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Effects of length in stem cutting and its planting position on cassava yield

Anselmo Eloy Silveira Viana[1]*, Tocio Sediyama[2], Sandro Correia Lopes[1], Carlos Sigueyuki Sediyama[2] and Valterley Soares Rocha[2]

*[1]Universidade Estadual do Sudoeste da Bahia, C.P. 95, 45100-000, Vitória da Conquista-Bahia, Brazil. [2]Universidade Federal de Viçosa, Av. P. H. Rolfs, 36571-000, Viçosa-Minas Gerais, Brazil. *Author for correspondence.*

ABSTRACT. Stem cuttings selected from mature portions of parent plants are used for cassava reproduction. Cuttings may be of different lengths and may be planted horizontally, vertically or in an inclined position. Conducted at the State University of Southwestern Bahia, Vitória da Conquista, BA Brazil, the experiment evaluated the effects of cutting length and planting position on cassava. Ten treatments combining five planting positions (horizontal, inclined, upside-down inclined, vertical, and upside-down vertical) and two cutting lengths (20 and 30 cm) were tested. The best treatments for tuberous root yield were 20-cm cuttings planted horizontally (21.292 $kg.ha^{-1}$) and 30-cm cuttings planted in the inclined position (20.236 $kg.ha^{-1}$). Cassava cuttings planted in vertical or inclined position sprouted faster, while those planted in the horizontally gave rise to plants with heavier aerial part. Treatments with higher root yield produced higher starch and dry matter content in the roots, higher starch yield per hectare, and higher root weight per plant. Plants with heavier aerial part had lower harvest index and lower dry matter and starch content in the tuberous roots.

Key words: *Manihot esculenta*, cultural practices, cutting length, planting position.

RESUMO. Efeitos do tamanho de manivas e da posição de plantio sobre a colheita da mandioca. A mandioca é propagada vegetativamente pelo plantio horizontal, vertical ou inclinado de segmentos de caule denominados manivas, com diferentes tamanhos. Este experimento foi conduzido na Universidade Estadual do Sudoeste da Bahia, em Vitória da Conquista, Bahia, Brasil, com o objetivo de avaliar o efeito do tamanho e da posição de plantio das manivas na cultura da mandioca. Foram avaliados dez tratamentos formados pela combinação de cinco posições de plantio (horizontal, inclinada, inclinada-invertida, vertical e vertical-invertida) e dois comprimentos de maniva (20 e 30 cm). Maiores produções de raízes tuberosas foram obtidas com manivas de 20 cm plantadas horizontalmente (20.292 $kg.ha^{-1}$) e manivas de 30 cm plantadas inclinadas (20.236 $kg.ha^{-1}$). O brotamento das manivas foi mais rápido quando plantadas na vertical ou inclinadas, enquanto as plantadas horizontalmente produziram plantas com maior peso de parte aérea. Os tratamentos que proporcionaram maior produtividade de raízes promoveram maior concentração de amido e matéria seca nas raízes, maior produção de amido por hectare e maior peso de raízes por planta. Plantas com maior peso da parte aérea apresentaram menor índice de colheita e menores concentrações de matéria seca e de amido nas raízes.

Palavras-chave: *Manihot esculenta*, práticas culturais, comprimento da maniva, posição de plantio.

Cassava (*Manihot esculenta* Crantz) is a high-energy starchy root crop used in animal and human diets. The crop from the Euphorbiaceae family is widely grown in most tropical regions between latitude 25° North and South latitudes. It is a short-lived shrubby perennial plant that grows up to 5 meters in height. Originally from tropical America, it is one of the most important crop in the tropics (Cock, 1989). Its roots are the main source of calories to approximately 600 million people in Africa, Asia, Latin America and Oceania (Roca et al., 1991). About 47 million hectares of roots and tubers are cultivated in the world, including approximately 14 million hectares occupied by cassava, concentrated in the developing countries (Sarma and Kunchai, 1989).

From 1990 to 1999 the world production of this crop registered a 10.44% growth. Nevertheless, in Brazil, the total production of approximately 24.2 million tons in 1990 decreased to 20.9 million in 1999. This number represents its lowest production in the last 37 years (FAO, 2000).

In 1999 the state of Bahia, the third greatest cassava producer in Brazil, accounted for 14.79% of the national production (IBGE, 2000). The crop is explored throughout Bahia and the more productive zones lie in the Jequié district and its surroundings and in the Planalto de Conquista district (Conceição, 1983).

Cassava is drought tolerant, develops satisfactorily in poor soils, and is relatively resistant to disease and insects. Since, as a rule, it is reproduced by stem cuttings, the cutting size and quality are of fundamental importance for obtaining greater yields in any productive system (Toro and Atlee, 1984).

Cuttings may be planted horizontally, vertically or in an inclined position. The planting position of cassava cutting depends on the plant variety and on environmental conditions, both requiring the undertaking of experiments in different ecological zones to determine the best position (Toro and Atlee, 1984). When the planting position is vertical or inclined, sometimes farmers insert the cuttings upside-down with a reduction in tubers' yield.

The available information on cropping management is not sufficient for a more secure recommendation of some of the productive system components. This is mainly true to cassava cutting lengths, which may be influenced by several factors, such as the number of buds, environmental conditions and disponibility of material for multiplication (Filgueira, 1980).

The objective of this work was to evaluate the effects of planting position and length of stem cuttings on yield and other cassava agricultural characteristics in the micro-region of Vitória da Conquista BA Brazil.

Material and methods

The experiment was conducted from August 1992 to July 1994 in the experimental area of the State University of Southwestern Bahia, at Vitória da Conquista BA Brazil, located at 14°51' S 40°50' W and at a mean altitude of 928m. Average maximum and minimum temperatures are 25.3 and 16.1°C respectively, and the annual average rainfall is 733.9mm, mostly from November to March.

Rainfall precipitation data (mm), averages of maximum and minimum temperature (^{0}C) and relative air humidity (%) during the experimental period are shown in Table 1.

Table 1. Mean monthly temperatures, rainfall and relative air humidity from July 1992 to July 1994. Vitória da Conquista BA Brazil

Month	Temperature (°C)		Rainfall (mm)	Air relative humidity (%)
	Maximum	Minimum		
1992				
July	21.9	13.9	31.1	86
August	22.8	14.6	14.9	85
September	24.6	15.1	24.3	82
October	26.3	20.0	82.1	86
November	25.2	(na)	126.0	81
December	25.0	(na)	190.3	81
1993				
January	27.6	(na)	46.8	74
February	27.2	(na)	139.2	78
March	29.0	(na)	1.2	66
April	28.3	(na)	9.6	74
May	24.9	(na)	32.9	84
June	22.8	(na)	20.1	84
July	23.8	14.4	39.6	71
August	24.2	14.3	1.2	82
September	27.7	15.8	3.7	69
October	27.5	16.7	34.4	71
November	28.7	17.2	25.0	68
December	28.1	18.1	93.7	71
1994				
January	29.0	18.6	20.3	74
February	29.7	18.6	90.0	72
March	27.5	18.0	250.0	82
April	27.7	18.6	52.2	85
May	24.5	17.3	23.9	85
June	23.2	15.4	11.1	83
July	22.0	14.6	22.2	86

(na) – Data not available

The soil of the experimental area was classified as alic Yellow Latosol, A moderate, plain relief. Soil analysis is given in Table 2. To simulate the cassava production system used in the region, pH correction and fertilization were not applied in the experiments.

Table 2. Chemical characteristics of soil samples collected in the experimental area

Determination	Depth (cm)		
	0 - 15	15 - 85	85 - 200
pH H_2O (1:1)	5.5	4.9	4.1
Ca^{++} (cmol.kg^{-1})	0.6	0.0	0.1
Mg^{++} (cmol.kg^{-1})	0.4	0.0	0.0
K^+(cmol.kg^{-1})$^{1/}$	0.31	0.14	0.03
Na^+(cmol.kg^{-1})	0.01	0.01	0.01
S Value(cmol.kg^{-1})	1.3	0.1	0.1
Al^{+++}(cmol.kg^{-1})	0.1	0.7	0.7
H^+(cmol.kg^{-1})	5.8	6.9	2.6
T Value(cmol.kg^{-1})	7.2	7.7	3.4
P (mg/kg)$^{1/}$	3.0	nil	nil
Organic Matter (%)	1.95	1.29	1.09

$^{1/}$ Melich-1 extractant

Cassava cuttings from the Lisona variety were planted in 1.0 x 0.6m spacing. This variety is largely cultivated in the region for food production and the extraction of starch. It presents light-gray colored branches, the roots are white-pulp, and the cortex and subereous epidermis are cream-colored. Cuttings were taken from a healthy twelve-month-old crop and planted in the same day. Depending on the treatment, the cassava cuttings were either 20 or 30 cm long, while minimum diameter was two centimeters. In the horizontal position treatment, the planting depth was 10 cm. In the vertical and inclined positions, two thirds of the cassava cuttings were buried, and the other third was kept above ground level.

A randomized block experimental design was used with 10 treatments and four replicates in 40 experimental units. Each plot had a total area of 21.6 m^2, while the effective area containing l6 plants was 9.6 m^2. Treatments were composed of a factorial combination of five planting positions (horizontal, vertical, inclined, upside-down inclined and upside-down vertical) and two cutting lengths (20 and 30 cm).

The following variables were evaluated: number of days from planting to 50% emergence level, aerial part weight at harvest, harvest index, dry matter and starch percentages in the tuberous roots, starch yield and tuberous root yield. Dry matter and starch percentages were calculated according to Grossmann and Freitas (1950).

Results and discussion

Stem cutting and planting position affected the number of days for crop to reach 50% emergence level. The fastest emergence occurred in treatments in which cassava cuttings were planted in the vertical and inclined positions. It assured a faster development in plants which, according to Conceição (1983), is one of the advantages of these planting systems. Cassava cuttings planted upside-down or horizontally presented slower emergence (Table 3). Cassava cuttings planted horizontally were completely covered by soil. This fact may have retarded shoot emergence. Similarly, when cassava cuttings were planted upside-down, there was the development of buds at the apical end of the cuttings located below soil level, with a consequent retarding of the shoot emergence. Retarded shoot emergence with cassava cuttings planted upside down has also been noted by Onwueme (1978).

Weight of aerial part varied according to planting position. Cuttings planted horizontally gave rise to plants with heavier aerial part, while cuttings planted upside-down originated plants with intermediate aerial part weight. Lowest values were recorded in plants from vertical or inclined cuttings (Table 4).

For harvesting index the position x length interaction was statistically significant. In the horizontal and upside-down vertical positions, the 20-cm cuttings produced plants with highest harvesting index. In the case of inclined and upside-down inclined positions there wasn't any difference between the two cutting lengths as a function of this characteristic. In the case of vertical position, the highest harvest index was obtained in those plants produced from 30-cm cuttings (Table 5).

Percentage of dry matter in root, a quality factor of the cassava, is largely related to crop age, variety, rainfall, and soil moisture contents (Toro and Cañas, 1982). In this experiment there were no treatment effects on this characteristic. Starch percentage in the roots was not influenced by stem cutting length or planting position. This characteristic varies mainly as a function of the variety and environment and, according to Fukuda and Caldas (1987), its values ranged from 21.36 to 38.17% when 310 cassava varieties were evaluated.

The position x length interaction was significant for starch yield per hectare. In the horizontal position, 20-cm cuttings had greater starch yield than that from 30-cm cuttings. For other positions, no effect resulted from cutting lengths. In 20-cm cuttings, a greater yield of starch was obtained with the horizontal planting. When plantings were performed in the vertical, inclined and the upside-down vertical positions, values of starch yield were intermediate, albeit lower for those roots of plants originated from cassava cuttings planted in the vertical and upside-down position. In 30-cm cuttings, the horizontal and the upside-down positions presented lower starch yield per hectare than that obtained from the vertical and the inclined ones (Table 6).

When tuberous root yield per hectare was analyzed, the position x length interaction became statistically significant. When horizontally planted, greater tuberous root yield was obtained with 20-cm cuttings. On the other hand, for inclined planting better results were obtained with 30-cm cuttings. The other positions were not affected by cutting length. In the case of the behavior of the five planting positions combined with the two cutting lengths, it may be noted that for 20-cm cuttings the best result was obtained with the horizontal planting position. Cuttings planted in the vertical and upside-down positions presented an intermediate behavior, with lower for the vertical, inclined and the upside-down inclined positions. In 30-cm cuttings the horizontal position together with the upside-down position had the worst behavior, whereas highest values were obtained from the inclined and vertical positions (Table 7). The correlation coefficients (Table 8), estimated by averages of the treatments, showed that the weight of the aerial part was negatively correlated with the harvest index, starch and dry matter content in the roots. All other correlations were positive. Therefore, treatments that allowed higher root yield promoted higher starch and dry matter in the roots, higher starch yield per hectare, and higher root weight per plant. Plants presenting heavier aerial part presented lower harvest index and lower percentage of dry matter and starch in the tuberous roots. According to Cock (1982) this indicates that the growth of branches and leaves has preference over root growth on the carbohydrate distribution. In other words, the roots are supplied after the needs of the aerial parts are met, and there must exist an optimum development of the aerial part for maximum root development. As discussed above, cassava cuttings planted in the vertical or inclined positions sprouted faster. Those planted horizontally gave rise to plants with heavier aerial part. The best root yield was obtained with 20-cm cuttings planted horizontally and with 30-cm cuttings planted in an inclined position. Treatments with higher root yield produced higher starch and dry matter percentages in the roots, higher starch yield per hectare, and higher root weight per plant. Plants presenting heavier aerial part presented lower harvest index and lower percentage of dry matter and starch in the tuberous roots.

Table 3. Effects of planting position and cutting length on number of days to 50% emergence[1/]

	Position					
Length	Horizontal	Vertical	Inclined	Upside-down vertical	Upside-down inclined	Mean
20 cm	25.04	15.00	15.00	33.81	26.19	22.44 a
30 cm	29.00	15.97	15.00	30.98	19.97	21.69 a
Mean	26.98 AB	15.48 C	15.00 C	32.38 A	22.98 B	

1/ - Means followed by the same capital letter in the line and small letters in the column do not differ at 5% significance level by Tukey's test

Table 4. Effects of planting position and cutting length on aerial part weight at harvesting ($kg.ha^{-1}$)[1/]

	Position					
Length	Horizontal	Vertical	Inclined	Upside-down vertical	Upside-down inclined	Mean
20 cm	23.854	21.778	17.777	24.028	18.278	21.142 a
30 cm	28.819	18.999	20.347	22.362	24.791	23.064 a
Mean	26.337 A	20.389 B	19.063 B	23.195 AB	21.535 AB	

1/ - Means followed by the same capital letter in the line and small letter in the column do not differ at 5% significance level by Tukey's test

Table 5. Effects of planting position and cutting length on harvesting index (%)[1/]

	Position					
Length	Horizontal	Vertical	Inclined	Upside-down vertical	Upside-down inclined	Mean
20 cm	47.24 Aa	44.12 Ab	51.56 Aa	49.72 Aa	45.14 Aa	47.55
30 cm	35.12 Cb	50.43 Aa	50.72 Aa	40.37 BCb	44.18 ABa	44.16
Mean	41.18	47.28	51.14	45.05	44.66	

1/ - Means followed by the same capital letter in the line and small letter in the column do not differ at 5% significance level by Tukey's test

Table 6. Effects of planting position and cutting length on starch yield ($kg.ha^{-1}$) [1/]

	Position					
Length	Horizontal	Vertical	Inclined	Upside-down vertical	Upside-down inclined	Mean
20 cm	6.356 Aa	5.143 ABa	5.214 Aba	5.691 ABa	4.996 Ba	5.480
30 cm	4.268 Cb	5.914 ABa	6.121 Aa	5.135 ABCa	4.699 BCa	5.227
Mean	5.312	5.529	5.668	5.413	4.848	

1/ - Means followed by the same capital letter in the line and small letters in the column do not differ at 5% significance level by Tukey's test.

Table 7. Effects of planting position and cutting length on tuberous root yield ($kg.ha^{-1}$) [1/]

	Position					
Length	Horizontal	Vertical	Inclined	Upside-down vertical	Upside-down inclined	Mean
20 cm	21.292 Aa	17.188 Ba	17.569 Bb	18.896 ABa	17.055 Ba	18.400
30 cm	15.660 Cb	18.972 ABa	20.236 Aa	17.479 ABCa	16.333 BCa	17.736
Mean	18.476	18.080	18.903	18.188	16.694	

1/ - Means followed by the same capital letter in the line and small letters in the column do not differ at 5% significance level by Tukey's test

Table 8. Linear correlation among the characteristics aerial part weight at harvest (APW), harvest index (HI), tuberous root weight per plant (RWP), dry matter percentage (DM), starch percentage (S), starch yield (SY) and tuberous root yield (RY)

	HI	DM	S	SY	RY
APW	– 0.91*	– 0.67*	– 0.67*	0.31	– 0.23
HI		0.82*	0.82*	0.67*	0.60
RWP		0.70*	0.62	0.76*	0.75*
DM			0.95*	0.81*	0.70*
S				0.81*	0.69*
SY					0.97*

*Significant at 5% level by Student's *t* test

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