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RESEARCH ARTICLE

Impact of planting techniques and cutting sizes on cassava (*Manihot esculenta* Crantz) sprouting and subsequent vegetative growth in various nursery environments

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ABSTRACT

Cassava (Manihot esculenta Crantz) is a perennial woody shrub, mainly propagated via stem cuttings. Propagation methods and growth environment have been reported to affect sprouting and vegetative growth significantly. This study aimed to examine the effect of planting methods and cutting sizes on cassava's sprouting and subsequent vegetative growth. The experiment was conducted at the Agricultural Research Institute-Tumbi Centre Tanzania. The cassava varieties used were TARICASS2, TARICASS3, TARICASS4, TARICASS5, Kiroba, Kizimbani, Mkumba, and Mwasunga. They differed significantly on the days they first sprouted. Days to 50% first sprouting was observed three days after transplanting in the low tunnel from Mkumba, Kizimbani, Mwasunga, and TARICAS5, compared to six days in the open field nursery. The early sprouting from the low tunnel may be attributed to its high relative humidity (86.5%) and soil temperature (37.4 OC). Cuttings with four nodes had the highest number of sprouts compared to cuttings with two nodes for horizontal planting. Therefore, horizontal planting should be adopted in low tunnels to ensure a massive multiplication of planting materials.

Keywords: Cassava planting methods, cassava varieties, cutting size, growth environments, sprouting ability.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a perennial woody shrub from the *Euphorbiaceae* family. Cassava, being a drought-tolerant crop, is regarded as food security when cereals fail to produce grain, particularly in semi-arid areas (Reincke et al., 2018; Narmilan & Puvanitha, 2020). Hence, cassava is among the most valuable crops for food security in drought-prone areas of the world (Onyediako & Adiele, 2022). The crop is mainly propagated using stem cuttings (referred to as "cassava seeds"), while true seeds are primarily used in breeding programs (Coutinh et al., 2020). Generally, cassava grows well in tropical and subtropical areas between the latitudes of 25° north and south of the equator up to altitudes of 1800 meters above sea level (m.a.s.l.), (Wattel et al., 2019; Ogunyinka & Oguntuase, 2020). It attains maturity within 6 to 24 months after planting, depending on the variety and growing environment (Mdenye, 2016; Tokunaga et al., 2019).

In 2020, the global cassava production was estimated to be 302.66 million metric tons, with Africa being the largest producer with a total production of 193.62 million metric tons, which is equivalent to 64% of the total global production (Agahiu, 2016; FAO, 2022). With an average fresh tuber yield of 8.5 t/ha, Tanzania ranks sixth in Africa and twelfth globally in cassava production. The lack of improved, sufficient planting materials is the reason for these lowest yields compared to the recommended worldwide productivity of 60 tons per hectare (FAOSTAT, 2022; Kidasi et al., 2021). About 84% of produced cassava tubers are used for human consumption, and the remainder is used to feed livestock, processed to produce starch, and exported in the form of chips, pellets (Makopa), and flour (Nyanda, 2015; Ogunyinka & Oguntuase, 2020; Misganaw & Bayou, 2020).

In Tanzania, the major producing cassava regions are Mwanza, Geita, Mara, Kagera, Simiyu Shinyanga, Lindi, Mtwara, and Ruvuma, which produce about 48.8% of total cassava production in the country. Also, Kigoma, Tabora, and Katavi regions produce around 7.9% of cassava, while Morogro, Tanga, Coast regions, and Zanzibar produce about 5% of the total cassava production in the country (Ndunguru et al., 2015; Nyanda, 2015). Cassava accounts for 8.5% of the total calorie diet, making it the country's third most important crop after maize and paddy (Reincke et al., 2018).

Even though the contribution of cassava to food security is high, its productivity was constrained by the use of low genetic potential varieties, outbreaks of insect pests and diseases, drought, poor soil fertility, a lack of improved seed systems, a shortage of planting materials, and a lack of appropriate planting methods by farmers (Mukiibi et al., 2019; Shirima et al., 2019). To account for the use of low genetic potential varieties, Tanzania Agricultural Research Institute (TARI) Centers have developed and released about 26 new, improved cassava seed varieties with high yields, resistance to cassava diseases, farmer- and consumer-preferred qualities (TOSCI, 2022). Among the released varieties, nine were selected and accepted as farmers' best choices and are currently widely cultivated in the regions. While the demand for planting materials is increasing, its multiplications are limited (URT, 2021). Few research centers and farmers' organizations are producing seed-cutting cassava, which is lower than the demand (Pugalendhi & Velmurugan, 2020). For instance, in 2020, the United Republic of Tanzania (URT) report showed that improved planting materials produced were less than 1% of the total area under cassava production. Various rapid multiplication techniques like tissue culture, meristem culture, hydroponics, multiple shoot generation, leaf bud techniques, and stem cuttings have been developed to elevate the availability of planting materials (Shiji et al., 2014; Tokunaga et al., 2019). Apart from the reported techniques, massive seed production in cassava has yet to be achieved due to the high infrastructure cost, labor, and time.

On the other hand, spouting in cassava is constrained by cutting sizes and planting methods (Ogundare, 2017; Chiona et al., 2018). Developing quick cassava seed multiplication techniques will increase the availability of improved planting materials for producers. The technique should enhance cassava's sprouting quickly, governed by high temperatures and relative humidity (Alan, 2015; Elgimabi, 2009). However, farmers use low tunnel technology in cold areas for crop production since it can raise the temperature and relative humidity necessary for seed germination and plant growth (Delaquis, 2023). Apart from the significant contribution of low tunnels to crop production, the technology is yet to be tested in cassava seed multiplication, particularly in the western regions of Tanzania. Therefore, this study was conducted to determine the effect of planting methods and cutting sizes on cassava varieties' sprouting and subsequent vegetative growth in a low tunnel and open field nursery.

MATERIALS AND METHODS

Experimental site

The study was conducted at TARI-Tumbi station in the Tabora region, located between 4°7'S and 31°34'E, at 1190 meters above sea level (m.a.s.l) from November 2022 to January 2023. The area has an average mean annual rainfall of 810 to 890 mm received between November and April, with a mean minimum and maximum temperature of 26 and 30

OC, respectively (TMA, 2023). The soil is sandy to sandy loam, suitable for cassava production (Nyanda, 2015; URT, 2021).

Experimental materials and design

Planting materials were collected from mature, healthy, improved, and certified cassava varieties. The varieties were obtained from the TARI-Ukiruguru Center in the Mwanza region and a locally adapted landrace from a farmer's field at Tumbi village in the Tabora region. Seven registered varieties were used: TARICASS2, TARICASS3, TARICASS4, TARICASS5, Kizimbani, Mkumba, and Kiroba. A locally adapted landrace, Mwasunga, was included as a control treatment. The improved varieties were reportedly high-yielding and resistant to Cassava Mosaic Virus and Cassava Brown Streak Diseases (TOSCI, 2022). Planting materials were prepared following the Rapid Multiplication Guidelines Otoo (1996) reported. All leaves were stripped off the stems using a sharp knife to avoid damage to the axillary buds. Cassava stems were cut into pieces with 2, 3, and 4 nodes using a sharp machete sterilized with methylated spirit (70% v/v). The stem cuttings were treated with Bellet 400 WP (Thiram 300g + Thiophanate-Methyl 100% g/kg) at rates of 2 grams per litre of water to prevent fungal infection. The prepared cuttings were immersed in the fungicide solution for five minutes and air-dried for 10 minutes before planting.

The experimental area was ploughed and harrowed to a fine soil tilth. A hand hoe prepared a raised nursery bed of 360 x 200 cm and 20 cm in height. The cuttings were planted at inter and intra spacing of 20 x 20. The prepared cuttings of two, three, and four nodes were planted in plots vertically, silently, and horizontally. Each plot had 3 rows of 18 cuttings, equivalent to 250,000 cuttings per hectare. Data were collected from 12 cuttings, excluding the border cuttings, in an area of 60 cm x 40 cm, equivalent to 2400 cm2. These treatments were laid out in a Randomized Complete Block Design, arranged in a split-split plot with cassava variety in the main plot, cutting size in the sub-plot, and planting methods in the sub-sub-plot replicated three times. The pathways were 0.5 m and 1.5 m between plots and replications, respectively. These arrangements generated eight main plots, 24 sub-plots, and 72 sub-sub-plots per experiment. In the low tunnel experiment, plastic sheets were used to cover the nursery beds, as proposed by Maughan et al. (2014). The sheets were, however, removed 14 days after planting (DAP) when sprouting was completed.

Low tunnel establishment and nursery management

Low tunnels measuring 1.2 m high, 2.0 m wide, and 32.8 m long were constructed with modifications of the procedures described by Maughan et al. (2014). Iron steel 8 mm in diameter rods were driven slowly by hand into the ground and bent to make hoops. The hoops were spaced 3 meters apart on the raised beds. Wooden T-posts were inserted at the center of each hoop to strengthen the tunnel and anchor the plastic sheet. Wooden sticks were arranged parallel on both sides of the hoops and tied with strings to support the plastic sheet spread over them. Cassava cuttings were planted in vertical, horizontal, and slant beds. A transparent plastic sheet was slowly pulled and tightly stretched over the constructed hoops. One edge of the plastic sheet was buried in the soil, and the other sides were stretched and held down with small plastic bags filled with sand to allow the opening and closing of the tunnels for accessible crop management practices, including irrigation, weeding, and ventilation on sunny days. Irrigation in the nurseries was carried out whenever water stress signs were observed. Termites were controlled by Mupa Force 720 EC (Profenofos 720 g/l) at a rate of 1 mL per liter of water. The plastic sheet was removed 14 days after planting to avoid plant stress. Transplanting was done 60 days after planting when shoots had about six leaves. The uprooted plantlets were assembled in a container with 1.5 liters of water to reduce evapotranspiration stress.

Data collected

Crop Data

Twelve plantlets covering an area of 0.24 m2(0.6 m × 0.4 m) were used to gather information on cassava varieties' sprouting and subsequent vegetative growth.

Sprouting of cassava

Data on sprouting days were collected when 50% of cuttings sprouted. Ten days after planting, the quantities of sprouted cuttings were determined in averages as follows: Average number of sprouted cuttings = Sum of sprouted cuttings / Total number of cuttings in the area.

Vegetative growth of cassava

Growth parameters of cassava were collected from twelve sampled plantlets per unit area six weeks after planting. These include plantlet height, relative chlorophyll content, quantity of leaves, and the number of developed branches. The parameters were determined as described below:

Relative chlorophyll content

The relative chlorophyll content of cassava leaves was measured using LEAF CHL PLUS by Dey et al. (2016). The average relative chlorophyll content per plantlet was calculated as averages of relative chlorophyll contents = The sum of relative chlorophyll content / Total number of plantlets in the area.

Plantlets height

A meter ruler was used to measure the plantlet height in centimetres, and the averages per plantlet were calculated as the averages of plantlet height = the sum of heights (cm) / the total number of plantlets in the area.

Cassava branches

The number of branches produced was counted in each sampled plantlet, and their average was recorded as follows: Averages number of branches = the sum of branches counted / the total number of plantlets in the area.

Cassava leaves

The number of branches produced was counted in each sampled plantlet, and their average was recorded as follows: Averages number of branches = Sum of branches / Total number of plantlets in the area.

Data Analysis

Data on sprouting and vegetative growth were subjected to analysis of variance (ANOVA) using GENSTAT 16th edition statistical software. Differences between treatment means were compared by Duncan's Multiple Range Test (DMRT) at $p \leq 0.05$. Correlation coefficients were used to compare relationships between variables.

RESULTS

Low tunnel and open field nurseries

Analysis of variance revealed that all tested treatments had significant effects on cassava's sprouting and subsequent vegetative growth (Tables 1 and 2). The days to first sprouting and the number of cuttings sprouted were influenced by variety and planting methods in the low tunnel and the open field. Evaluated treatment significantly ($p < 0.001$) impacted the plantlet height, number of cassava branches, and leaves in low tunnels and open fields. However, the planting methods and varieties interacted significantly with the number of leaves and plantlets' height. Also, variety, cutting size, and planting methods interacted significantly with the number of leaves ($p = 0.051$) and the relative chlorophyll contents ($p = 0.011$) (Table 3).

Table 1. Summary of ANOVA for the low tunnel and open field nurseries

Source of variation	Sprouting days		Number of branches		Number of leaves	
	Low tunnel	Open field	Low tunnel	Open field	Low tunnel	Open field
Varieties	71.526**	64.706***	28.241***	8.259ns	1068.07***	47.704ns
Cutting sizes	6.843ns	21.907**	36.977***	60.847***	187.92***	76.292*
Variety*cuttings	5.568*	3.532ns	4.215	1.969ns	16.21ns	18.106ns
Planting methods	17.118ns	42.241***	85.282***	19.5***	2078***	112.667***
Variety*Planting methods	3.478ns	3.214ns	2.013	0.638ns	64.16***	5.434ns
Cuttings*Planting Methods	2.09ns	2.789ns	1.588	4.222ns	24.69ns	3.625ns
Variety*cuttings*Planting methods	1.296ns	0.739ns	1.255	2.455ns	19.1*	5.17ns

Table 2. Summary of ANOVA for the low tunnel and open field nurseries

Source of variation	Plantlets height		Number of sprouted cuttings		Relative chlorophyll content	
	Low tunnel	Open field	Low tunnel	Open field	Low tunnel	Open field
Varieties	658.57ns	21.75ns	18.063***	31.143***	104.24ns	83.69ns
Cutting sizes	168.22*	229.29**	3.56ns	15.542***	13.5ns	157.75ns

Variety*cuttings	17.31ns	29.2ns	0.761ns	1.097ns	31.36ns	60.21ns
Planting methods	1096.16***	1.59ns	7.727**	15.167***	67.7*	37.3ns
Variety*Planting methods	63.4*	14.25ns	1.69ns	2.357*	16.44ns	38.01ns
Cuttings*Planting Methods	16.45ns	36ns	1.477ns	1.021ns	22.33ns	30.14ns
Variety*cuttings*Planting methods	29.74ns	19.06ns	1.233ns	1.41ns	20.01ns	61.19*

ns = not significant, *, **, *** = significant at 0.05, 0.01 and 0.001 probability levels, respectively. Means separation by DMRT at $p \leq 0.05$.

Sprouting of cassava cuttings

Days to 50% of the first sprouting of cuttings were significantly dependent on cassava varieties in low tunnels ($p = 0.003$) and open fields ($p < 0.001$), respectively (Table 3). Mkumba, Kizimbani, and Mwasunga sprouted on average of three days after planting in a low tunnel, whereas in an open field, TARICAS2, Kiroba, Mwasunga, and TARICAS5 sprouted in six days. TARICAS3 sprouted 7 and 11 days after planting in the low tunnel and open field nurseries, respectively (Fig. 1). The sprouting days varied based on the planting method. Planting methods differed significantly ($p < 0.001$) on days to sprout in an open field as opposed to a low tunnel (Table 3). For example, 50% of the cuttings sprouted in the low tunnel in four days when planted vertically, compared to 5 days for horizontal planting (Table 3). Also, cutting sizes significantly ($p = 0.002$) affected days for sprouts in an open field, unlike in the low tunnel (Table 3).

Cuttings with three and four nodes sprouted seven days after planting, compared to 8 days for two nodes. Moreover, planting methods significantly affected the number of sprouted cuttings at ($p = 0.004$) and ($p <.001$) for low tunnel and open field, respectively (Table 3). The maximum sprouts were found in the low tunnel rather than the open field. The highest number of sprouts was 10 in horizontal planting, and the lowest was nine cuttings in vertical planting for low tunnels. Compared to open fields, the highest number of sprouts was 9, and the lowest was eight cuttings.

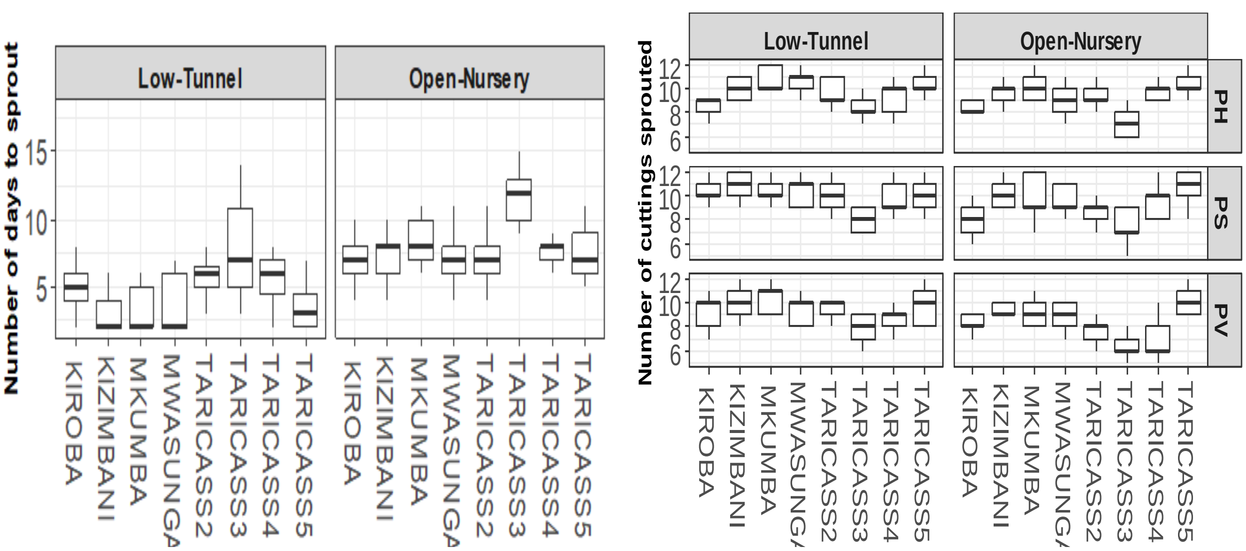

Figure 1. Comparison of low-tunnel and open-field nurseries in the sprouting of cassava varieties

Table 3. Means comparisons of cassava on sprouting and early vegetative growth in low tunnel and open field nurseries. Means followed by different letters within columns are significantly different at the 0.05 probability level. Means separation by DMRT at p ≤ 0.05 SED = standard error of difference of means and CV = coefficient of variation.

Treatments	Days to sprouts		Number of sprouted cuttings		Number of leaves		Number of branches		Plantlets height		Relative chlorophyll content	
	Low tunnel	Open field	Low tunnel	Open field	Low tunnel	Open field	Low tunnel	Open field	Low tunnel	Open field	Low tunnel	Open field
Varieties												
Kiroba	5b	7ab	9b	8a	5a	10a	1a	1a	11.1ab	15a	48.7a	51a
Kizimbani	3a	7ab	10cd	9ab	17cd	10a	2b	2ab	16.4ab	15.6a	48.9a	49a
Mkumba	3a	8b	11cde	9bc	20d	12a	3c	2ab	21.7b	15.3a	44.6a	48a
Mwasunga	3a	7ab	10cd	9bcd	9ab	10a	2b	2ab	9.2a	16.2a	45.4a	51a
TARICASS2	5b	6a	9bcd	8bcde	11abc	11a	2b	2ab	17.9ab	17.5a	49.7a	46.3a
TARICASS3	7c	11c	8a	7cde	5a	12a	1a	3b	9.3a	15.1a	46.4a	47a
TARICASS4	5b	7ab	9b	8de	12bc	10a	1a	3b	8a	15.2a	46.2a	46.7a
TARICASS5	4ab	7ab	10cd	10e	20d	15a	4d	3b	15.6ab	16.6a	49.4a	48a
p-value	0.003	< 0.001	< 0.001	0.001	< 0.001	0.813	< 0.001	< 0.001	0.11	0.99	0.131	0.636
Cuttings size												
Two	5a	8b	10a	8a	11a	10a	1a	1a	12.4a	14a	46.9a	46.6a
Three	5a	7a	10a	9b	13b	12b	2b	2b	13.3ab	16ab	47.7a	49.5a
Four	5a	7a	10a	9b	14bc	11ab	3c	3c	15.3b	17b	47.7a	48.8a
p-value	0.061	0.002	0.248	< 0.001	< 0.001	0.051	< 0.001	< 0.001	0.019	0.002	0.641a	0.145
Planting Methods												
Horizontal	5ab	8b	10b	9b	18c	12c	3b	3b	16.6bc	16a	48.4ab	48.7a
Slant	5ab	7a	10b	9b	11b	11b	3b	2a	15b	15.7a	47.5ab	48.7a
Vertical	4a	7a	9a	8a	8a	10a	1a	1a	9a	15.7a	46.4a	47.5a
p-value	0.012	< 0.001	0.004	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.915	0.035	0.316
Grand Mean	4.71	7.954	9.7	8.944	12.46	11.13	2.12	2.292	13.65	15.8	47.41	48.29
SED	0.321	0.4588	0.19	1.1386	3.464	2.449	0.542	1.4207	5.376	4.221	4.41	5.654
CV%	18.3	17.4	11.8	12.7	27.8	22	13	23	39.4	26.7	9.3	11.7

Early vegetative growth of cassava

The plantlet height of cassava varieties was significantly affected by planting methods and cutting sizes ($p < 0.001$) and ($p = 0.002$) in the low tunnel and open field nurseries, respectively (Table 3). The highest plant height on average was 16.6 cm in horizontal planting, higher than 9 cm in vertical planting in a low tunnel. Also, in an open field, cuttings with four nodes had a height of 17 cm higher than 15.3 cm in low tunnels (Table 3). There was a substantial variation in stem branching in low-tunnel and open-field nurseries. In the open field, three cassava varieties (TARICAS3, TARICAS4, and TARICAS5) produced more than three branches, and only one variety (TARICAS5) produced four branches in the low tunnel. Unlike other cassava varieties, Kiroba, TARICAS3, and TARICAS4 produced an average of one branch per plant. The stem sizes with four nodes produced three branches, compared to more than one branch for cuttings with two nodes. Planting methods significantly affected the number of branches. Cuttings planted horizontally produced an average of three branches higher than one in vertical planting. Moreover, there was a significant difference in the number of cassava leaves produced in the low tunnel ($p < 0.001$) as compared to the open field (Table 3). The highest amount of leaves was 20 in the Mkumba and TARICAS5 varieties, and the lowest was 5 for Kiroba and TARICAS3 in the low tunnel. Many leaves were counted for cuttings planted horizontally, slanting, and vertically. However, there is no statistical variation in the relative chlorophyll content of cassava leaves except for planting methods in low tunnels. Their average relative chlorophyll content ranged from 46.3 to 51 (Table 3).

Relative humidity and Temperature in the nurseries

Both low tunnel and open field nurseries experienced a period of maximum and minimum relative humidity and soil temperature. The Geek Lab HTC-1 digital hydrometer and the H-B DURAC bi-metallic thermometer were used to measure the relative humidity and soil temperature nurseries. Data were collected at 9:00 a.m. for two weeks until sprouting was complete. The maximum and minimum temperatures recorded in the low tunnel were 37.4 ^{0}C and 24.3 ºC as opposed to 26.9 ºC and 20 ºC in the open field, respectively. Similarly, the maximum and minimum relative humidity measured in the low tunnel was 86.5% and 70%, in contrast to 68.3% and 40% in the open field, respectively.

Combined analysis

The results of the variance showed that there was significant variation in cassava sprouting and growth (Table 4). Days to 50% sprouting were significantly ($p < 0.001$) affected by the growth environments, varieties, and planting methods. However, cutting sizes had no significant effect on sprouting. Grown environments impacted plantlets height ($p = 0.002$) and number of produced leaves ($p = 0.005$). Cassava varieties, cutting sizes of stems, and planting methods significantly ($p < 0.001$) interacted with plantlet height. The number of cassava branches and leaves varied significantly ($p < 0.001$) among varieties, cutting sizes, and planting techniques. Growth environments interacted significantly ($p < 0.001$) with cassava varieties for days to sprout, plantlet height, number of branches, and leaves. It also interacted significantly ($p = 0.011$) with relative chlorophyll content. Days to sprouting interacted significantly ($p< 0.001$) with environments and cutting sizes. Highly significant ($p < 0.001$) interactions were found between environment and planting methods for plant height and amount of cassava leaves. Besides, it has interacted significantly ($p = 0.011$) with the number of cassava branches (Table 5).

Sprouting and early vegetative growth of cassava

The growth environments, varieties, and planting methods showed highly significant ($p < 0.001$) differences in days to 50% of first sprouting (Table 5). Cutting sprouted on average for 4 and 7 days in low tunnels and open fields, respectively. TARICAS5 and Kizimbani sprouted on average five days after planting compared to the late ten days in TARICAS3. Vertically planted cuttings sprouted five days after planting compared to horizontal and vertical planting. The maximum number of sprouted cuttings observed was 10 in Kizimbani, Mkumba, TARICAS5, and Mwasunga, while the minimum sprout was 7 in TARICAS3 in the low tunnel. Increases in the number of nodes per cutting were found to increase sprouting. The number of cassava branches and leaves and the plantlets' height were significantly ($p < 001$) influenced by varieties, cutting sizes, and planting techniques. Similarly, the growing environment significantly affected plantlet height ($p = 0.002$) and the number of leaves (0.005), except for the branches (Table 5). In general, plantlets in an open field had higher heights than in a low tunnel. Mkumba had an average height of 18.4 cm higher than TARICAS4 (11.6 cm). Cuttings with two nodes had fewer branches and leaves than those with four nodes for horizontal planting. TARICAS5 had three branches and 17 leaves, greater than one branch in TARICAS4 and seven leaves in Kiroba. There was no significant effect on their relative chlorophyll content.

Table 4. Combined effect of environments and propagation methods for sprouting and growth of cassava varieties

Treatments	Days to sprouts	Number of sprouted cuttings	Plantlets height	Number of branches	Number of leaves	Relative chlorophyll content
Environments						
Low tunnel	4.73	9.72	13.65	2.12	12.46	47.41
Open Field	7.95	8.94	15.80	2.29	11.13	48.29
P value	<0.001	<0.001	0.002	0.27	0.005	0.138
Varieties						
KIROBA	6.07	8.83	13.06	1.78	7.28	49.74
KIZIMBANI	5.22	10.13	16.00	2.56	13.69	48.91
MKUMBA	5.82	10.15	18.45	2.44	16.13	46.28
MWASUNGA	5.52	9.74	12.72	1.83	9.65	48.11
TARICASS2	6.24	9.15	17.70	2.39	11.19	47.99
TARICASS3	9.78	7.56	12.19	2.02	8.20	46.63
TARICASS4	6.59	8.85	11.57	1.35	11.13	46.46
TARICASS5	5.48	10.24	16.09	3.28	17.13	48.68
P value	<0.001	<0.001	<0.001	<0.001	<0.001	0.026
Cutting sizes						
Two	6.559	8.958	13.09	1.368	10.44	46.77
Three	6.271	9.417	14.76	2.257	12.44	48.56
Four	6.194	9.618	16.32	2.993	12.52	48.22
P value	0.208	<0.001	<0.001	<0.001	<0.001	0.033
Planting methods						
Horizontal	6.986	9.458	16.3	2.799	15.42	48.52
Slant	6.302	9.639	15.4	2.528	11.01	48.09
Vertical	5.736	8.896	12.47	1.292	8.97	46.94
P value	<0.001	<0.001	<0.001	<0.001	<0.001	0.079
Grand mean	6.341	9.331	14.72	2.206	11.8	47.85
SE	1.84	1.27	7.13	1.61	4.86	6.14
CV%	29.00	13.60	48.50	73.10	41.20	12.80

Correlation analysis

A correlation analysis was performed to assess the contribution of growing environments, cassava varieties, cutting sizes, and planting methods to cassava's sprouting and subsequent vegetative growth. Significant positive and negative associations were found (Table 6). Relative chlorophyll content was significantly and positively correlated only to the number of branches ($p = 0.03$) and plantlet height ($p = 0.002$). Days to 50% sprouting were negatively correlated to other variables except the number of sprouts ($p < 0.001$) and leaves ($p = 0.003$). The number of leaves was significant ($p < 0.001$) and positively correlated with plantlet height, sprouted cuttings, and branches. The number of branches was highly significant ($p < 0.001$) and positively correlated to plantlet height and the number of sprouted cuttings. The number of sprouted cuttings was significantly ($p = 0.02$) positively correlated to plantlet height.

Table 5. Correlation between sprouting and early vegetative growth parameters of cassava

	Relative chlorophyll content	Days to sprouts	Number of Leaves	Number of branches	Number of sprouts	Plantlets height
Relative chlorophyll content	-					
Days to sprouts	-0.0052	-				
Number of Leaves	0.0211	-0.1455**	-			

Number of branches	0.1047*	-0.0352	0.4409***	-		
Number of sprouts	0.041	-0.3596***	0.2296***	0.1918***	-	
Plantlets height	0.1528**	-0.0319	0.4046***	0.4063***	0.1158*	-

*, ** = significant correlation at 0.05 and 0.01 probability levels, respectively.

DISCUSSION

Vertical planting influenced the early sprouting of cassava cuttings compared to late sprouting in horizontal planting. This may be because large portions of the stem cuttings were exposed above the soil and received high relative humidity and temperature (87% and 37°C) in the tunnel, which favor sprouting (Abdullahi et al., 2014). Elgimabi (2009) and Faivor (2014) reported the ability of the low tunnel to increase relative humidity and air temperature conditions that promote earlier callus formation of buds and rooting development for propagated cuttings. However, cardinal temperatures defined for sprouting and early growth of cassava cuttings were reported to range from 12 to 17 °C minimum, 28.5 to 30°C optimum, and 36 to 40°C maximum, with growth proceeding up to 2 weeks after emergence; however, young shoots remain stable in their active photosynthesizing (Keating & Evenson, 1979). Early sprouting of cassava was reported to range from 10 to 12 days after planting (DAP), followed by small leaves that emerge 15 days after planting (Alves, 2002). Delayed sprouting of 6 to 11 DAP in an open field nursery may result from dried-out cuttings, especially when soil moisture is limited, which reduces sprouting ability. However, in the days to 50% of the first sprouting of cassava, the number of sprouted cuttings, plantlet height, number of leaves, and number of branches produced were negatively correlated, as new shoots and leaves needed extra assimilation for growth. Edet (2015) reported a higher accumulation of starch in stem cuttings converted into glucose due to excessive demand by the shoot system, like shoot yield, leaf area index, and plant height, during the early stages of cassava growth. Also, the variation in cassava cuttings' sprouting was probably due to differences in variety, planting methods, size of planting materials, and environmental conditions. Oguzor (2017) reported that the sprouting of cassava cuttings depends on planting practices, variety, planting time, quality of planting materials, and soil characteristics. According to Masisila (2020), the variation in sprouting of cassava varieties at Naliendele, Nachingwea, and Ilonga, with Kiroba having (76.56%), Chereko (77.67%), and Mkuranga 1 (82.56%), was due to differences in the genetic makeup of the varieties and the environments in which they were grown. Moreover, Bah et al. (2004) reported that sprouting occurs when the plant attains independence in the utilization of above- and underground soil resources after a period of depending on its internal resources; therefore, the auxiliary buds initiate the growth phase of the crop (CIAT, 1984).

On the other hand, a larger number of sprouted cuttings counted in horizontal and slant planting as compared to vertical planting may result from a large portion of the cutting having been inserted into the soil, receiving favorable heat for emergence and hence increasing their chance of sprouting and elongation (Keating & Evenson, 1979; Elgimabi, 2009). Similarly, horizontal and slant planting conserved high moisture in the soil and around the color of cuttings near the soil surface, which supported sprouting and increased the quantity of sprouted cuttings. Hence, a greater number of nodes sprouted and emerged into shoots in horizontal planting than in vertical planting, which plays a key role in increasing the planting materials of cassava (Schoffel et al., 2022; Pugalendhi & Velmurugan, 2020). Vertical planting tends to expose a larger portion of cassava cuttings above ground, leading to desiccation, failure to sprout, and the production of little planting material (Legese et al., 2011). The findings were, however, contrary to Oguzor (2017), who reported the highest sprouting of cassava cuttings planted vertically (88.8%), followed by slanting (79.9%) and horizontal planting (71.1%).

Cassava plantlets grown in low tunnels varied significantly in height, number of leaves, and branches; horizontal planting outperformed the vertical planting method. The outstanding performance observed in cassava cutting planted horizontally may be attributed to more leaves being produced than those counted in the vertical planting. Many leaves in cassava were reported to have increased photosynthetic rates used to synthesize enough food for plant growth (Edet, 2015). He also reported that the plant height of cassava has a strong and positive correlation with leaf area, fresh root, and dry matter yield. In the same way, branching in cassava has been proven to increase the production of the leaves, which in turn increases light interception, photosynthesis, and consequently yield and yield components (Alves, 2002; Agahiu, 2016; 2024).

Furthermore, plantlets from the nurseries had good vegetative growth based on the relative chlorophyll content measured. Dey et al. (2016) reported that if the relative chlorophyll contents tested in leaves are above 35, plants are said to have a good indicator of their nitrogen status, which is essential for supporting plant growth. The other contributing reason may be that there was a high possibility of many adventitious roots being formed from each node of cuttings in horizontal planting compared to vertical planting; these promoted nutrient absorption from the soil to support more biomass growth above the ground. The higher height recorded for Mkumba than other varieties, including TARICAS4, may be due to genetic variation and adaptability to the grown environment (Bah et al., 2004; Masisila, 2020). Moreover, cassava cuttings with four nodes were found to have better vegetative growth than those with two nodes. Chiona et al. (2016) reported that cuttings of large size have greater food reserves than shorter cuttings; hence, the newly emerged shoots obtained provide enough nutrients needed for plant growth (Varshini et al., 2021).

CONCLUSION

The methods employed for cassava propagation had a considerable impact both on sprouting and vegetative growth. The vertical planting method, which showed significant importance for sprouting, should be used in a controlled environment with higher relative humidity and temperature to avoid dehydration of planting materials. In this environment, half of the cuttings, specifically Mkumba, Kizimbani, Mwasunga, and TARICAS5, sprouted three days on average after planting. Instead of open fields, few quantities of cassava cuttings sprouted due to excessive dehydration, and, ultimately, the drying up of cuttings caused plantlets to fail to establish. Moreover, cassava propagation using cuttings with four nodes has more sprouts and shoots than cuttings with two nodes, which has the potential for massive stem multiplication. This technique is essential to cassava growers, seed multiplication entrepreneurs, and farmers as they influence the massive production of improved planting materials. Lastly, investigations on sprouting hormones and the effect of plastic sheets' solar radiation on cassava's sprouting and growth are important.

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CONFLICT OF INTEREST

The authors declare no conflict of interest

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