CROP BREEDING AND APPLIED BIOTECHNOLOGY

CULTIVAR RELEASE

BRS Boitatá and BRS Ocauçu: cassava cultivars for the industry

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Abstract: *BRS Boitatá and BRS Ocauçu cassava cultivars for the industry have high root and starch yields and high starch contents in first-cycle and second-cycle harvests, medium tolerance to the main diseases, adequate architecture for mechanized planting and stability in starch contents.*

Keywords: *Genetic breeding,* Manihot esculenta *Crantz, dry matter, starch yield, starch*

INTRODUCTION

Cassava roots contain around 35% dry matter, of which 65 to 90% correspond to starch (Sánchez et al. 2009). Cassava is the second most important source of starch, a product with wide application in the food, paper, textile, and pharmaceutical industries (Bashir and Aggarwal 2019).

This paper reports the selection process of the 2010 55-04 and 2010 56-18 cassava clones for the industry, registered under the names BRS Ocauçu and BRS Boitatá, respectively, for cultivation in the Midwest, Southwest, and West regions of the São Paulo state, Brazil (Brasil 2023).

STAGES OF THE PROCESS FOR OBTAINING AND SELECTING GENOTYPES

Crosses were carried out at Embrapa Cassava & Fruits, in 2009. The seeds were sown in tubes, and the plants obtained were transplanted at 60 days after sowing. Clone 2010 55-04 has Col-22 (BGM 0289 accession) as female parent and Pretinha (BGM 2029) as male parent. In turn, 2010 56-18 clone originated from the cross between BRS Guaíra (female) and IPR Baianinha (male). In 2011, 1600 genotypes (including 2010 55-04 and 2010 56-18) were sent to Embrapa Western Agriculture, in Dourados, Mato Grosso do Sul state, where they were evaluated in augmented blocks in 2011/12. In the year 2012/13 and subsequent years, the experiment was arranged in a randomized block design. The selection method employed was phenotypic mass selection.

EVALUATED CHARACTERISTICS

Reaction to superelongation (*Sphaceloma manihoticola*) was evaluated according to Alvarez and Molina (2000), while anthracnose (*Colletotrichum*

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gloeosporioides f. sp. *manihotis* Henn (Penz) Sacc) and bacterial blight (*Xanthomonas axonopodis* pv. *manihotis*) following Oliveira et al. (2016).

At the moment of harvesting, plant architecture (scale from 1 = best to 5 = worst; Ceballos et al. 2012) was evaluated, as well as root yield (RY), and a root sample was taken from each plot to determine the weights in air and in water, with a hydrostatic balance, to estimate the dry matter content (DMC), according to Kawano et al. (1987):

$$DMC\ (\%) = 158.3 \times \left[\frac{\text{weight in air}}{\text{weight in air} - \text{weight in water}}\right] - 142$$

Starch content (SC) was obtained by subtracting the constant 4.65 from DMC, and starch yield (SY) was calculated as the product of RY and SC. In 2013/14, the clones selected in Dourados were sent to other locations in the states of Mato Grosso do Sul, Paraná and São Paulo.

EVALUATION RESULTS

Disease reaction and plant architecture

The scores (1 to 5) of the reaction to bacterial blight (BB), superelongation (SE) and anthracnose (ANT) transformed into disease index (DI), according to Czermainski (1999), and of plant architecture (ARC), without transformation, are in Table 1. In BB, the DIs of BRS Ocauçu (0.40) and BRS Boitatá (0.43) were similar to those of the checks Cascuda, Fécula Branca and IAC 90 (0.40 to 0.47), and higher than the DI value of the check IPR Baianinha (0.30). In terms of SE and ANT, the DIs of BRS Ocauçu (0.30 in SE and ANT) were only lower than those of IAC 90 (0.47 in SE and ANT), while BRS Boitatá had the lowest DI (0.20 for both characteristics). In ARC, both cultivars had a score of 1, being suitable for mechanized planting (Table 1 and Figure 1).

Agronomic performance

In São Paulo, cassava is harvested around 12 months after planting (first cycle) or from 18 to 20 months (second cycle). Tables 2 and 3 show the data of the harvests in the first cycle (8 to 12 months after planting, MAP), and Tables 4 and 5 show the data of the second cycle (14 to 20 MAP).

Agronomic performance in the first cycle

In Table 2, in terms of RY and SY, BRS Ocauçu and BRS Boitatá surpassed the check IPR Baianinha in Dourados (2013/14) and Naviraí (2014/15), with 24.41 to 53.99% of superiority in RY and 26.27 to 59.44% in SY. In SC, the differences were not significant, except in Dourados (2012/13), where both surpassed IPR Baianinha by 11.05% and 9.45%, respectively, and Naviraí (2014/15), where BRS Boitatá was 10.35% superior. The CVs of RY (41.11%) and SY (43.63%) in Paranavaí (2014/15) were high. Akinbo et al. (2011) reported CV value higher than 40% for RY in cassava.

In Table 3, only in Marília and Campos Novos Paulista (12 MAP) the SC means of BRS Ocauçu and BRS Boitatá were significantly different from the mean of the check IAC 14, being lower (-3.71 and -2.37%, respectively) in Campos Novos Paulista and higher (9.94 and 12.09%) in Marília. Regarding to RY and SY, in Campos Novos Paulista (8 MAP), BRS Ocauçu and IAC 14 did not differ significantly, while BRS Boitatá was inferior (33.77% in RY and 34.60% in SY). In Campos Novos Paulista (12 MAP), the SY means of the two cultivars were 8.92 and 13.06% higher than those of IAC 14, due to the superiority in RY (12.27 and 15.20%). In Marília, although BRS Ocauçu did not differ from IAC 14 in RY, its superiority in SC (9.94%) allowed its SY mean to be 30.55% higher than that of the check, while BRS Boitatá was superior in terms of both RY (40.74%) and SY (47.74%). In Ocauçu, although the means of RY (52.67 t ha^{-1} and 59.10 t ha^{-1}) and SY

Table 1. Disease index (DI) values of bacterial blight (BB), superelongation (SE) and anthracnose (ANT) and plant architecture (ARC, scores 1 to 5, without transformation)

Genotype	Disease index*			ARC
	BB	SE	ANT	
BRS Ocauçu	0.40	0.30	0.30	1.0
BRS Boitatá	0.43	0.20	0.20	1.0
IPR Baianinha	0.30	0.23	0.23	1.7
Cascuda	0.47	0.23	0.23	1.0
Fécula Branca	0.43	0.27	0.27	1.0
IAC 90	0.40	0.47	0.47	1.0

* Disease index (DI) = score (of BB, SE or ANT) of each clone divided by the highest score of the disease in question.

Figure 1. Aerial part and roots of the cultivars BRS Ocauçu (photos on the left) and BRS Boitatá (photos on the right), highlighting the large soil cover and the erect growth habit (architecture), favorable to mechanized planting.

(16.70 t ha^{-1} and 18.60 t ha^{-1}) of BRS Ocauçu and BRS Boitatá were much higher than those of IAC 14 (RY: 20.93 t ha^{-1} and SY: 6.60 t ha^{-1}), the differences were not significant, probably due to the high CVs.

Agronomic performance in the second cycle

In Table 4, in Dourados, despite being 5.66% inferior to IAC 90 in SC, BRS Ocauçu was 14.04% superior in SY, due to its superiority (19.05%) in RY. BRS Boitatá was also superior to IAC 90 in terms of SY (15.28%), although the differences in RY and SC were not significant. In Naviraí, BRS Ocauçu did not differ significantly from IAC 90 in any characteristic, and BRS Boitatá was superior to the check in SC (6.03%). In Paranavaí, BRS Boitatá did not differ significantly from BRS 420 in RY, SC and SY. In turn, BRS Ocauçu also did not differ significantly from BRS 420 in SY,

Table 2. Means of root yield (RY, in t ha^{-1}), starch content (SC, in %) and starch yield (SY, in t ha^{-1}) in the municipalities of Dourados and Naviraí, Mato Grosso do Sul state and Paranavaí, Paraná state, in harvests carried out in the first cycle (10 to 11 MAP*)

Clones	Dourados 2012/13 (10 MAP)			Dourados 2013/14 (10 MAP)			Naviraí 2014/15 (10 MAP)			Paranavaí 2014/15 (10 MAP)			Paranavaí 2017/2018 (11 MAP)		
	RY	SC	SY	RY	SC	SY	RY	SC	SY	RY	SC	SY	RY	SC	SY
BRS Ocauçu	27.82a	33.95a	9.49a	41.59a	31.64a	13.29a	50.80a	33.49b	16.88a	20.54a	34.20a	7.09a	30.31a	37.31a	11.32a
BRS Boitatá	25.56a	33.35a	8.52a	37.15a	32.84a	12.24a	54.92a	35.18a	19.33a	26.46a	35.82a	9.51a	35.78a	34.51b	12.37a
BRS CS-01	-	-	-	-	-	-	-	-	-	-	-	-	35.36a	37.56a	13.28a
IPR Baianinha	24.28a	29.26c	7.14a	25.84b	32.01a	8.28c	25.27b	31.54b	7.84b	10.38a	30.48a	3.20a	-	-	-
Sup. Ocauçu (%)[1]	-	11.05	-	32.48	-	32.09	50.26	-	53.55	-	-	-	-	-	-
Sup. Boitatá (%)	-	9.45	-	24.41	-	26.27	53.99	10.35	59.44	-	-	-	-	-	-
CV (%)	17.43	3.41	18.48	19.42	4.95	21.01	20.23	4.9	20.24	41.11	6.37	43.63	14.92	1.89	14.5

* months after planting. [1] superiority (Sup.) = (mc-mt)/mc*100, where mc is the mean of the BRS Boitatá or BRS Ocauçu, and mt is the mean of the local check. In Dourados and Naviraí, as well as in Paranavaí (2014/15), mt is the mean of the check IPR Baianinha, while in Paranavaí (2017/18), the check is BRS CS 01. Superiority was not calculated in cases in which the difference between the means of the cultivar and the check was not significant. Means followed by the same letter in the column belong to the same group, by the Scott-Knott test at 5% probability level.

despite being 14.55% inferior in RY, due to its superiority of 3.48% in SC. BRS 420 (Rangel et al. 2022) and BRS CS 01 (EMBRAPA 2016) checks are two recently released cultivars, with high performance in root yield and starch yield. Therefore, the similarity of the cultivars BRS Ocauçu and BRS Boitatá with them indicates that both cultivars are also materials with superior performance.

Table 5 shows the means of the second cycle in the state of São Paulo. For SC, BRS Ocauçu and BRS Boitatá were inferior to the check IAC 14 in Ocauçu and did not differ significantly in Marília. For RY and SY, both were superior to the check in both sites, with superiority ranging from 7.17 to 37.17% in RY and from 9.00 to 32.10% in SY.

Supplemental evaluations

As starch is a reserve product, its content in cassava roots varies throughout the year. However, it is important that this content is as stable as possible, since starch factories and flour mills consider the starch content in the payment for the roots. Rangel et al. (2021) evaluated the variation in starch content of 6 clones, including 2010 55-04 (BRS Ocauçu) and 2010 56-18 (BRS Boitatá), in nine harvests, between 10 and 23.5 MAP. In terms of SC BRS Boitatá stood out among the best in six of the nine harvests (from 16 months onwards), while BRS Ocauçu stood out in eight harvests, showing their stability in relation to SC. Regarding to SY, except for BRS Ocauçu at 22 months, both cultivars were significantly superior to the others in all nine harvests, and BRS Boitatá stood out in terms of starch content recovery after pruning performed at 11 months. Silva et al. (2023) evaluated the cultivars BRS Boitatá and BRS Ocauçu at two sites in the state of São Paulo, in nine harvesting times between 7 and 21 MAP at one of the sites and ten harvesting times between 5 and 19 MAP at the other site. The starch contents of both cultivars were among the highest in most of the harvests.

Table 3. Means of root yield (RY, in t ha^{-1}), starch content (SC, in %) and starch yield (SY, in t ha^{-1}) in the municipalities of Campos Novos Paulista, Ocauçu and Marília, state of São Paulo, in harvests carried out in the first cycle (8 to 12 MAP*)

Clones	Ocauçu 2015/16 (11 MAP)			Marília 2016/17 (12 MAP)			Campos Novos Paulista 2017/18 (8 MAP)			Campos Novos Paulista 2017/18 (12 MAP)		
	RY	SC	SY	RY	SC	SY	RY	SC	SY	RY	SC	SY
BRS Ocauçu	52.67 a	31.30 a	16.70 a	42.80 b	33.90 b	14.50 b	34.21 a	33.97 a	11.63 a	29.90 a	33.69 b	10.09 a
BRS Boitatá	59.10 a	31.57 a	18.60 a	55.57 a	34.73 a	19.27 a	23.90 b	33.13 a	7.92 b	30.93 a	34.13 b	10.57 a
IAC 14	20.93 a	31.63 a	6.60 a	32.93 b	30.53 c	10.07 c	31.97 a	33.56 a	10.66 a	26.23 b	34.94 a	9.19 b
Sup. Ocauçu (%)[1]	-	-	-	-	9.94	30.55	-	-	-	12.27	-3.71	8.92
Sup. Boitatá (%)	-	-	-	40.74	12.09	47.74	-33.77	-	-34.60	15.20	-2.37	13.06
CV (%)	43.07	1.83	43.34	17.99	2.83	17.37	17.26	3.12	16.88	20.97	3.26	21.47

* months after planting. [1] superiority (Sup.) = (mc-mt)/mc*100, where mc is the mean of BRS Boitatá or BRS Ocauçu, and mt is the mean of the check IAC 14, in the four environments. Superiority was not calculated in cases in which the difference between the means of the cultivar and the check was not significant. Means followed by the same letter in the column belong to the same group, by the Scott-Knott test at 5% probability level.

Table 4. Means of root yield (RY, in t ha^{-1}), starch content (SC, in %) and starch yield (SY, in t ha^{-1}) in the municipalities of Dourados and Naviraí, Mato Grosso do Sul state and Paranavaí, Paraná state, in harvests carried out in the second cycle (14 to 20 MAP*)

Clones	Dourados 2013/15 (20 MAP)			Naviraí 2014/16 (19 MAP)			Paranavaí 2017/2018 (14 MAP)		
	RY	SC	SY	RY	SC	SY	RY	SC	SY
BRS Ocauçu	42.83 a	30.55 b	13.03 a	42.23 a	33.49 b	14.03 a	33.13 b	33.04 b	10.95 a
BRS Boitatá	40.68 b	32.49 a	13.22 a	48.06 a	35.18 a	16.91 a	37.34 a	31.82 c	11.88 a
BRS 420	-	-	-	44.50 a	31.94 b	14.27 a	37.95 a	31.89 c	12.10 a
IAC 90	34.67 b	32.28 a	11.20 b	37.54 a	33.18 b	12.45 a	-	-	-
Sup. Ocauçu (%)[1]	19.05	-5.66	14.04	-	-	-	-14.55	3.48	-
Sup. Boitatá (%)	-	-	15.28	-	6.03	-	-	-	-
CV (%)	38.33	6.55	40.33	24.55	4.37	23.79	8.95	1.4	8.74

* months after planting. [1] superiority (Sup.) = (mc-mt)/mc*100, where mc is the mean of BRS Boitatá or BRS Ocauçu, and mt is the mean of IAC 90 in Dourados and Naviraí, and BRS 420 in Paranavaí. Superiority was not calculated in cases in which the difference between the means of the cultivar and the check was not significant. Means followed by the same letter in the column belong to the same group, by the Scott-Knott test at 5% probability level.

Table 5. Means of root yield (RY, in t ha^{-1}), starch content (SC, in %) and starch yield (SY, in t ha^{-1}) in the municipalities of Ocauçu and Marília, state of São Paulo, Brazil, in harvests carried out in the second cycle (18 MAP*)

Clones	Ocauçu 2015/17 (18 MAP)			Marília 2016/18 (18 MAP)		
	RY	SC	SY	RY	SC	SY
BRS Ocauçu	42.97 a	31.92 b	15.80 a	58.67 a	34.10 a	20.00 a
BRS Boitatá	54.83 a	32.05 b	17.57 a	74.33 a	32.70 a	24.30 a
IAC 14	34.45 b	34.56 a	11.93 b	54.40 b	33.70 a	18.23 b
Sup. Ocauçu (%)[1]	19.83	-8.27	24.49	7.17	-	9.00
Sup. Boitatá (%)	37.17	-7.83	32.10	26.78	-	25.1
CV (%)	28.93	3.08	30.34	14.12	3.7	13.51

* months after planting. [1] superiority (Sup.) = (mc-mt)/mc*100, where mc is the mean of BRS Boitatá or BRS Ocauçu, and mt is the mean of the cultivar IAC 14, in both locations. Superiority was not calculated in cases in which the difference between the means of the cultivar and the check was not significant. MEANS followed by the same letter in the column belong to the same group, by the Scott-Knott test at 5% probability level.

OTHER IMPORTANT CHARACTERISTICS

The BRS Boitatá cultivar has roots with a white outer skin (Figure 1), which makes it interesting for both starch and flour production, another advantage of this cultivar. The plant architecture and leaf arrangement of both cultivars allow them to cover quickly the soil (Figure 1), reducing the need for weeding and the evaporation of water. Based on these results, BRS Ocauçu and BRS Boitatá were recommended for cultivation in the Midwest, Southwest and West regions of the state of São Paulo.

REGISTRATION, BASIC PLANT AND LICENSING OF PRODUCERS OF PLANTLETS AND STEM CUTTINGS

The cassava cultivars BRS Ocauçu and BRS Boitatá are registered in the Brazilian Registry of Cultivars (Registro Nacional de Cultivares – RNC) of the Ministry of Agriculture, Livestock and Food Supply (MAPA), under the numbers RNC 52403 (12/29/2022) and RNC 52400 (12/06/2022), respectively. The production of basic plants is under the responsibility of Embrapa Mandioca e Fruticultura, Rua Embrapa s/n, Bairro Chapadinha, Cruz das Almas, Bahia – CEP 44.380-000, Brasil. The strategy to make plantlets and stem cuttings available begins with the public offering of basic propagation material. The companies that want to produce and commercialize plantlets and/or stalk/stem cuttings of BRS Boitatá and BRS Ocauçu must buy lots and then produce by micropropagation or conventional multiplication. The licensing of producers of stem cuttings-seeds is under the responsibility of Embrapa Mandioca e Fruticultura and Balcão de Negócios Embrapa (Diretoria de Negócios – DENE), Parque Estação Biológica - PqEB, s/nº, Brasília, DF - CEP 70770-901 / Phone +55 (61) 3448-4433. The propagation material produced by licenses will be available for commercial crop cultivation for the 2024/2025 growing season.

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