BRS 429: sweet cassava with yellow pulp and high technological and sensory qualities

Eduardo Alano Vieira[1*], Marco Antônio Sedrez Rangel[2], Josefino de Freitas Fialho[1], Rudiney Ringenberg[2], Marcelo Ribeiro Romano[2], Maria Madalena Rinaldi[1], Charles Martins de Oliveira[1] and Jorge Cesar dos Anjos Antonini[1]

Abstract: *BRS 429 is a sweet cassava cultivar with yellow pulp and technological qualities (high root yield, early maturity, and favorable plant architecture) and sensory qualities (short cooking time, little fiber, and soft texture) that make it an excellent option for cultivation in the Distrito Federal, Paraná, and São Paulo, Brazil.*

Keywords: *Manihot esculenta Crantz, plant breeding, culinary qualities, short cooking time.*

INTRODUCTION

The growing and the commercial trade of sweet cassava have been going through a process of expansion and professionalization in the green belt areas of large Brazilian cities (Mendonça et al. 2020). Readjustment of the market has been motivated by a continuous and growing demand of consumers for products that combine practicality for consumption, as well as health (Rinaldi et al. 2017), sensory (Vieira et al. 2018), and nutritional (Carvalho et al. 2011) qualities.

In the Brazilian Distrito Federal and in the states of Paraná and São Paulo, there has been an integration of the sweet cassava production system with cultivation of horticultural crops such as bell pepper, tomato, cauliflower, carrot, and strawberry (Vieira et al. 2018, Mendonça et al. 2020). This has led to the use of technologies that were not imagined in growing cassava up to a short time ago, such as liming, gypsum application, fertilization, mechanized planting, use of plant beds, irrigation, staggered planting, and use of plastic cover (Fialho and Vieira 2013, Antonini et al. 2020). In a parallel manner, technologies are being developed by research for overcoming technological bottlenecks in processing root crops (Rinaldi et al. 2017), for agricultural production (Antonini et al. 2020), and for diversification of growing options (Vieira et al. 2018, Vieira et al. 2019).

In this context, the Empresa Brasileira de Pesquisa Agropecuária (Embrapa) is making the sweet cassava cultivar BRS 429 available to growers of the Distrito Federal and states of São Paulo and Paraná. It is a superior cultivar regarding technological characteristics (high tuberous root yield, architecture favorable to mechanized planting, responsiveness to irrigation, ease of outer and inner peel removal, and early maturity) and sensory characteristics (low HCN contents in

*Corresponding author:
E-mail: eduardo.alano@embrapa.br
ORCID: 0000-0003-4931-3895

[1] Embrapa Cerrados, Rodovia BR 020, km 18, Planaltina, 73310-970, Brasília, DF, Brazil
[2] Embrapa Mandioca e Fruticultura, Rua Embrapa, s/n, 44380-000, Cruz das Almas, BA, Brazil

the roots, yellow root pulp color, short cooking time, characteristic flavor, and soft texture).

BREEDING METHOD

The segregating population, from which the yellow-pulp sweet cassava cultivar BRS 429 was selected, was obtained in the 2008/2009 crop year from a cross between the cultivars IAPAR 19 and IAC 576-70. The parents were chosen for combining high agronomic performance with genetic (0.58) and phenotypic (0.44) divergence (Vieira et al. 2011), which, as a rule, facilitates transgressive segregation and selection among descendants.

In the 2009/2010, 2010/2011, and 2011/2012 crop years, the first evaluation and selection cycles were conducted in an experimental area of Embrapa Cerrados in Planaltina, DF, Brazil (lat 15º 35.467' S, long 47º 42.617' W, alt 1,007 m asl), according to the breeding method commonly used at Embrapa Cerrados (Vieira et al. 2018, Vieira et al. 2019, Vieira et al. 2020, Rangel et al. 2022). Planting and harvest activities were carried out in November of the respective years, and management practices followed the recommendations of the cassava production system for the central Brazilian Cerrado area (Fialho et al. 2013, Fialho and Vieira 2013).

In the 2009/2010, 2010/2011, and 2011/2012 crop years, selection was made considering technological criteria such as i) root yield, ii) resistance to pests and diseases, iii) early maturity, iv) height of the first branching favorable to mechanized planting, v) root uniformity, vi) ease of harvest, vii) ease of outer and inner peel removal, and vii) responsiveness to irrigation; as well as sensory criteria, such as i) low hydrogen cyanide (HCN) content in the roots, ii) yellow-colored root pulp, iii) short cooking time, iv) characteristic flavor, v) quality of the pulp, and vi) little fiber. In the Embrapa Cerrados selection phase, the cultivar BRS 429 received the name clone 900/10, and it remained with this name throughout the validation process conducted in the Distrito Federal, São Paulo, and Paraná from 2010 to 2021.

For two crop years (2015/2016 and 2016/2017), the distinguishability, homogeneity, and stability trials of cassava cultivars of the Brazilian Ministry of Agriculture (Ministério da Agricultura, Pecuária e Abastecimento - MAPA) were conducted at the Northwest regional campus of the Universidade Estadual de Maringá (UEM) in Diamante do Norte, PR (lat 22º 37.933' S, long 52º 54.017' W, alt 370 m asl). In this step, in addition to the traits evaluated in the last two selection cycles in each plot of the experiments, HCN content in the roots was also estimated in mg kg^{-1} by the qualitative method, described by Willams and Edwards (1980), taking five roots at random per plot.

EVALUATIONS IN THE STATES OF PARANÁ AND SÃO PAULO

In Paraná, the experiments were conducted at Marechal Cândido Rondon (lat 24º 29.500' S, long 54º 18.217' W, alt 410 m asl) in the 2014/2015 crop year, Diamante do Norte (lat 22º 37.933' S, long 52º 54.017' W, alt 370 m asl) in the 2015/2016 and 2016/2017 crop years, and in Sertanópolis (lat 23º 10.017' S, long 51º 05.001' W, alt 525 m asl) in the 2017/2018 crop year. In São Paulo, the experiments were conducted in the municipalities of Bebedouro (lat 20º 53.250' S, long 48º 28.417' W, alt 601 m asl) in the 2017/2018 crop year and Limeira (lat 22º 28.750' S, long 47º 17.817' W, alt 607 m asl) in the 2017/2018 crop year. The sweet cassava cultivars IAC 576-70, IAPAR 19, and BRS 399 were the check cultivars, as they are recommended for planting in the states of Paraná and São Paulo and because IAC 576-70 and IAPAR 19 are the parents of BRS 429.

A randomized block experimental design was used with three replications, and each plot was composed of four rows with ten plants at a spacing of 0.9 m between rows and 0.8 m between plants in the row. The area used for data collection was represented by the 16 center plants. Selection of the propagation material and the crop practices followed the recommendations for growing cassava in the South-Central region of Brazil (Otsubo and Lorenzi 2004). Cassava was planted in July and August and harvested from May to June of the respective crop years.

At 11 months after planting, the technological traits of root yield (RY) in t ha^{-1} and percentage of commercializable roots (CR) were assessed. Commercializable roots were considered as those with diameter greater than 45 mm and length from 20 to 45 cm. The following sensory traits were also assessed: cooking time (CT) in minutes, root pulp color, fiber content in the roots, and texture of the cooked pulp, according to Borges et al. (1992).

In the state of Paraná, the cultivar BRS 429 had root yield (RY) 25.7% greater than the mean value of the check cultivars, and it statistically exceeded the mean of at least one of the check cultivars in all the evaluation locations (Table 1). In

relation to percentage of commercializable roots, the cultivar BRS 429 exceeded the mean value of the check cultivars by 10.5% and did not have a percentage of commercializable roots lower than any of the check cultivars used in any of the evaluation locations (Table 1). In the experiments conducted in São Paulo, the cultivar BRS 429 exhibited root yield 53.9% greater than the mean of the check cultivars and was numerically greater than the mean of the percentage of commercializable roots of the check cultivars (Table 2).

In evaluations regarding sensory traits, no significant differences were detected regarding cooking time among the cultivars tested. All the cultivars exhibited cooking times of less than 30 minutes, that which is expected for good sweet cassava cultivars (Borges et al. 2002), with mean values ranging from 23.17 minutes (BRS 399) to 19.10 minutes (IAPAR 19); the cultivar BRS 429 exhibited a mean value of 20.23 minutes for cooking. For the traits of root texture and presence of fiber, variation among the cultivars was likewise not detected, since all had a starchy texture and absence of fiber in the roots, which indicates good quality pulp (Borges et al. 1992).

Regarding the color of the root pulp, a variation was found among the cultivars tested; BRS 399 and BRS 429 were classified as having yellow pulp color, and IAC 576-70 and IAPAR 19 were classified as having cream-colored pulp. The yellow root pulp color is a competitive advantage for BRS 429 since it is associated with the presence of carotenoids in the roots (Carvalho at al. 2011), and it is preferred by consumers (Vieira et al. 2018). All the cultivars had low values (25-40 ppm) for HCN content in the roots, which confirms their classification as sweet cassava.

The BRS 429 cultivar has potential for growing in the states of Paraná and São Paulo due to its technological qualities (high root yield and percentage of commercializable roots) and sensory qualities (short cooking time, yellow root pulp color, starchy texture, and absence of fiber).

EVALUATION IN THE DISTRITO FEDERAL AND SURROUNDING AREA

In the Distrito Federal and surrounding area, the agronomic performance of the cultivar BRS 429 was estimated through overseeing 23 participatory research units (UPP) in the 2018/2018, 2018/2019, 2019/2020, and 2020/2021 crop years (Table 3). In the UPPs, the sweet cassava cultivar IAC 576-70 was used as a check cultivar, as it is recommended

Table 1. Mean root yield in t ha^{-1} and percentage of commercializable roots evaluated in sweet cassava cultivars in the municipalities of Marechal Cândido Rondon (MCR), Diamante do Norte (DN), and Sertanópolis (ST) in the state of Paraná, Brazil, in the 2014/2015 (14/15), 2015/2016 (15/16), 2016/2017 (16/17), and 2017/2018 (17/18) crop years

Cultivar	Root yield (t ha^{-1})					Percentage of commercializable roots (%)			
	MCR (14/15)	DN (15/16)	DN (16/17)	ST (17/18)	Mean	DN (15/16)	DN (16/17)	ST (17/18)	Mean
BRS 429	19.0 A[*]	24.8 A	27.1 A	28.8 A	24.9	84.4 A	93.0 A	90.6 A	89.3
IAC 576-70	-	18.2 B	20.4 B	19.8 B	19.5	72.8 B	66.3 C	90.6 A	76.6
IAPAR 19	12.5 B	21.0 B	19.7 B	27.3 A	20.1	70.6 B	85.8 B	90.6 A	82.3
BRS 399	-	26.2 A	20.8 B	26.9 A	24.6	71.2 B	88.2 B	91.1 A	83.5
Mean - check cultivars	12.5	21.8	20.3	24.7	19.8	71.5	80.1	90.8	80.8
Superiority (%)	52.0[**]	13.8	33.5	16.6	25.7	18.0	16.1	0.0	10.5

[*] Mean values followed by the same letter in the column belong to the same group at 5% probability of error by the Scott and Knott means clustering test; [**] Percentage of superiority of BRS 429 in relation to the mean of the check cultivars.

Table 2. Mean root yield in t ha^{-1} and percentage of commercializable roots evaluated in sweet cassava cultivars in the municipalities of Bebedouro (BD) and Limeira (LM) in the state of São Paulo, Brazil, in the 2017/2018 crop year

Cultivar	Root yield (t ha^{-1})			Percentage of commercializable roots (%)		
	BD	LM	Mean	BD	LM	Mean
BRS 429	24.1 A[*]	15.2 A	19.7	82.0 A	92.1 A	87.1
IAC 576-70	10.5 B	9.9 B	10.2	73.6 B	92.0 A	82.8
IAPAR 19	16.5 B	14.2 A	15.4	72.9 B	94.9 A	84.1
Mean – check cultivars	13.5	12.1	12.8	73.3	93.5	83.5
Superiority (%)	78.5[**]	25.6	53.9	11.9	-1.5	4.3

[*] Mean values followed by the same letter in the column belong to the same group at 5% probability of error by the Scott and Knott means clustering test; [**] Percentage of superiority of BRS 429 in relation to the mean of the check cultivars.

Table 3. Locations of evaluation of the cultivar BRS 429 in the Distrito Federal and surrounding area with respective geographic coordinates, altitude, planting date, harvest date, and cycle in months

Location	Geographic coordinates		Altitude (m)	Planting date (dd/mm/yyyy)	Harvest date (dd/mm/yyyy)	Cycle in months
	S	W				
1. Planaltina, DF	15º45.625'	47º35.254'	813	01/02/2018	01/11/2018	9
2. Paranoá, DF	15º59.650'	47º34.992'	1034	15/08/2018	30/05/2019	10
3. Planaltina de Goiás, GO	15º27.923'	47º38.603'	926	21/08/2018	26/06/2019	10
4. Planaltina, DF	15º38.663'	47º40.951'	957	06/06/2019	15/05/2020	11
5. Paranoá, DF	15º59.650'	47º34.992'	1034	23/06/2019	29/05/2020	11
6. Gama, DF	15º59.796'	48º07.191'	954	28/06/2019	12/06/2020	12
7. Gama, DF	15º59.927'	48º07.398'	928	28/06/2019	12/06/2020	12
8. Planaltina de Goiás, GO	15º27.923'	47º38.603'	926	21/07/2019	22/06/2020	11
9. Planaltina, DF	15º45.634'	47º35.251'	978	01/08/2019	16/06/2020	11
10. Paranoá, DF	15º59.650'	47º34.992'	1034	07/06/2020	27/05/2021	12
11. Paranoá, DF	15º58.347'	47º30.046'	913	01/06/2020	21/05/2021	12
12. Gama, DF	15º59.796'	48º07.191'	954	26/06/2020	14/05/2021	11
13. Gama, DF	16º00.049'	48º07.156'	925	01/08/2020	04/08/2021	12
14. Planaltina de Goiás, GO	15º27.923'	47º38.603'	926	05/08/2020	06/05/2021	9
15. Planaltina, DF	15º37.843'	47º31.310'	1010	27/08/2020	21/07/2021	11
16. Planaltina, DF	15º40.643'	47º38.184'	968	10/09/2020	15/06/2021	9
17. Paranoá, DF	15º27.923'	47º38.603'	926	01/10/2020	06/08/2021	10
18. Brazlândia, DF	15º43.424'	48º11.183'	1065	23/10/2020	10/08/2021	10
19. São Sebastião, DF	15º53.702'	47º43.183'	950	06/11/2020	13/10/2021	11
20. São Sebastião, DF	15º54.595'	47º43.335'	955	10/11/2020	22/09/2021	11
21. Planaltina, DF	15º40.184'	47º38.383'	963	30/11/2020	25/10/2021	11
22. Recanto das Emas, DF	15º54.041'	48º04.817'	1156	05/12/2020	03/11/2021	11
23. Paranoá, DF	15º44.669'	47º44.025'	1125	05/11/2020	04/11/2021	12

for growing in the Distrito Federal. The cultivars were evaluated in plots of 5 rows with 10 plants per row at a spacing of 1.20 m between rows and 0.80 m between plants; the area used for data collection consisted of the 24 central plants. The crop treatments followed that which was commonly applied by the growers selected for the participatory research; the only change in the production process was the cultivar factor (Fialho and Vieira 2011).

Although the mean value for plant height (PH) of the cultivar BRS 429 (2.47 m) was numerically greater than that of the check cultivar (2.18 m), statistically significant differences were not observed (Table 4). This indicates that both BRS 429 and the check cultivar have PH within the range of variation expected for a good sweet cassava cultivar (Vieira et al. 2018).

For first branch height (FBH), a significant variation was detected between BRS 429 and the check cultivar (Table 4). The FBH is very important at the time of cassava cultivar selection because it is directly related to plant architecture and, consequently, the ease of crop treatments, availability of plant propagation material, and ease of mechanized planting. Plants that have higher FBH or those that do not branch out are preferable. The results obtained showed the superiority of BRS 429, with a mean FBH of 1.47 m, which represents an increase of 0.66 m or 89% in the FBH in relation to the check cultivar (Table 4).

For root starch content (RS), no significant difference was observed between BRS 429 (29.97%) and the check cultivar (29.12%) (Table 3). RS is not very important in selection of sweet cassava cultivars, unless the intention is to make use of the roots for dual purposes (direct consumption and industrial processing).

In relation to mean root yield (RY), a characteristic that is directly reflected in profitability, BRS 429 (51 t ha^{-1}) was superior to the check cultivar (36 t ha^{-1}). The yield difference was 15 t ha^{-1}, around 42% (Table 4). For the cooking time variable, there was no variation between BRS 429 and the check cultivar, since the roots of both cultivars cooked up in less than 30 minutes in all the evaluations, showing that both have good qualities for culinary purposes.

Table 4. Mean values of the traits of first branch height (FBH) in meters, plant height (PH) in meters, root yield (RY) in kg ha^{-1}, and root starch content (RS), evaluated in the sweet cassava cultivars BRS 429 and IAC 576-70 (check cultivar), obtained through over-seeing 23 participatory research units in the 2018/2018, 2018/2019, 2019/2020, and 2020/2021 crop years in the Distrito Federal and surrounding areas

Location	FBH (m)		PH (M)		RY (kg ha^{-1})		RS (%)	
	BRS 429	IAC 576-70	BRS 429	IAC 576-70	BRS 429	IAC 576-70	BRS 429	IAC 576-70
1	1.50	0.80	2.80	2.50	31.67	25.33	25.31	25.01
2	1.75	0.80	3.20	2.80	46.15	38.30	30.61	30.01
3	1.05	0.75	2.70	1.80	41.20	28.84	29.49	28.54
4	1.80	0.95	2.80	2.30	36.25	29.36	30.53	30.01
5	1.80	0.95	3.30	2.80	71.84	56.75	33.73	32.98
6	1.05	0.75	2.00	1.80	45.00	32.40	30.95	30.54
7	1.90	1.00	3.10	2.85	49.60	32.74	29.10	29.00
8	0.90	0.70	1.90	1.80	105.63	52.94	30.23	29.01
9	1.50	0.80	3.00	2.85	36.52	32.14	28.13	27.65
10	1.50	0.70	2.50	2.20	61.08	40.98	29.93	29.04
11	1.25	0.65	2.60	2.35	76.43	43.50	33.25	32.58
12	1.30	0.45	2.50	1.60	42.48	25.91	30.18	30.53
13	2.15	0.90	3.30	2.80	54.17	47.67	28.65	28.04
14	1.25	0.55	2.25	2.00	47.27	33.29	30.65	29.85
15	1.80	1.00	3.10	3.00	71.54	50.00	29.34	29.10
16	1.05	0.75	2.30	2.20	54.00	32.92	31.78	30.89
17	2.00	1.00	3.90	2.95	35.33	22.97	28.34	28.24
18	1.25	0.70	2.90	2.70	56.98	39.57	31.09	30.58
19	1.68	0.65	1.10	0.95	45.08	37.87	32.50	31.58
20	1.56	0.55	1.20	1.00	38.49	29.64	30.25	29.57
21	1.55	0.75	2.00	2.30	33.63	28.24	27.01	22.65
22	1.00	0.70	2.00	1.80	48.13	37.92	27.43	24.38
23	0.45	0.30	1.50	1.20	28.44	20.46	26.14	25.87
Mean	1.40*	0.74*	2.47	2.18	51.15*	36.11*	29.97	29.12

* Significant at 5% probability of error by the *t*-test of means comparison.

The cultivar BRS 429 has agronomic performance that justifies recommendation for growing in the region of the Distrito Federal and surrounding area as it has yellow root pulp color (market requirement), low hydrogen cyanide content in the roots (25-40 ppm), high root yield (42% superior to the check cultivar), good cooking qualities (cooks up within the standards required by the market), plant architecture that facilitates crop treatment and mechanized planting (high first branch height), plant height within the interval desired for good sweet cassava cultivars, moderate resistance to bacterial and superelongation diseases (the main diseases in the region), and early maturity (harvest as of 9 months after planting).

REGISTRATION, PROTECTION, BASIC PLANT AND LICENSING OF PRODUCERS OF STEM CUTTINGS-SEEDS

The cultivar BRS 429 is registered (no. 42613) and protected (no. 20200145) by the Brazilian Ministry of Agriculture (MAPA). The production of basic plants and the licensing of producers of stem cuttings-seeds are under the responsibility of the Secretaria de Inovação e Negócios da Embrapa - Escritório de Brasília, Rodovia DF 001, km 69, Caixa Postal 999, Riacho Fundo I, CEP 71805-970, Brasília/DF. Telephone (61) 3333-0417, E-mail: spm.ebsb@embrapa.br.

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