CROP BREEDING AND APPLIED BIOTECHNOLOGY

CULTIVAR RELEASE

BRS A502: an upland rice cultivar for intensive sustainable cropping systems in the Brazilian Cerrado

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Abstract: *BRS A502 is an upland rice cultivar with a medium cycle, high resistance to lodging, superior yield potential and grains of excellent industrial and cooking quality. The cultivar is indicated for crop rotation and succession in areas under intensive agriculture in the main field crop regions of Brazil.*

Keywords: Oryza sativa *L., grain yield, breeding, crop rotation and succession, intensive agriculture*

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INTRODUCTION

The two most important ecosystems for rice (*Oryza sativa* L.; Poaceae) cultivated in Brazil are categorized as irrigated and upland, and these systems are responsible for around 90% and 10% of the national production, respectively (Embrapa Arroz e Feijão 2021). Although, in recent years, upland rice has suffered considerable losses, both in cultivated area and in production, this cropping system presents the greatest potential for expansion in the country, especially in the Brazilian Cerrado, where rice can be planted in rotation and succession with soybean and other crops. Cultivation of upland rice would provide many benefits for the sustainability of agriculture in this vast biome where, for the most part, succession cropping is performed mainly with soybean in the summer and maize in the second-season. Moreover, upland rice could assist to offset costs in the renewal of degraded pastures whilst helping to meet the increasing world demand for food (Carvalho et al. 2020).

With the aim of contributing to the ecological intensification of production and the expected increase in consumption, the rice breeding program conducted by Embrapa has developed modern upland rice cultivars with desirable traits such as disease and lodging resistance, rapid maturation and high yield potential that render them appropriate for single or integrated production systems. The purpose of this study was to describe the breeding and agronomic characteristics of the new upland rice cultivar BRS A502.

BREEDING METHOD

The cultivar BRS A502 was developed with the aim of aggregating resistance to lodging, resistance to *rice blast disease* (causal agent *Magnaporthe oryzae;* Ascomycota), increased rusticity, high yield potential and good grain quality. The cultivar was derived from the double cross between the genotypes Aimoré/CNAs8934//CNAs8983/CNAs8934. The progenitor Aimoré is a rustic and lodging-resistant early-flowering cultivar, whereas the lines CNAs8983 and CNAs8934 are well adapted to Brazilian upland ecosystems and exhibit high yield with good grain quality. The crossing was performed in 2002 and registered at Embrapa Rice and Beans (Santo Antônio de Goiás, GO, Brazil) as CNAx9977. The F_1 generation was cultivated in the 2003/2004 season while F_2 seeds were harvested in 2004. Individual plants were selected from the F_2 generation, each of which represented a family that gave rise to generations $F_{2:3}$ and $F_{2:4}$ in 2005/2006 and 2006/2007, respectively. In the 2007/2008 cycle, individual F_5 plants were selected within the family CNAx9977-6-M1-B-B, and their seeds gave rise to the F_6 generation, grown in the 2008/2009 cycle.

One of the F_6 inbred lines was selected and designated as line AB092014. This line was evaluated in the following national network of yield tests: Preliminary Trial (2009/2010), Regional Trial (2010/2011 and 2011/2012) and Value for Cultivation and Use trial (VCU; 2012/2013 and 2013/2014). In addition, line AB092014 was assessed with regard to lodging and disease resistance as well as grain quality. Distinctness, uniformity and stability testing (DUS) of AB092014 were performed at Embrapa Rice and Beans during the 2014/2015 and 2015/2016 seasons, with the aim to register AB092014 as the new cultivar BRS A502 (Law number 9.456). Table 1 shows some of the characteristics determined in the DUS assays.

Table 1. Agronomic and morphological traits of the upland rice cultivar BRS A502 according to the distinctness, uniformity and stability (DUS) tests performed during the 2014/2015 and 2015/2016 cultivation cycles

Descriptor	Phenotype
Flag leaf angle	Erect
Leaf blade pubescence	Absent
Leaf auricle color	Light green
Leaf ligule color	Colorless to green
Culm length	Medium (66 cm)
Panicle length	Short (22 cm)
Presence of awns	Absent/very short
Spikelet stigma color	Purple
Spikelet glume color	Pale yellow/Golden
Spikelet apiculus *color* (at ripening)	Black
Length of hulled grains	Long (7 mm)
Mass of a thousand grains	25.6 to 27.0 g

PERFORMANCE OF BRS A502

Thirty-five VCU trials were performed with cultivar BRS A502 (line AB092014) during the 2012/2013 and 2013/2014 seasons in various states of the North, Northeast and Mid-West regions of Brazil. The mean yield and flowering time of the cultivar were similar to the cultivars BRS Esmeralda and AN Cambará (Table 2), used as controls. However, the maximum yield of BRS A502 in the VCU trials was 9.075 kg ha^{-1}, demonstrating the superior genetic potential of this cultivar for high yielding when grown under favorable climatic conditions and with appropriate crop management.

Cultivar BRS A502 exhibited a notable performance with respect to lodging resistance, a fundamental attribute in intensive cropping systems. In this context, BRS A502 plant height was, on average, 5 cm shorter than those of BRS Esmeralda and AN Cambará (Table 2), which renders them less prone to lodging. In a field trial carried out at Embrapa Rice and Beans, the lodging resistance of cultivars BRS A502 and BRS A501 CL was evaluated with/without nitrogen input (180 kg ha^{-1}) or fungicide. In all treatments, BRS A502 presented a score of 1, corresponding to the absence of lodged plants at harvesting, whereas the score for BRS A501 CL, which is classified as moderately susceptible to lodging (Rangel

Table 2. Agronomic characteristics of BRS A502 and check cultivars according to the value for cultivation and use (VCU) trials[1] performed during the 2012/2013 and 2013/2014 seasons

Characteristic	BRS A502	BRS Esmeralda	AN Cambará	Overall mean (*n* = 35)	Coefficient of variation (%)
Grain yield (kg ha^{-1})	4025	3901	3773	3922	17.8
Flowering time (days)	76	76	76	78	4.7
Plant height (cm)	101	106**	106**	107	6.3

[1] VCU trials were performed using a randomized complete block design with four replicates
** Mean values are different at 1% probability level according to the Scheffé test

et al. 2020), was 6.5 in the treatment with nitrogen and without fungicide (Figure 1). An additional characteristic that is correlated with greater resistance to lodging in BRS A502 is the persistence of the green color of the leaves during the grain maturation phase (the stay-green trait) (Castro et al. 2014).

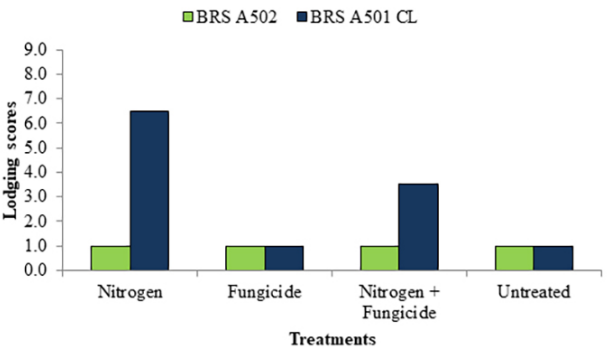

Figure 1. Lodging resistance of cultivars BRS A502 and BRS A501 CL with/without nitrogen input (180 kg ha^{-1}) or fungicide (Tricyclazole). Scores varied between 1 (absence of lodging) to 9 (100% of lodged plants at harvesting). Three applications of fungicides were carried out: (i) at full tillering coinciding with the second topdressing nitrogen fertilization; (ii) at panicle emission; and (iii) seven days after the emergence of panicles. Field trials were performed at Embrapa Rice and Beans, Santo Antônio de Goiás, GO, Brazil, during the 2017/2018 cultivation cycle using a randomized complete block design with four replicates.

When evaluated under field conditions, the severity of leaf and panicle blast, leaf scald and brown spot disease in BRS A502 plants was low (Table 3). Moreover, in the Rice Blast National Nursery (VNB) performed during cultivation cycles 2012/13 and 2013/14, BRS A502 received a maximum score of 6 on a scale of 0 (absence of symptoms) to 9 (highest incidence) (Pinheiro et al. 2009). That result indicates higher resistance than cultivars BRS Esmeralda and AN Cambará (Table 3). Considering both cultivation cycles, BRS A502 plants presented scores ≤ 3 for leaf blast in 62.5% of the VNB sites. BRS A502 was more susceptible to brown spot (*Bipolaris oryzae*) than cultivars BRS Esmeralda and AN Cambará. Nevertheless, this disease is considered of lower importance, compared to blast. These results reinforce that the application of fungicides is required as a complementary strategy in controlling disease and protecting yield potential and grain quality of the new cultivar. Considering the antecedents of the area, the climatic conditions, the planting season and the crop management system, protective spraying with fungicides is recommended, once in the vegetative phase and twice during the reproductive phase, the first at the end of the booting stage before panicle emission and the second 7 to 10 days later, depending on the fungicide employed. Preventive fungicide spraying not only avoids disease outbreaks but also contributes to increasing the duration of resistance in the released cultivars (Filippi et al. 2015).

Grain quality is a fundamental factor for the success of a new cultivar, because it affects directly the market value and consumer acceptance of the product. Grain quality is defined by several parameters, among which are industrial attributes and cooking characteristics. In tests carried out at Embrapa Rice and Beans, samples of BRS A502, BRS Esmeralda and AN Cambará were harvested at 25, 32, 39, 46 and 53 days after flowering, and the moisture content and milling yield (percentage of whole grains) were determined. Maximum whole grain yields for all cultivars were obtained

Table 3. Incidence/severity of disease and grain quality traits of BRS A502 and control cultivars, as evaluated during the 2012/2013 and 2013/2014 seasons

Characteristics	BRS A502	BRS Esmeralda	AN Cambará
Disease incidence/severity[1]			
Leaf blast *(Magnaporthe oryzae)*	2.0	2.1	2.5
Panicle blast (*Magnaporthe oryzae)*	2.8	2.5	3.4
Mean VNB scores[2]	2.2	2.7	2.9
Maximum VNB scores[2]	6	9	8
Leaf scald *(Monographella albescens*)	2.5	2.4	2,9
Brown spot (*Bipolaris oryzae*)	3.6	2.8	2,9
Grain discoloration (several fungi)	2.1	1.9	2.1
Grain quality			
Length of grain (mm)	6.44	6.53	6.35
Width of grain (mm)	1.93	1.88	1.88
Length/width ratio	3.34	3.47	3.38
Chalky grains (%)	2.95	5.15	2.40

[1] Scores: 1 (absence of symptoms) to 9 (> 50% of leaves or panicles with lesions) (Pinheiro et al. 2009).
[2] Evaluation according to the Rice Blast National Nursery (VNB).

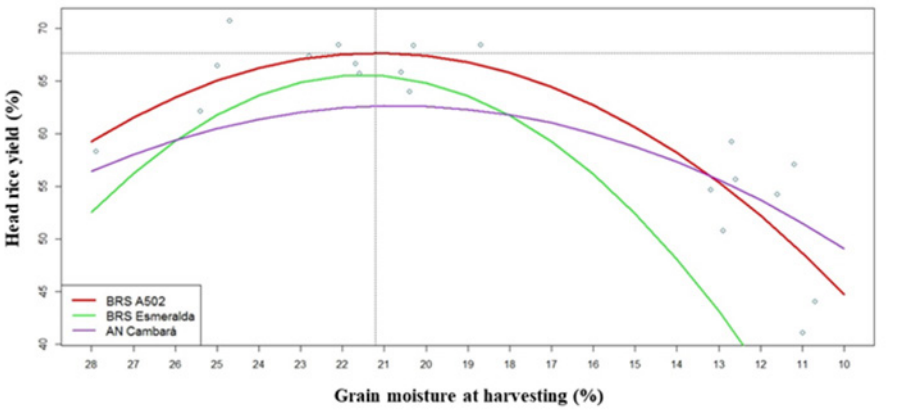

Figure 2. Head rice yield as a function of grain moisture at harvesting for the upland rice cultivars BRS A502, BRS Esmeralda and AN Cambará. Tests were performed at Embrapa Rice and Beans, Santo Antônio de Goiás, GO, Brazil, during the 2017/2018 cultivation cycle using a randomized complete block design with four replicates and five harvest dates with 7-day intervals.

when grain moisture was between 20% and 22%, but the performance of BRS A502 was consistently superior to that of the other cultivars, even when harvests were carried out with grain moisture between 15% and 25% (Figure 2). A high whole grain yield represents a significant economic advantage for growers, and stability of this trait allows harvesting to be carried out at different grain moistures without substantial losses, thereby expanding the harvesting window. Industrially processed grains from BRS A502 were categorized as long-slender and translucent, with a small percentage of chalky grains, as outlined in Table 3.

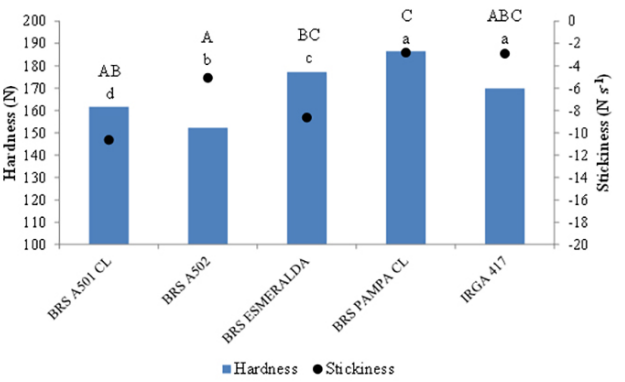

Figure 3. Hardness (■) and stickiness (●) of polished cooked grains of five rice cultivars evaluated using a texture analyzer. Uppercase letters for hardness and lowercase letters for stickiness indicate significant differences according to the Tukey's test at 5% probability (*n* =3).

Regarding cooking traits, the amylose content of BRS A502 (19.6%) is considered low/intermediate while the gelatinization temperature, estimated indirectly by the degree of dispersion and clarification of grains in alkaline solution, was intermediate (score 3.9). Both parameters are compatible with a superior cooking performance. A technique that is often employed to establish the culinary attributes of a new cultivar is the cooking test, where parameters such as cooking time and texture are evaluated and sensory tests are performed (Carvalho et al. 2015). According to the tests performed at the Laboratory of Grains and By-products of Embrapa Rice and Beans (Santo Antônio de Goiás, GO, Brazil), the BRS A502 cooked grains were soft and non-sticky, as demanded by Brazilian consumers.

Currently, instrumental texture analysis is widely used to evaluate specific parameters relating to the mechanical properties of foods, such as hardness, stickiness and cohesiveness, thereby replacing human perception with more precise and quantitative assessments. The lower the hardness indicated by a texturometer, the softer the sample because the compression forces required to break the material are reduced. Furthermore, the closer the stickiness value is to zero, less sticky is the sample (Carvalho et al. 2015). As shown in Figure 3, BRS A502 exhibited the lowest degree of hardness of all of the upland and irrigated cultivars analyzed, whilst the stickiness of the new cultivar was similar to that of the irrigated cultivar IRGA 417, considered a premium standard for cooking quality. Hence, in terms of culinary traits, BRS A502 is similar to irrigated varieties that are highly appreciated by rice industrials and consumers.

SEED PRODUCTION

BRS A502 is registered at the National Register of Cultivars (RNC; Ministry of Agriculture, Livestock and Food Supply, Brasília, DF, Brazil) under protocol number 39.138 (November 14, 2018) for cultivation in the states of Goiás, Maranhão, Mato Grosso, Pará, Piauí, Roraima, Rondônia and Tocantins. Intellectual property rights are registered under protocol number 20190281 at the National Service for Cultivar Protection (June 19, 2019).

CONCLUSION

BRS A502 is an upland rice cultivar with an intermediate cycle, high lodging resistance and high yield potential, high and stable head rice yield and excellent cooking quality. These attributes make BRS A502 advantageous for cultivation in upland areas subjected to intensive agriculture, particularly when planted in rotation and succession with soybean.

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