ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 15, Issue, 04, pp. 68193-68196, April, 2025
https://doi.org/10.37118/ijdr.29291.04.2025

RESEARCH ARTICLE OPEN ACCESS

BRS 1668: SWEET CASSAVA WITH YELLOW PULP AND QUICK COOKING

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ARTICLE INFO

Article History:
Received 14th January, 2025
Received in revised form
06th February, 2025
Accepted 23rd March, 2025
Published online 30th April, 2025

KeyWords:
Genetic breeding, Manihot esculenta Crantz, Dry matter, Early maturity.

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ABSTRACT

BRS 1668 is a sweet cassava cultivar with yellow pulp, high root yield, early maturity, and short cooking time. It is the first cassava cultivar registered for cultivation in Rondônia, Brazil.It is an excellent option for growing at different altitudes, from the north to the south of the state.

Citation: Alexsandro Lara Teixeira, Rogério Sebastião Corrêa da Costa, Rodrigo Barros Rocha, Francisco das Chagas Leonidas, Vanderlei da Silva Santos, Eder Jorge de Oliveira, Tania Maria Alberte, Ladyslene Christhyns de Paula and Ana Carolina Andrade Silva, 2025. *"*BRS 1668: Sweet Cassava with yellow pulp and quick cooking*". International Journal of Development Research*, 15, (04), 68193-68196.

INTRODUCTION

Cassava production in the Amazon plays a crucial role in the region's economy, culture, and food security. Cassava, also known as manioc or yuca, is grown in several traditional agricultural systems adapted to the Amazon's climate and soil conditions. This crop serves as a staple food source for local communities, providing carbohydrates essential for their diets. The cultivation of cassava involves diverse indigenous and traditional knowledge passed down through generations (Modesto Junior & Alves 2016). Grown under different edaphic and climatic conditions, cassava is important for the food security of different regions of Brazil, especially because of the high adaptability of this species, which is able to produce in zones considered marginal due to low fertility or irregular rainfall distribution (Mendonça *et al*. 2020). The mean cassava root yield worldwide is around 12 t/ha, while the mean yield in Brazil is around 16 t/ha (IBGE 2024). In recent years, the North region of Brazil is the next to the last region in terms of yield, with a mean of 15.28 t/ha of roots, a yield greater only than that of the Northeast region (CONAB 2024).

This paper reports on the selection process of a sweet cassava clone for cooking and subsequent direct consumption registered under the name BRS 1668 for growing in all regions of the state of Rondônia, Brazil (Brazil 2024).

MATERIAL AND METHODS

Stages of the process for obtaining and selecting genotypes: The accession BGM 1668 was introduced into the active germplasm bank (BAG) of Embrapa Mandioca e Fruticultura in 1999, from the collection of Embrapa Amazônia Oriental - CPATU. The accession was collected from the side of the road BR 316 in the state of Pará at the following coordinates: 1º23' S, 45º25' W, and altitude of 21 meters. In 2014, 17 selected genotypes were sent to the experimental field of Embrapa Rondônia in the municipality/county of Ouro Preto do Oeste, RO, Brazil, including the accession BGM 1668, where they were evaluated over three crop seasons in three environments representing different regions of the state of Rondônia. The breeding

method used was mass selection. Quick cooking and yellow color were the most important characteristics in the selection process.

Experimental design and characteristics evaluated": Clonal competition trials were conducted in the environments of Porto Velho, Ouro Preto do Oeste, and Vilhena in the 2016/17, 2017/18, and 2018/19 crop years. The experimental units were set up in a randomized block experimental design with three replications at a spacing of 1 × 1meter and 16 treatments (cassava clones). The soil was amended with 2metric tons (t) of dolomitic limestone and fertilized in the plant hole with 50 g of triple superphosphate. Crop management and treatments followed the cassava production systems for the state of Rondônia (Costa *et al*. 2018). The traits evaluated were: weight of tuberous roots (kg.plant^{-1}), plant height (m), weight of the aerial part of the plant (kg.plant^{-1}), number of roots (count), number of rotted roots (count), percentage of rotted roots (%), root weight in water (kg.plant^{-1}), dry matter, starch content, and cooking test.

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

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

Starch content (SC) was obtained by subtracting the constant 4.65 from the DMC, and starch yield (SY) was calculated as the product of RY and SC.

RNC/MAPA) required for registration of the species *Manihot esculenta* Crantz (Table 1).

Agronomic performance: The clones were ranked according to their yield potential using the index proposed by Linn & Binns (1988), which considers the Euclidean distance between clone performance and an ideal plant of optimal performance in all the environments (Table 2). The performance of the clones in all the environments was represented in two planes using the centroid method (Rocha *et al*. 2005). This method uses the dispersion of the first principal components associated with reference points (ideotypes) of known response (Figure 1). After classification of the environments as favorable (f) or unfavorable (u), the genotypes were classified in relation to five ideotypes of known response described as follows: I – high general adaptability (Max.fav., Max.unfav.), II – specific adaptability to favorable environments (Max.fav., Min.unfav.), III – specific adaptability to unfavorable environments (Min.fav, Max.unfav.), IV – little adapted (Min.fav, Min.unfav.), V – high stability, low adaptability (Med.fav., Med.unfav.). The accession BGM 1668 showed yield performance above the mean of the experiment in all the environments. This accession had mean yield over the three year of 16.7 metric tons.ha^{-1}, with 25.6 t/ha in Ouro Preto do Oeste, 16.4 t/ha in Porto Velho, and 9.9 t/ha in Vilhena (Table 3). Starch, which constitutes around 70-80% of the dry matter of cassava roots, is one of the root properties most important for cooking. In the environments of Porto Velho, Ouro Preto, and Vilhena, the dry matter contents of this cultivar were 31.98%, 33.27%, and 27.60%, respectively, while the starch contents were 27.33%, 28.62%, and 22.95% (Table 4). The mean percentage of rotted roots of this cultivar was 2.72%. This cultivar had better performance than the varieties Pirarucu and Cacau, widely grown in

Table 1. Main morphological traits of the roots and shoots of the accession BGM 1668

Root traits	Shape: conical-cylindrical
	Peel color: medium brown
	Pulp color: cream
	Cortex color: white
Shoot traits	Terminal bud color: green
	Color of terminal branches: green
	Petiole color: light green
	Stem color: light brown
	Leaf lobe shape: narrow lanceolate

Table 2. Yield of 16 cassava clones measured in kg.plant-1 in the environments of Porto Velho, Ouro Preto do Oeste, and Vilhena, Rondônia, Brazil, over three crop years (2016/17, 2017/18, 2018/19)

Clone	Porto Velho			Ouro Preto do Oeste			Vilhena		
	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019	2016-2017	2017-2018	2018-2019
CPM09[2]	1.24	2.14	2.60	1.89	1.46	1.89	1.65	1.32	0.67
Acre1	1.52	1.23	0.59	1.46	1.58	1.98	1.38	1.97	0.81
91-21-05	1.48	1.27	0.47	2.04	1.64	1.13	1.03	0.89	0.33
BRS Gema de Ovo[1]	2.33	2.70	2.24	2.92	2.64	2.77	1.63	2.10	1.11
EAB 451 E[1]	2.33	2.38	0.76	1.63	3.88	5.08	1.38	2.63	0.86
BGM 1668[3]	1.47	1.68	1.78	3.14	1.75	2.77	1.32	1.13	0.51
Caipó[3]	1.87	2.09	1.25	2.39	3.04	3.42	0.95	1.99	0.54
Pirarucu	1.92	1.21	1.24	2.17	1.56	2.19	1.43	2.09	0.91
BRS Kiriris[1]	2.84	3.63	0.89	1.88	1.96	2.00	1.93	1.51	1.14
Xingu[2]	2.73	2.24	1.13	1.73	1.38	2.14	1.46	2.11	1.11
17-21	1.29	1.35	1.08	2.33	0.73	1.00	1.25	0.52	0.69
BRS Dourada[1]	1.98	2.00	2.91	2.89	3.02	3.88	1.51	2.79	1.38
Cacau	1.68	1.60	0.65	1.25	0.94	1.39	1.81	1.76	1.06
Vara-de-canoa[4]	1.30	1.32	1.38	2.06	1.98	2.69	1.68	1.89	1.24
CNPMF 043	1.39	1.95	0.64	1.71	1.23	2.21	1.39	1.95	0.64
96-07-07	0.96	1.01	0.51	0.50	0.44	0.48	0.96	1.01	0.51
MEAN	1.77	1.86	1.26	2.00	1.83	2.31	1.42	1.73	0.84

1Clones that showed good yield performance in the three environments, 2Clones that showed better yield performance in the municipality/county of Porto Velho, 3Clones that showed better yield performance in the municipality/county of Ouro Preto do Oeste, 4Clones that showed better yield performance in the municipality/county of Vilhena.

EVALUATION RESULTS

Morphological traits: The data on morphological characterization of the shoots and roots were evaluated according to the descriptors of the National Cultivar Registry (Registro Nacional de Cultivares –

the region, which had rotted root percentages of 7.59% and 9.31%, respectively (Table 5). The high adaptability of this crop, understood as its capacity to produce in regions considered marginal, makes the yield potential measured in kilograms of roots produced per plant one of the most important traits for plant selection.

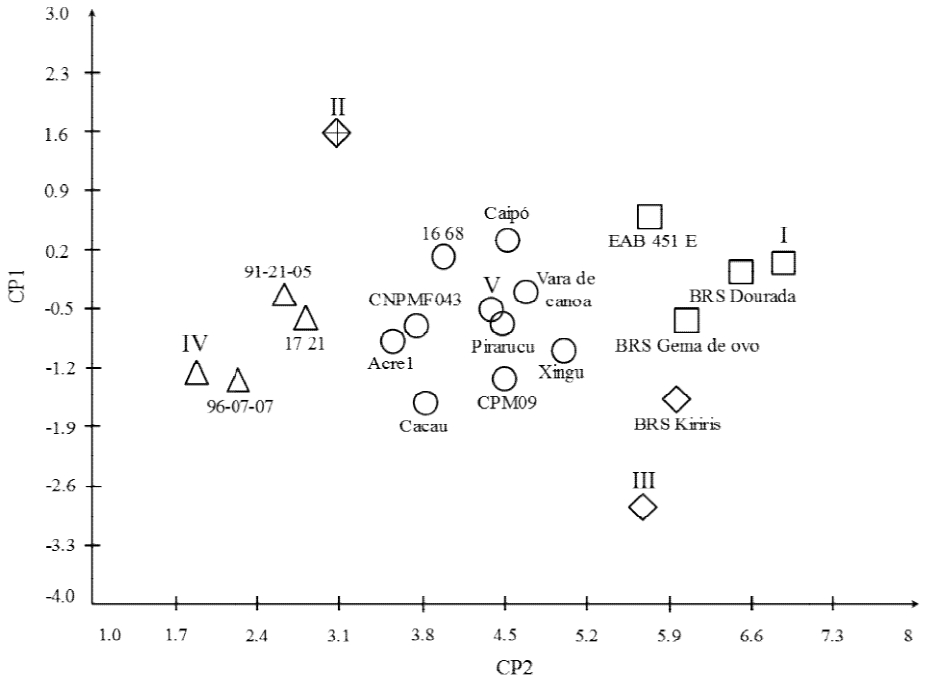

Figure 1. Scatter plot of the first two principal components of the root weight of 16 clones of Manihot esculenta evaluated in 3 clonal competition trials (environments) conducted in the municipalities/counties of Porto Velho, RO; Ouro Preto do Oeste, RO; and Vilhena, RO. The points numbered with Roman numerals represent the reference points that show maximum and minimum performances in environments classified as favorable (f), or unfavorable (u): I – high general adaptability, II – specific adaptability to favorable environments, III – specific adaptability to unfavorable environments, IV– little adapted, V – high stability, low adaptability

Table 3. Mean yield over three years measured in tons.hectare-1 of 16 cassava clones evaluated in the environments of Porto Velho (A1), Ouro Preto do Oeste (A2), and Vilhena (A3), Rondônia, Brazil, over three crop years, ranking the clones from greatest general adaptability to those of lowest adaptability, according to the criteria of Linn & Binns (1988).

Clone	A_1	A_2	A_3	Ranking (P_i general)
BRS Dourada	22.9	32.6	18.9	1
EAB 451 E	18.3	35.3	16.3	2
BRS Gema de Ovo	24.3	27.8	16.1	3
BRS Kiriris	24.6	19.4	15.3	4
Caipó	17.4	29.5	11.6	5
Xingu	20.3	17.5	15.6	6
BGM 1668	16.4	25.6	9.9	7
Vara-de-canoa	13.3	22.4	16	8
CPM09	19.9	17.5	12.1	9
Pirarucu	14.5	19.8	14.8	10
CNPMF 043	13.3	17.1	13.3	11
Acre1	11.1	16.8	13.9	12
Cacau	13.1	11.9	15.4	13
91-21-05	10.7	16.1	7.5	14
17-21	12.4	13.6	8.2	15
96-07-07	8.3	4.8	8.3	16
MEAN	16.3	20.5	13.3	

Table 4. Mean yield (T/ha), dry matter content (DM), starch content, and percentage of rotted roots of the accession BGM 1668 in three municipalities/counties of the state of Rondônia, Brazil. Crop years 2016/17, 2017/18, 2018/19

Environment	T/ha	DM (%)	Starch (%)	Rotted roots (%)
Porto Velho	16.40	31.98	27.33	3.68
Ouro Preto	25.60	33.27	28.62	1.99
Vilhena	9.90	27.60	22.95	2.51
Overall mean	17.30	30.95	26.30	2.72

Table 5. Mean yield (T/ha), dry matter content (DM), starch content, and percentage of rotted roots of the accession BGM 1668 in comparison with the Pirarucu and Cacau "varieties" used by farmers in Rondônia. Crop years 2016/17, 2017/18, 2018/19

Clone	T/ha	DM (%)	Starch (%)	Rotted roots (%)
BGM 1668	17.30	30.95	26.30	2.72
Pirarucu	16.36	32.88	28.23	7.59
Cacau	13.46	32.51	27.86	9.31

Root yield depends on the response of plants to the environments in which they are grown. This interaction between plants and environments, called the genotype × environment interaction, must be evaluated through growing plants in different locations, seeking to identify cultivars of general adaptation that have good yield performance in a series of environments, cultivars with specific adaptation, and cultivars with low adaptability in a certain region (Cruz *et al*. 1989, Falconer 1987).

Cooking Test: Cooking time (C.T.; minutes) was evaluated in harvests carried out at 6, 9, and 12 months after planting. The roots were collected in the experimental fields of Porto Velho, RO. Ten random roots were used per plot. A piece of around 5 cm was removed from the central region of each of these roots. These ten pieces were peeled and washed and then placed in a pot containing 1.5 liters of boiling water, where they were cooked for a maximum time of 30 minutes. The level of cooking of the root was evaluated using a fork, considering that the root is cooked when the pulp no longer resists fork penetration. The cooking time of the sample is considered when 50% +1 of the pieces are cooked. An FFI 440 industrial stove, LP gas, was used, with burner output of 6.00kW. Cooking time of the accession BGM 1668 was 10 minutes, at 6 and 9 months, with 100% of the roots cooked; and 25 minutes at 12 months, with 70% of the roots cooked (Table 6). The cooking time, softness, and absence of fiber, associated with the yellow color of the pulp, were the main differentials for recommendation of registration of the accession BGM 1668 in MAPA. The morphological and agronomic traits of the cultivar BRS 1668 are shown in Figure 2.

Table 6. Mean values of cooking time (in minutes) among the cassava roots collected in the three harvest phases (harvested at 6, 9, and 12 months after planting), 2024.

Harvest (after planting)	Cooking time (min.) before freezing	Cooking time (min.) after freezing
6 months	14.27	14.32
9 months	14.33	14.45
12 months	15.80	16.10

Figure 2. Cultivar BRS 1668 - (A) Shoots, highlighting the extensive soil cover and upright growth habit. (B) Root volume and distribution for the plant. (C) Visual appearance of the roots with peel. (D) Visual appearance of the peeled roots.

Registration, basic plants, and licensing of producers of plantlets and stem cuttings: The cassava cultivar BRS 1668 is registered in the Brazilian Cultivar Registry (Registro Nacional de Cultivares – RNC) of the Brazilian Ministry of Agriculture (MAPA) under number RNC 51131 (28 April 2022). The production of basic plants is under the responsibility of Embrapa Rondônia, Rodovia BR 364, km 5,5 - s/n, Cidade Jardim, Porto Velho, RO, Brazil, CEP 76815-800. The strategy for making plantlets and stem cuttings available begins with a public offer of basic propagation material. The companies that want to produce and commercialize plantlets and/or stalk/stem cuttings of BRS 1668 must buy lots and then produce plantlets by micropropagation or conventional multiplication. Producers of stem cuttings-seeds are licensed under the responsibility of Embrapa Rondônia and the Balcão de Negócios Embrapa (Diretoria de Negócios – DENE), Parque Estação Biológica - PqEB, s/nº, Brasília, DF, Brazil - CEP 70770-901 / Phone +55 (61) 3448-4433.

Conflict of Interests: The authors have not declared any conflict of interests.

Acknowledgements: The authors thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Capes) and the Empresa Brasileira de Pesquisa Agropecuária (Embrapa) for the scholarship granted, and JIRAU Energia for funding.

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