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Growth and Tuberization in Seed-Propagated Cassava

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Abstract

Purpose: This study aimed to assess the growth and tuberization dynamics in seed-propagated cassava in order to offer insights into the morphological and anatomical characteristics of cassava during various stages of growth.

Materials and Methods: Cassava seeds of line TMS 30555 obtained from IITA were planted at a distance of 25 cm by 25 cm in prepared beds. Regular observations were made on plant morphological characteristics, tuber formation, stem height, taproot length and lateral root length with data obtained analyzed using Microsoft Excel. Microscopic analysis was conducted on root samples to assess tuberization using a detailed slide preparation procedure involving fixation, dehydration, infiltration with paraffin wax, embedding, sectioning with a microtome, staining and mounting on slides for examination under a microscope.

Findings: There was a steady weekly increase in the average number of nodes with an almost constant number of lobes and number of adventitious roots on the hypocotyl. The true leaf produced on the second node was simple and the shape was ovate. The study confirmed that starch synthesis begins in cassava roots around six weeks post-sowing, initially visible in cortical cells before spreading to xylem arms and lateral roots. By eight weeks after sowing, there was a notable increase in starch grain accumulation across various parts of the lateral roots. There was also strong positive correlations among stem height, taproot length and lateral root length, suggesting that these traits are interdependent and influenced by shared genetic factors and environmental conditions.

Unique Contribution to Theory, Practice and Policy: The findings provide valuable insights into the growth and development of seed-propagated cassava plants, which can help guide breeding efforts aimed at improving cassava yield and quality. The understanding gained in the growth and development of seed-propagated cassava plants, including factors influencing tuberization and starch accumulation, is essential as it informs breeding efforts aimed at improving crop yield, resilience and nutritional content, partly contributing to resolutions towards food insecurity.

Keywords: *Tuberization, Seed-propagated cassava, Tap root, Lateral root, Starch grain.*

JEL Code: Q10

1.0. INTRODUCTION

Cassava (*Manihot esculenta* (Crantz)) is one of the major tuber crops produced and consumed in sub-Saharan Africa and the world at large (FAO, 2013; Onwueme & Winston, 1994). It is a perennial plant with a limited lifespan that grows through vegetative means and produces starchy tuberous roots close to the soil's surface. Cassava is not only a staple food crop but also an important cash crop for many smallholder farmers. With a steady increment in cassava production since 2009, Ghana produced 25.6 million metric tonnes (MMT) of cassava in 2022, a rise above the 25 MMT produced the year before (Sasu, 2024). Cassava is also known to support the dietary needs of millions across diverse regions. As a primary source of carbohydrates, its significance for food security cannot be overstated (FAO, 2013). Despite the interesting facts available about cassava, less is seen in terms of its impact on food security and climate resilience (CGIAR, 2019) largely due to lack of knowledge about these interesting insights by leaders and policymakers (Onwueme & Winston, 1994).

Seed propagation plays a critical role in the cultivation of cassava, as it ensures the availability of quality planting material, genetic diversity and improved crop productivity, however, the collection, dormancy breakage and optimal storage conditions are vital factors that impact its germination viability and overall seed quality (Wossen et al., 2020). The fruit of the cassava plant is a three-chambered capsule, and inside each capsule is a single seed. It takes about 75-90 days after pollination for a cassava fruit to reach physiological maturity (Fei, 2023). When the mature fruits burst open, they release their seeds explosively. To collect seeds through controlled crosses, it is necessary to bag the fruits before they reach maturity. Freshly harvested seeds are typically dormant, and they require 3-6 months of dry storage at room temperature to break this dormancy. Cassava seeds that are physiologically active can germinate easily in approximately 15 days (Cock & Connor, 2021). The ideal temperature for germination is between 30 and 35 °C. Cassava seeds can be stored at a temperature of 4-5 °C and a relative humidity of 60%.

With its ability to thrive in diverse agroecological conditions and resistance to drought, cassava plays a crucial role in ensuring food security and livelihoods in resource-limited regions (El-Sharkawy, 2006). Several genes have been found to contribute to its resistance against drought and many other unfavorable abiotic stressors with anticipation that the use of molecular techniques can help unfold how these traits can be harnessed in various ways to increase productivity (Muiruri et al., 2021; Okogbenin et al., 2013). However, despite its economic significance, the productivity of cassava is often hindered by the lack of quality planting material, specifically in areas where vegetative propagation is practiced, even though it has its advantages (Olsen & Schaal 2007; Ceballos et al., 2004).

Seed-propagated cassava refers to the use of botanical seeds, also known as true seeds or botanical propagules, as opposed to the traditional method of using stem cuttings for propagation due to its many advantages. Some of these advantages include enhancing genetic diversity, reducing the spread of diseases by drastically decreasing the viral load in vegetative material, dealing with stake storage issues, and facilitating the dissemination of improved varieties (Uke et al., 2022; Kawano, 2003; Iglesias et al., 1994). Understanding seed-propagated cassava's growth and tuberization processes is crucial for harnessing its full potential and addressing the challenges associated with cassava seed systems.

Seed propagation not only provides genetic diversity but also has direct implications for cassava tuberization. Unlike stem cuttings, botanical seedlings exhibit significant variation in early root architecture, shoot vigor, and initial carbohydrate partitioning, factors known to strongly influence tuber initiation and bulking. Studies have shown that differences in seedling morphology, including storage parenchyma development, vascular tissue arrangement, and fibrous-root proliferation, can affect how quickly and efficiently tuberous roots are formed (Ceballos et al., 2020; Hyde et al., 2022). Because these developmental processes begin long before visible tubers are formed, an anatomical and morphological examination is essential to understand the physiological mechanisms that drive tuber formation in seed-propagated cassava. Such insights can reveal early predictors of high-yielding genotypes, support breeding programs, and improve the design of seed-based propagation systems.

Moreover, research into the growth and tuberization of seed-propagated cassava has the potential to lead to the development of improved varieties that possess desirable traits, such as high yield, disease resistance and high market demand. This, in turn, can contribute to increased income for farmers and foster rural economic development. Knowledge about the growth and tuberization processes obtained can enhance farmers' knowledge and farm productivity through extension. Therefore, studying the anatomical and morphological traits associated with early growth and tuberization in seed-propagated cassava is essential for improving seed systems, enhancing varietal selection, and supporting breeding programs aimed at increasing productivity and resilience.

Problem Statement

Despite cassava's central role in food security and rural livelihoods across Sub-Saharan Africa, its productivity remains constrained by biological, agronomic, and propagation-related challenges. Existing studies on cassava growth and tuberization from seed-propagated plants have largely emphasized root system architecture, genetic variability, and environmental stress responses, particularly drought (Chaweewan, 2015; Kengkanna et al., 2019; Ceballos et al., 2019; Henry et al., 2015). These studies highlight the importance of root traits, such as deeper rooting depth, increased storage root initiation, and efficient nutrient uptake, in determining cassava yield performance. However, despite these insights, there remains a cassava-specific knowledge gap on how root traits expressed in sexually propagated cassava seedlings (botanic seeds) translate into stable, heritable traits useful for breeding programs.

A critical constraint in cassava production is the persistent reliance on vegetative propagation using stem cuttings, which often results in the spread of systemic diseases such as Cassava Mosaic Disease (CMD) and Cassava Brown Streak Disease (CBSD) (Olsen & Schaal, 2007; Ceballos et al., 2004; Kawuki et al., 2016). This leads to the continuous recycling of infected planting material, ultimately contributing to low yields and poor field performance. Exploring the growth dynamics and tuberization behavior of cassava plants derived from true seeds is therefore essential, not only to understand their physiological development but also to evaluate their potential for generating clean, disease-free planting material.

Objective

This study aimed to assess the growth and tuberization dynamics in seed-propagated cassava, in order to enhance the understanding of the morphological and anatomical characteristics of cassava during various stages of growth.

The findings of this study will also serve as a valuable resource for researchers and practitioners involved in cassava breeding, agronomy and seed systems considering its great impact on the economy and its use as a major staple food in parts of the ecosystem. By shedding light on the intricacies of seed-propagated cassava, we aim to facilitate the development and adoption of sustainable production practices, ensuring the availability of high-quality planting material and promoting the resilience of cassava-based food systems.

2.0. MATERIALS AND METHODS

Seed Characteristics and Planting

The cassava seed, characterized by its ellipsoidal shape with a length ranging between 1 – 1.5 cm, exhibits a hard and brittle greyish testa mottled with dark patches. Notably, a large caruncle is found at the micropylar end of the seed.

The experimental setup was conducted at the Botanic Garden of the University of Cape Coast (5°7'0" North, 1°17'45" West). Two beds, each measuring 1.2 m × 3.0 m, were meticulously prepared for seed planting. The beds were of moist sandy loam with soil pH of 5.5 and organic carbon of 2.3% (Table 1). Cassava seeds of line TMS 30555, introduced by IITA, were assessed prior to sowing for viability using the flotation method. Subsequently, seeds that floated were discarded, and the remaining viable seeds were planted at a spacing of 25 cm × 25 cm. Approximately, 58 cassava seedlings were raised on each bed.

Table 1: **Soil Properties of Experimental Site**

Property	Value at Depth 0-20cm
pH $_{(1:2.5)}$ (H_2O)	5.5
Organic Carbon (%)	2.3
Sand (%)	48
Silt (%)	23
Clay (%)	29
Textural class	Clay loam
Soil class (group, suborder, order)	Haplorthox, Orthox, Oxisols

(Hengl et al., 2021; Hengl & Nauman 2018)

Morphological and Tuberization Measurements

Seedling Stage

Plant morphological characteristics and tuber formation were regularly observed and documented throughout the experiment. Weekly, an average of seven plants were uprooted to measure stem height, taproot length and lateral root length. The diameter of the largest portions of the stem and taproot using a meter rule while diameter of lateral roots was measured using a Vernier caliper. From the third to the ninth week after emergence, both lateral and tap roots were observed for tuberization.

Microscopic Analysis of Tuberization

Root samples were collected and transverse sections prepared for microscopic analysis. A carefully crafted slide preparation procedure was implemented to unravel the microscopic details of tuber development within root samples. The process was initiated with fixation using Formalin-Aceto

Acid-Alcohol (F.A.A.) to preserve structural integrity. Subsequent dehydration involved a series of alcohol solutions, culminating in pure chloroform to eliminate moisture. Infiltration followed, saturating materials with paraffin wax in the presence of chloroform. After an overnight process, samples were exposed to molten wax for stability. For the embedding phase, materials were placed in molten wax-filled ice cube trays. Oriented and labeled blocks were then sectioned using a microtome, unveiling internal structures. Sections were mounted on slides coated with Mayer's glycerine albumen. Staining enhanced cellular visibility, involving dewaxing in xylene, dehydration and rehydration in alcohol solutions. Safranin staining, fast green counter staining and differentiation refined specimens. Slides were mounted in DPX with a cover slip, finalizing preparation. The slides were allowed to dry and subsequently examined under a microscope to assess the extent of tuberization.

Data Analysis

Microsoft Excel was used to determine the Pearson's correlation analysis between the growth rate of cassava seedlings using their morphological characteristics. The general growth rate of cassava seedlings per week over the nine weeks were also determined using the formular below:

Growth Rate = (Final Value - Initial Value) / Time

3.0 FINDINGS

Morphological Observations of Sprouted Cassava Seeds

Germination started 10 days after sowing and, by the 16^{th} day, most seeds had sprouted. An epigeal germination process was indicated by the hypocotyl's elongation, which raised the cotyledons above the earth. The radicle formed the primary tap root and three to five lateral roots at its base as the seed coat burst, emerging through the micropyle. The more unicellular hairs that tap roots possessed set them apart from lateral roots. The first leaves appeared when the cotyledons spread, taking the form of an oval or elliptical shape with an obtuse apex. The leaves had one lobe each, got larger over time, became green, and had a glossy, smooth surface. By the third day, the plumule, which was concealed by the cotyledons, had grown and was able to produce the first real leaf at the second node. This trilobed leaf, which was sometimes bilobed or singly lobed, represented the dorsiventral anatomy or separate upper and bottom surfaces of the cassava leaf. By the third week, signs of the cassava mosaic virus became apparent, causing twisted, deformed leaves with yellow patches mixed with the normally green sections.

Pearson's Correlation Analysis among Characters Measured

The results of Pearson's correlation analysis conducted among stem height, taproot length and lateral root length showed strong positive correlations among characteristics measured (Table 2). For the correlation analysis between stem height and tap root length, a correlation coefficient of 0.976 ($n = 9$, $df = 7$, $P < 0.001$) was obtained. This indicates a strong positive correlation between these two variables. Similarly, the correlation between stem height and lateral root length yielded a correlation coefficient of 0.991 ($n = 9$, $df = 7$, $P < 0.001$), indicating a very strong positive correlation. The correlation between taproot length and lateral root length resulted in a Pearson's correlation coefficient of 0.969 ($n = 9$, $df = 7$, $P < 0.001$), indicating a strong positive correlation as well.

Table 2: Pearson's Correlation Matrix for Stem Height, Tap Root Length and Lateral Root Length of the Cassava Seedlings

	Pearson's r between Stem Height and Tap Root Length	Pearson's r between Stem Height and Lateral Root Length	Pearson's r between Tap Root Lateral Root Length
r	0.976083443	0.990943623	0.968514665
N	9	9	9
t statistic	11.87911248	19.52500908	10.29275729
DF	7	7	7
p-value	6.80519E-06	2.307E-07	1.76826E-05

The correlation between the diameter of the largest portion of the stem base and tap root base was 0.895 (n =9, df =7, P = 0.001), indicating a strong positive correlation (Table 3). The correlation between the diameter of the largest portion of the stem base and the lateral root base yielded was 0.973 (n =9, df =7, P < 0.001), indicating a very strong positive correlation. Finally, the correlation between the diameter of the tap root base and lateral root base was 0.849 (n =9, df =7, P = 0.004), also indicating a strong positive correlation.

Table 3: Pearson's Correlation Matrix for the Diameter of the Largest Portion (DLP) of the Stem Base, Tap Root Base and Lateral Root Base of the Cassava Seedlings

	Pearson's r between DLP of Stem Base and Tap Root Base	Pearson's r between DLP of Stem Base and Lateral Root Base	Pearson's r between DLP of Tap Root Base and Lateral Root Base
r	0.895351912	0.972595757	0.848769147
N	9	9	9
t statistic	5.319027151	11.06759961	4.246949158
DF	7	7	7
p-value	0.001100431	1.09212E-05	0.003807456

The Rate of Growth of the Cassava Seedlings

Growth rate ranged from as high as 42.3 mm in the lateral root to as low as 0.3 mm in the diameter of largest portion of the stem base per week. Thus, growth rate was fastest in the lateral root followed by the stem (30.8 mm per week), tap root (10.6 mm per week), diameter of largest portion of tap root base (2.5 mm per week), diameter of largest portion of lateral root base (0.7 mm per week) and then stem base (*Figure 1*).

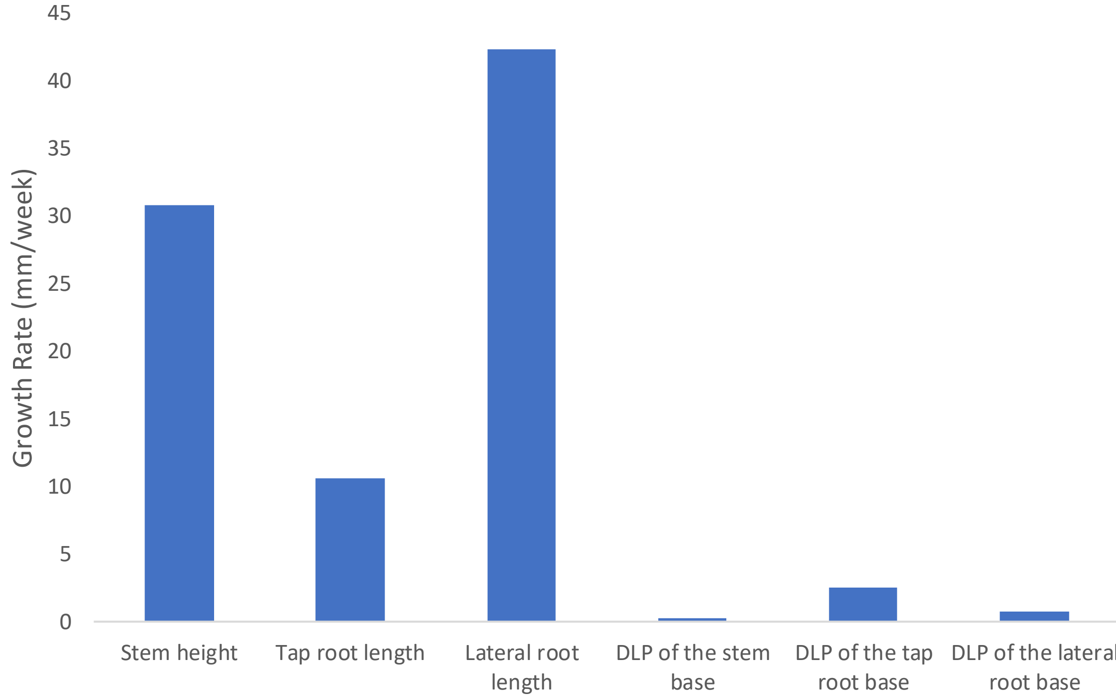

Figure 1: Growth Rate of Lateral Root Length, Stem Height, Tap Root Length and DLP of Lateral Root Base, Stem Base and Tap Root Base

Table 4: Mean Number of Nodes on the Stem, Mean Number of Adventitious Roots on Hypocotyl, and Number of Lobes on a Leaf From Weeks 1 To 9 after Emergence Seed-Propagated Cassava Seedlings

Week	Average Number of Nodes	Number of Lobes	Average Number of Adventitious Roots on Hypocotyl
1	4	1-3	4
2	6	3 or 5	4
3	9	3 or 5	4
4	11	5 or 7	4
5	14	5 or 7	4
6	21	5 or 7	4
7	25	5 or 7	4
8	28	5 or 7	3
9	30	5 or 7	3

Source: Field Data 2023

The mean number of nodes, mean number of nodes, and adventitious roots on the hypocotyl are presented in Table 4. The mean number of nodes on the stem increased from 4 at week 1 to 30 at week 9. The number of lobes on a leaf ranged also increased from 1-3 to 5 or 7 at week 4 and remained same thereafter up to week 9. The adventitious roots on the hypocotyl were 4 from weeks 1 to 7 and then reduced slightly to 3 at weeks 8 and 9.

Figure 2: Stages of Tuberization of Seed-Propagated Cassava at Weekly Intervals (from Left to Right; 2nd Week to 9th Week)

For the first three weeks, the rate of growth of the stem height was quite normal but increases sharply between the 5th and 6th week. It then continues its normal growth rate to the 9th week. For the length of lateral root, growth rate was very slow for the first three weeks but increases sharply afterwards up to 9th week (*Figure 2*). The growth rate of the length of tap root was slow for the first 5 weeks and increases sharply between the 5th and 6th weeks. It then declines from the 7th week to the 9th week.

Tuberization of Seed-Propagated Cassava

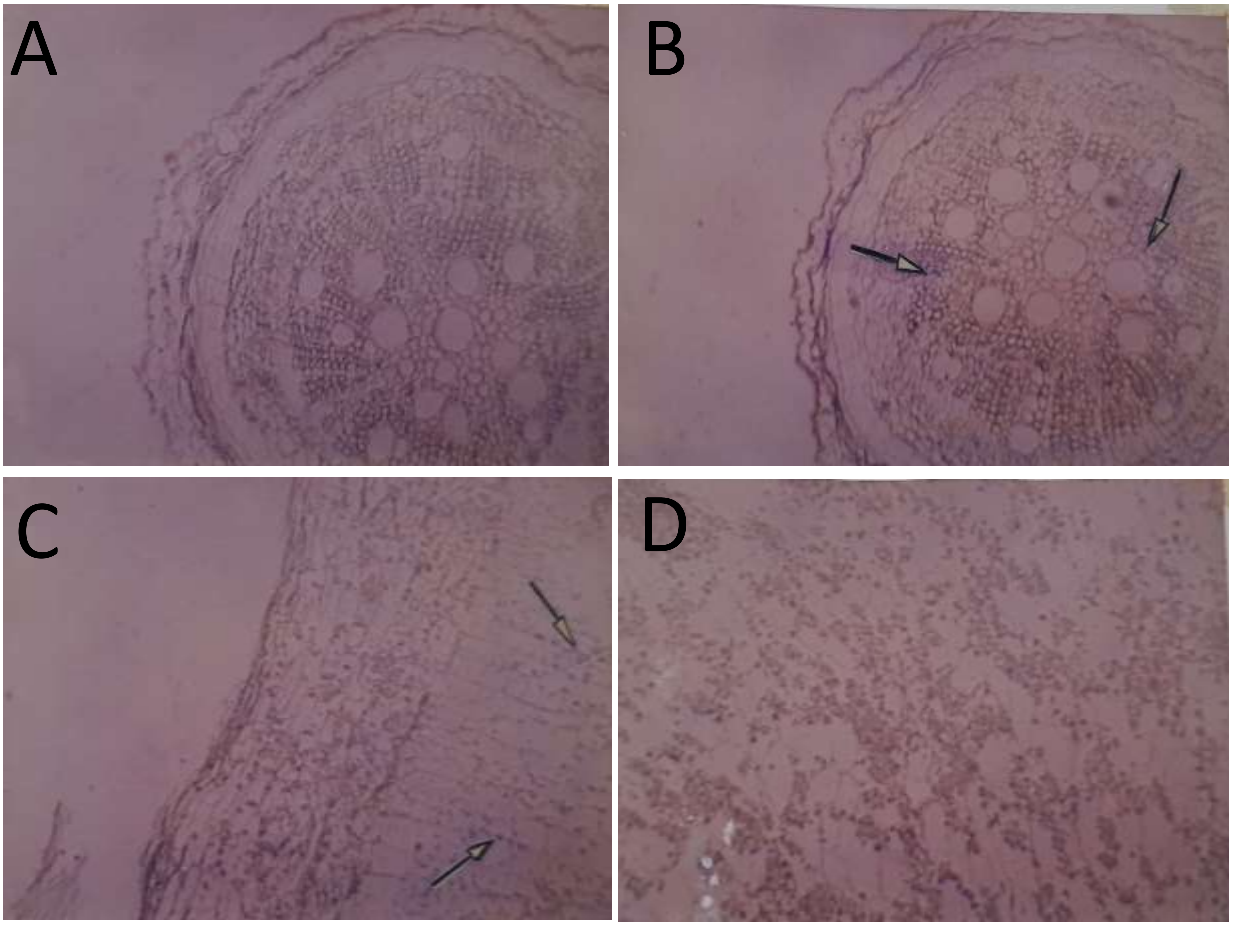

*Figure 3**:** Transverse Sections of Tap Root of Seed-Grown Cassava Stained with Safranin (A-D).* ***A:*** *3 Weeks after Sowing, Showing no Starch Grains ormation yet**;*** ***B:*** *4 Weeks after Sowing, Showing Distribution of Tissues with Starch Grains (Arrows Pointing) Present in the Xylem Arms and Cortical Cells;* ***C:*** *6 Weeks after Sowing, with the Presence of Starch Grains (Arrows Pointing) in the Cortical Cells* ***D:*** *Enlarged Portions of the Cortical Cells and their Contents.*

An outer periderm, sclerenchyma cells, cortical parenchyma cells, and a cambium dividing the phloem and xylem were visible in the anatomic transverse section of the cassava tap root (*Figure 3*). By the fourth week, starch grain buildup had started in the parenchyma cells between the cortical areas and xylem arms; and it became stronger until the ninth week. Starch granules steadily accumulated and became plentiful in the xylem and cortical cells by the eighth week, with lateral roots displaying a similar pattern but smaller tissues (*Figure 4*).

Lateral Root System

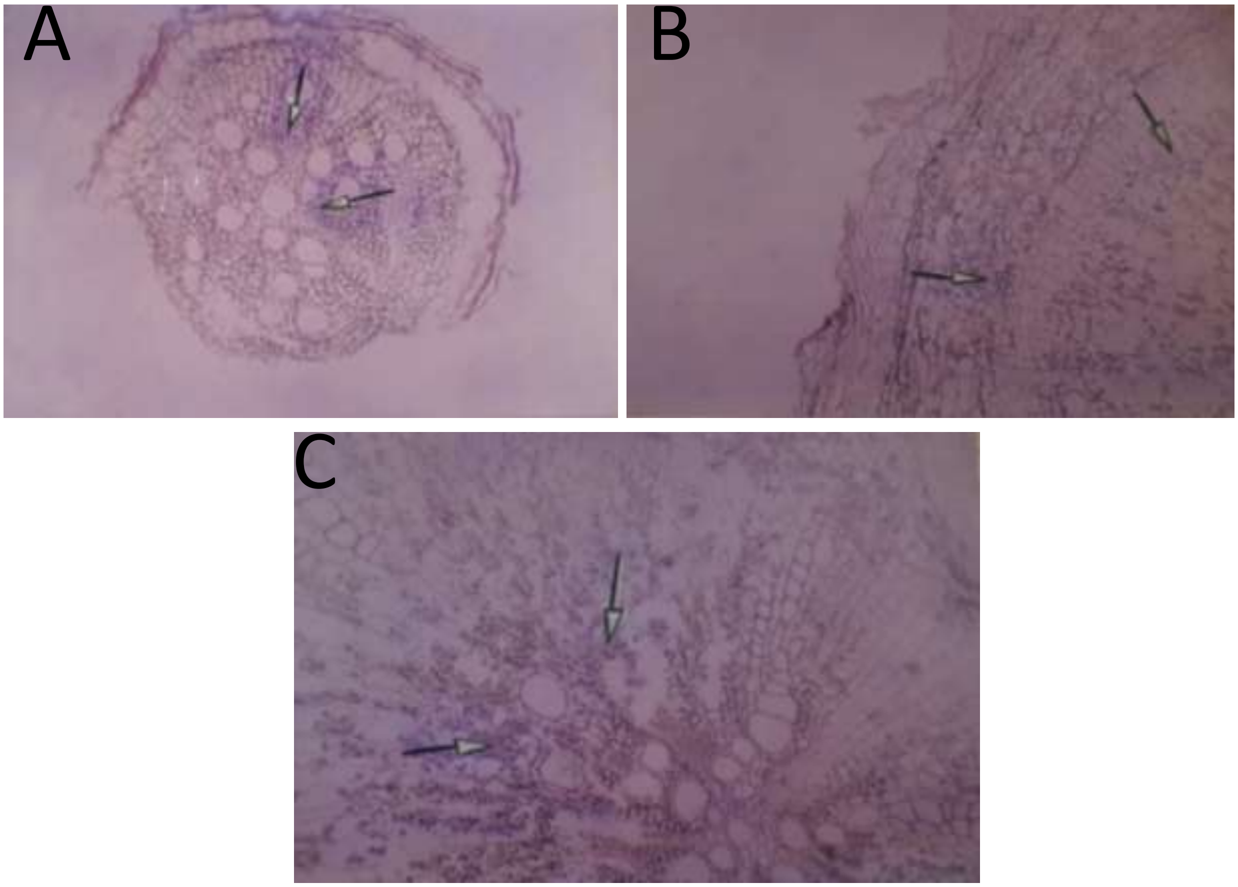

Figure 4: Transverse Sections of the Lateral Root System of Seed-Propagated Cassava Stained with Safranin (A-C). ***A:*** *5-Week-Old Root after Sowing Indicating the Presence of a Small Amount of Starch Grains Accumulating in the Xylem Arms;* ***B:*** *8-Weeks after Sowing, with the Presence of Starch Grains in the Cortical Cells;* ***C:*** *8-Weeks after Sowing, with the Presence of Starch in The Xylem Arms (Arrows Pointing to Starch Grains).*

4.0. DISCUSSION

Cassava plants exhibited epigeal germination, in which the hypocotyl elongates to elevate the cotyledon above the ground. This is in line with other reports on the germination of cassava, which have demonstrated that the cotyledons are raised above the soil surface during germination due to the fast elongation of the hypocotyl (Okogbenin et al., 2013). As seen in (*Figure 2*), the radicle generated the main tap root, which was accompanied at its base by three to five lateral roots. Compared to lateral roots, the tap root had a higher number of unicellular hairs. This finding is in agreement with earlier findings on the growth of cassava roots, indicating that the tap root has a higher root hair density than the lateral roots (Okechukwu et al., 2019). When the two cotyledons spread, the first leaves emerged, forming an elliptical or oval shape with an obtuse tip. Each leaf had a single lobe, grew larger with time, turned green, and had a smooth, glossy surface, which is accordance with the findings reported by Okechukwu et al. (2019) that the initial leaves are simple, alternating, and smooth. Cassava mosaic disease, caused by the cassava mosaic virus, results in the deformation and discoloration of the leaves (Legg et al., 2014). In the current study, we found that the leaves had become twisted and distorted, with areas of yellow mixed with the normally green portions in the third week after planting, indicating the virus was present in the material used.

There was a highly significant ($P < 0.001$) strong positive correlation between the stem height and tap root length, stem height and lateral root length, as well as tap root length and lateral root length, as indicated by Pearson's correlation coefficients. Significant associations between the root characteristics of cassava plants have also been reported in earlier studies. For instance, in cassava genotypes grown under drought stress conditions, Oyiga et al. (2021) found strong positive associations between stem height and tap root length as well as between stem height and lateral root length. Similarly, Njoku et al. (2021) have reported substantial positive associations between tap root length and lateral root length as well as between taproot length and root dry weight in cassava genotypes cultivated in low-phosphorus environments. Furthermore, taproot length, number of lateral roots and root dry weight were found to be significantly correlated with one another in a study by Egesi et al. (2018) which assessed the genetic diversity of cassava root properties in Nigeria. With the significant strong positive association between these charateristics, selection of one could indirectly be used to select for the other in breeding programs.

Moreover, each of these characteristics has a significant role in determining how a plant develops. While tap root length and lateral root length are indications of below-ground biomass accumulation and nutrient uptake, stem height is a measure of above-ground biomass accumulation (Njoku et al., 2021). These qualities may share genetic control, which would explain the positive relationships found between them. Past studies have demonstrated the strong heritability and multigene regulation of cassava root characteristics (Egesi et al., 2018). It is, therefore, plausible that the existence of shared genetic elements influencing the development of these features is the cause of the positive correlations seen between stem height, taproot length, and lateral root length. These traits' favorable associations with one another might also result from how these attributes react to their surroundings. For instance, a recent study by Oyiga et al. (2021) found that the plant's capacity to devote more resources to root growth in response to water stress was responsible for the positive association between stem height and tap root length in cassava genotypes cultivated under drought stress conditions. Similarly, Njoku et al. (2021) have argued that the capacity of the plants to generate a more extensive root system to promote phosphorus uptake was responsible for the positive connection between taproot length and lateral root length in cassava genotypes cultivated under low phosphorus conditions. The relevance of stem height, taproot length and lateral root length in cassava plant growth and development, as well as their common genetic control and responsiveness to environmental factors, maybe the main causes of the positive, high relationships between these three plant characteristics. The stem base, tap root base, and lateral root bases show substantial positive relationships in their diameters, suggesting that during the growth of cassava seedlings, they rise simultaneously (Legg et al., 2014; Egesi et al., 2018; Njoku et al., 2021; Oyiga et al., 2021). These robust positive associations could be explained by several causes. According to Egesi et al. (2018), there is a good chance that the diameters of the major stem base, tap root base and lateral root bases are influenced by similar genetic variables that affect their growth and development. Moreover, as cassava seedlings develop, they devote resources to the growth of their tap root, lateral roots and stems based on their requirements. As these components expand, preferential resource allocation may cause their widths to rise (Njoku et al., 2021). A significant factor in determining the growth rates of the components of cassava seedlings is the environment. For instance, all components develop when there is sufficient water available, increasing their diameters (Oyiga et al., 2021). Gaining knowledge about these relationships is crucial to understanding how cassava plants grow and develop. Additionally, it can help create improved cassava varieties that are suited to the needs of agriculture (Egesi et al., 2018; Oyiga et al., 2021).

Throughout the study, stem height showed a consistent increase with an average weekly growth rate of about 30.8 mm (Table 4). This result is consistent with research demonstrating that cassava plants often develop continuously upward, which greatly contributes to the final plant stature (Mattos & Cardoso 2003). Even though the tap root length grew at a slower rate than the stem height, roughly 10.6 mm per week (*Figure 1*), it was still apparent. Research has shown that the length of the tap roots significantly affects how well cassava plants function overall, especially when it comes to absorbing nutrients and water (Kutner et al., 2005; Mattos & Cardoso 2003). Of the three variables, the lateral root length showed the fastest rate of growth, averaging about 42.3 mm per week. This finding emphasizes how important lateral roots are in increasing the surface area that may be exploited by plants for water and nutrients absorption, which, in turn, increases plant productivity. The interconnectivity of these structural features is further shown by the strong positive correlations found between the diameters of the greatest sections of the tap root base, lateral root base, and stem base. These associations imply that intricate interactions between these elements play a role in the growth and development of cassava plants, requiring a comprehensive strategy to maximize plant performance (Kutner et al., 2005; Mattos & Cardoso 2003). Gaining insight into the growth patterns of cassava seedlings can help agricultural production systems be targeted for development. Farmers working in difficult environments (such as arid lands and nutrient-poor soils) may benefit from concentrating on increasing the growth rates of tap root and lateral root lengths, for example, as this could lead to the development of cassava varieties with superior water and nutrient acquisition capabilities (Sawatraksa, 2019). Additionally, by understanding the fundamental processes driving cassava plant growth and development, new paths for crop enhancement through genetic engineering or selective breeding may become available (Kutner et al., 2005; Mattos & Cardoso 2003).

The anatomical transverse sections of the cassava tap root (*Figures 3 & 4*), displayed a cambium separating the phloem and xylem, an outer periderm, sclerenchyma cells, and cortical parenchyma cells. This is in line with other studies on the anatomy of cassava roots, which have demonstrated that the root is made up of multiple layers, including the cambium layer, sclerenchyma cells, periderm and cortical parenchyma cells (Okechukwu et al., 2019; Okogbenin et al., 2013; Tetteh et al., 1997). The accumulation of starch grains in the parenchyma cells between the xylem arms and cortical areas grew stronger with time. By the eighth week, the xylem arms and cortical cells were overflowing with starch granules, which had been accumulating rapidly. Lateral roots showed a similar pattern but with smaller tissues. This is in line with other studies on the development of cassava roots by Okechukwu et al. (2019) and Okogbenin et al. (2013) which demonstrated that a crucial component of the nutritional value of cassava is the starch accumulation in the root. No starch grains were seen in the cortical cells or xylem arms four weeks after seeding, suggesting that starch synthesis had not yet begun (Sillero & Vuylsteke, 2009). However, starch granules were visible in the cortical cells six weeks after sprouting, indicating the start of starch accumulation.

The onset of starch accumulation in the lateral roots was signaled by the appearance of smaller amounts of starch grains in the xylem arms five weeks after emergence. More significant starch grain accumulation was visible in the cortical cells and xylem arms eight weeks after emergence, confirming the progression of starch accumulation in the lateral roots and work also done by Mwanga et al. (2007). This research contributes to our understanding of how cassava storage roots develop, which is vital for enhancing crop yields and quality. It also underscores the importance of studying starch accumulation patterns in the context of plant breeding efforts aimed at increasing cassava productivity.

5.0. CONCLUSION AND RECOMMENDATIONS

Conclusion

We can therefore conclude that morphologically, ten days after seed sowing (at germination) the first leaf produced are not typical of the actual developed plants. The shape of the leaf is oval and the apex is obtuse. The true leaf produced on the second node is simple and the shape is ovate with an acute and undulating apex and margin respectively. There was a steady weekly increase in the average number of nodes with an almost constant number of lobes and number of adventitious roots on the hypocotyl.

Six weeks after sowing, starch production started in cassava roots, first appearing in cortical cells and then spreading to xylem arms and lateral roots. Eight weeks after seeding, there was a discernible rise in the deposition of starch grains in different areas of the lateral roots. There was a strong positive connection between stem height, tap root length, and lateral root length. These correlations suggest that common genetic components and environmental variables influence these features in an interdependent manner. The study offers insightful information about the growth and development of cassava plants raised from seed, which can direct breeding initiatives meant to raise the yield and quality of cassava crop.

Recommendations

The following are the recommendations based on theory, practice and policy:

Theory

The understanding gained from studying the growth and development of seed-propagated cassava plants, including factors influencing tuberization and starch accumulation, advances the theoretical framework surrounding plant physiology and genetics. This contributes to the broader scientific knowledge on cassava, a critical food crop in many developing regions.

Practice

These findings can directly inform breeding programs and agricultural practices aimed at improving cassava yields and quality. By identifying key factors that influence tuberization and starch accumulation, breeders can select for traits that enhance these processes, leading to more productive and resilient cassava varieties. This practical application has the potential to improve the livelihoods of farmers who depend on cassava as a staple crop.

Policy

On a policy level, the insights from this research can support the development of policies that promote agricultural innovation and food security. Policymakers can use this information to advocate for increased funding for cassava research, support the dissemination of improved cassava varieties, and implement agricultural extension services that help farmers adopt best practices for growing seed-propagated cassava plants.

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Declarations of interest

None.

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