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EVALUATION OF PRODUCTION IN ELITE GENOTYPES OF CASSAVA IN THE AGRARIAN SEASON OF UMBELUZI - UAE, DISTRICT OF BOANE – MAPUTO

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Abstract: This experiment aimed to evaluate the production of elite cassava genotypes (*Manihot esculenta* Crantz) resistant and tolerant to adverse and noteworthy factors in productivity, due to the fact that it is an important crop for small producers in Mozambique, both domestic and industrial. The elite cassava genotypes came from five African countries (Tanzania, Malawi, Kenya, Uganda and Mozambique), at the Umbeluzi Agricultural Station, in the district of Boane in the province of Maputo in the period 2015/16, where the design was used. of incomplete blocks with twenty-seven genotypes planted in seven blocks and three replications, in which each block received four treatments. The variables studied were: plant height (ALTPL) in meters, number of roots/plant (NURPL), commercial root production (PRACO), shoot biomass yield (BIOPA), tuberous root yield (RENRA), index yield (INDCO) in percent, dry matter (DM) in percent. Results of the research carried out through the RStudio statistical package, show that there were significant differences of cassava genotypes on yield, the highest being achieved with the KE01 genotype that presented 32.03t.ha-1, followed by the UG01 genotypes (29.25t. ha-1), UG05 (25.56t.ha-1), KE05 (24.69t.ha-1), MW04 (24.42t.ha-1), MW03 (24.09t.ha-1), UG04 (22.80t.ha-1), TZ08 (21.68t.ha-1), KE04 (19.80t.ha-1), UG02 (19.75t.ha-1) and MZ123 (18t.ha-1). The average dry matter among the genotypes studied ranged from 21.89% (UG03) to 33.09% (MZ125); the harvest index of the evaluated genotypes ranged from 4.96% (KE03) to 39.83% (KE01).
Keywords: Manioc (*Manihot esculenta* Crantz); elite genotypes; Yield.

INTRODUCTION

Cassava (Manihot esculenta Crantz) is native to tropical America and constitutes an important source of energy for more than 700 million people in tropical countries in Africa, Asia and the Americas (FAO, 2009). The culture is widely disseminated and known worldwide, due to its economic and social role, mainly in developing countries such as Mozambique (Avijala, 2013). All parts of the plant can be used: the roots are a rich source of starch, which is processed into countless products, and the aerial part can be used for animal feed. Like other starchy crops, cassava starch can be converted into alcohol and, therefore, it is a strong ally as a source of renewable energy.

About 30 to 40% of the root is dry matter which is composed of carbohydrates, proteins, iron, zinc, carotenes and dry matter. Starch represents 85% of the carbohydrates present in the root. Proteins range from 2 to 4% in the roots and are more abundant in the leaves (20 to 23%). For native species, particularly those from Central America, protein levels in roots can reach 6 to 8% (Silva, Cuambe & Mutaca, 2010).

Mozambique stands out for its significant agricultural production, currently being the fifth largest producer of cassava in Africa, behind Nigeria, the Democratic Republic of Congo, Ghana and Angola (FAO, 2009; Groxko, 2011), with an estimated average yield of 10.5 t *ha-1. Cassava and maize are the most important food crops in the country, however, cassava ranks first among the root crops. Known for its rusticity and the social role it plays with low-income populations, cassava is highly adaptable to different ecosystems, which makes it possible to grow it throughout the country (Zacarias & Cuambe, 2004).

The provinces of Zambézia, Nampula and Cabo Delgado represent around 85% of the country's total production. It is mostly produced by the family sector in areas ranging from 0.25 to 2.0 hectares. In the northern zone, cassava serves as a staple food and food security for more than 50% of the population (Silva, Cuambe & Mutaca, 2010). The objectives of a cassava breeding program are established according to production, processing and market needs, based on resistance to diseases and pests, and mainly on increasing the productivity of tuberous roots.

The introduction of elite varieties, from other countries, capable of resisting and tolerating different factors during production can be an alternative means of improving crop productivity in Mozambique. Although the national production of cassava has increased from 6 thousand tons in 2011 to 40 thousand tons since 2012 (Sutton, 2014), research on the culture is limited and the productivity of tuberous roots achieved in the different regions of the country is low (Avijala, 2013).). Due to the importance of cassava cultivation in African countries, in the case of Mozambique, the production chain lacks investment, mainly in agricultural research, requiring the elaboration and implementation of projects aimed at obtaining resistant and higher yielding varieties (Avijala, 2013).). Therefore, this work aimed to evaluate the production in elite cassava genotypes, under conditions of water stress and without pest and disease control at the Umbeluzi Agricultural Station, Maputo province in the district of Boane.

MATERIALS AND METHODS

The research presents a quantitative approach, in which, according to Fonseca (2002), the results are quantified, because mathematical language is used for the causes of the phenomena and the relationships of the variables. Also according to the same author, it is of an applied nature because knowledge was generated for practical application, aimed at solving specific problems, involving local truths and interests.

DESCRIPTION OF THE STUDY AREA

The study was carried out at the Umbeluzi Agricultural Station (EAU), where the cassava root collection of the Maputo Agricultural Research Institute (IIAM) is being maintained, in the district of Boane, in Maputo province. The area is located southwest of Maputo province, Longitude (E) 032°22.301' Latitude (S) 26°02.888', Altitude 5m at sea level. With an average annual temperature of 23.7°C and with the coldest month of June and the hottest January and February, with an average annual relative humidity of 80.5% in July and a minimum value of 73.5% in November. The average annual rainfall is 752mm, varying between the average values of 563.6mm in the wet season and 43.6mm in the dry season (MAE, 2005).

INSTALLATION AND CONDUCT OF THE EXPERIMENT

The experiment was carried out in an incomplete randomized block design, with twenty-seven elite cassava genotypes from five African countries (Malawi, Mozambique, Kenya, Tanzania and Uganda), of which 5 local genotypes (Eyope, Nziva, Colicanana, Okhumelela and Orera) of varieties resistant to root rot and with high yield potential (Table 02). The experiment consisted of three replications, with four treatments and seven blocks. The plots were properly labeled using ID codes.

MATERIALS

For the purpose of harvesting the roots and collecting the data, the following materials were used: Scales (hydrostatic and spring/hand); machetes and knives; hoes; wooden ruler; plastic bags (complete and perforated); buckets with water; notebooks; templates and tablets.

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Genotype name	Id. Code
KBH2002/066 (Mkuranga1)	TZ01
Pwani	TZ02
Mkumba	TZ03
KBH2006/026 (Kipusa)	TZ04
Kizimbani	TZ05
Albert	TZ08
Sangoja	MW01
Sauti	MW02
Yizaso	MW03
Kalawe	MW04
CH05/203	MW05
Colicanana	MZ123
N'ziva	MZ124
Okhumelela	MZ125
Orera	MZ126
Eyope	MZ127
LMI/2008/363	KE01
F19-NL	KE02
Tajirika	KE03
Shibe	KE04
F10-30-R2	KE05
Kibandameno	KE06
TZ130	UG01
NASE14	UG02
NASE18	UG03
NASE1	UG04
NASE3	UG05

Table 01.Coding of genotypes.

Source: Experiment protocol II 2015.

DATA COLLECTION

At 12 months after planting (MAP), the roots of the useful area of the plots of the genotypes consisting of twenty plants were harvested, uprooting individual cassava plants with the help of machetes and knives. The roots were placed in plastic bags for weighing. Data on the number of plants harvested and the number of plants with roots, and number of roots were recorded directly on the tablet. For the five plants initially marked, the weight of the roots was recorded on the plant by root basis, weighing each root, before cutting it. The weight of aboveground biomass was recorded on a plant basis. However, roots and biomass were separately collected and stacked and weighed to obtain root and biomass weights, respectively. From the pile of joined roots, a random sample of 5 undamaged roots was taken and used to estimate root dry matter.

VARIABLES STUDIED

During the harvest, data were collected regarding quantitative traits of the crop, namely: plant height (ALTPL) in meters; number of roots per plant (NURPL); commercial root production (PRACO) in ton/ha; aerial part biomass yield (BIOPA), in ton/ha; tuberous root yield (RENRA), in ton/ha; harvest index (INDCO) in percent, dry matter (DM) in percent.

In order to obtain the collected data referring to the aforementioned traits, the methods referenced by the author Avijala (2013) were followed: Plant Height (ALTPL) in meters: for this purpose, it was done by measuring the vertical distance from the base to the highest point of the canopy, at harvest time, in 6 plants per plot of useful area; Starch content (TA) in percentage: it was obtained by weighing root samples outside and inside the water, using the formula:

$$TA = \left(\frac{Root\ weight\ off}{Root\ weight\ off + Root\ weight\ in\ water} \times 112.1\right) - 106.4$$

Weight of aerial part biomass: by weighing the aerial part of all useful plants in the experimental plots, right after the roots are harvested; average number of tuberous roots per plant: by the ratio between the number of roots produced and the respective number of plants submitted to the evaluation; tuberous root yield: by weighing the tuberous roots of all useful plants in the experimental plots; production of commercial roots: calculated by weighing roots with ideal phenotypic characteristics for commercialization, with a mass greater than 200g (later converted into ton/ha), harvested from the plots; Harvest index: evaluating the relationship between the fresh weight of tuberous roots and the total fresh weight of the plants (roots + shoots), using the formula:

$$INDCO\ \frac{Root\ fresh\ weight}{Fresh\ root\ weight\ +\ Fresh\ shoot\ weight} \times 100$$

Dry matter content: to determine the dry matter content in the roots, separating three roots in each plot, which will be cut into small cubes. From the ratio between the weight of the dry and fresh mass of roots, the dry matter content will be obtained, using the formula:

$$MS\left(\frac{Root\ weight\ off}{Root\ weight\ off + Root\ weight\ in\ water} \times 158.3\right) - 142$$

All plants harvested by genotype were divided into roots and biomass (stems and foliage). Then, separate weights of roots and aboveground biomass and crop index were made as the ratio of roots to total biomass. The difference between fresh and dry weights was then used to calculate the percentage of dry matter for each genotype. It must be noted that the total root yield was determined by the sum of commercial and non-commercial root yield of all plants in the useful area of each treatment.

Yield per hectare was calculated using the following formula:

$$Y(t.ha^{-1}) = \frac{10000*\text{"Yield"}(\text{"portion"})}{1000*C*\text{"Number of Harvested Plants"}}$$

Where:
Yield per installment in – (kg);
C – Measure in (m2);
10000 – Conversion factor from m2 to ha;
1000 – Conversion factor from kg to ton (t);

DATA ANALYSIS

The analyzes performed were: Analysis of variance (ANOVA), with assumptions of normality of residuals (ShapiroWilk test); means comparison test (Scott-Knott-1974); The statistical package RStudio version 1.0.136 was used, with a significance level of 5%.

Statistical analyzes were performed according to the mathematical model corresponding to the experimental design used, according to Zimmerman (2004):

$$Y_{ijl(j)} = m + R_j + B_{l(j)} + T_i + e_{ijl(j)}$$

Where:
m - is the average;
R_j- the effect of repetition j (j=1, 2,...,r);
$B_{l(j)}$- the effect of block l (l=1, 2,...,b) within repetition j;
T_i – the treatment effect: i (i=1, 2,...,t);
$e_{ijl(j)}$ – the error associated with the observation: $Y_{ijl(j)}$, with normal distribution, mean 0 and variance: σ^2. The errors are assumed to be independent and of homogeneous variance.

RESULTS AND DISCUSSION

Before the analysis of variance (ANOVA), the data were submitted to the assumption of normality of the residuals (p.value Shapiro-Wilk test), and this indicated that it is reasonable to study the data through the normal distribution (Pr<W greater than the level 5% significance level. The ANOVA data contained in Table 03, from the experimental results, allow us to conclude that there was no significant effect of the different genotypes on the starch content (Pr=0.0842), root dry matter (Pr=0.0863) and biomass (Pr=0.086), and there was a significant effect on the harvest index (Pr=<0.001), number of roots (Pr=<0.001), plant height (Pr=<0.001) and Yield in ton/ha (Pr=<0.001). Thus, it can be concluded that the studied agronomic characteristics differ among the studied genotypes.

The coefficients of variation (CV), in percentage, range from 6.09% (ALTP) to 30.06% (Yield), expected value for a characteristic of a quantitative nature, since, according to Avijala (2013) they can be greatly influenced by the environment. According to Gomes et al., (2006), the percentage variation coefficients depend on each characteristic. For ALTPL it ranges from 8.86 to 16.01; Biomass 16.38 to 31.77; NR 26.72 to 31.07; RENRA 16.12 to 37.20; PRACO 20.47 to 35.10; INDCO 11.22 to 21.17 and MS 2.66 to 12.48. Therefore, the coefficients obtained in this work show a good experimental precision in the evaluation of all the characteristics studied.

YIELD OF GENOTYPES

The experimental results allow us to conclude that there was a significant effect of different cassava genotypes (p=0.001) on yield. This time, three groups of means were formed (a, b and c). The highest yields were achieved by the genotypes of group a, which although the means did not differ statistically from each other at a 5% significance level by the Scott-Knott test, the KE01 genotype presented the highest mean with 32.03ton/ha, followed by the genotypes UG01 (29.25ton/ha), UG05 (25.56ton/ha), KE05 (24.69ton/ha), MW04 (24.42ton/ha), MW03 (24.09ton/ha), UG04 (22.80ton /ha), TZ08 (21.68ton/ha), KE04 (19.80ton/ha), UG02 (19.75ton/ha) and MZ123 (18ton/ha). The remaining

FV	GL	MEDIUM SQUARES						
		TA	MS	INDCO	NR	ALTP	Biomass	Performance (ton/ha)
B. d. R	18	5,54	11,07	64,21	3061,68	0,39	377,09	41, 22
Genotype	26	8,28^{NS}	16,52^{NS}	191,58*	5894,55*	0,32*	414,74^{NS}	143,69*
Mistake	34	5,01	10,04	48,20	1549,39	0,03	251,93	22,74
CV(%)		16,99	11,81	26,76	28,50	6,09	20,36	30,06

(*)-Significant, NS- not significant at 5% probability by the F test; TA- Starch Content; MT- Dry Matter; INDCO- Harvest Index (%); NR- Number of Roots; ALTP- Plant Height; FV- Source of variation; GL- Degree of freedom; B.d.R- Block within the Repetition; CV(%)- Coefficient of Variation;

Table 02. Analysis of variance, means and coefficients of variation for six agronomic traits evaluated in twenty-seven cassava genotypes.

genotypes, from groups b and c, showed lower yield when compared to the others, highlighting the KE03 genotype as the lowest of all with 0.71ton/ha.

The yields obtained by half of the genotypes are higher than the average yield of 15ton/ha mentioned by Zacarias et al. (2010) for this production system. The yields of all genotypes, except MZ127 (5.30ton/ha), MZ124 (4.79ton/ha) and KE03 (0.71ton/ha), are higher than the average yield of 5 ton/ha obtained in Mozambique in the year 2012 as mentioned by INE (2014), and the yields of group a are higher than 8.46 ton/ha obtained in Africa, 10.23 ton/ha in the world and 14.37 ton/ha in Asia as referenced by FAOSTAT (2013). However, the yield of the KE01 genotype (32.03ton/ha) is between the optimal range 30 -50 ton/ha mentioned by Howeler & Kawano (1988), and still according to the same author, higher than the maximum of total root yields. (32 ton/ha of Mz89192 and 22.9 ton/ha of MZ89105) obtained in the study conducted by Langa (2003) in the Umbelúzi and Nhaccongo fields, and higher than the maximum of total root yields (17.8 ton/ha of clone MZ95113-5 , 15 ton/ha of MZ95092-12 and 12.4 ton/ha of MZ95064-5) obtained in the study conducted by Chicuele (2005) in the Umbelúzi field; to the maximum total root yields obtained by Macia et al. (2007) in the test fields of Chókwé (21.95 ton/ha of clone Mz 2001082-2), Nhacoongo (9.65 ton/ha of Local), Nhamatanda (14.25 ton/ha of clone Mz 2001059-2), Sussundenga (16.5 ton /ha of clone Mz 2001057-2), Namacurra (17.85 ton/ha of Mz 2001057-2) and Umbelúzi (26.95 ton/ha of clone Mz 2001082-2). However, lower than the yield of 40 ton/ha mentioned by Zacarias et al. (2010) for the irrigated system with the use of inputs. However, the genotypes KE01, UG01, UG05, KE05, MW04, MW03, UG04, TZ08, KE04, UG02 and MZ123 are the ones that stood out for presenting high productivity of tuberous roots.

ROOT DRY MATTER

The dry matter content in the roots is the characteristic that determines the greater or lesser industrial yield of the roots, since it is directly related to the various products derived from cassava (Sarmento, 1997). For this trait, the mean among the genotypes studied ranged from 21.89% (UG03) to

33.09% (MZ125). Therefore, after analyzing the results, ANOVA and the comparison of means test, two groups were formed (a and b) of which group A presented statistically equal means but higher than the others, consisting of the MZ125 genotypes (33.09%) , TZ08 (30.92%), KE06 (30.83%), KE05 (30.59%), MW03 (30.14%), UG04 (29.65%), TZ04 (29.03%), TZ03 (28.54%), MW05 (28.45), KE01 (28.06%), MZ123 (27.94%) and MW01 (27, 39%).

HARVEST INDEX

The harvest index represents the efficiency of production of reserve roots and is normally determined by the ratio of the weight of the reserve roots to the total weight of the plant (Alves, 2006). For the authors, the harvest index has been used as a selection criterion for higher yields in cassava. The harvest index of the evaluated genotypes ranged from 4.96% (KE03) to 39.83% (KE01). The genotypes KE01 (39.83%), UG04 (39.28%), UG01 (38.65%), KE05 (38.56%), KE04 (37.82%), MW03 (33.21%), UG05 (33.03%), MZ123 (32.52%), MW04 (31.99%), TZ08 (30.82%), UG02 (29.26%) and MZ126 (27.60%), presented statistically equal means, but better in relation to the others.

For Alves (2006), the harvest index is an important characteristic because it reveals the distribution of dry matter to economically useful parts of the plant. Since the roots are the organs of greatest interest in cassava cultivation, the harvest index can provide a good balance between the total production of carbohydrates by the plants and their distribution to the roots.

According to Avijala (2013), in an experiment carried out in Paraná, Vidigal et al. (2000) observed values for this characteristic that ranged from 38 to 79%, but according to Peixoto et al. (2005), the harvest index is considered satisfactory when it is above 50%. In the present study, this index was not reached in any genotype. However, Silva et al. (2002) report that cultivars with better harvest rates do not always present higher production of tuberous roots, since plants with low production of tuberous roots, but which also have low production of shoots, will provide high harvest index values.

BIOMASS

The productivity of aerial part biomass is a very important characteristic in cassava cultivation because it represents the amount of green matter produced by the plant, which can be used in animal feed, mainly in obtaining cuttings for subsequent planting (Avijala, 2013). As for the production of biomass, after analyzing the results, ANOVA and the test of comparison of means, there was the formation of two groups of means (a and b) highlighting the genotypes MW05 (110.22kg), MW01 (107.93kg), MZ125 (99.16kg), TZ08 (92.50kg), MW02 (92.09kg/ha), MW03 (90.54kg), TZ04 (89.31kg) and UG01 (86.72kg) as the ones with the highest average, group a, than the other genotypes, group b. The lowest average, although statistically equal among those in group b, was from the MZ124 genotype, which presented 47.49kg.

NUMBER OF ROOTS

The number of roots per plant is another very important characteristic in cassava production. The genotypes that produced or presented the highest number of roots were: KE04 (274 roots), UG01 (221r), MW01 (209r), UG05 (200r), MW03 (196r), and MZ123 (193r), which presented statistically equal means, however superior when compared with the averages of the other genotypes, belonging to the group b.

STARCH CONTENT

The starch content of the different genotypes evaluated ranged from 9.67% (UG03) to 17.55% (MZ125). Therefore, two groups of averages were formed regarding the content of starch produced between the different genotypes, with the first group (a), consisting of genotypes MZ125 (17.55%), TZ08 (16.02%), KE06 (16.01%), KE05 (15.82%), MW03 (15.48%), UG04 (15.16%), TZ04 (14.74%), TZ03 (14.38%), MW05 (14.35 %), KE01 (14.01%), MZ123 (13.93%) and MW01 (13.61%), presented statistically equal means, but higher in relation to group (b).

PLANT HEIGHT

For the characteristic plant height, the averages between the genotypes ranged from 1.29m (UG04) to 3.53m (MW05). The authors Kvitschal et al. (2003); Fukuda & Iglesias (2006) reported average height of cassava plants ranging from 1.0 to 5.0 m, with plants with 1.0 to 3.0 m being more common. For Rimoldi et al., (2006), the heights of the different genotypes evaluated are in this range, and according to the same author, evaluating cassava cultivars obtained results for plant height ranging from 1.58 to 2.60 m, similar to those obtained in this work for the genotypes.

According to Avijala (2013) and Fukuda et al., (2002), plant height is very important, since it is positively correlated with tuberous root yield, but to a lesser extent when compared to shoot weight. All genotypes evaluated, except UG04 (1.29m), produced plants with greater height, compared to the general average of 2.14m obtained in (Avijala, 2013).

CONCLUSION

For the dry matter characteristic among the different genotypes studied, the results allow us to conclude that the genotype MZ125, presented a higher percentage in relation to the others with 33.09%, followed by genotypes TZ08 (30.92%), KE06 (30, 83%), KE05 (30.59%), MW03 (30.14%), UG04 (29.65%), TZ04 (29.03%), TZ03 (28.54%), MW05 (28.45) , KE01 (28.06%), MZ123 (27.94%) and MW01 (27.39%).

The harvest index, in the evaluated genotypes, varied from 4.96% to 39.83% of the KE03 and KE01 genotypes, respectively. The best means were achieved by the genotypes KE01 (39.83%), UG04 (39.28%), UG01 (38.65%), KE05 (38.56%), KE04 (37.82%), MW03 (33.21%), UG05 (33.03%), MZ123 (32.52%), MW04 (31.99%), TZ08 (30.82%), UG02 (29.26%) and MZ126 (27.60 %). Since the harvest index can be used as a selection criterion for higher cassava yields, based on the results it can be concluded that genotypes with higher averages can be considered as producers of higher cassava yields.

Based on the results, it can be concluded that the best genotypes in relation to starch content are: MZ125 (17.55%), TZ08 (16.02%), KE06 (16.01%), KE05 (15.82%), MW03 (15.48%), UG04 (15.16%), TZ04 (14.74%), TZ03 (14.38%), MW05 (14.35%), KE01 (14.01%), MZ123 (13.93%) and MW01 (13.61%), as they presented higher percentages of starch content in relation to the other genotypes, where the UG03 genotype presented the lowest average of all with 9.67%.

Based on the results, it can be concluded that the genotypes UG01 (29.25ton/ha), UG05 (25.56ton/ha), KE05 (24.69ton/ha), MW04 (24.42ton/ha), MW03 (24.09ton/ha), UG04 (22.80ton/ha), TZ08 (21.68ton/ha), KE04 (19.80ton/ha), UG02 (19.75ton/ha) and MZ123 (18ton/ha) show better average yields, but lower than 32.03ton/ha obtained by the KE01 genotype. However, it can be concluded that the KE01 genotype produced the highest yield in terms of roots in tons per hectare, standing out as the best genotype.

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