CROP BREEDING AND APPLIED BIOTECHNOLOGY

CULTIVAR RELEASE

BRS 901 and BRS 902: red rice cultivars bred for Brazil

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Abstract: *BRS 901 and BRS 902 are red pericarp rice cultivars developed by Embrapa for irrigated and rainfed lowland production systems in Brazil. These cultivars have medium and early maturation cycles, respectively, and both have high grain yield potential, good lodging tolerance and short to medium length grains.*

Keywords*: Oryza sativa L., special rice breeding, pigmented rice, red-grained rice, proanthocyanidins*

INTRODUCTION

White or polished rice is preferred by consumers worldwide, however due to cultural aspects and characteristics such as flavor and texture, red rice is traditionally cultivated in Asia, particularly in India, China, Japan, Vietnam, Korea, Indonesia, Philippines, Malaysia, Bhutan, Nepal, Sri Lanka and Thailand (Ahuja et al. 2007). In Europe, it is grown in France, Italy and Russia and in Africa, in Madagascar and in Mozambique. In the Americas, red rice is found only in Brazil, where it has been traditionally cultivated in the northeastern region since the XVI century, mainly in the states of Paraiba and Rio Grande do Norte, where it is called 'arroz da terra' ('land rice'), after the introduction by Portuguese colonizers (Pereira 2004).

The Brazilian red rice varieties were selected by the farmers themselves, and specific characteristics were developed according to the respective geographic microregion (Pereira and Morais 2014, Morais Júnior et al. 2017). Generally, the maturation cycle is early, tillering ability low and the plants tall; the leaves are long and droopy and become yellow during grain development; stems are weak and tend to lodge at maturity and the percentage of head grain is low (Pereira et al. 2008, Pereira et al. 2009). In Brazil, although red rice is still being produced in the traditional areas with low-input farming, it has aroused the interest of growers of other Brazilian regions who use high-input production systems, e.g., in the South and Southeast. These are regions of high purchasing power, where consumers are in search of their physical well-being, nutritional health or new culinary options. Red rice is known as a product with high added value, due to its functional properties and unique flavor, color and texture. In Brazil, rice

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types for specific culinary uses or with new characteristics of cooking, appearance, aroma and flavor are called 'special rice' (Colombari-Filho et al. 2018).

Whole red rice grains are rich in proteins, lipids, dietary fibers, minerals, vitamins and phenolic compounds, including phenolic acids and flavonoids. The flavonoids are proanthocyanidins, which are beneficial not only because of their antioxidant and anti-inflammatory, but also the immunomodulatory, anticancer, cardioprotective and antithrombotic properties (Liu 2004). In addition, the fifth attribute of grain quality, which is color, is only worth mentioning for colored rice, whereas different shapes, flavors, fragrances and textures may also be present in non-colored rice (Colombari-Filho et al. 2018).

Despite the long tradition and preference of a considerable part of the population, mainly in the Northeast, the red rice varieties available are still the same or derived from the varieties of this rice type introduced in Brazil in the period of colonization. To overcome this gap, the Embrapa rice breeding program has developed dozens of red rice lines in recent years, resulting in the release of cultivars BRS 901 and BRS 902. In this context, this paper aimed to describe the main characteristics of these red rice cultivars developed for Brazil.

GENETIC ORIGIN AND DEVELOPMENT

The cultivars BRS 901 and BRS 902 were developed from the same simple cross between the parents PB 01(female) and PB 05 (male), labeled CNAx15411, performed in the first semester of 2006, at Embrapa Rice and Beans, in Santo Antônio de Goiás, Goiás. The plant architecture of the red rice parents PB 01 and PB 05, respectively, is traditional and modern, and they were crossed to combine the rusticity of PB 01 with the high grain yield of PB 05. Derived from the F_1 generation, in the second half of 2006, lines were developed in Teresina, Piauí, Embrapa Mid-North. Selection by the pedigree method was applied in the early generations and, at some later points, other breeding protocols such as Mass (M) or Bulk (B) selection were included, in two crop cycles per year, from 2007 to 2009.

As of the second half of 2009, two lines from among the advanced generations were included in the trials for Value of Cultivation and Use (VCU), to meet the legal prerequisites of the Brazilian Government, by fulfilling the minimum requirements for release as commercial cultivars. The pedigree of these lines (MNA 901 and MNA 902), was CNAx15411-B-M-M-1-1-B and CNAx15411-B-M-M-9-4-B, respectively. In the period between 2009 and 2012, these lines were tested in 12 VCU trials in the Northeast (Teresina/PI, Aparecida/PB, Itaporanga/PB and Apodi/RN); North (Cantá/RR) and Center-West Region (Goianira/GO). MNA 902 was also evaluated at seven locations in the Southeast in 2012 and 2013, all in the Paraíba River Valley, in the Southeast Region (Canas/SP, Roseira/SP, Tremembé/SP, Taubaté/SP, Pindamonhangaba/SP, Guaratinguetá/SP and Campos dos Goytacazes/RJ).

In Piauí, Rio Grande do Norte, Roraima, Goiás, São Paulo and Rio de Janeiro, the trials were cultivated in a conventional system, with chemical fertilization and herbicide application, as recommended for the crop. On the other hand, in Paraiba, the trials were managed in an organic system, according to the regional tradition. However, all trials were cultivated under flood irrigation at water levels between 5 cm (V_4 stage) and 20 cm (R_8 stage).

MORPHO-AGRONOMIC CHARACTERIZATION

The main morpho-agronomic traits of cultivars BRS 901 and BRS 902 are shown in Table 1. In Teresina/PI (lat 5° 05' 21" S, long 42° 48' 07" W, alt 70 m asl), cv. BRS 901 reaches physiological maturity around 124 days after emergence and cv. BRS 902 after around 116 days, and they were classified as medium and early-maturing, respectively. Important traits of both cultivars were improved in relation to those of the check 'Vermelho', e.g., the plant height was shorter and lodging tolerance greater. The seed dormancy period of cultivars BRS 901 and BRS 902, a common characteristic of red rice, lasts until around 100 and 80 days after harvest, respectively.

With regard to the grain quality traits, red rice is traditionally consumed as semi-polished grain, cooked with milk, salt and spices (Pereira et al. 2009). In some market segments it can also be found as whole grain, i.e., processed without grain polishing (Figure 1). Under this condition, the grains of cultivars BRS 901 and BRS 902 were classified, respectively, as short and medium. In contrast to the white rice cultivars, this classification is a value-added factor of red rice, since the traditional consumers of this product prefer short or medium grain with a rounded shape. Another

relevant characteristic is the high percentage of head rice, i.e., 73% and 65% for BRS 901 and BRS 902, respectively, with a moisture content variation from 20 to 22%.

In terms of disease reaction, BRS 901 and BRS 902 responded similarly to the main diseases as the traditional red rice varieties, mainly with regard to rice blast.

YIELD PERFORMANCE

In the Northeast region, where the national production of red rice is concentrated, from 2009 to 2012, the cultivars BRS 901 and BRS 902 produced 24.6% and 30.8% more than the traditional check cultivar (Vermelho) based on the mean of 10 environments, respectively. The higher grain yield of the new cultivars certainly results from the selections for a longer biological cycle and for redued plant height (Rangel et al. 2019), since rice grain yield is positively correlated with cycle and negatively with tall plants (Table 2). Similarly, since the lodging index is positively correlated with carbohydrate translocation from shoots to spikelets, yield is also favored by the higher lodging resistance of the shoots.

The grain yield data of BRS 901 and BRS 902 and of the check cultivars Vermelho (traditional red rice cultivar), SCS 119 Rubi (modern red rice cultivar) and BRS Fronteira (modern white rice cultivar) in different regions of Brazil are listed in Table 3.

Table 1. Morpho-agronomic characteristics of the rice cultivars BRS 901 and BRS 902

Traits	BRS 901	BRS 902
Flag leaf attitude	upright	upright
Leaf color	dark green	dark green
Leaf blade pubescence	pubescent	pubescent
Plant height	107 cm	88 cm
Ligule length	1.93 cm	2.06 cm
Days to heading	94	86
Awn	partly awned	absent
Panicle exsertion	fully exserted	fully exserted
Panicle length	24.3 cm	22.2 cm
Awn color	straw	straw
Apiculus color	straw	white
Kernel length	5.84 mm	6.10 mm
Kernel width	2.59 mm	2.88 mm
Kernel color	red	red
1000-grain weight	28.1 g	32.8 g
Amylose content	26.0 %	26.5 %
Gelatinization temperature	low	low
Grain class	short	medium
Percentage of head rice	73%	65%
Lodging tolerance	intermediate	moderately strong
Panicle shattering	low	low
Panicle threshability	intermediate	intermediate
Seed dormancy	100 days	80 days
leaf and panicle rice blast	susceptible	susceptible

In the North and Central-West regions, in evaluations of 2012, the two new red rice cultivars produced > 6,300 kg ha^{-1}. On the other hand, in the Southeast region, in 2012 and 2013, in seven environments, the high yield capacity of cultivar BRS 902 was observed, similar to that of cultivar BRS Fronteira, with white grain and modern plant architecture, developed for flood irrigation in the South and Southeast of Brazil. A similar performance was observed for the red grain cultivar SCS119 Rubi, commercially released for the cultivation conditions of the state of Santa Catarina.

Figure 1. Paddy and whole grain of (a) BRS 901 and (b) BRS 902. Photo: Sebastião José de Araújo (Embrapa Rice and Beans).

Based on these result, cultivars BRS 901 and BRS 902 were registered (no. 33216 and 33217) in the Brazilian Catalogue of Nationally Registered Varieties (associated with the Ministry of Agriculture, Livestock and Supply) for the cultivation conditions given by the soils and climate of the following states: Piauí, Ceará, Rio Grande do Norte and Paraíba. This had been a long-standing demand of red rice farmers in the Northeast, since no improved red rice cultivars were available for the region before. It is worth mentioning that cv. BRS 902 is also recommended for cultivation in the states of São Paulo and Rio de Janeiro. Thus, the new cultivars are excellent options for producers of the Northeast and Southeast regions of Brazil. In addition, cultivar BRS 902 also had a high performance in Santa Catarina and Rio Grande do Sul States, in the South of Brazil.

CULTIVATION CONDITIONS

Cultivars BRS 901 and BRS 902 were selected for irrigated rice cultivation and rainfed lowland rice cultivation, under conventional or organic management. This means that to express their full genetic yield potential, the level of soil moisture can be from a saturated (soaked) soil to a flooded soil with a water depth of 5 - 20 cm. The recommended sowing density varies between 200 and 300 viable seeds per m^2. The lowest density is indicated for rainfed lowland rice (without water level control or saturated soil). For irrigated rice, with controlled water levels, 300 viable seeds per m^2 are recommended. For example, at a row spacing of 30 cm, considering the seed size and a feasibility rate of 90%, from 60 to

Table 2. Biological cycle, plant height, lodging index and grain yield ($kgha^{-1}$) of the red rice cultivars BRS 901 and BRS 902 and the check cultivar Vermelho, in 10 environments of the northeastern region

Cultivar	Biological cycle (days after emergence)	Plant height (cm)	Lodging index (scale from 1 to 9)	Grain yield ($kg\ ha^{-1}$)
BRS 901	124 a	107 b	2.1	6,040 a
BRS 902	116 b	88 c	1.4	6,343 a
Vermelho	109 c	133 a	5.2	4,846 b

Means followed by the same letters are not significantly different at 5% probability by the Tukey test.

Table 3. Grain yield ($kg\ ha^{-1}$) of the red rice cultivars BRS 901 and BRS 902 and the check cultivars Vermelho, SCS 119 Rubi and BRS Fronteira in 19 environments in different regions of Brazil

Environment	Year	Cultivars					CV
		BRS 901	BRS 902	Vermelho	SCS119 Rubi	BRS Fronteira	
Teresina/PI	2009	9,124 a	10,166 a	4,624b	-	-	12.6
Aparecida/PB	2009	5,383 a	4,374 b	5,283a	-	-	19.0
Teresina/PI	2010	8,411	8,049	7,244	-	-	10.0
Aparecida/PB	2010	3,108 a	3,088 a	1,941b	-	-	7.1
Itaporanga/PB	2010	5,866 a	6,716 a	5,024b	-	-	13.0
Teresina/PI	2011	5,890 b	8,208 a	3,625c	-	-	15.6
Aparecida/PB	2011	3,184 a	3,155 a	2,110b	-	-	7.6
Apodi/RN	2011	3,289	3,122	2,615	-	-	14.0
Teresina/PI	2012	10,566 a	10,633 a	8,483b	-	-	14.1
Apodi/RN	2012	5,753b	6,371 ab	7,515a	-	-	10.0
Cantá/RR	2012	6,377	6,908	-	7,559	-	8.7
Goianira/GO	2012	6,454 b	6,431 b		9,025 a	-	8.9
Canas/SP	2012	-	6,288	-	-	5,102	21.4
Roseira/SP	2012	-	6,858	-	-	6,809	10.5
Tremembé/SP	2012	-	7,468	-	-	7,823	10.7
Taubaté/SP	2012	-	5,636	-	-	5,972	14.6
Pindamonhangaba/SP	2013	-	5,862	-	5,415	-	9.7
Guaratinguetá/SP	2013	-	6,543 b	-	7,748 a	-	11.5
Campos/RJ	2013	-	3,990	-	4,541	-	18.5

In the row, means followed by the same letters are not significantly different at 5% probability by the Tukey test. CV (%): Coefficient of variation

90 kg of seeds per hectare are required, while the highest density (300 seeds per m^2) is recommended for irrigated rice.

BASIC SEED PRODUCTION

The Management of the Integration of Processes, Products and Markets of Embrapa is in charge of the supply of basic seed of the described cultivars.

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