous canopy reaches its highest yield with a lower plant density of 8,000-10,000 plants/ha as compared to the compact and erect variety, which can yield up to 12,000-15,000 plants/ha. Reference [4] reported great variation in  $\beta$ -carotene and root yield existing between the erect type and spreading type of cassava. Reference [8] stated that spacing can be manipulated as a tool for quality regulation, even though

significant interaction exists between dry matter content and fresh yield. However, interaction is further modified by environmental factors.

## 2. MATERIALS AND METHOD

### 2.1. THE STUDY AREA

Bali, in the Bali Local Government Area, is located between latitude 7046/N and 7054/N of the equator and longitude 10030/ E to 11000/E of the prime meridian [13]. It has mountainous geo-physical features and is located in the dry guinea savanna [13]. The rainy season starts around April and ends in October, with about 1,350 to 1,500 mm of rainfall annually [13]. The majority of the soils occurring in the area are of the suborders Fluvents or recently deposited alluvial soils on river banks and other shallow rocky soils [11]. Others are Ustults, the reddish brown low base status soils [11]. Some chemical properties of the soils on an average basis were 0.93% organic carbon, 1.7% organic matter, with a pH of 4.9 and EC 0.48 [7].

### 2.2. MATERIALS

Experimental plot, pegs, line, NPK 15:15:15, hoe, cutlass, cassava cuttings, herbicide, record book, weigh balance, measuring tape, meter rule.

### 2.3. METHODS

The experiment was carried out at the teaching and research farm of the School of Agricultural Technology, Federal Polytechnic, Bali. The design adopted was a Randomized Complete Block Design (RCBD) in which a plot of 32 m by 35 m was cleared at the onset of rainfall in the year 2025. The land was tilled and nine beds of size 5 m x 10 m were raised, and three varieties of cassava (Danjalango, TMC 0066 and TMT 419) were planted at varying spacing of 1m x 0.9m, 1m x 0.7m and 1m x 0.5m intervals using 30 cm long stem cuttings. The certified improved cassava stem cuttings (i.e. TMC 0066 and TMT 419) were obtained from an Agro-allied agent (farm) in Wukari, while the local cultivar (Danjalango) was obtained from Mutum-Biyu market. The nine beds were replicated three times, giving a total of twenty-seven beds. Manual weeding and application of post-planting herbicides were alternately used to control weeds at four weekly intervals. Data were recorded at 3 months after planting (MAP), 6 MAP, 9 MAP and at harvest. The zigzag sampling method was adopted, where nine cassava stands were tagged for data collection. The parameters assessed were plant heights at 3, 6, and 9 MAP; stem girth at 3 and 6 MAP; number of tubers per plant, tuber thickness and average weight of a tuber at harvest. Analysis of Variance (ANOVA) was used to analyze the data with the help of the SPSS statistical package, and means were separated using Tukey honestly significant difference (HSD). Most of the data for the parameters assessed had conformed to the assumptions of ANOVA for the parametric test, while the stem girth at 9 MAP, cassava branches at 3, 6 and 9 MAP and tuber length at harvest, whose data were not normally distributed, were subjected to the Kruskal-Wallis test.

## 3. RESULTS AND DISCUSSION

Figures 1 to 8 represent the outputs of the analyses of variance (ANOVA) carried out on the various parameters assessed, and the intersections of the line graph indicate the interactions of the factors variety and spacing.

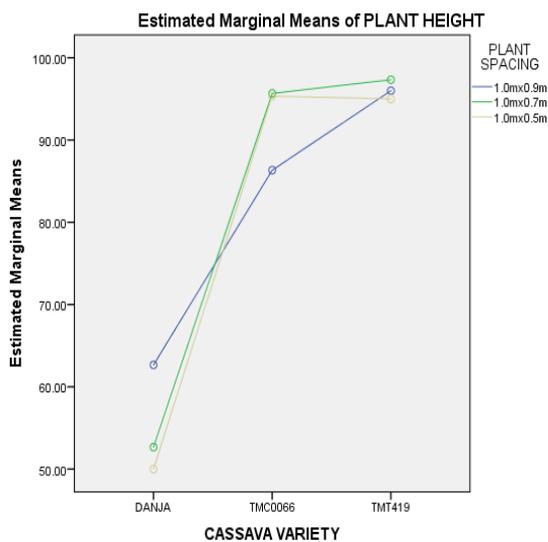


FIGURE 1 Average stem height at 3 MAP

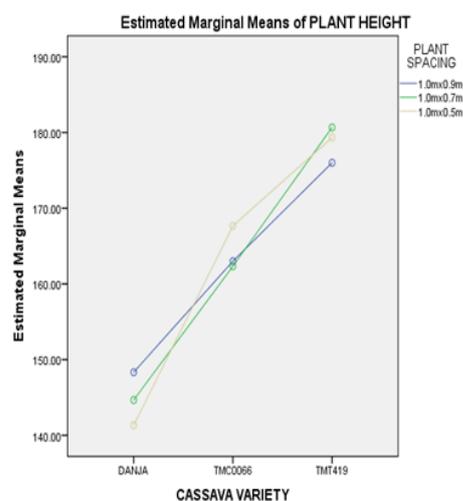


FIGURE 2 Average stem height at 6 MAP

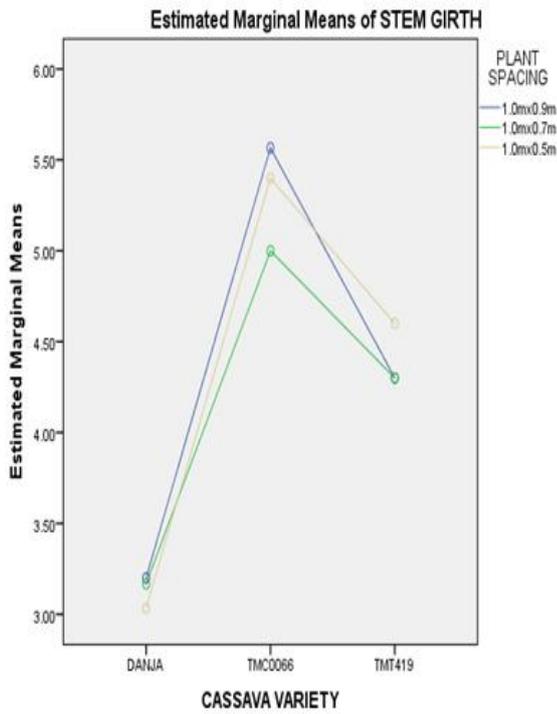


FIGURE 3 Average stem height at 9 MAP

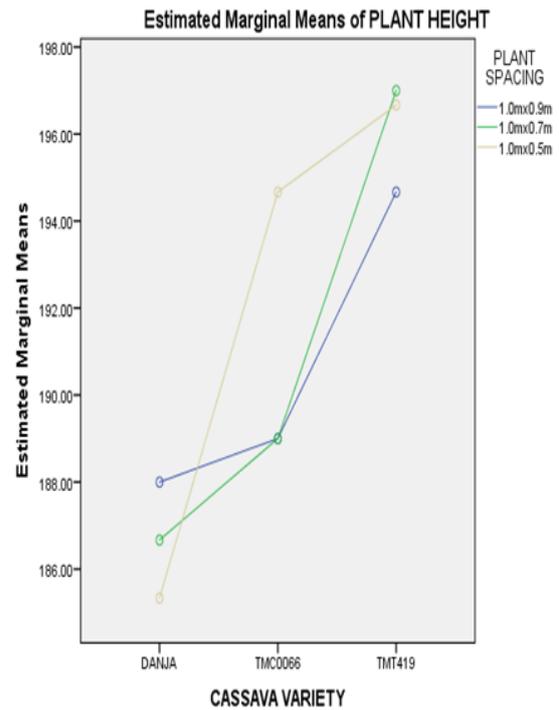


FIGURE 4 Average stem girth at 3 MAP

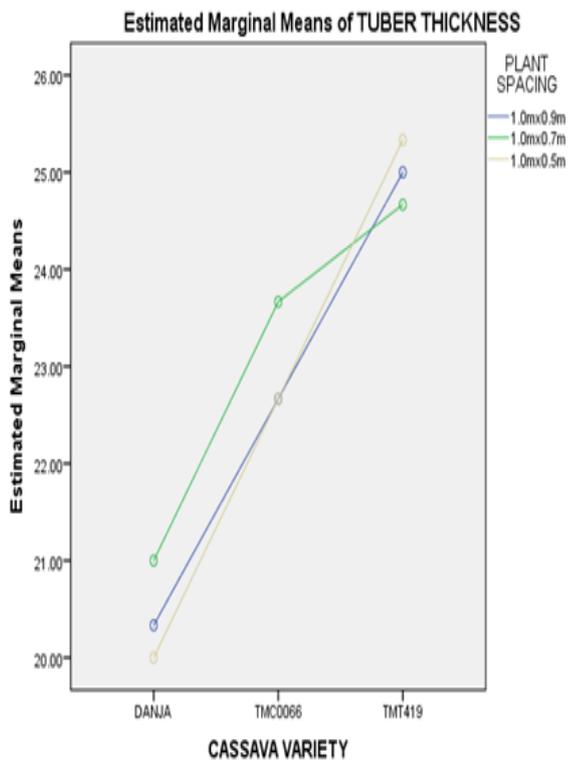


FIGURE 5 Average stem girth at 6 MAP

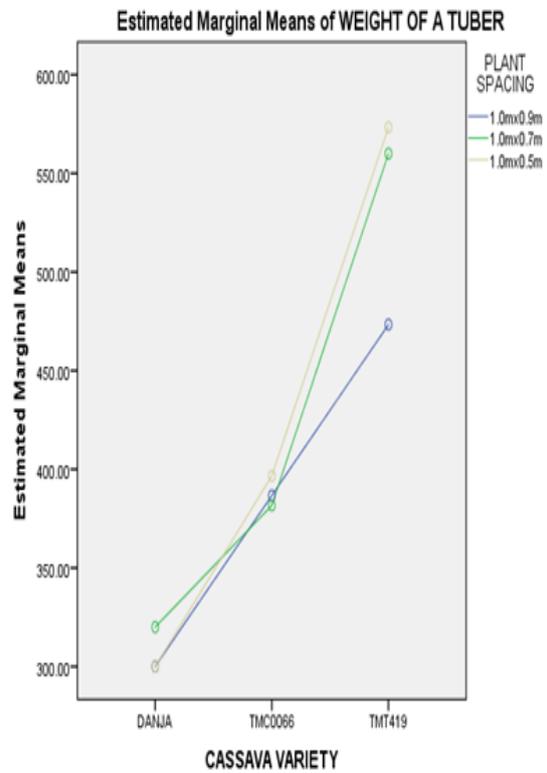


FIGURE 6 Average number of tubers per plant

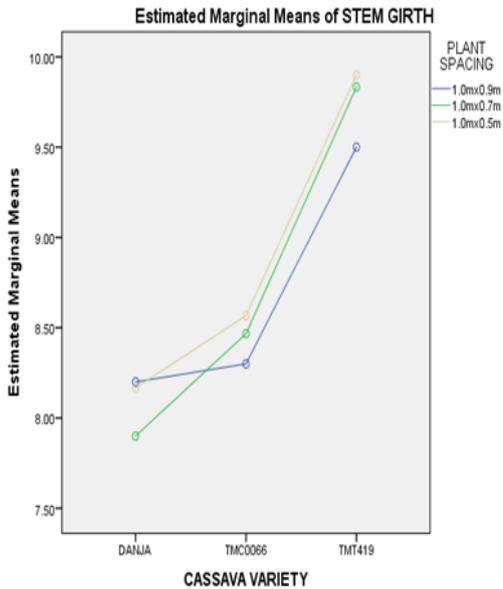


FIGURE 7 Average thickness of a tuber

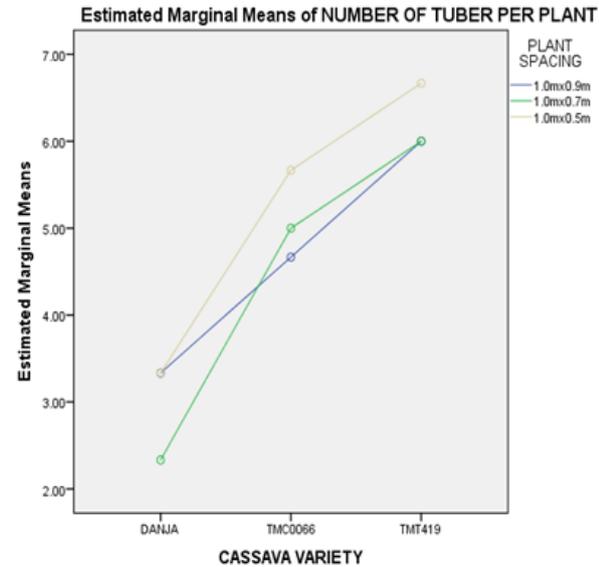


FIGURE 8 Average weight of a tuber

Source: Self

Figure 1 depicts the effects of variety and spacing on the mean stem height of cassava at 3 MAP. The cultivar “Danjalango” recorded the shortest stem for all three spacing distances. Variety “TMT 419” gave the highest stem height at 0.7m and 0.9m spacing. However, at 0.5m spacing, TMC 0066 produced taller stems than TMT 419. The figure also indicated a significant interaction between the varieties and the planting distance. Figure 2 showed a consistent pattern with TMT 419 producing the highest stem height at all the spacing distances, followed by TMC 0066, while Danjalango recorded the shortest stem at 6 MAP. Significant interactions also existed between variety and spacing distance.

Figure 3 showed that at 9 MAP, variety TMT 419 recorded the greatest stem height at the spacing of 0.7m instead of 0.9m, which shows that height is a function of the genetic makeup of a variety instead of planting distance, as reported by [21]. However, there are significant interactions at some points between the variety and the spacing distance. Figure 4 shows the average stem girth at 3 MAP. The result indicates that for all the spacing distances, variety TMC 0066 showed the thickest stem girth (at 0.9m) compared to TMT 419 and local cultivar Danjalango. There is also significant interaction between variety and spacing for stem girth at 3 MAP. Figure 5 showed the average stem girth at 6 MAP, and TMT 419 recorded the thickest stem girth, though at the lowest planting distance of 0.5m. This overtake in stem girth over that of variety TMC 0066 could probably be due to sudden physiological response to the fertilizer applied instead of the planting distance used, although, little interaction was noticed from the graph.

Figure 6 gives the average number of tubers per plant, and it indicates that spacing of 0.5m consistently yielded the highest number of tubers for all the varieties involved. This contradicts the assertions by [3] who showed that, as plant density increases, individual plant yield (root number and size) usually decreases due to increased competition. The deviation recorded in this experiment could be due to a fertility gradient in the soil of the experimental site. However, some level of interaction is exhibited between the variety and spacing.

Figure 7 shows the average thickness of the tuber at harvest. The result indicated that variety TMT 419 consistently produced the thickest tubers at all the 3 spacing, but in a reversed order, with the closest spacing being the best. However, significant interaction continued to exist between the variety and spacing. Lastly, Figure 8 similarly followed the same trend for the average weight of a tuber produced at harvest by each plant, with TMT 419 producing the highest tuber weight at the closest plant density, while the local cultivar “Danjalango” recorded the lowest, even at the most spacious planting distance.

#### 4. CONCLUSION

It is therefore concluded that, regardless of the planting distance, variety TMT 419 consistently showed the highest performance for all the parameters recorded, while the local cultivar “Danjalango” exhibited the lowest performance. Moreover, the results showed that the crop performance in some instances is more dependent on the variety rather than the planting distance adopted. However, significant interaction existed between the two factors for all the parameters assessed. Under improved management practices, farmers in Bali and its environs may be recommended to adapt to the cultivation of the

improved variety TMT 419 at any given planting distance, because it is highly prolific for most of the parameters assessed compared to other varieties and the local cultivar under investigation.

## CONFLICTS OF INTEREST

There is no conflict of interest concerning the publishing of this paper.

## ACKNOWLEDGEMENT

The research team wishes to acknowledge and thank the Tertiary Education Trust Fund (TETFund) for providing the financial backing for the research and the Management of Federal Polytechnic Bali for cooperation and provision of an enabling environment for the smooth conduct of the research work. Authors 2 and 3 contributed equally to this work.

## REFERENCES

- [1] V Abirami *et al.*, "Cassava intercropping systems for enhanced land productivity and farmer livelihoods: A review," *Plant Science Today*, vol. 12, no. 3, Jul. 2025, doi: <https://doi.org/10.14719/pst.8409>.
- [2] J. G. Adiele, A. G. Schut, R. P. van den Beuken, "Towards understanding factors influencing cassava canopy development," *Field Crops Research*, vol. 255, 2020.
- [3] J.G.Adiele, A.G.T.Schut, R.P.M.van den Beuken, "Determination of optimum plant density for cassava in Nigeria using canopy cover features," *Field Crops Research*, vol. 271, 2021.
- [4] A. Agbona, P. Peteti, B. Teeken, "Planting density and variety interaction effects on cassava root yield and carotenoid content," *Agronomy Journal*, vol. 114, no. 4, pp. 2215-2228, 2022.
- [5] S. Danladi, I. Ojeaga and A. Abdulmumini "Evaluation of Fertility Status of Soils for Sustainable Productivity of Crops in Bali, North-Central. Taraba State, Nigeria," *International Journal of Innovative Science and Research Technology*, pp. 665-702, 2019.
- [6] W. Esuma, R.S. Kawuki, A. Ozimati, "Genetic and planting density effects on yield and dry matter content of cassava in Uganda," *Journal of Agricultural Science*, vol. 158, no. 7-8, pp. 580-590, 2020.
- [7] W. Esuma, A. Ozimati, P. Kulakow, "Genetic analysis and association studies of yield and yield-related traits in cassava (*Manihot esculenta* Crantz), *Agronomy*, vol. 11, no. 2, 2021.
- [8] K. S. Ezui, A. C. Franke, B. D. K. Ahiabor, "Understanding cassava yield response to soil and nutrient management from long-term trials in West Africa," *Experimental Agriculture*, vol. 56, no. 6, pp. 862-878, 2020.
- [9] Federal Fertilizer Department-FFD, "Fertilizer use and Management Practices for Crops in Nigeria," 4<sup>th</sup> edition, Federal Ministry of Agriculture and Rural Development, Abuja, 2012.
- [10] S. Hauser *et al.*, "Cassava System Cropping Guide," Africa Soil Health Consortium, Nairobi, 2015.
- [11] A.D. Jugulde, A. Abdulkadir, and S. Danladi, "Evaluation of Soil Fertility Potentials of some Soils of Bali Local Government Area," TETFUND, 2020.
- [12] R.S. Kawuki, R. Agaba, M. Kanaabi, "Harvest index and trait correlations in elite cassava genotypes evaluated in Uganda," *Journal of Plant Breeding and Crop Science*, vol. 12, no. 2, pp. 54-63, 2020.
- [13] P. Ntawuruhunga, K. Ngoma, and K.S. Ezui, "The role of disease-resistant varieties in sustaining cassava productivity in sub-Saharan Africa," *Crop Protection*, vol. 145, 2021.
- [14] Ogidi Olu Farms, Cassava Farming Techniques, Online Farm Advisor, 2019.
- [15] J. O. Omondi, K. Yermenno, and S. Dutta, Evaluating skip-row planting configurations for improved light interception and yield in mechanized cassava production, *Agricultural Systems*, vol. 205, 2023.
- [16] N. Sanginga and A. Mbabu, *Root and Tuber Crops*, United Nations Commission for Africa, 2015.
- [17] M. C. Spittel and A. van Huis, "Effect of cassava mosaic disease, soil fertility, plant spacing and their interactions on cassava yields in Zanzibar," *International Journal of Pest Management*, vol. 46, no. 3, pp. 187-193, Jan. 2000, doi: <https://doi.org/10.1080/096708700415517>.
- [18] Amit Kumar Srivastava *et al.*, "Cassava yield gap—A model-based assessment in Nigeria," *Frontiers in sustainable food systems*, vol. 6, Jan. 2023, doi: <https://doi.org/10.3389/fsufs.2022.1058775>.
- [19] T. Terna, *et al.*, "Influence of Variety and Plant Density on Growth and Yield of Cassava in Makurdi, Nigeria," *Nigeria Agricultural Journal*, vol. 54, no. 1, pp. 320-329, 2023.