CROP BREEDING AND APPLIED BIOTECHNOLOGY

CULTIVAR RELEASE

BRS Progresso and BRS Rendeira – new cassava cultivars with tolerance to post-harvest deterioration

Crop Breeding and Applied Biotechnology
23(1): e444723110, 2023
Brazilian Society of Plant Breeding.
Printed in Brazil
http://dx.doi.org/10.1590/1984-70332023v23n1c10

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Abstract: *BRS Rendeira and BRS Progresso are cassava (Manihot esculenta Crantz) cultivars with tolerance to post-harvest deterioration and high mean yields of fresh root (31.1 and 27.9 t ha^{-1}) and starch (8.9 and 8.1 t ha^{-1}) in annual production cycles. Both new varieties are recommended for the flour and starch industry.*

Keywords: *Manihot esculenta Crantz, industrial variety, shelf-life, root yield*

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a staple food crop for millions of people, and is the third most important source of calories in those regions (Burns et al. 2010). The crop, with high drought resilience and grown on marginal low-fertility soils, has a high yield potential, even on low-tech farms. On the other hand, the roots are more perishable after harvesting than those of other root and tuber crop species. This is mainly due to the occurrence of postharvest physiological deterioration (PPD), indicated by the appearance of dark streaks in the xylem vessels, as a result of the formation of tylose occlusions within the secondary vessels (Djabou et al. 2017).

Post-harvest deterioration symptoms occur 24-72 h after harvesting, making the roots unpalatable and resulting in a significant reduction in shelf life for fresh consumption and industrial use. Therefore, farmers depend on sophisticated market and transport logistics for a rapid sale of the roots prior to symptoms, as estimated PPD losses can reach 30%, depending on the susceptibility of the variety.

Brazil is the fifth largest cassava producer and accounts for about 6% of the global production, with an annual contribution to the national economy of about US$1.0 billion (FAOSTAT 2021). Over the last 70 years, the world cassava production has increased by 2.3% per year. In Brazil however, the mean root production decreased by 0.4% per year. Many factors can explain this reduction in the domestic cassava output, e.g., the high agricultural diversification and competition with other commodities. However, an inadequate crop management and use of obsolete varieties susceptible to various biotic and abiotic stresses contribute to the low root yields.

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Received: 01 February 2023
Accepted: 07 March 2023
Published: 20 March 2023

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In this article, the new varieties BRS Rendeira and BRS Progresso for use in the flour and starch industries are described, as alternatives for cultivation in the state of Bahia, to diversify varieties and meet the farmers' demand for PPD-tolerant varieties. In addition, the yield potential of the two varieties is high and they are suited for mechanized planting and harvesting.

CROSSING AND SELECTION

The varieties BRS Progresso and BRS Rendeira resulted from phenotypic selection in segregating populations derived from the cross between the variety BRS Kiriris (female parent) and BGM0142 (male parent) (Figure 1). The crosses were made in 2010/11, according to the standard procedure of Embrapa Cassava and Tropical Fruits. Physiologically mature male and female flowers were selected and covered with a voile bag in the morning before opening, to prevent undesirable pollination. Pollinations was carried out by hand by well-trained staff between 10:00 and 16:00. Then the pollinated flowers were covered again and the basic data of each cross (parent names, date of the cross, number of crossed flowers) were recorded. After 60 to 80 days, seeds were harvested and stored at 4 ºC for a period of two months before germination in substrate trays (coconut fiber, vermiculite, and plantimax, at 1:1:1 v/v).

In the 2012/2013 growing season, the seedlings were planted in a seedling evaluation trial (SET) without any experimental design (single-plant trials), only to grow and generate F_1 plants (heterozygous plants from non-inbred parents) for the next steps of clonal propagation. Eleven months after planting, the plants were harvested and evaluated for high-heritability traits such as leaf retention, plant architecture, color of the pulp, skin, and cortex, and root shape. Also, clones unable to produce at least five viable stems were discarded.

The clonal evaluation trial (CET) was planted in the 2013/2014 growing season in a randomized block design with 15 replications and 10 improved varieties and landraces as controls. The latter were included for having a tradition of cultivation in the region. At this stage, the clones in the first phase of clonal propagation were planted in single rows with 5-6 plants per plot and the clones were evaluated for germination rate, plant vigor and root quality traits. Both SET and CET were performed in Cruz das Almas (BA).

In the preliminary yield trial (PYT) in 2014/15, the best F_1 clones were selected based on resistance to shoot diseases, dry matter content and fresh and dry root yield. The PYT was planted in double 8-plant rows (16 plants per plot). Three advanced yield trials (AYT) were performed in Santo Amaro (BA) and Laje (BA) in the 2015/16 season, in order to select the best clones based on the highest fresh and dry root yields compared to the improved Embrapa varieties and other landraces widely used in the target region. In the third phase of clonal propagation, the clones were evaluated in four 8-plant rows (32 plants per plot).

The uniform yield trials (UYT) involved the evaluation of the yield performance and root quality of the new clones in different regions of the state of Bahia. The UYTs were installed in five growing seasons (2016/17, 2017/18, 2018/19, 2019/20, and 2020/21) in the districts of Alagoinhas, Cruz das Almas, Laje, Santo Amaro, and Valença, Bahia. The plots consisted of six 10-plant rows (60 plants total per plot). The UYT were harvested 11 to 12 months after planting. In

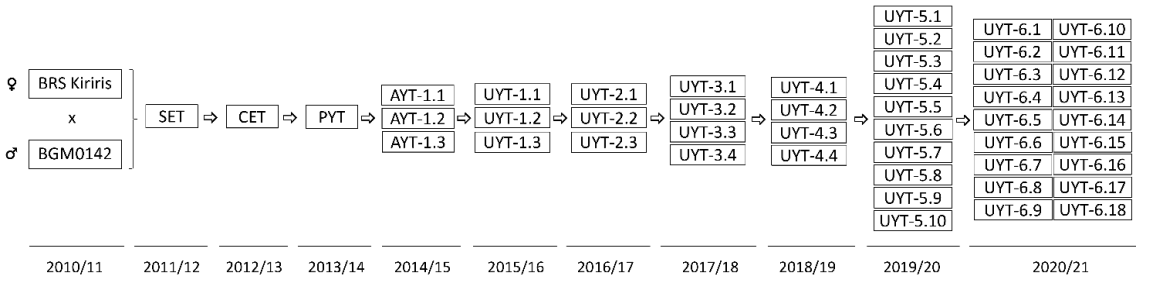

Figure 1. Breeding scheme for the development of the cassava varieties BRS Progresso and BRS Rendeira. After the initial cross (BRS Kiris x GBM0142), phenotypic selection was performed according to the different stages of the cassava breeding pipeline: SET: seedling evaluation trial, CET: clonal evaluation trial, PYT: preliminary yield trial, AYT: advanced yield trial, UYT: uniform yield trial (six growing seasons).

addition to the diverse agronomic shoot and root traits, PPD symptoms were evaluated in the eight UYT (four in 2017/18 and four in 2018/2019). In these evaluations, roots with standard size and shape were selected, washed and immersed in a disinfectant solution (200 mg L^{-1} sodium hypochlorite) and fungicide (50ug mL^{-1} methyl-benzimidazol-2-ylcarbamate). Then the roots were identified and stored in an open shed with fresh air circulation for 10 days. Thereafter, the roots were peeled and cut, and eight pieces of the median region of at least five different roots were photographed with a single RGB camera. The images were analyzed by ImageJ software (Rasband 1997) to estimate the PPD area. Selection was performed for PPD severity, as well as the phenotypic characteristics fresh and dry root yields, dry matter content, plant height and root pulp and cortex color, in comparison with landraces (Cigana Preta, Correntão, Corrente, and Vasoura Preta) and improved varieties (BRS Formosa, BRS Kiriris, BRS Mulatinha, BRS Novo Horizonte, and BRS Poti Branca).

A spacing of 0.90 m between rows and 0.80 between plants was used in all trials, and crop fertilization and management according to the technical recommendations (Souza et al. 2006) for the experimental region. The main agronomic traits analyzed were fresh root yield (FRY, in t ha^{-1}); tolerance to post-harvest deterioration (PPD, in %), root dry matter content (DMC, in %, according to Andrade et al. 2019); shoot yield (ShY, in t ha^{-1}); dry root yield (DRY, t ha^{-1}, calculated as dry matter content multiplied by fresh root yield), and number of roots per plant (NRP).

ADAPTATION AND YIELD DATA

Some characteristics of the evaluation sites and trials of the new cassava varieties from 2012 to 2021 are presented in Table 1. Data of the 47 trials (AYT to UYT) were analyzed together and the overall mean of the main agronomic traits is shown in Table 2. In terms of PPD tolerance, the main agronomic trait of the new cassava varieties, less than 1% of PPD symptoms were observed 10 days after harvest on BRS Progresso and BRS Rendeira roots, while this percentage

Table 1. Characteristics of locations and soils of the trials for testing prior to release of the varieties BRS Progresso and BRS Rendeira

City	Altitude (m)	Coordinates	Soil classification
Alagoinhas	130	12°05’ S, 38°21’ W	Yellow oxisol
Cruz das Almas	225	12º40’ S, 39º06’ W	Yellow Oxisol and Argisol
Laje	190	12º36’ S, 38º44’ W	Red to Red Yellow Oxisol - Medium Texture
Santo Amaro	88	13º10’ S, 39º25’ W	Cambisols and vertisols
Valença	40	13°15’ S, 39°14’ W	Red Yellow Oxisol

Table 2. Overall mean of the fresh root yield (FRY), tolerance to post-harvest deterioration (PPD), dry matter content (DMC), shoot yield (ShY), dry root yield (DRY) and number of roots per plant (NRP) of the varieties BRS Progresso and BRS Rendeira

Variety	FRY		PPD		DMC		ShY		DRY		NRP	
	Mean	LSD	Mean	LSD	Mean	LSD	Mean	LSD	Mean	LSD	Mean	LSD
BRS Rendeira	31.1	a	0.3	d	33.4	g	22.4	b	8.9	a	7.2	a
BRS Progresso	27.9	b	0.1	d	33.8	g	22.3	b	8.1	bc	6.4	bc
BRS Formosa	28.3	b	35.2	c	35.3	e	16	d	8.7	ab	6.5	b
BRS Kiriris	26.6	bc	-	-	35.3	e	17.3	cd	8.2	bc	6	cd
BRS Mulatinha	24.3	d	44.2	b	37.6	b	24.6	a	8.1	bc	5.5	de
BRS Novo Horizonte	27.5	b	71.6	a	38.3	a	25.2	a	9.3	a	6.3	bc
BRS Poti Branca	25.3	cd	-	-	34.6	f	25.1	a	7.7	cd	6.3	bc
Cigana Preta	17.8	f	43.5	b	35.7	d	21.4	b	5.7	e	4.5	g
Correntão	19.5	ef	-	-	35.6	de	22.3	b	6.1	e	4.6	fg
Corrente	21.4	e	66.5	a	37	c	19.2	c	7	d	5.1	ef
Vasoura Preta	24.4	cd	-	-	35.6	de	15.9	d	7.7	cd	6.2	bc
Coeficient of variation	17		20.7		2.8		18.3		17.3		15.1	

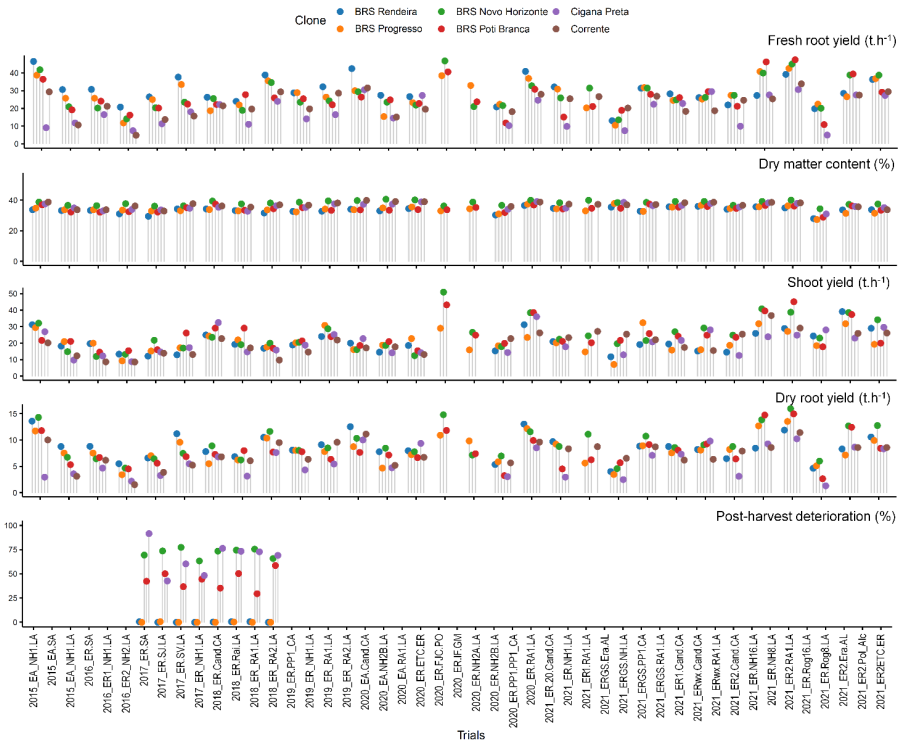

Figure 2. Agronomic performance of the cassava varieties BRS Progresso and BRS Rendeira and key controls (BRS Poti Branca, BRS Novo Horizonte, Cigana Preta, and Corrente) from 2015-2021 in different districts of the state of Bahia.

varied from 35% (BRS Formosa) to 71% (BRS Novo Horizonte). A high incidence of PPD symptoms (43% and 67%, respectively) on roots of some landraces, e.g., Cigana Preta and Corrente was also observed (Figure 2). The PPD tolerance of BRS Progresso and BRS Rendeira cultivars can improve the flexibility of logistics of cassava harvest and mitigate post-harvest losses, which currently represent major bottlenecks for the farmers.

Regarding the other agronomic traits, the fresh root yield (FRY) of variety BRS Progresso was 27.9 t ha^{-1} (10.5 - 42.7 t ha^{-1}), while BRS Rendeira produced 31.1 t ha^{-1} (13.1 - 46.6 t ha^{-1}) (Figure 2). In other words, the yield potential of variety BRS Rendeira is around 17% and 49% higher than that of the improved varieties and landraces, respectively, while this percentage is lower for BRS Progresso (6% and 34%, respectively), although the competitive advantage is still meaningful.

Figure 3. General appearance of stems and roots of BRS Progresso and BRS Rendeira harvested 12 months after planting.

The white root pulp of BRS Progresso and BRS Rendeira, as well as the cream-colored root skin and cortex are advantageous for root processing for raising the chances of whiter starches, which ensure higher starch quality (Figure 3). However, the mean dry matter content (DMC) of both varieties was lower (33.8 and 33.4%, respectively, in a range of 28-36% for BRS Progresso and 27-38% for BRS Rendeira),

Table 3. Main morphological traits of the varieties BRS Progresso and BRS Rendeira

	Trait	BRS Progresso	BRS Rendeira
Stem	Color of the outer layer of the epidermis	Golden	Golden
	Color of the inner layer of the epidermis	Orange	Orange
	Cortex color	Light green	Light green
	Phyllotaxis length	Medium	Medium
	Predominant number of primary branches	None	Two
Leaf	Apical leaf color	Purplish green	Purplish green
	Color of fully expanded leaf	Dark green	Dark green
	Central vein color	Red-greenish	Green-redisch
	Shape of the central lobe	Lanceolate	Lanceolate
	Sinuosity of lobes	Present	Present
Petiole	Petiole color	Red	Green
Plant	Pubescence of young leaves	Present	Present
Root	Cortex color	Cream	Cream
	Skin color	Dark brown	Dark brown
	Shape	Conic-cylindrical	Conic-cylindrical
	Presence of peduncle	Mixed	Mixed
	Epidermis texture	Smooth	Smooth

in comparison with the landraces and improved varieties (-7%). Nevertheless, in terms of mean dry root yield (DRY) of variety BRS Rendeira (8.9 t ha^{-1}) did not differ statistically from that of BRS Novo Horizonte (9.3 t ha^{-1}), mainly because it is a high-yielding variety. In the case of variety BRS Progresso, the mean DRY was 8.1 t ha^{-1}, which is still about 23% higher than that of the landraces.

The shoot yield (ShY) of the varieties BRS Progresso and BRS Rendeira varied from 11.8 to 39.2 t ha^{-1} and 7.2 to 32.5 t ha^{-1}, respectively, with an approximate mean of 22 t ha^{-1}. Both varieties had about 13% more ShY than the landraces, but still about 10% less than the varieties with higher shoot production (BRS Novo Horizonte and BRS Poti Branca).

Regarding the number of roots per plant (NRP), variety BRS Rendeira was the most promising (7.2), while the NRP of BRS Progresso (6.4) was comparable to that of the varieties BRS Formosa, BRS Novo Horizonte and BRS Poti Branca. The NRP gains in the varieties BRS Progresso and BRS Rendeira over the landraces were about 25 and 40%, respectively.

Regarding plant architecture, BRS Progresso has an upright growth with almost negligible late branching (>2 m) (Figure 3). Plant height is around 2.5 m (12% taller than improved varieties and 17% than landraces), resulting in a high multiplication rate. Variety BRS Rendeira is an upright variety with late branching (>1.5 m) as well, with a plant height of about 2.2 m, which is very similar to the other cassava varieties evaluated. The growth pattern of both varieties indicates their use for mechanized cropping systems. In addition, due to the high shoot yield and large number of leaves, soil cover is improved, with a consequent reduction in the number of agrotechnical measures required for weed control.

OTHER TRAITS

Resistance to shoot diseases (anthracnose, bacterial blight, brown leaf spot, white leaf spot, and blight leaf spot) and root diseases (root rot) was similar to that of the improved and landraces, including better leaf retention at the end of the maturation cycle. The main morphological descriptors that distinguish the varieties BRS Progresso and BRS Rendeira from other varieties grown in the recommended regions are listed in Table 3.

TECHNICAL RECOMMENDATIONS AND CUTTING PRODUCTION

The cultivation sUYTem in the agronomic evaluations of the varieties BRS Progresso and BRS Rendeira followed technical recommendations for cassava management in the State of Bahia, with conventional tillage (plowing, harrowing, furrowing) and planting of the cuttings (length 16 - 18 cm), at a spacing of 0.90 m between rows and 0.80 m between

plants. Weeds were controlled with pre-emergence herbicides as well as by hand weeding performed approximately 60 days after planting. Fertilization was applied as recommended by Souza et al. (2006) and harvest occurred 11–12 months after planting.

The varieties BRS Progresso and BRS Rendeira were registered by the Ministry of Agriculture, Livestock and Food Supply, in December 2022 (N. 51249 and 52395, respectively). The Brazilian Agricultural Research Corporation (Embrapa) is in charge of the basic seed production.

ACKNOWLEDGMENTS

We thank Fundação de Amparo à Pesquisa do Estado da Bahia (FAPESB PNE 15-2014), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq 409229/2018-0, 442050/2019-4 and 303912/2018-9), and Bahiamido SA for the finantial suppport.

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