



## Effect of cutting planting orientation on early plant establishment and yield of cassava

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### Abstract

Cassava (*Manihot esculenta* Crantz) is the second main staple food crop grown in Zambia after maize. Despite the ability of cassava to tolerate a wide range of climatic conditions and to grow under marginal soil fertility, its production is affected by inappropriate cultural practices. Vertical, slanting (inclined) and horizontal cutting planting orientations were evaluated in a field trial using a randomized complete block design in four replications on plant establishment and storage root yield on Mweru, a high yielding cassava variety popularly grown by the farmers in Mansa District. Significantly ( $P < 0.05$ ) the tallest plants with longer leaves and bigger stems were recorded in vertical orientation while plants derived from horizontal cutting orientation had short and small stems with short leaves. Horizontal orientation produced significantly ( $P < 0.05$ ) the highest number of storage roots (12 roots) per plant, while the plants derived from the slanting orientation yielded the smallest number (8 roots), yet the mass of individual storage roots was highest in plants from the vertical orientation (321.12 g) and lowest in horizontal orientation (253.2 g). Significantly ( $P < 0.05$ ) the highest cassava fresh storage root yield of 31.45 t ha<sup>-1</sup> was recorded in plants from vertical orientation while plants from horizontal orientation recorded significantly ( $P < 0.05$ ) the lowest yield. Horizontal orientation of cuttings at planting appears to be most suitable for farmers who grow cassava for the fresh root market, while vertical orientation could be suitable for farmers targeting the market for dry chips, four or industrial use.

**Keywords:** Stake, yield, fresh root tubers, cassava variety

### Introduction

Cassava is the second main staple food crop grown in Zambia after maize and it is a vital crop for food security as well as poverty reduction. The crop is commonly grown in Luapula, Northern, North-Western, Copperbelt, and Western provinces where it is considered as a staple food crop (Chalwe *et al.*, 2017<sup>[6]</sup>; Poole, 2010)<sup>[23, 24]</sup>. Cassava is mostly consumed in its traditional form for its leaves as vegetables, roots as a snack, and flour for preparing nshima (Alamu *et al.*, 2019)<sup>[3]</sup>. It also finds use as livestock feed (fresh storage roots and leaves for sweet cassava and processed cassava), medicine or as raw material for several industrial products and source of employment (Chalwe *et al.*, 2017<sup>[6]</sup>; Alamu *et al.*, 2019<sup>[3]</sup>; Chitundu *et al.*, 2009). Industrial applications of cassava in Zambia have extended to alcohol production, and mineral processing and biofuel production by a number of private companies in recent years (Kangali, 2021)<sup>[12]</sup>. These industries are located in both traditional (Luapula and North-western provinces) and non-traditional cassava producing areas (Copperbelt and Central provinces) of the country (Poole *et al.*, 2010)<sup>[23, 24]</sup>. Though these companies are serving as catalysts for increased cassava production in Zambia, they are also contributing to the dynamics in the crop husbandry of cassava among the farmers. Observed increase in cassava production in Zambia has been largely attributable to the increase in area under cultivation as the crop is now promoted for commercialisation (Poole *et al.*, 2013)<sup>[25]</sup>. Cassava production is dominated by small holder producers and yield still remains considerably low (Chalwe *et al.*, 2017<sup>[6]</sup>;

Poole *et al.*, 2013<sup>[25]</sup>; Chiona, 2012<sup>[8]</sup>; Poole *et al.*, 2010)<sup>[23, 24]</sup>. Average yield of 5.2 to 5.8 t ha<sup>-1</sup> is reported for small scale farmers growing traditional cultivars, while the potential yield ranges from 22 to 41 t ha<sup>-1</sup> for the available improved varieties (Chikoti *et al.*, 2019<sup>[7]</sup>; Khonje *et al.*, 2015<sup>[14]</sup>; Poole *et al.*, 2010)<sup>[23, 24]</sup>.

To exploit the cassava potential yield, the farmer has to provide a better crop environment (Chiona *et al.*, 2016)<sup>[9]</sup>. According to Tandzi and Mutengwa, (2020)<sup>[26]</sup>, crop environment can be grouped into three basic factors; Technological (agricultural practices and managerial decision), Biological (diseases, insects and weeds) and Environmental (climatic condition, soil fertility, topography, water quality, etc.). The choice of suitable cutting planting orientation is a technological factor. Unless crop management is improved among farmers, productivity might not increase despite the availability of improved varieties and high demand for industrial use.

The failure of farmers to use appropriate cutting planting orientation could be a contributing factor to low yields among small scale farmers. Currently, three cutting planting orientations (horizontal, vertical and incline) are used (Malumo, 2001<sup>[17]</sup>; Abdullahi *et al.*, 2014)<sup>[1]</sup>. The choice of planting method is determined by ease of planting, harvesting and expected yield (IITA, 1990; Lebot, 2009)<sup>[15]</sup>. These planting methods promote cassava establishment, growth and yields (IITA, 1990).

There exist conflicting reports about the appropriate cutting planting orientations among scientists. Keating *et al.*, (1988)<sup>[13]</sup> reported that cutting planting orientation did not have

significant effect on growth and yield of cassava. Oguzor (2007) [21] found statistically similar germinated nodes and plant heights among the three planting orientation. Using horizontal and incline planting orientation, Mbah *et al.*, (2008) [18] reported no differences on number of tubers per plant and on the fresh tuber yields.

To the contrary, Ogundare (2017) [20] reported low number of tuber per plant in vertical and higher number in horizontal; short plants in vertical and similar and taller plant in horizontal and incline; heavier individual tubers of 374 g in incline and lighter tubers of 251 g in vertical; and highest yield of 32.5 t ha<sup>-1</sup> in incline and lowest yield of 14.7 t ha<sup>-1</sup> in vertical. According to Abdullahi *et al.*, (2014) [1], found similar and highest number of tubers per plant using horizontal and incline and lowest in vertical and highest yields and similar in vertical and incline and lowest in horizontal. Polthanee and Wongpichet (2017) [22] also recorded fresh cassava yields of 60.6 t·ha<sup>-1</sup> in the vertical orientation which was significantly higher than those of horizontal orientation (54.3 t·ha<sup>-1</sup>). Research done in Zambia shows that in loamy and rich soils, cuttings planted

horizontally produce multiple stems and more storage roots which, however, were relatively smaller in size with yield of 18 t ha<sup>-1</sup> (Chiona *et al.*, (2016) [9].

In the study of Polthanee and Wongpichet (2017) [22], vertical orientation gave significantly higher number of storage roots per plant (10.7) than those of horizontal orientation (8.9). However, Legese *et al.*, (2011) [16] found higher cassava yields of 20.7 t ha<sup>-1</sup> in incline orientation and lowest yield of 9.8 t ha<sup>-1</sup> in horizontal orientation. It is against this background that this research was carried in 2019 to identify the most suitable planting orientation that can be recommended to farmers in order to encourage crop establishment, growth and improve on yields.

## Material and methods

### Experimental site

The research was conducted in Mansa District in the Luapula Province of Zambia during the 2019/2020 growing season. The soil in the site is Sandy clay loam with soil pH<sub>(CaCl)</sub> of 5.5 (Table 1). The field had been planted to maize the previous season.

**Table 1:** Soil characteristics and rainfall for the experimental site

Chemical Parameters						Physical Properties				Climate
N	P	K	Mg	OM	pH (CaCl <sub>2</sub> )	Texture (%)			Bulky Density	Rainfall
%	Mg/kg	Mg/kg	Mg/kg	%		Sand	Clay	Silt	g/cm <sup>3</sup>	mm yr <sup>-1</sup>
25	13.3	380.5	331.5	3.32	5.5	60.8	19.6	19.6	1.22	1,077

### Research materials

Mweru a cassava variety mostly used by local farmers due to its characteristics of being sweet, high yielding and relatively early maturing (12 -16 months), was used in the current study. The variety is widely grown in the area because of its ability to establish fast, coupled with its resistance to Cassava Mosaic Disease, Cassava Green Mite and Cassava Mealybug, and tolerance to drought.

### Experimental design and treatments

Three stake orientations (Horizontal, Vertical and Incline) were laid out in a Randomized Complete Block Experimental Design. The treatments were randomly assigned to treatment plots per block and were replicated four times. Each treatment plot consisted of four ridges. Cassava cuttings were planted at the spacing of 1 m between planting stations on 6 m long ridges spaced at 1 m apart in each plot, giving plant population equivalent to 10,000 plant ha<sup>-1</sup>.

### Ridge and weed management

Weeding was done regularly using a hand hoe. Ridges were frequently hilled-up whenever damaged due to heavy rains.

### Pest and disease control

The site was fenced to protect the trails from damage by people and marauder animals. In order to protect the newly blossomed leaves from grasshoppers and fungal diseases that are commonly observed in cassava fields in the area, copper oxy-chloride (fungicide) and cypermethrin (insecticide) were applied at 3 kg ha<sup>-1</sup> and 500 ml ha<sup>-1</sup> respectively.

### Harvesting

The harvesting was done by completely uprooting the plant from the soils at 12 months after planting.

### Data collection

The following parameters were collected from the middle 2 rows per plot and the middle two plants were tagged per row leaving one row on both sides as border area.

### Leaf length

The size of leaves was determined by measuring the length and width of the middle lobe according to Chalwe (2013) [5]. Lobe length was measured from the point of intersection of leaf lobes to the apex of the middle lobe. The measurements of leaf size were taken on the fourth and fifth fully expanded leaves from the top on each of the two plants per clone in each replication at a 14-day interval.

### Stem size

A measuring tape was used at intervals of 14 days to determine the circumference of the stem same at 20 cm above the soil according to Alabi *et al.*, (2001) [2]. The mean for the plot was taken to represent the treatment.

### Plant height

At fortnight interval, plant height was measured with a measuring tape. For horizontal orientation, it was measured as the distance from ground surface to the growing point of the plant. For vertical and inclined orientation, the distance from the point of sprouting to growing tip was measured as plant height. The mean for the plot was taken to represent the treatment.

### Numbers of storage roots per plant

The harvested storage roots were counted and the mean for the plot was taken to represent the treatment.

### Mass of individual harvested storage roots per plant

Immediately after harvesting the storage roots, the mass for the fresh storage roots was determined in grams in order to determine the individual storage root mass per plant. The mean for the plot was taken to represent the treatment.

### Cassava yield

Fresh storage root yield was estimated by recording the weight of all storage roots from the net area of each plot. For each treatment, plot yield was converted to  $t\ ha^{-1}$ .

### Data management and analysis

The collected data on different growth parameters and yield and yield components were compiled and analysed statistically using the GENSTAT 18<sup>th</sup> Edition. Data were subjected to analysis of variance (ANOVA) at 5% level of significance using General linear model procedure after the assumptions of ANOVA were tested. Means were separated using Fisher's protected LSD test.

### Results

#### Effects of cutting planting orientation on early establishment of cassava

##### Plant height

Planting orientation influenced early establishment of cassava in terms of plant heights. Horizontal orientation yielded significantly ( $P < 0.05$ ) the shortest stems throughout the trial period, while plants derived from vertical orientation produced tallest plants at 36, 62 and 90 DAP. There were, however, no significant difference in heights between a plants derived from vertical and incline orientation at 20, 48, and 76 DAP (Table 2).

**Table 2:** Effects of cassava cutting planting orientation on plant height (cm)

Treatment	20 DAP	34 DAP	48 DAP	62 DAP	76 DAP	90 DAP
Vertical	15.49a	38.60a	72.50a	87.10a	110.25a	123.12a
Incline	15.26a	35.81b	70.25a	85.50b	107.38a	119.12b
Horizontal	11.74b	30.00c	61.50b	74.09c	87.71b	99.88c
Mean	14.16	34.8	68.08	82.23	101.78	114.04
LSD $T(0.05)$	0.523	1.663	3.516	1.501	5.129	2.912

**KEY:** DAP: Days after planting, Means followed by the same letter at the same DAP are not significantly different at 5% probability level ( $P < 0.05$ ) using Fishers Protected LSD test

##### Leaf length

Leaf growth was not significantly ( $P > 0.05$ ) influenced by the planting orientation at 34, 62 and 76 DAP. The cassava planted using vertical and incline orientation statistically remained similar and longest at 20, 48, and 90 DAP while those for horizontal planting orientation were significantly the shortest (Table 3).

**Table 3:** Effects of cassava cutting planting orientation on leaf length (cm)

Treatment	20 DAP	34 DAP	48 DAP	62 DAP	76 DAP	90 DAP
Vertical	17.24a	22.84	29.21a	35.48	41.19	47.24a
Incline	16.99a	23.29	27.32a	31.56	36.75	44.61a
Horizontal	15.06b	19.32	23.75b	28.26	33.41	37.81b
Mean	16.43	21.82	26.76	31.77	37.12	43.22
LSD $T(0.05)$	0.976	NS	7.395	NS	NS	5.039

**KEY:** DAP: Days after planting, Means followed by the same letter at the same DAP are not significantly different at 5% probability level ( $P < 0.05$ ) using Fishers Protected LSD test; NS: Non-significant at 5% probability

##### Stem size

Stem size in terms of circumference were significantly ( $P < 0.05$ ) affected by planting orientation. The stem circumferences for vertical and incline planting orientation were statistically the same but bigger than plant stems obtained from horizontal orientation. Stem size of plants derived from horizontal orientation remained smaller than plants from vertical and incline orientation (Table 4).

**Table 4:** Effects of cassava cutting planting orientation on stem size (cm)

Treatment	20 DAP	34 DAP	48 DAP	62 DAP	76 DAP	90 DAP
Vertical	3.12a	4.00a	4.80a	5.38a	5.92a	6.11a
Incline	3.11a	3.85a	4.70a	5.11a	5.74a	5.93a
Horizontal	2.76b	3.19b	3.42b	4.01b	4.16b	4.31b
Mean	3.00	3.68	4.31	4.83	5.28	5.45
LSD $T(0.05)$	0.244	0.241	0.805	0.113	0.310	0.113

**KEY:** DAP: Days after planting, Means followed by the same letter at the same DAP are not significantly different at 5% probability level ( $P < 0.05$ ) using Fishers Protected LSD test

#### Effect of cassava cutting planting orientation on cassava yield and yield parameters

##### Number of storage roots per plant

Planting orientation influenced the number of fresh storage roots produced by each cassava plant at harvest. Both horizontal and vertical orientation produced four and one more storage roots than inclined orientation (Table 5).

**Table 5:** Effects of cassava cutting planting orientation on number of fresh roots plant<sup>-1</sup>, mass of individual fresh roots plant<sup>-1</sup> and yield

Treatment	Number of fresh roots per plant	Mass of individual fresh roots per plant	Yield
Vertical	9.05c	321.12a	31.45a
Incline	7.85b	287.3b	25.2b
Horizontal	12.4a	253.41c	26.0b
Mean	9.77	27.27	27.55
LSD $T(0.05)$	1.7414	0.395	1.714

**KEY:** Means followed by the same letter in a column are not significantly different at 5% probability level ( $P < 0.05$ ) using Fishers Protected LSD test

##### Mass of individual storage roots

Orientation of cuttings at planting had significant influence on the mass of individual storage roots plant<sup>-1</sup>. The vertical orientation gave significantly ( $P < 0.05$ ) the highest mean mass of 321.12 g plant<sup>-1</sup> while the horizontal orientation yielded the lowest mass of 253.4 g plant<sup>-1</sup> (Table 5).

##### Fresh storage root yield

Cassava planting orientation had significant ( $P < 0.05$ ) effect on fresh storage root yield. The vertical planting orientation gave the highest fresh storage root yield of 31.45 t ha<sup>-1</sup> compared to incline and horizontal orientation. In this regard, there were no significant different between incline and horizontal orientation (Table 5).

## Discussion

The study found significant differences among plant heights of cassava in different orientations during the early development phase. Cassava plant heights for vertical and incline orientation statistically remained the same and tallest throughout the assessment period of early development phase while those for horizontal were the shortest. Our findings contradict those published by Malumo (2001) [17] who did not find any significant difference among plant heights of cassava. Malumo (2001) [17] attributed the non-significance of the results to competition among plants which were not observed in this current study. Although cassava grows up to heights of 2.5 m (Chiona, 2012) [8], in this study the tallest plants in the vertical planting orientation only attained 1.23 m. Horizontal orientation recorded the shortest plants due to high competition of photosynthates between storage root development and plant height.

Although leaf length in cassava is determined by genetic make-up, there were significant differences among the leaf length among the planting orientation at 20 DAP, 48 DAP and 90 DAP and non-significant in the other DAPs. The longest leaf was 47.24 cm for vertical planting orientation and shortest was 37.81 cm for horizontal planting orientation. Abdullahi *et al.*, (2014) [1] studying effect of orientation on leaf length of two cassava varieties in three environment also found longest leaf length in vertical and shortest in horizontal just like obtained in this study. The scholars also found non-significant difference among similar orientation used in this study in a different environment and attributed the results to reaction of the varieties in the environment.

The stem size in terms of circumferences for vertical and incline planting orientation were statistically the same and biggest at all assessed DAP compared to horizontal orientation in this study. These results are supported by findings of Malumo (2001) [17] who reported statistically similar and bigger stems in vertical and incline orientation compared to horizontal orientation which was the smallest. According to Biratu *et al.*, (2008) [4] and Chiona *et al.*, (2016) [9], stem diameter is determined by the availability of the growth requirements such as nutrients, temperature, water, age of the plant and the part from which the diameter is to be measured. Cassava stem can grow up to 12.54 cm (John *et al.*, 2020) [11] but in this study stem diameter was very small (3.56 cm for biggest stem of vertical) probably due to genetic make-up of the variety used in the study and that harvesting was at one year rather than the normal maximum of two year recommended for cassava. Secondly, the higher number of storage roots for horizontal orientation meant that less secondary growth which resulted in smaller stems while the opposite was true for the vertical orientation. Thirdly, most of the photosynthates produced by the plants in the horizontal orientation could have been directed towards root development.

Different planting orientation significantly influenced the number of storage roots produced at harvest. Vertical and incline produced statistical similar and lowest number of storage roots per plant which was lower than those for cassava plants in horizontal orientation. These results contradict research findings of Malumo (2001) [17] who reported the lowest number of storage root numbers in horizontal orientation (2.9) and highest and similar storage root numbers in vertical (6.5) and inclined (5.4) orientation.

However, Abdullahi *et al.*, (2014) [1] reported lowest storage root numbers of 11 per plant in the vertical orientation and highest and statistical similar of 14-15 per plant in horizontal and Incline using three cassava varieties. Abdullahi *et al.*, (2014) [1] attributed the low storage root numbers to low light penetration in the cassava canopy and inhibition of assimilate production to support storage root formation.

Heavier individual storage root mass was found in vertical orientation compared to the other two orientations. Individual storage root mass of 321.12 g were produced in the vertical which were 21% and 11% heavier than that of horizontal and Incline, respectively. Similarly, Incline orientation storage roots (287.3 g) were 12% heavier than those of horizontal orientation. The bigger stems and taller plants appear to have contributed to the heavier storage roots due to remobilisation of stored food to storage roots. Misganaw and Bayou (2020) [19] attributes assimilate partition as a reason for the differences in storage root mass in cassava with different heights. However for the lighter storage roots of horizontal orientation could be due to high numbers of sinks (developing storage roots) for the produced assimilates and smaller stems with less stored sugars that could have been remobilised to storage roots. Cassava on different planting orientation statistically produced different number of storage roots. The vertical orientation gave the highest yield of 31.45 t ha<sup>-1</sup> which was 19.87% more than the yield of incline orientation which was statistical similar with that of horizontal. The higher yield of the vertical orientation is attributed to heavier storage roots and bigger stems a sign of high photoassimilate production which can be remobilised for storage root development. Obtained results in this study agrees with Malumo (2001) [17] who reported high cassava storage root yields in vertical orientation of 10.45 t ha<sup>-1</sup> which was 43.73% more than yield of horizontal orientation. Mweru cassava variety has potential to produce up to 41 t ha<sup>-1</sup> when allowed to grow up to two years (Khonje *et al.*, 2015) [14], therefore the obtained yield in this study is 9.55 t lower than the potential yield due to harvesting at first year of research.

## Conclusion

Crop productivity still remains the function of good husbandry practices and use of improved and adapted varieties. In the case of cassava, several high yielding varieties have been bred and are available in Zambia but farmers still use traditional varieties and record lower yields. In this study, the obtained results suggests that planting cassava cuttings using the vertical orientation could promote early plant establishment, growth and subsequently gives higher yields. Implications of the results are twofold; if cassava is grown for sale as fresh storage root tubers for snacks on the market; horizontal orientation is more preferable due to high fresh storage root numbers which can be sold. However if it is grown for cassava chips to be ground for flour or ethanol production, vertical orientation should be used.

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