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SCIENTIFIC NOTE

Performance of cassava genotypes for industrial use in areas of the Urucuia River Valley region

Desempenho de genótipos de mandioca industriais em áreas da região do Vale do Rio Urucuia

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ABSTRACT: The aim of this study was to evaluate agronomically in two environments seventeen genotypes of cassava for the flour and starch industry. The trials were conducted in areas of Cerrado in the municipality of Arinos, Minas Gerais state, Brazil, between November 2006 and May 2008 and November 2007 and May 2009. Eighteen months after planting, the following characters were evaluated in the plots: mass of shoots, tuberous root yield, percentage of starch in tuberous roots, and starch yield. The results revealed that the genotypes differ in all traits. Environmental influence was observed on the expression of these characters with significant interaction between genotype and environmental factors. The genotypes BGMC 993 and BGMC 991 showed high agronomic performances in the two environments, with emphasis on tuberous root yield and starch yield.

RESUMO: *O objetivo do estudo foi avaliar agronomicamente em dois ambientes, dezessete genótipos de mandioca de indústria de farinha e fécula em áreas de Cerrado no município de Arinos em Minas Gerais. Os experimentos foram conduzidos entre novembro de 2006 e maio de 2008 e entre novembro de 2007 e maio de 2009. Aos 18 meses após o plantio foram avaliados os caracteres massa da parte aérea, produtividade de raízes, porcentagem de amido nas raízes e foi estimado o rendimento de amido. Os resultados revelaram que genótipos diferiram quanto a todos os caracteres avaliados, também foi detectada influência do fator ambiente sobre a manifestação desses caracteres e a presença de interação significativa entre os fatores genótipos e ambientes. Os genótipos BGMC 993 e BGMC 991 revelaram elevado desempenho agronômico nos dois ambientes, com destaque para a produtividade de raízes e o rendimento de amido.*

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1 Introduction

Cassava crop is grown throughout Brazil targeting the use of the starch stored in its tuberous roots. Starch is widely used in feed and food industry. Shoots (stems and leaves) have also been used in combination with the tuberous roots as food (Helbig et al., 2008) and fodder (Souza et al., 2011).

Most of the cassava grown in Brazil is used in the production of cassava flour and starch. Overall, the cassava flour production is operated by small farmers, while the starch production is operated by lagers farmers and manufacturers that are largely located in the states of Paraná, Mato Grosso do Sul, São Paulo and Santa Catarina. However, in these states, the cassava crop has suffered high competition for plantation areas with other crops (Vilpoux, 2008), which points towards the need to diversify cassava production areas for industrial purposes in Brazil, whether for the production of flour and/or starch.

Although the Brazilian Cerrado region presents climate and soil characteristics favorable to cassava cultivation (Fialho et al., 2013), currently, only 10% of the planted area is located in this region, which is responsible for only 10% of the national production, with an average yield of tuberous roots of 13 t ha^{-1} in a harvested area of 242,528 ha (IBGE, 2011).

The Urucuia River Valley in the Brazilian Cerrado region may constitute a new agricultural frontier for the national production of cassava. The region consists of eleven municipalities: Arinos (MG), Buritis (MG), Cabeceiras de Goiás (GO), Formoso (MG), Chapada Gaúcha (MG), Pintópolis (MG), Uruana de Minas (MG), Urucuia (MG), Riachinho (MG), Bonfinópolis de Minas (MG), and São Romão (MG), and it stands out for agricultural production, mainly in family farming establishments and land reform settlements, where cassava could be an alternative in the diversification of crops. Studies developed in the Cerrado region, with industrial cassava varieties, have demonstrated the high potential of crop yield (Otsubo et al., 2009; Sagrilo et al., 2010; Vieira et al., 2013).

However, research works aimed at introducing industrial cassava genotypes in the Urucuia River Valley and determining the productive potential of the same under local soil and climatic conditions have not yet been developed. Therefore, introduction and evaluation of varieties are the first step in determining the potential of a culture growing in a certain place for possible indication for commercial planting. The objective of this study was to evaluate agronomically in two environments seventeen genotypes of cassava for industrial use in areas of Cerrado in Arinos, Minas Gerais state, Brazil.

2 Materials and Methods

The experiments were conducted in the municipality of Arinos, Minas Gerais (MG) state (Aw climate, tropical, six-month dry season) between November 2006 and May 2008 and between November 2007 and May 2009, allowing two harvest crop seasons in 2006/2008 and 2007/2009, respectively. Records of local weather conditions for the harvest seasons of 2006/2008 and 2007/2009 included maximum daily temperatures (32.65 and 32.33°C), minimum daily temperatures (20.11 and 16.69°C), average daytime temperatures (26.42 and 26.05°C), average relative air humidity (61.47 and 64.11%), average wind speeds (0.99 and 0.77 m sec^{-1}), daily sunshine average hours (7.19 and 6.84 h), average daily radiation (19.72 and 19.16 MJ m^{-2}), cumulative rainfall (1963 and 2029 mm), and average potential evaporation (3.66 and 3.57 mm), respectively.

Field plots were located at the Campus Arinos of the Federal Institute of the North of Minas Gerais – IFNMG, in an Oxisol or at the Plan Settlement Creek course, in a Yellow Oxisol. The physical and chemical properties of the soils were, respectively, clay percentage: 44 and 32.10%, silt percentage: 3 and 14.67%, coarse sand: 13 and 0.75%, fine sand: 40 and 52.48%, pH: 5.70 and 4.94, Al^{+++}: 0.19 and 2.06 $cmol_c\ dm^{-3}$, Ca^{++}: 2.50 and 0.45 $cmol_c\ dm^{-3}$, Mg^{++}: 0.92 and 0.53 $cmol_c\ dm^{-3}$, H+Al: 5.14 and 4.22 $cmol_c\ dm^{-3}$, phosphorus: 3.90 and 3.08 mg dm^{-3}, potassium: 61 and 51.27 mg dm^{-3}, and organic matter: 2.02 and 1.09%.

The experiment included seventeen cassava genotypes preserved in the Regional Germplasm Bank of the Cerrado Cassava – BGMC: two varieties, BGMC 1297 (BRS Mani Branca) and BGMC 993 (BRS Formosa), and seven clones, BGMC 991 (clone 03), BGMC 994 (clone 6), BGMC 996 (clone 9), BGMC 1298 (clone 9794/06), BGMC 1299 (clone 9607/07), BGMC 1304 (clone 9661/06), and BGMC 1305 (clone 9661/06) of the cassava breeding program of Embrapa Cassava and Tropical Fruits; four varieties of the cassava breeding program of the Agronomic Institute of Campinas (IAC), BGMC 436 (IAC 12), BGMC 1130 (IAC 13), BGMC 788 (IAC 14), and BGMC 1270 (IAC 15); and four traditional varieties, Paraná BGMC 1170 (Fécula Branca) and BGMC 1265 (Fibra), Tocantins BGMC 1262 (Enita Brava), and Santa Catarina BGMC 1286 (Roxinha). The experimental plots were composed of four lines, with 10 plants spaced 1.20 m between rows and 0.80 m between plants, with a floor area in each plot for 16 central plants. The experimental design was conducted in randomized blocks. All cultural treatments were performed in accordance with the technical recommendations for cassava in the Cerrado region (Fialho et al., 2013; Fialho & Vieira, 2013). Eighteen months after planting, the following characters were assessed in the 16 plants of the floor area of each plot: mass of shoots without strain in kg ha^{-1} (PPA), tuberous root yield in kg ha-1 (PR), percentage of starch in tuberous roots by the method of hydrostatic balance (AM) described by Grossmann & Freitas (1950), starch yield (RA) based on the root yield, and percentage of starch in tuberous roots.

The data were submitted to individual and combined analysis of variance. The means of characters were grouped by the agglomerative Scott & Knott test, $p < 0.05$ error probability.

3 Results and Discussion

The individual variance analysis pointed to the occurrence of significant differences ($p < 0.05$) among genotypes for all traits evaluated in both environments (Tables 1 and 2). Genotypes showed different agronomic performance for tuberous root yield, mass of shoot without strain, percentage of starch in tuberous roots, and starch yield.

Previous studies by Otsubo et al. (2009) and Vieira et al. (2013) reported the presence of wide variability of agronomic performance between industrial cassava genotypes in Cerrado areas of Mato Grosso do Sul state and the Federal District, respectively. These results reflect the fact that they evaluated

Table 1. Mass of shoots without strain (PPA) and tuberous root yield (PR) of cassava genotypes for industry in the 2006/2008 (S1) and 2007/2009 (S2) crops.

Tabela 1. Massa da parte aérea sem a cepa (PPA) e produtividade de raízes tuberosas (PR) de genótipos de mandioca de indústria, nas safras 2006/2008 (S1) e 2007/2009 (S2).

Genotypes	PPA*	PPA	PR	PR
	kg ha^{-1}			
	(S1)	(S2)	(S1)	(S2)
Average	26024 A	17741 B	26293 B	34348 A
Amplitude$^{\#}$	34816	19560	23611	42740
CV_i (%)$^{+}$	6.78	7.40	17.91	8.39
CVc (%)$^{++}$	7.11		12.87	

*means followed by the same uppercase letter horizontally and the same lowercase letter vertically do not differ significantly ($p < 0.05$) by the grouping test means (Scott and Knott). $^{\#}$difference between the highest and the lowest average. $^{+}$individual variance analysis of the variation coefficient. $^{++}$variation of the coefficient of variance analysis.

Table 2. Percentage of starch in tuberous roots (AM) and starch yield (RA) of cassava genotypes for industry in the 2006/2008 (S1) and 2007/2009 (S2) crops.

Tabela 2. Porcentagem de amido nas raízes (AM) e rendimento de amido (RA) de genótipos de mandioca de indústria, nas safras 2006/2008 (S1) e 2007/2009 (S2).

Genotypes	AM*	AM	RA	RA
	%		kg ha^{-1}	
	(S1)	(S2)	(S1)	(S2)
Average	27.72 B	29.26 A	7272 B	10119 A
Amplitude$^{\#}$	6.17	4.70	6370	12328
CV_i (%)$^{+}$	3.33	2.66	19.08	8.39
CV_c (%)$^{++}$	3.00		13.23	

*means followed by the same uppercase letter horizontally and the same lowercase letter vertically do not differ significantly ($p < 0.05$) by the grouping test means (Scott and Knott). $^{\#}$difference between the highest and the lowest average. $^{+}$individual variance analysis of the variation coefficient. $^{++}$variation of the coefficient of variance analysis.

genotypes from different backgrounds and improvement levels and, consequently, with different phenotypic responses to environmental variations, as seen in our study. The coefficients of variation of the individual variance analyses ranged from 2.66% for the character percentage of starch in tuberous roots (AM) in the harvest season of 2007/2009 to 19.08% for the character starch yield (RA) in the harvest season of 2006/2008, which indicates higher experimental precision of experiments (Tables 1 and 2).

The joint analysis of variance revealed significant differences ($p < 0.05$) between the means of environments for all measured traits (Tables 1 and 2), indicating that the environmental factor was decisive in the phenotypic expression of these traits. This can be explained by the fact that the experiments were conducted in different years and in different areas, which contributes to the differential phenotypic response of genotypes to environmental variation. In the 2006/2008 harvest season, the highest average was detected for the character mass of shoots without strain, while the other measured characters showed higher averages in the 2007/2009 harvest season (Tables 1 and 2). Results similar to those obtained in this study were reported in an experiment conducted in northwestern Paraná state with three crops by Vidigal Filho et al. (2000), who observed the influence of this factor in the manifestation of the means of the characters percentage of starch in tuberous roots, mass of shoots without strain, and tuberous root yield. This is indicative of the need to evaluate cassava genotypes for industrial use for more than one season and in more than one location in order to obtain more reliable results, as to the manifestation of adaptability and stability of phenotypic characters.

The combined analysis of variance also detected significant differences ($p<0.05$) between the measured genotypes average for all characters, indicating the presence of individual variation in the group of genotypes. This high variation can be proven by the high ranges of variation of the characters mass of shoots without strain (34816 and 19560 kg ha^{-1}), tuberous root yield (23611 and 42740 kg ha^{-1}), percentage of starch in tuberous roots (6.17 and 4.70%), and starch yield (6370 and 12328 kg ha^{-1}), respectively, in the 2006/2008 and 2007/2009 crops (Tables 1 and 2).

The combined analysis of variance also detected the presence of significant interaction ($p < 0.05$) between environmental factors and genotypes for all measured characters (Tables 1 and 2). These results agree with those reported by Vidigal Filho et al. (2000), who also reported the existence of a significant interaction ($p < 0.05$) between crop factors and genotypes for the characters mass of shoots without strain, tuberous root yield, and the percentage of starch in tuberous roots. This reveals the sort order of the genotypes for the measured characters was influenced by the environmental effect, depending on whether genotypes have shown different responses to soil and climatic changes. This points towards the need to evaluate genotypes in more than one crop/environment to obtain a more reliable estimate of the expression of these characters, as reported for cassava by Vidigal Filho et al. (2000) and Vieira et al. (2009), as well as the need to consider the genotype/environment interaction at the time of selection of promising genotypes for a particular region. The coefficients of variation of combined analyses of variance ranged from 3.00% for the character percentage of starch in tuberous roots to 13.23% for the character starch yield, showing the high experimental accuracy of the genotype competition assay (Tables 1 and 2).

In this group of genotypes, only BGMC 1304 (which corresponds to clone 9661/06 of Embrapa Cassava and Tropical Fruits) presented mass of shoots without strain average significantly higher than the others ($p < 0.05$) in the 2006/2008 season. In the 2007/2009 crop, genotypes that presented mass of shoots without strain average significantly higher than the others ($p < 0.05$) were BGMC 991 (which corresponds to clone 03 of Embrapa Cassava and Tropical Fruits) and BGMC 436 (which corresponds to the range of 12 IAC industrial cassava from the Agronomic Institute of Campinas) (Table 1). This character is considered, at the time of selection of genotypes, to be related to the possibility of use of the aerial part of cassava as a source of protein in animal feed (Souza et al., 2011), land cover (erosion control, moisture maintenance in soil, and weed control), and for supplying cuttings for new planting seed (Ceballos et al., 2004), especially

for sites that feature expression in animal production and can constitute an option for income generation and food security through cassava cultivation.

The means grouping test revealed that, in the 2006/2008 crop, genotypes BGMC 1286, BGMC 1304, and BGMC 923 statistically presented higher means compared with the other genotypes ($p < 0.05$) for the character tuberous root yield, and that, in the 2007/2009 harvest, only the genotype BGMC 436 statistically showed means superior to the others ($p < 0.05$) (Table 1). No genotype stood out for the character tuberous root yield in both harvests. As for that same character, the BGMC 993 genotype had already been highlighted in an experiment conducted by Vieira et al. (2013) in Planaltina, Federal District. The character tuberous root yield is one of the most important characteristics for selection of industrial cassava genotypes because it is one of the factors related to the final yield potential for flour and starch of certain genotypes in the site of the experiments (Ceballos et al., 2004).

As for the percentage of starch in tuberous roots, the following genotypes presented averages significantly higher than the others ($p < 0.05$) in the 2006/2008 season: BGMC 1299, BGMC 436, BGMC 993, BGMC 1130, BGMC 996, BGMC 1262, BGMC BGMC 1305, and 1304. In the 2007/2009 crop, the following genotypes presented averages significantly higher than the others ($p < 0.05$): BGMC 788, BGMC 1305, BGMC 993, BGMC 1130, BGMC 1299, BGMC 991, and BGMC 996 (Table 2). The only genotypes that stood out in both harvests were BGMC 996 (corresponding to the variety of cassava BRS Formosa of Embrapa Cassava and Tropical Fruits), BGMC 993, BGMC 1299, BGMC 1305 (corresponding, respectively, to 03 clones, 9607/07 and 9688/07 of Embrapa Cassava and Tropical Fruits), and BGMC 1130 (which corresponds to the variety of IAC 13 industrial cassava of the Agronomic Institute of Campinas). The genotypes BGMC 993 and BGMC 1299 had already been highlighted for the percentage of starch in tuberous roots in an experiment conducted by Vieira et al. (2013) in Planaltina, Federal District. Percentage of starch in tuberous roots is one of the most important characters for the selection of genotypes of industrial cassava; along with tuberous root yield, they determine the production potential for flour and starch of a certain genotype (Ceballos et al., 2004).

The following group of genotypes evaluated presented significantly higher means of starch yield compared with the others ($p < 0.05$) in the 2006/2008 season: BGMC 1304, BGMC 923, BGMC 1286, BGMC 1130, and BGMC 991. In the 2007/ 009 harvest, the following genotypes showed averages significantly higher than the others ($p < 0.05$) for starch yield: BGMC 436, BGMC 993, BGMC 991, and BGMC 1305 (Table 2). Regarding starch yield, only the genotypes BGMC 993 and BGMC 991 (which correspond, respectively, to the variety of BRS Formosa and clone 03 of the cassava breeding program of Embrapa Cassava and Tropical Fruits) stood out compared with the others in both harvests. Starch yield is arguably the most important parameter when selecting industrial cassava genotypes for a particular region, since it reveals the ultimate productive potential of genotypes and, therefore, the profitability of the crop (Ceballos et al., 2004). It should also be considered when recommending a certain genotype for growing factors such as architecture, pulp color of tuberous roots, skin coloring of tuberous roots, resistance to pests and diseases, uniformity of roots, etc. (Ceballos et al., 2004).

Based on the analysis of the results, we can state that the region of Arinos in Minas Gerais state shows potential for cassava because i) the average of tuberous root yield of the experiments was greater than 30 t ha^{-1}, which is much higher than the average productivity of cassava in the Cerrado region –13 t ha^{-1} (IBGE, 2011); ii) the average starch yield in tuberous roots was greater than 28%; iii) the average starch yield was 8.6 t ha^{-1}; and iv) the average mass of shoots without strain was higher than 21 t ha^{-1}, which can be considered a good productivity fodder since the aerial part of cassava has approximately 13% of crude protein (Souza et al., 2011).

Over all, the genotypes that stood out compared with the others depending on the agronomic performance presented were BGMC 993 and BGMC 991 (which correspond, respectively, to the variety of BRS Formosa cassava and clone 03 of the cassava breeding program of Embrapa Cassava and Tropical Fruits). Among these, the BGMC 993 genotype had already been highlighted in an agronomical experiment conducted by Vieira et al. (2013) in Planaltina, Federal District.

Despite the fact that the genotypes BGMC 993 and BGMC 991 have been widely highlighted in this study, it is important to note that prior to recommending any of them for commercial planting in the Urucuia River Valley region, it is necessary to validate the agronomic performance of the same in a greater number of sites by using the methodology of participative selection of cassava varieties (Fialho & Vieira, 2011), which would obtain, in addition to agronomic data, information on the preference of producers.

4 Conclusions

The genotypes assessed differed in traits such as tuberous root yield, percentage of starch in tuberous roots, starch yield, and mass of shoots without strain. It was also possible to detect the influence of environmental factors on the expression of these characters and the presence of significant interaction between the genotypes and environmental factors.

The genotypes BGMC 993 and BGMC 991 showed high agronomic performance in both environments/crops, mainly with respect to the characters tuberous root yield and starch yield.

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