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Optimizing Sweet Potato Productivity through Precision Propagation by Vine Cutting Position and Variety Synergy in Tropical Nigeria

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ABSTRACT: Sweet potato (Ipomoea batatas (L.) Lam) is critical for food security in developing nations, yet yields are limited by suboptimal propagation practices. Vine cutting is the main method, but interaction between varietal genetics and cutting position on growth and yield is poorly understood. This study investigated vine cutting position and variety effects on sweet potato performance in southeast Nigeria. A 2x2 factorial experiment, conducted in 2024 at University of Nigeria, used a randomized complete block design with three replications. Two varieties (Beauregard and Hannah) were propagated using 30 cm top (apical) and basal cuttings. Beauregard outperformed Hannah across all traits ($P < 0.05$), yielding 34.17% more roots (32. 55 vs. 24.26 Kg/plot), with larger tubers (13.22 cm vs. 12.40 cm length). Top part cuttings surpassed basal, with 87 % more roots (102.60 vs. 55.00 No./plot) and 72% higher yield (35.89 kg/plot vs 20.92 kg/plot). A significant genotype x cutting position interaction ($p < 0.05$) revealed Beauregard-Top part of vine cutting combinations as optimal achieving peak yield (44.97 Kg/plot) -123% higher than Beauregard-basal. Hannah showed stability but lower yields. Strong correlations emerged between root yield and both root number ($r= +0.93$) and stem count ($r= +0.92$), to establish them as reliable key yield predictors. GGE biplot confirmed revealed Beauregard-Top part of vine cutting as the highest yielding, most stable combination, and driving resources efficient tuber enlargement. In conclusion, top part cuttings of high performing varieties (e.g. Beauregard) synergistically enhance productivity though optimized physiological vigor. This precision propagation strategy offers small holder farmers a low input solution to sustainably intensify sweet potato production, addressing both yield gaps and climate resilience in tropical agroecologies.

KEYWORDS: Top part of vine, Genotype X Environment İnteraction, Propagation Efficiency, Food Security, Root Yield, Sustainable İntensification.

1. INTRODUCTION

In the least developed countries, food security remains a big challenge. In 2023, about 733 million people out of the world's 8.1 billion population went hungry on a regular basis (FAO, The State of Food Security and Nutrition in the world, 2024). The Global Report on Food Crises (GRFC, 2024) reports that 295 million people in 53 countries and territories are living in areas of acute food insecurity, a considerable jump over prior years (FSIN, 2024). Globally, food insecurity and undernutrition are worsening and continue to be serious threats to human well-being and sustainable development, even though overnutrition and diet-related non-communicable diseases continue to rank among the top public health concerns in many nations (Xiao et al., 2022).

The long-term impacts of the COVID-19 pandemic, compounded by ongoing conflicts Russia-Ukraine war, crises in locations Gaza, Sudan and South Sudan (Xiao et.al, 2022) and the recent suspension of food aid to several African nations by the United State Agency for International Development. Government (USAID) have worsened global hunger. Disruptions to supply chains, rising food and energy prices, aid cutbacks, export restrictions, and economic setbacks have created overlapping shocks in many developing countries, making the goal of zero hunger (SDG2) by 2030 increasingly precarious. Rapid population growth in developing countries is intensifying land use pressure, prompting rural to urban migration and threatening food production, leading to increased food insecurity and malnutrition (Kousar et.al, 2021; Sanyaolu and Sadowski, 2024).

While expanding and intensifying agricultural production may help meet rising food demand, it often comes at significant environmental cost. An alternative solution to the problem of meeting increasing food demand, according to Roy et.al. (2024) and Khaspuria et al. (2024) is through precision farming practice. Precision farming practice offers a promising approach to optimize propagation practices such as vine cutting selection to enhance yield while conserving resources aligning with goals of sustainable and climate-smart agriculture.

Sweet potato [*Ipomoea batatas* (L.) Lam] is a plant from the morning glory family and is one of the world's most important non-grain food crops, feeding over a billion people (Devaux et al. 2020; Sun et al. 2025). In 2023, global production reached 93.5 million tonnes, with Africa producing 29.5 million tonnes and Asia producing 51.6 million tonnes (Xiao, et.al., 2022; United Nations, 2025; FAOSTAT, 2025) (Figure 1).

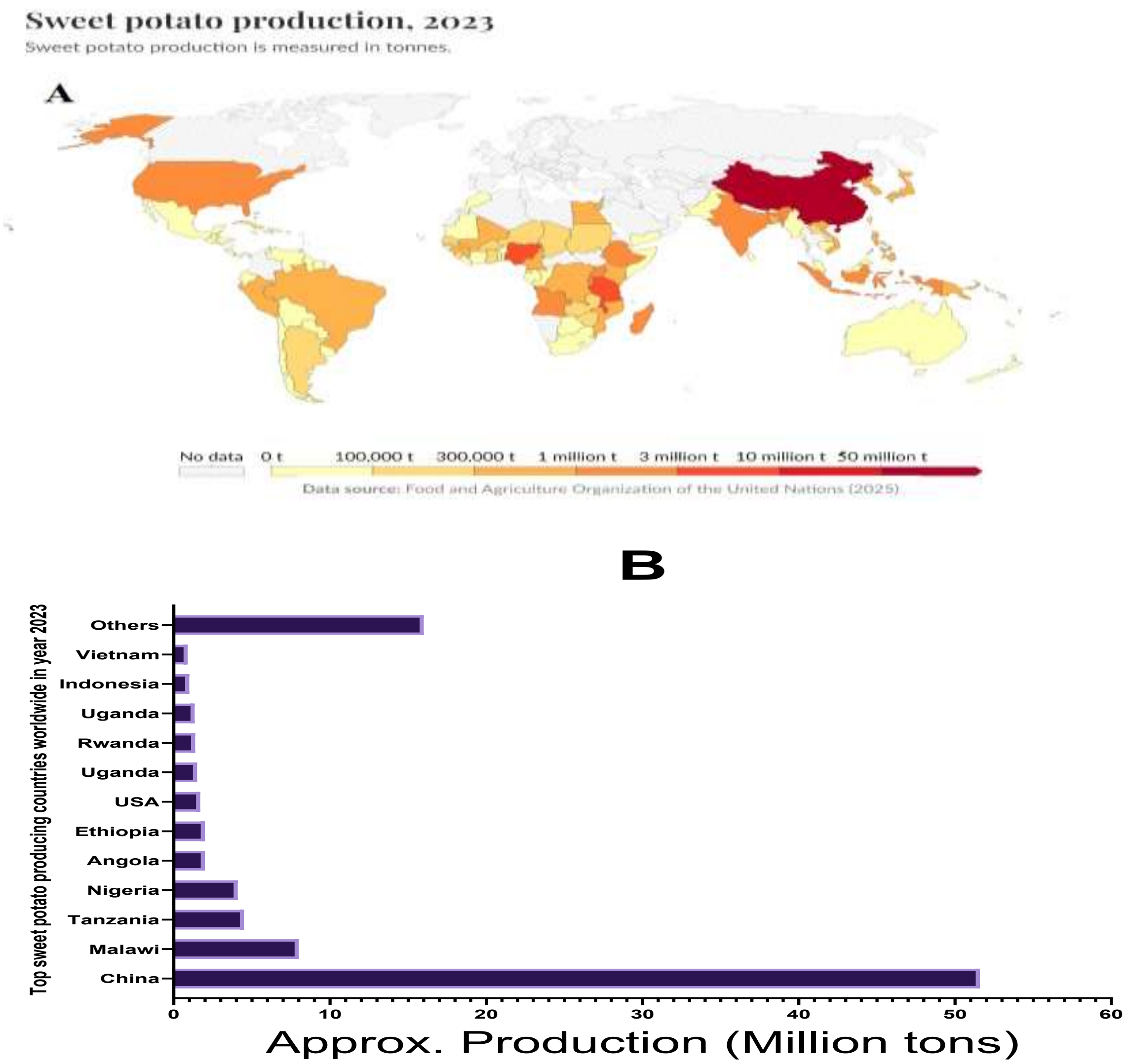

Figure 1. Sweet potato yield. (A) The distribution of sweet potato cultivation in the world. (B) Top 10 sweet potato producing countries worldwide in year 2023. China, Malawi, United Tanzania, Nigeria, Angola, Ethiopia, the United States of America (USA), Uganda, Indonesia, and Vietnam ranked among the top 10 in the world with only one developed country. Data source is (Xiao et.al, 2022; FAO,2025).

Sweet potatoes are grown in about 110 countries, mostly in developing nations where many farmers rely on root and tuber crops for food, nutrition, and income. In Nigeria, sweet potato is the fourth most important root and tuber crop. In 2022, farmers produced 40.01 million tonnes from around 1.5 million hectares of land, compared to cassava (59.6 million tonnes from about 10 million hectares), yam and cocoyam (47.5 million tonnes from about 3 million hectares) (Helgi Library, 2024; FAOSTAT, 2024). It is recognized as an important, versatile, and underutilized crop that contributes to food security (Abukari et al. 2024) and nutrition (NRCRI, 2022). Although national level food insecurity data for sweet potato-growing household is limited, rural poverty remains high, underscoring the importance of climate-smart crops like sweet potato in achieving Sustainable Development Goal (SDG) 1 (No poverty) (UNDP,2024; Udemezue, 2019).

Sweet potato thrives across Nigeria's diverse agroecological zones; it is moderately drought-tolerant, matures within 3-4 months, and supports sequential planting systems enabling year-round food supply. Despite these advantages, average farm yields remain low around 2.6 t/ha in 2022 well below the genetic potential evidenced by trial yields of 7-16 t/ha and research optimal yields exceeding 30t/ha.

In Nigeria, small farmers who grow subsistence crops like sweet potatoes with simple methods are generally more food secure than those who do not (Glenna et.al., 2017). Planting in stages allows for continuous harvesting, which helps ensure steady food and nutrition (Abukari et al. 2024). Sweet potatoes are especially valuable because they provide more edible energy than many other crops, while also serving as food, a source of family income, and even livestock feed (Lencha et.al., 2016). Nowadays, potatoes are considered highly nutritious because they contain more vitamins A and C, beta-carotene, anthocyanins, calcium, and fiber than most staple foods. The orange-fleshed types are especially important for fighting vitamin A deficiency (Xiao et.al, 2022). Their leaves are also very nutritious, tasty, and versatile as a vegetable. Altogether, sweet potatoes are an excellent natural source of health-promoting nutrients (Xiao et.al, 2022). Grown mainly by women, sweet potatoes are an essential crop for food security in many of the world's poorest regions (Lencha et al., 2016). However, in Nigeria, yields and production remain relatively low due to challenges such as poor-quality planting materials and limited adoption of proper agronomic practices.

The easiest way to grow sweet potatoes is by planting a 30-cm piece of vine with four to six nodes (Achebe et al., 2015; Idoko et al., 2017; Akinyemi et al., 2024). The length of the vine affects the number of roots and overall yield. According to IITA (2011), vine cuttings give a higher multiplication rate than traditional planting methods (Akinyemi et al., 2024). Both the length and part of the vine used influence growth and yield, though most farmers plant sweet potatoes using any available vine cutting, regardless of its size or node number (Achebe et al., 2015). Tanaka and Sekioka (2010) found that vine cuttings of 25–30 cm gave higher sweet potato yields than shorter (20 cm) or longer (40 cm) cuttings, which produced lower yields. Godfrey (2000) also noted that vines longer than 30 cm waste planting material, while shorter ones grow slowly and result in poor yields. Similarly, FAO (2010) and Achebe et al. (2015) reported that 25–30 cm vine cuttings produce higher marketable yields, whereas 20 cm cuttings take longer to sprout and give smaller harvests.

IITA (2011) identified 30 cm as the best vine size for sweet potatoes, with 25 cm giving almost the same yield, while 35–40 cm was seen as wasteful due to low output (Achebe et al., 2015). Achebe et al. (2015) also tested orange-fleshed sweet potatoes on Ultisol soils in southeast Nigeria and found that 30 cm cuttings gave the best growth and yield, making it the most suitable length in that region. However, Akinyemi et al. (2024) reported that 40 cm cuttings improved growth and yield in Makurdi, Nigeria, due to more viable nodes and higher photosynthetic capacity. In sum, 30 cm is still considered the ideal cutting length for sweet potato production in tropical climates.

The position on the mother vine from which cuttings are taken (e.g. apical/top, middle, or basal parts) can impact their rooting ability, initial vigor, and subsequent development. Apical cuttings are often considered physiologically younger and potentially possess higher concentrations of growth hormones, which might favour rapid establishment and growth (Hartmann et.al, 2011). Furthermore, different sweet potato varieties exhibit distinct genetic characteristics influencing their growth habits, yield potential, and response to environmental and management factors, including the types of planting material used. Understanding the interaction between genotype (variety) and the source of planting material (Vine part) is crucial for optimizing sweet potato production systems. Identifying the best combination of variety and cutting type can lead to improved resources use efficiency and higher yields for farmers.

Despite the considerable potential of sweet potatoes, their use has declined in many countries, and improvement efforts have been less successful compared to other crops. A major challenge to their cultivation is the limited availability and accessibility of improved planting materials for farmers. Moreover, research on the interaction between sweet potato varieties and the vine segments used for propagation remains insufficient. Most studies emphasize variety selection or general propagation methods, with little attention to how these factors interact. This study seeks to fill that gap by developing more precise, variety-specific propagation guidelines, based on the hypothesis that both the position of the vine cutting and the variety influence sweet potato growth and yield. Accordingly, the study is significant as it aims to recommend the optimal vine cutting position for farmers and producers to enhance yield. The main objective, therefore, is to examine the effects of vine cutting position and variety on the growth and yield of sweet potatoes.

2. MATERIALS AND METHODS

2.1 Description of experiment site

The field experiment was conducted in 2024 cropping season (15th July to 30th December, 2024) at the Department of Crop Science Teaching and Research Farm, Faculty of Agriculture, University of Nigeria, Nsukka (6°51'57"N 7°24'57"E;elevation 447 m). The site is characterized by lowland humid tropical conditions with a bimodal annual rainfall distribution (1276 ± 706 mm annually), solar radiation of 1452 ± 269 Wm $^{-2}$, temperature of 32±5°C, and a relative humidity of 69% to 85% (Okoro et al., 2021, Ukwu et al.,2025). Soil at the experimental site is classified as Ultisol according to the soil taxonomy of the USDA (Soil Survey Staff , 2003), is a sandy clay loam that contains low organic carbon (1.46%) and low contents of nitrogen, phosphorous, basic cations (potassium, magnesium, calcium) and base saturation contents but high exchangeable acidity. Nsukka, Enugu State, is located in the derived Savannah Zone with a pH ranging from 5.0 to 6. 5.

2.2 Weather conditions at the experiment site

Meteorological data obtained from the Department of Crop science Meteorological unit (Figure 2) revealed that peak rainy months (July-August) showed highest precipitation of (90% rainy days) and humidity (89%), which coincided with extensive cloudy cover (80%) and the minimal sunshine (16-17%), creating optimal conditions for moisture- dependent crops but increasing disease risks.

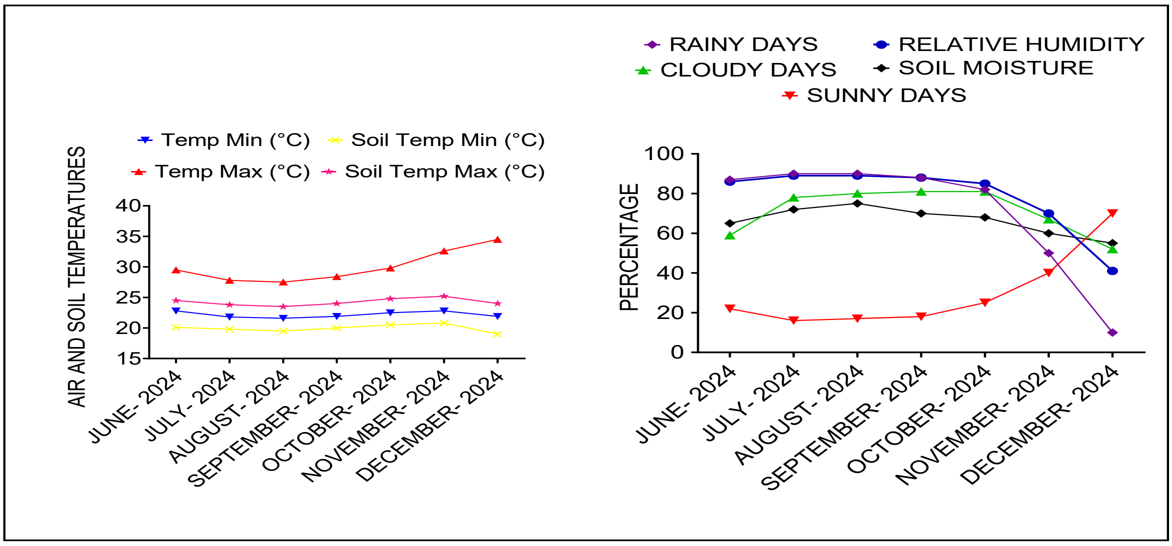

Figure 2: Climatic conditions of the experimental site from June 2024 to December 2024

Transition months (October-November) exhibited gradually decreasing rainfall (82% to 50%) and humidity (85% to 70%), while December marked the dry season onset with minimal rainfall (10%), low humidity (41%) and abundant sunshine (70%). Soil conditions mirrored these trends, with moisture content peaking at 75% in August and dropping to 55% by December. Wind patterns shifted from predominant southwesterly rainy season (June-November) to northeasterly harmattan winds in December with evapotranspiration rates highest (4.8 mm/day) during the dry period due to increased solar radiation.

2.3 Experimental Material

Two sweet potato varieties, Beauregard and Hannah, were used. Vines were sourced from Teaching and Research Farm and multiplied in nurseries prior to planting to ensure uniformity and availability of planting materials.

2.3.1 Soil Preparation

The soil was prepared 2 weeks before planting. Deep digging loosened the soil to prevent compaction and support root expansion. Medium sized ridges were constructed across a 2000 m^2 (1600 m^2 planted; 400 m^2 border). Vine cuttings were air-cured under shade for 48 hours prior to planting encourage early root development.

2.3.2 Planting material and selection

Planting material consisted of 30 cm long vine cutting with 4-6 nodes, derived from either the basal part or top part (apical portion) of vine mother vine.

2.3.3 Agronomic Maintenance

The plots were weeded three times manually to protect the crop from weed competition.

No synthetic fertilizers or pesticides were applied to simulate low-input conditions and assess vine performance under typical smallholder constraints.

2.4 Experimental Design and Treatments

The experiment consisted of a 2 x 2 factorial in randomized complete block design (RCBD) with three replications. The treatments were two sweet potatoes varieties (Beauregard and Hannah) and two Part of Vine -30 cm cuttings taken from two positions on the mother vine: Top Part (apical) and Basal Part. Each ridge measured 6 m x 0.8 m. with planting spacing 1m x 0.3 m. A total of 20 vine cuttings were planted per ridge of 6 m during the cropping seasons on 15th July, 2024 and planting vine cutting orientation was inclined. Harvest was done on 30th December, 2024.

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2.5 Data Collection

For data collection, four sweet potato plants were randomly chosen and tagged in the center of each plot. Observations and measurements were then taken per plot to record key agronomic traits. The traits assessed included stem count (the number of established stems per plot at harvest), mean root length (MRL, the average length of storage roots per plot), and mean root diameter (MRD, the average diameter of storage roots per plot). Additionally, root number (RN) was recorded as the total number of storage roots per plot, while root yield was measured as the total weight of harvested storage roots, expressed in kilograms per plot. These parameters together provided a detailed evaluation of the growth and yield performance of the sweet potato plants.

2.6 Statistical Analysis

The data were analyzed using analysis of variance (ANOVA) in GenStat 18th edition to test for significant differences among treatments. After ANOVA, mean separation was done with the least significant difference (LSD) test at the 5% level. Graphs were created using GraphPad Prism 10. Correlation analysis and hierarchical clustering heatmaps were generated in Python 3.11 with matplotlib and seaborn. In addition, GGEBiplot software was used to produce visualizations showing which-won-where, mean performance and stability, as well as the discriminatory power and representativeness of vine parts and varieties.

3. RESULTS

3.1 Effect of variety on growth and root yield attributes

Different sweet potatoes varieties significantly ($P<0.05$) influenced various root, stem characteristics as well as root yield (Figure 3).

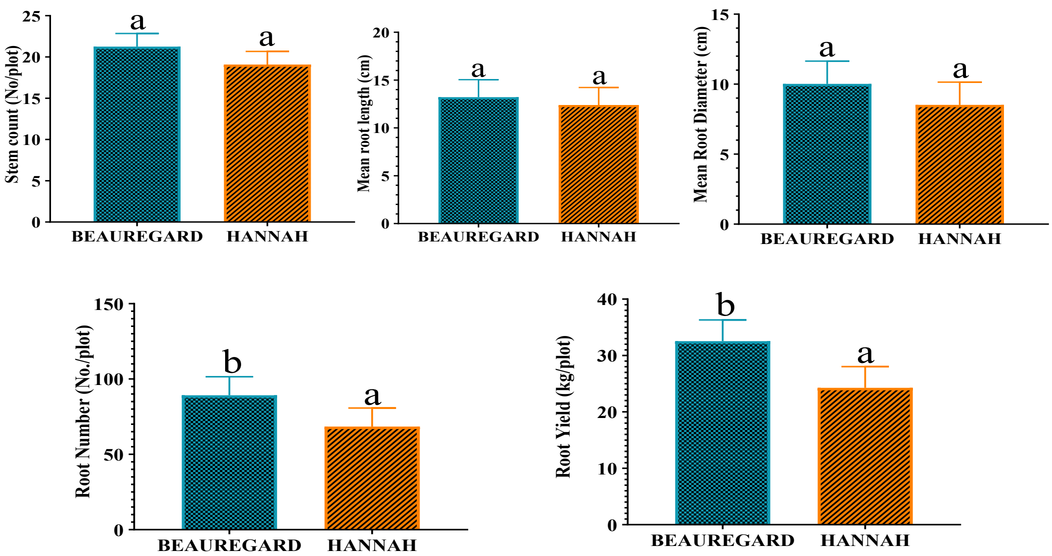

Figure 3: Effects of variety on growth and root yield attributes of sweet potato.

Note: Bars represent means values of three replicates (randomised blocks). Bars with similar letters are not significantly different at p<0.05.

It was observed that Beauregard consistently outperformed Hannah across most traits measured. Beauregard exhibited a greater stem count (21.25 stems/plot) compared to Hannah (19.08stems/plot), which correlates with superior root number (89.20 roots/plot), and significantly greater yield (32.55 kg/plot). Additionally, Beauregard demonstrated a longer mean root length (13.22 cm) and larger mean root diameter (10.02 cm) than Hannah, showed that Beauregard may have a more robust and productive root system in all these attributes, with a stem count of 19.08, mean root length of 12.40 cm, mean root diameter of 8.52 cm, root number of 64.80, and root yield of 24.60 kg/plot.

3.2 Comparison of sweet potato growth and yield characteristics derived from two distinct parts of the vine- top part and basal part.

The part of the vine used significantly differences ($P<0.05$) influenced stem count, root characteristics, and root yield (Figure 4).

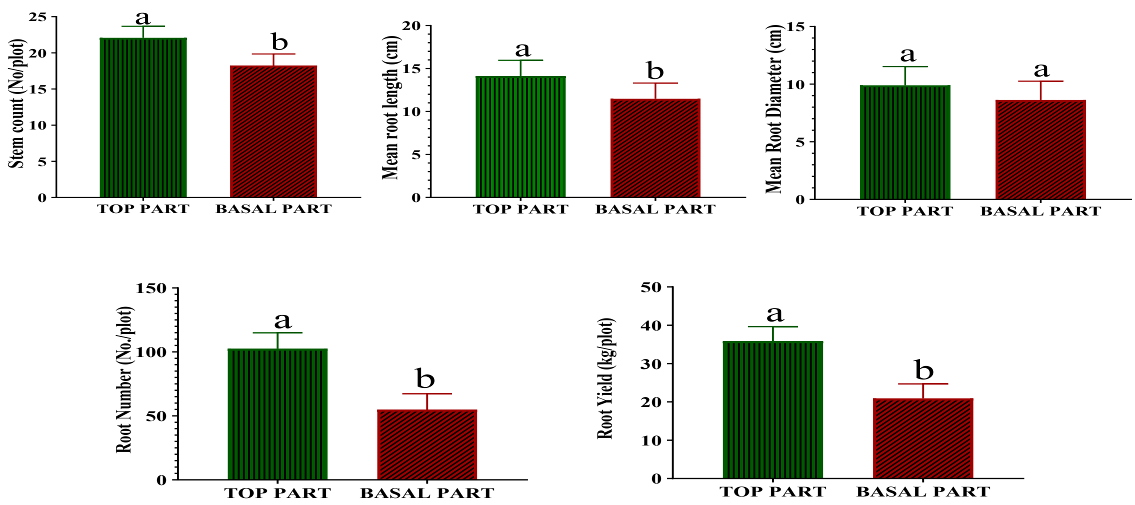

Figure 4: Comparison of sweet potato growth and yield characteristics derived from two distinct parts of the vine-top part and basal part.

Note: Bars represent means values of three replicates (randomised blocks). Bars with similar letters are not significantly different at p<0.05

It was observed that plants propagated from the top part of the vine cuttings exhibited significantly greater stem count (22.08 stems/plot), longer mean root length (14.13 cm), larger mean root diameters (9.90 cm), higher root numbers (102.60 roots/plot), and superior root yield (35.89 kg/plot) compared to those propagated from the basal part. In contrast, plants from the basal part showed relatively lower values across all traits.

3.3 Combined effect of the variety and part of the vine on growth and root yield attributes

The impact of vine part selection and genetic variability on sweet potatoes productivity (Figure 5).

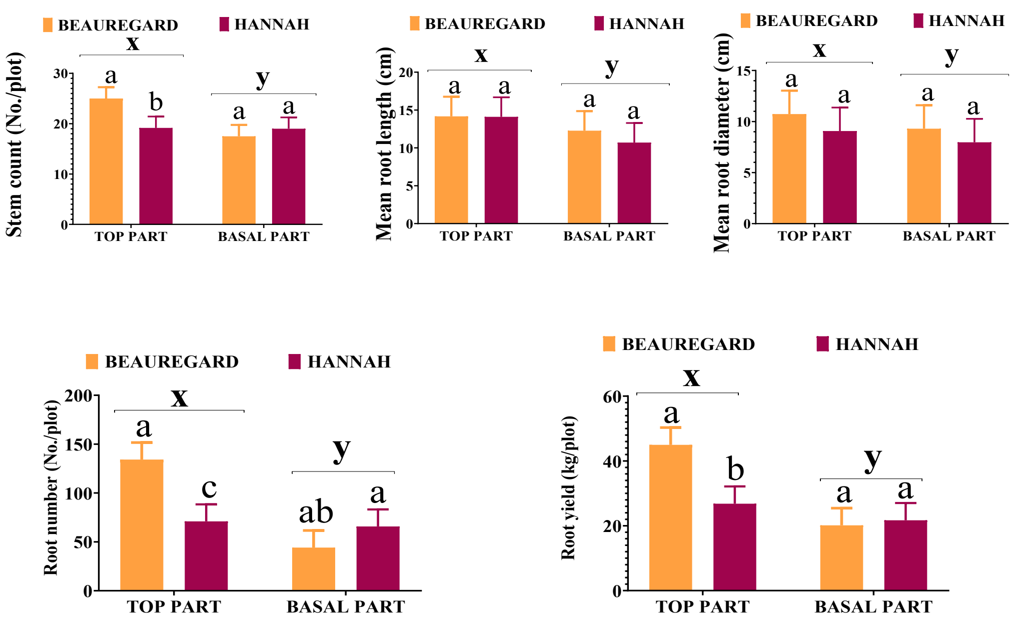

Figure 5: Combined effect of the variety and part of the vine on growth and Root yield attributes.

Note: Bars represent means values of three replicates (randomised blocks). Bars with similar letters are not significantly different at p<0.05.

Propagation from the top part of the vine used significantly (P< 0.05) enhanced agronomic performance across all measured traits for both varieties shown in figure 3. It was observed that cuttings derived from the top part of the vine consistently outperformed those from the basal part across all traits, regardless of the variety. For Beauregard, plants propagated from the top part recorded a significantly higher stem count (25.00 stems/plot), longer mean root length (14.17 cm), larger mean root diameter (10.73 cm), greater root number (134.20 roots/plot), and substantially higher root yield (44.97 kg/plot) compared to basal part, which showed notably lower values in all attributes. Similarly, the Hannah demonstrated superior growth metrics when propagated from the top part, though its overall performance is robust than in Beauregard's.

The interaction plot showed a significant cross-effect (labeled **S**) between sweet potato variety and vine cuttings position on root yield performance (Figure 6) revealed a non-additive relationship in how these two factors influence productivity.

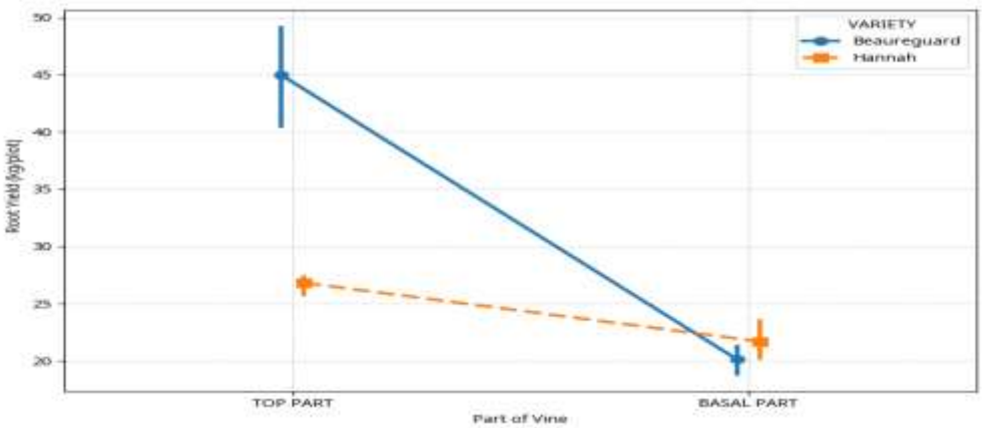

Figure 6: Interaction Plot - part of the vine and variety for root yield

Beauregard exhibited the highest root yield 45.30 kg/plot when propagated from the top of the vine ranking the first overall across all treatment combinations. However, this yield advantage was not maintained across cutting position as it sharply declined to 18.85 kg/plot when basal cuttings were used, dropping it to the lowest rank among the four combinations. While Hannah maintains relatively stable yield across both cutting parts. The crossing lines showed that the effect of cutting part of vine is variety -dependent, with Beauregard performing best with top cuttings and worst with basal, reversing the rank order compared to Hannah.

3.4 Correlation analysis and hierarchical clustering heatmap of growth and root yield attributes of two sweet potatoes varieties as impacted by parts of vine

Figure 7 showed root yield is strongly and positively correlated with root number (r = + 0.93**) and stem count (r =+ 0.92**), indicating that increase in these traits is associated with higher yields. A moderate positive correlation was observed between root yield and root length (r =+ 0.47*). Strong positive correlations were also observed between stem count and root number (r =+ 0.86**) and root diameter was moderately correlated with both root length (r =+ 0.69*) and stem count (r =+ 0.59*).

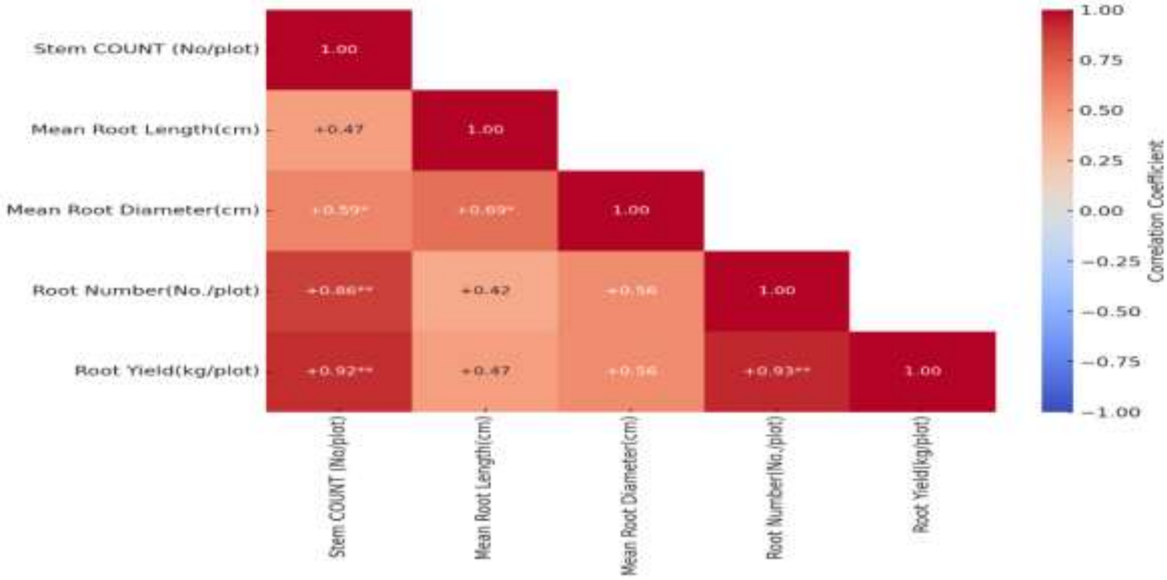

Figure 7: Correlation coefficient of growth and Root Yield attributes of sweet potatoes.

*Note: **Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed),+ or − signs indicating direction.*

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The Heatmap revealed the comprehensive visualization a standardized multivariate assessment of growth and root traits responses across two sweet potato varieties evaluated based on the parts of vine cutting for propagation (Figure 8).

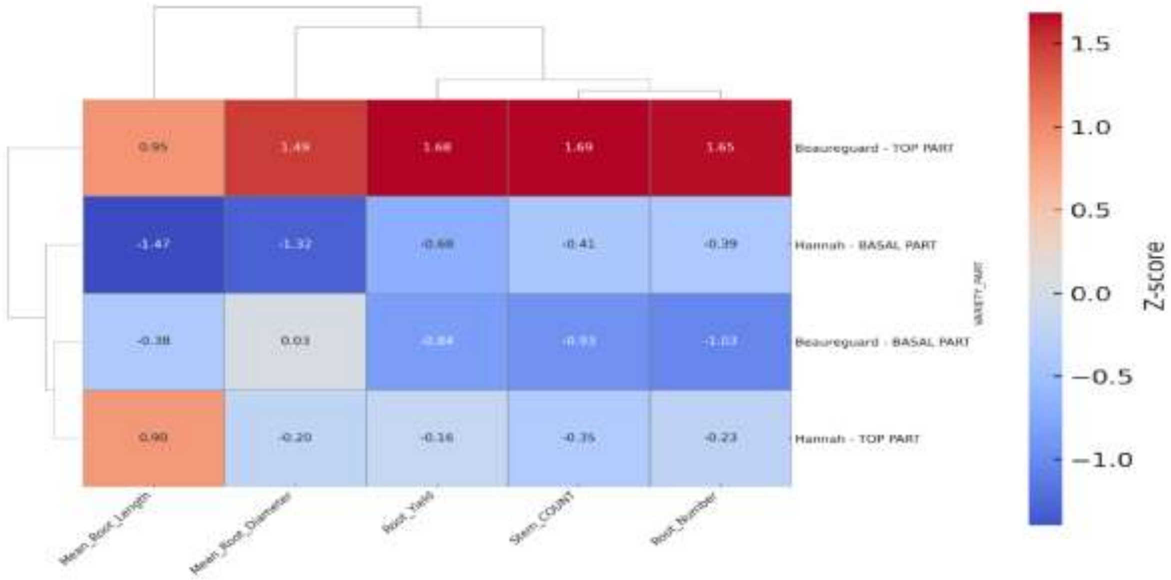

Figure 8: Hierarchical clustering heatmap analysis of sweet potato varieties as impacted by parts of vine. Z-score: Standardized Score

This analytical approach enabled a high-resolution interpretation of genotype by propagule position interactions and their influence on phenotypic trait expression, particularly for root yield components. Beauregard-Top part consistently clustered separately from all other combinations exhibiting the highest standardized scores across key agronomic traits such as stem count, root number and root yield. This suggests agronomic performance from the top portion of Beauregard vines. Conversely, Hannah-Basal part recorded standardized scores across most traits, particularly root number and diameter reflecting comparatively weaker performance. The moderate clustering of Hannah-Top part showed a slight improvement in traits but not to the same extent as observed in Beauregard, reinforcing the existence of genotypes -specific responses to cutting position.

3.5. Genotypic performance and stability of sweet potato varieties and vine parts using GGE Biplot: Accessing the relationships, mean performance, stability, discriminatory ability and winning performance.

The biplots derived from evaluations of vine parts (top part and basal part) from sweet potato varieties Beauregard (B) and Hanah (H), provide insights into their propagation performance based on traits including stem count, mean root length, mean root diameter, root number and root yield attributes explained 96.7% (PC 1 = 84.1% and PC 2 = 12.6%) of the variation in the parts of vine regardless of the varieties. The relationship among various traits of sweet potato and vine parts used for propagation view (Figure 9a) explained the top part (TP) of the varieties contributed more

Corresponding Author: Solomon Oluwaseyi ADEWUYI

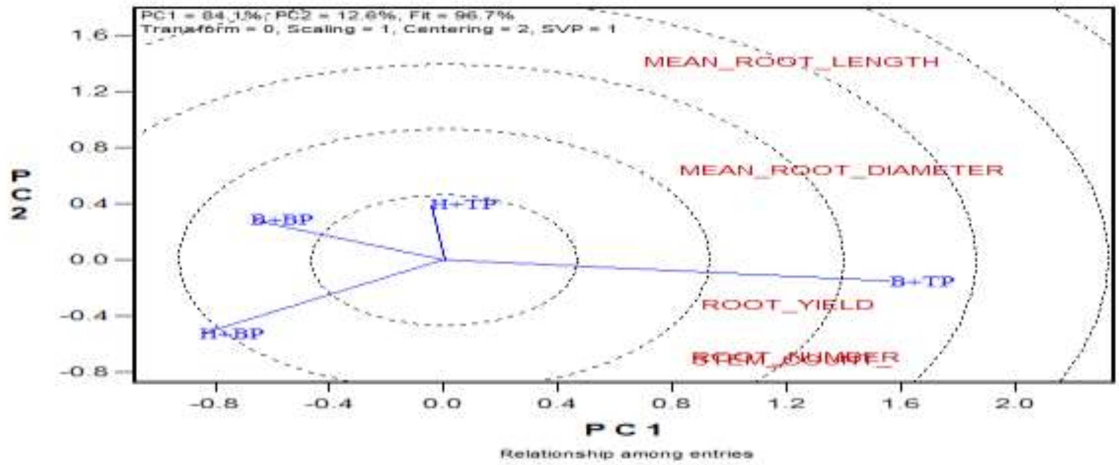

Figure 9a: The relationship among parts of vine and variety graphic view

to root length, diameter, and root yield, while basal parts (BP) leaned toward the negative PC1 and positive PC2 linked to root number and stem count. The separation observed between TP and BP highlighted that the choice of vine part for propagation can impact the resulting sweet potato traits differently for each variety. In the mean and stability performance chart (Figure 9b), the vine parts were ranked based on how well and how consistently they performed.

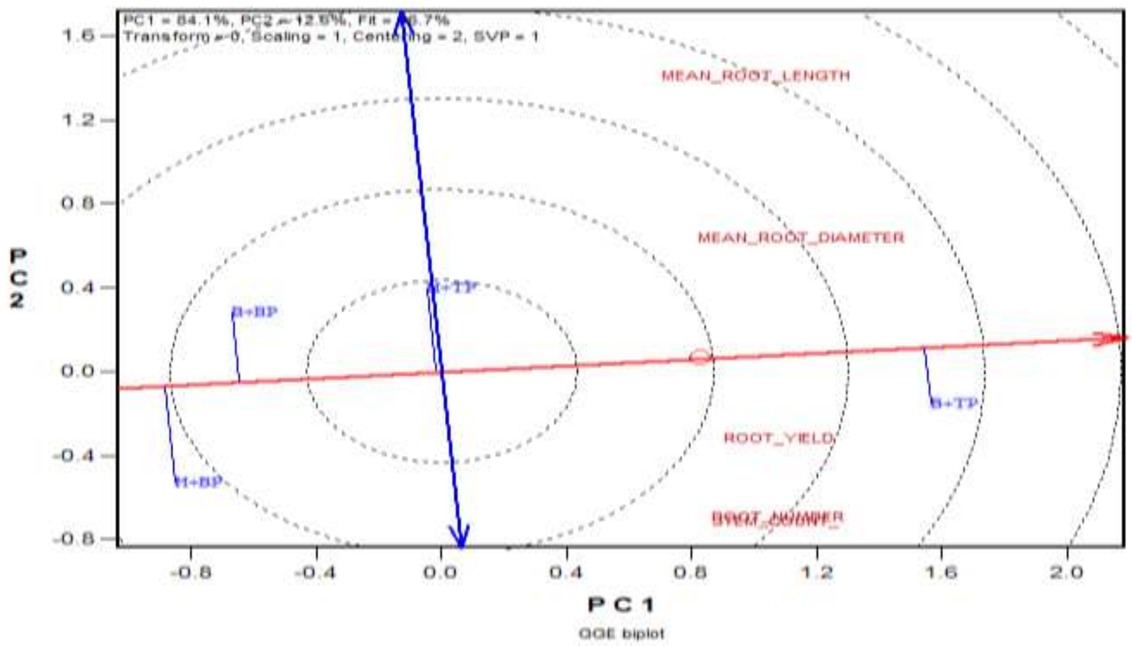

Figure 9b: The mean vs stability performance view of the parts of vine and varieties

The B+TP part ranked the highest, followed by H+TP. The horizontal red line (average tester axis) shows overall performance levels, while the vertical blue line (average tester ordinate) separates the well-performing vine parts and varieties from the weaker ones. The H+BP gave the least performance among the parts of vine and varieties, followed by the B+BP. The traits measured across B+TP recorded 34%, 15%, 22%, 112%, and 97 % higher stem count, mean root length, mean root diameter, root number, and root yield respectively than the others. The ability of the measured traits to explain differences among vine sections and types was assessed using the discriminatory and representative graphic view (Figure 9c).

Corresponding Author: Solomon Oluwaseyi ADEWUYI

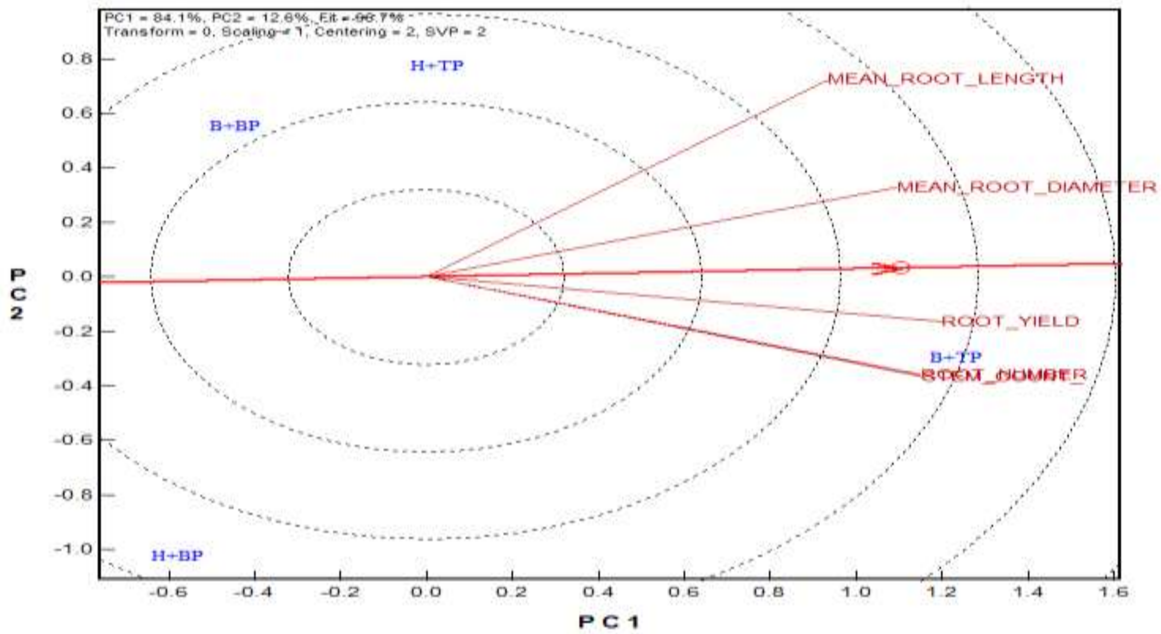

Figure 9c: The discriminatory and representative graphic view of the parts of vine and varieties

This evaluation was based on the length of each trait's vector from the biplot origin and how close its angle was to the average tester (the small circle on the tester axis). Root yield had the closest angle, followed by root number and stem count, even though all the traits showed long vectors. In the which-won-where graphic view (Figure 9d), each part of vine and varieties occupied a polygon vertex.

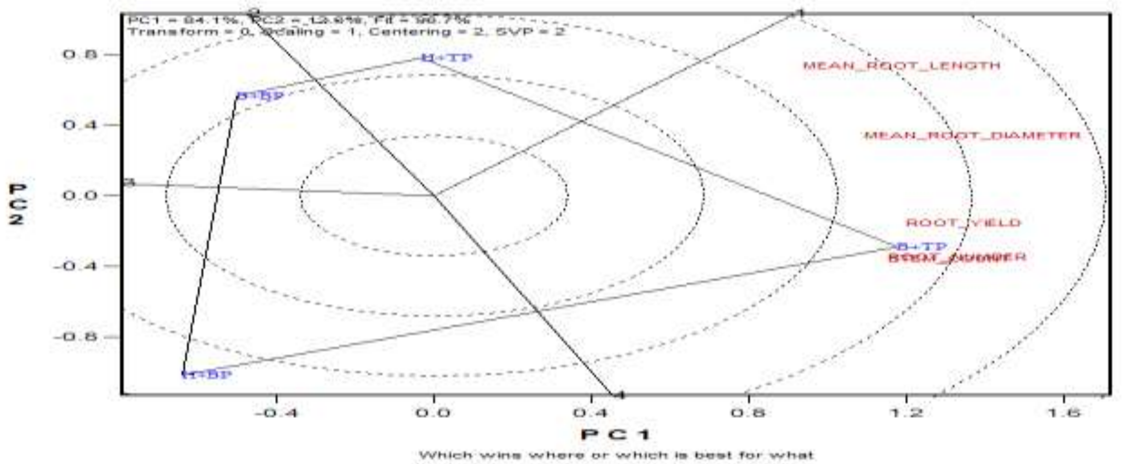

Figure 9d: The which-won-where view of the parts of vine and varieties

The stem count, mean root length, mean root diameter, root Number and root yield are within top parts (B+TP and H+TP). The view also comparing mean root yields, clearly showed the superior performance of the Beaureguard variety when planted using cuttings from the Top Part of the vine. This combination achieved the highest mean yield, substantially exceeding the other treatments. Hannah planted with Top Part cuttings was the second-best performer, while both varieties yielded considerably less when Basal Part cuttings were used. Collectively, results from views highlighted B+TP as the optimal choice for maximizing yield, root number and root size, with top parts generally outperforming basal parts.

4. DISCUSSION OF RESULTS

The findings of this study elucidate the critical influence of varietal selection and vine cutting position on the growth and root yield traits of sweet potato, which are key determinants of productivity in root and tuber crops. Among the two varieties, Beauregard consistently outperformed Hannah across all measured agronomic traits. Its superior stem count, root length and diameter, root number, and ultimately, root yield, emphasize the genetic advantage of Beauregard for vegetative vigor and root development which directly translates to higher productivity under the studied agroecological conditions. These results are consistent with previous studies affirming the role of genotype in influencing biomass allocation and root storage capacity in sweet potato (Low et al., 2017; Ebem et al., 2021; He et al., 2021; Maulana et al., 2023). Remarkably, these varietal traits directly affect nutrient use efficiency and photosynthetic output, which are pivotal components of climate-resilient crop systems (FAO, 2021).

A distinct outcome of this study is the demonstrated superiority of top (apical) part of the vine over the basal part as planting material. The top part of the vine was found to be significantly more effective as planting material than the basal part, regardless of variety. This aligns with general understanding that apical cuttings being physiology younger and have higher concentrations of endogenous auxins often promote faster rooting and more vigorous initial growth, more active meristematic cells, and greater carbohydrate reserves (Hartmann et.al, 2011; Ebem et al., 2021; Maulana et al., 2023). The use of top part of vine thus offers a practical and biologically sound method to enhance root initiation, rapid establishment, and robust tuber formation. From a sustainability standpoint, this finding is particularly important, as it provides a low-input propagation technique that improves plant performance without additional chemical inputs, aligning with the principles of sustainable intensification (Pretty et al., 2018).

Furthermore, the pronounced interaction effects between variety and cutting position emphasize the importance of genotype × propagule interaction observed especially in Beauregard indicates that optimized propagation methods must be variety-specific to maximize efficiency and yield. Beauregard propagated from top part of the vine (B+TP) recorded the highest root yield (45.00 kg/plot), while its performance drastically declined when basal cuttings were used (Labeled S). This interaction highlights the sensitivity of high-performing genotypes to propagation technique, where the physiological attributes of the cutting interact significantly with the genetic makeup of the variety. In contrast, the more stable performance of Hannah across vine parts suggests a greater tolerance to propagation variability but at the cost of lower overall yield, likely attributable to inherent varietal traits governing resource allocation and reduced apical dominance. These results align with the findings of Berchie et.al. (2018) and Makumbu et. al. (2024) on cassava and sweet potato, indicating that the source of planting material can modulate genotypic performance. These insights support the call for precision agriculture approaches in root crop propagation, where both genotype and propagation method are synergized to local conditions to optimize resource use and minimize waste (Cevallos et al., 2019; Gebbers & Adamchuk, 2020; Sheat et.al., 2024).

Correlation coefficients were calculated to establish magnitude and direction of interrelationships among the traits, its revealed strong positive relationships between root yield and root number ($r = +0.93$, $p < 0.01$) and stem count ($r = +0.92$, $p < 0.01$), indicating that increase in these traits are associated with higher yields. This aligned with finding where root number per plant was identified as primary contributor to root yield (Muhammad and Yahaya, 2018). Similarly, stem count's positive correlation with root yield suggests that a higher number of stems may enhance photosynthetic capacity, thereby supporting greater root development. This finding reinforced the relevance of these traits as early predictors of yield performance in sweet potato. These relationships are consistent with recent literature emphasizing the importance of early vigor and canopy development in predicting root performance (Sakaigaichi et al., 2023). A moderate positive correlation between root length and yield ($r= +0.47$, $p < 0.05$) implied that longer roots facilitate improved nutrient uptake and spatial soil exploration, which can enhance carbohydrate accumulation (Sakaigaichi et al., 2023). In contrast, root diameter showed moderate and non-significant correlation with yield, indicating its secondary role in determining harvestable biomass consistent with Singh et al. (2025). Importantly, these traits are phenotypically visible and could be easily integrated into mobile-based agronomic advisory tools, supporting smallholders in selecting optimal planting materials at scale.

The heatmap clustering further confirmed with a clear stratification of traits performance between the vine segments, with the Beauregard -Top part combination consistently exhibiting the highest standardized values across nearly all measured traits. This cluster distinctly separates from others, implying that apical cuttings from Beauregard are highly vigorous and biologically superior in rooting and biomass accumulation capacity. The enhanced performance from apical cuttings can be attributed to increase levels of endogenous auxins and cytokinins, higher meristematic activity and better vascular differentiation, which collectively facilitate improved root initiation and enlargement (Ncube and Mutetwa,2019).

GGE biplots visually validated superior performance profile B+TP as the most productive treatment, clearly distinguishing it in multivariate trait space. The "relationship among entries" view showed that top part (B+TP and H+TP) are strongly associated with MRL and MRD, suggesting their efficiency in producing larger roots with reduced need for additional land or inputs like fertilizers (Yan and kang 2003). This supports sustainable intensification, enhancing productivity while conserving resources, as emphasized by recent studies (Tilman et al., 2011). The "mean vs stability performance" view further highlighted B+TP's superior performance for root size and H+TP's balanced stability, enabling consistent yields with lower ecological footprints, thus promoting long-term soil health and biodiversity (Neupane et.al, 2024). The GGE biplot analysis also has implications for climate-smart agriculture (CSA), which focuses on adaptation, mitigation and resilience to climate variability. The "mean vs stability performance" view showed H+TP's stability across variable condition, making it a climate-smart option for farmer facing unpredictable weather, a critical adaptation strategy (Rosenstock et.al, 2016). The "which -won -where" view confirmed that top parts excel in producing larger roots, potentially increasing biomass and supporting carbon sequestration a key mitigation approach in CSA (Neupane et.al, 2024). The "discriminatory ability and representative view" showed B+TP's high discriminatory power for root number and stem count, enabling precise identification of plants with specific trait advantages, which can guide variable rate applications of water, photosynthesis and nutrients (Kassam et. al 2018). The "which-won -where" view supported precision farming by identifying B+TP and H+TP as ideal for size-focused propagation in high-yield zones, improving resources use efficiency (Kassam et. al 2018). Recent advancements in sensor technology and data analytics further complement these findings by enabling real time crop management with top vine parts (Singh, 2024). These results supported the development of decision support systems in sweet potato farming, where propagation strategies are optimized not only for yield but also for resource use efficiency and environmental resilience. The emphasis on top-cutting propagation to enhance food security, using high-performing varieties like Beauregard offers a low-cost yet high-impact intervention for sustainable intensification in root and tuber farming systems, particularly in vulnerable regions like sub-Saharan Africa where access to elite planting materials and fertilizers remains limited.

5. CONCLUSİON

The results of this study provided compelling evidence based significant effects of top vine parts (B+TP and H+TP) offer strategic advantages for modern farming and corroborate the findings of several studies. Integrating genotypic selection with cutting-edge propagation practices can greatly enhance the sustainability and climate resilience of sweet potato production systems. By selecting the appropriate part of vine for propagation, farmers can increase yields without additional inputs or land expansion. This approach represents a low-cost intervention that could significantly improve resources use efficiently in sweet potato production systems. Specifically, the use of top vine cuttings from the Beauregard variety, significantly improves yield outcomes and aligns well with the principles of climate-smart and precision agriculture. As the agriculture sector increasingly seeks low-emission, resource-efficient innovations to meet growing food demands, such tailored propagation strategies offer a viable pathway toward resilient, high-performing, and environmentally sound cropping systems.

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