

BRS Pampa CL: a new IMI herbicide-resistant premium quality grain irrigated rice cultivar

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Abstract: *BRS Pampa CL is a rice cultivar developed by Embrapa, recommended for irrigated cultivation in Rio Grande do Sul State, Brazil. It shows modern architecture, high tillering, early cycle, and tolerance to the imidazolinone herbicide Kifix®. It stands out for its high yield potential and excellent grain quality.*

Keywords: *Oryza sativa L., herbicide-tolerant, genetic improvement, yield*

INTRODUCTION

Red rice is the weed that causes the most damage to rice crops. This is because it reduces yield and final product quality and because it is difficult to control since it belongs to the same species as cultivated rice (Magalhães Jr and Oliveira 2008). Another reason concerns the extent and high degree of infestation of this weed in cultivated areas. Moreover, it increases production costs and decreases the value of arable land.


Chemical control of red rice was made possible by the development of the Clearfield® (CL) production system. This system relies on the use of rice cultivars resistant to selective herbicides that control this weed in commercial crops. In Rio Grande do Sul State, Brazil, the commercial use of this technology started in the 2003/04 crop, having grown rapidly due to its efficiency in controlling red rice (Rangel et al. 2018).

The supply of cultivars resistant to herbicides from the imidazolinone (IMI) group has been increasing, which has improved crop yield (Streck et al. 2018). This fostered the evolution of this management technology, providing greater safety and profitability of the system. Rio Grande do Sul State, responsible for more than 70% of the Brazilian production of rice (CONAB 2022), has more than 80% of the cultivated area covered with CL varieties.

On the other hand, in rice-consuming countries, grain quality characteristics dictate market value and play a key role in the adoption of new varieties (Magalhães Jr et al. 2020). These attributes encompass physical appearance, culinary and sensory properties and, more recently, nutritional value. Physical

Crop Breeding and Applied Biotechnology
22(3): e43062233, 2022
Brazilian Society of Plant Breeding.
Printed in Brazil
<http://dx.doi.org/10.1590/1984-70332022v22n3c26>



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Received: 25 May 2022
Accepted: 28 July 2022
Published: 11 August 2022

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properties include grain yield after processing, uniformity, whiteness and translucency of the grain. Culinary and sensory qualities typically include cooking time, texture of cooked rice, aroma and its retention after cooking, and the capacity to remain tender for several hours after cooking.

BRS Pampa CL was developed using a gene that confers resistance to herbicides. This gene was identified in the *Oryza sativa* species itself, without the need to import genes from other species for the composition of the genome of the new cultivar, maintaining the same premium quality standard of grains of the recurrent cultivar BRS Pampa. In this context, Embrapa presents a new cultivar of premium quality grains, BRS Pampa CL, which is a source of tolerance to herbicides of the imidazolinone group (IMI), being adapted to the Clearfield® production system.

PEDIGREE AND BREEDING METHOD

Cultivar BRS Pampa CL was developed by crossing BRS Pampa as a recurrent parent and PUITÁ INTA-CL as a donor parent of the tolerance gene to the Kifix® herbicide from the imidazolinone chemical group, followed by three backcrosses. The objective was to develop a new cultivar essentially derived from BRS Pampa, adding herbicide tolerance to the good agronomic characteristics of this cultivar. Figure 1 shows the genealogy of the cultivar.

For the selection of tolerant plants, seeds of the segregating generations were germinated in plastic trays in a greenhouse. Twenty days after seedling emergence, Kifix® herbicide was applied at a dose equivalent to 180 g of the commercial product per hectare, plus Dash at a dose of 0.5% v/v. Ten days later, tolerant plants were transplanted into pots to be backcrossed. At the end of the process, the progenies test was performed with the RC3F2:3 generation, in which four homozygous strains were selected for the herbicide tolerance gene. These strains were assessed in the different grain yield and Value of Cultivation and Use (VCU) tests.

The process of genetic purification of the selected strain was carried out from individual plants conducted in a greenhouse. The process included DNA extraction from leaves and genotyping using a DNA chip (Illumina BeadChip

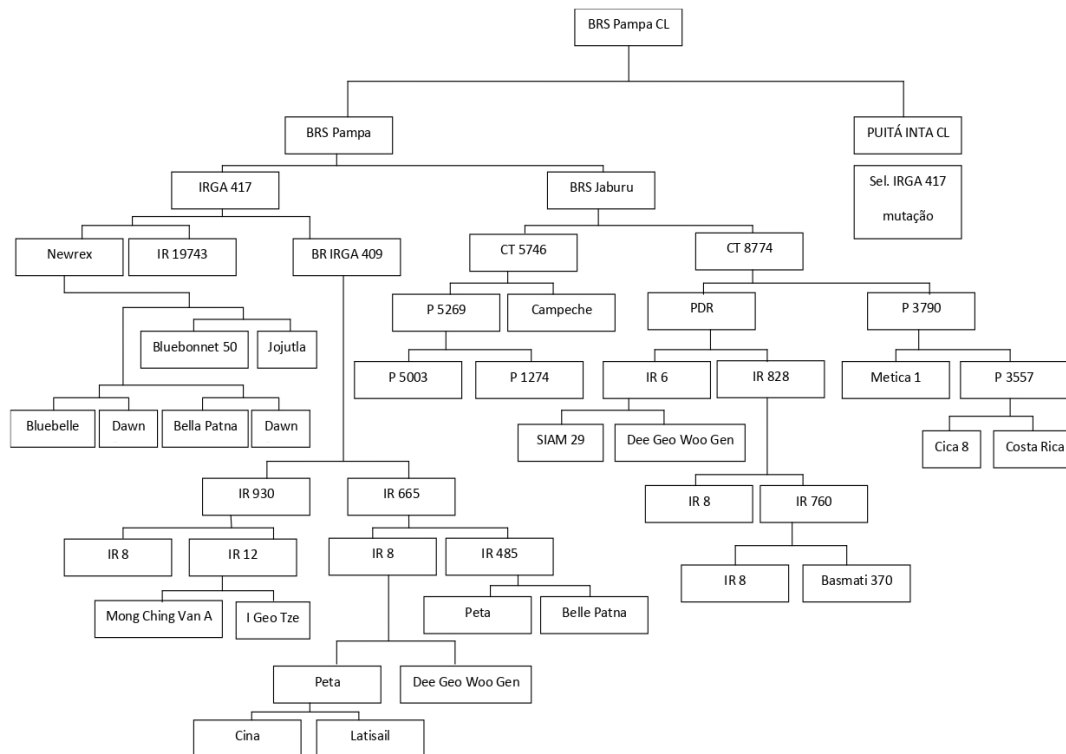


Figure 1. Genealogy of the irrigated rice cultivar BRS Pampa CL.

OSBR) composed of 4,300 SNPs distributed over 12 chromosomes of the species *Oryza sativa*. These polymorphism data allowed to estimate an average rate of 99.58% recovery of the BRS Pampa genome and to identify individual plants with complete recovery of their multilocus profile.

PERFORMANCE CHARACTERISTICS

Table 1 shows the main characteristics of cultivar BRS Pampa CL in relation to the recurrent cultivar BRS Pampa. As an essentially derived cultivar, BRS Pampa CL presents the same agronomic patterns of cultivar BRS Pampa in terms of maturation cycle, reaction to lodging and diseases, grain patterns, and yield, not differing statistically for these traits.

Table 1. Plant and grain characteristics of the new irrigated rice cultivar BRS Pampa CL in relation to the recurrent cultivar BRS Pampa

Characteristics	Cultivar	
	BRS Pampa CL	BRS Pampa
Plants*		
Plant type	modern	modern
Initial vigor	early	early
Cycle (days from emergence to 50% flowering)	87	88
Maturation	118	118
Plant height (cm)	95	96
Stem length (cm)	75	74
Panicle length (cm)	23	24
Panicle exertion	average	average
Leaf color	green	green
Flag leaf angle	erect	erect
Panicle type	intermediate	intermediate
Hairiness	present	presente
Degraining	intermediate	intermediate
Lodging	moderately resistant	moderately resistant
Tillering	high	high
Indirect iron toxicity	moderately resistant	moderately resistant
Leaf blast	moderately resistant	moderately resistant
Panicle blast	moderately resistant	moderately resistant
Grain staining	moderately resistant	moderately resistant
Herbicide resistance	resistant	susceptible
Grains*		
Class	long and thin	long and thin
Awn	absent	absent
Color of glumes	straw	straw
Color of the apiculus	white	white
Hairiness	present	present
Length with shell (mm)	9.80	9.82
Polished length (mm)	7.16	7.19
Widthwithshell	2.19	2.20
Polished width (mm)	2.00	2.00
Thickness with shell	1.95	1.96
Polishedthickness(mm)	1.74	1.76
Polished length/width ratio (mm)	3.58	3.59
Thousand grain weight (g)	25.1	25.6
Total productivity (%)	68	68
Whole grains (%)	62	62
Amylose	high	high
Gelatinization temperature	low	low
Yield (t ha ⁻¹)**	10.1	10.2

* Susceptible to change depending on the characteristics of the environment in which it grows.

** Grains with husk and 13% moisture as observed in experiments conducted by Embrapa.

Table 2. Yield of cultivar BRS Pampa CL in Value of Cultivation and Use (VCU) experiments in relation to the control cultivars in the different rice growing regions of Rio Grande do Sul State

Location	Crop year	Genotype			CV (%)
		BRS PAMPA CL	BRS PAMPA	PUITÁ INTA CL	
			Yield (kg ha ⁻¹)		
Capão do Leão	2016/17	11,034 a*	9,481 ab	8,279 b	17.0
Santa Vitória do Palmar	2016/17	7,190 a	7,216 a	5,214 b	18.3
Alegrete	2016/17	11,113 a	11,122 a	8,491 b	8.4
Uruguaiana	2016/17	10,375 a	10,534 a	7,997 b	8.5
Capão do Leão	2017/18	11,179 a	-	9,051 b	5.5
Santa Vitória do Palmar	2017/18	10,428 a	-	9,288 b	6.3
Alegrete	2017/18	10,459 a	9,101 b	9,702 ab	5.9
Uruguaiana	2017/18	10,419 ns	10,172 ns	9,706 ns	5.4
Mostardas	2017/18	8,660 a	-	5,489 b	8.1

* Anova performed separately per crop season; cultivars within each location compared by lsmeans (at $p=0.05$) in SAS statistical software. Application of Kifix® and death of cultivar BRS Pampa (control) for not having resistance to the herbicide.

Cultivar BRS Pampa CL has modern type plants with hairy leaves, average height of 95 cm, early cycle (around 118 days, ranging between 113 and 123 days from emergence to maturation), and wide adaptation in Rio Grande do Sul State.

Its grains are long and thin, *agulhinha* type, with light hairy husk, low incidence of white center, and loose and soft texture after cooking. The cultivar has a thousand grain weight of 25.1 g. Under normal conditions of environment and crop management, industrial grain yield is higher than 62% polished whole grains, with a total productivity of 68%. In indirect tests of cooking quality, the grain presents high amylose content (AC) and low gelatinization temperature (GT), as expected for a cultivar with good cooking characteristics (Table 1).

The average yield of BRS Pampa CL in the Value of Cultivation and Use (VCU) tests was 10.1 t ha⁻¹ (Table 2). The results of the performance of cultivar BRS Pampa CL demonstrate its excellent productivity in the different environments tested and a high yield when well managed. Grain yield was evaluated by means of analysis of variance and application of the Tukey test ($P < 0.05$) to discriminate treatments by using the SAS program. The 2017/18 crop in Capão do Leão city stood out in the assessments, in which cultivar BRS Pampa CL reached an average yield of 11.2 t ha⁻¹.

BASIC SEED PRODUCTION

BRS Pampa CL is registered under number 39476 in the Brazilian Registry of Cultivars, and protected under certificate number 20190155 of the National Service for the Protection of Cultivars (SNPC), bodies of the Ministry of Agriculture, Livestock, and Supply (MAPA). The seeds of cultivar BRS Pampa CL are made available in a coordinated manner between Embrapa and BASF, the latter being licensed by Embrapa for commercial exploitation. By mutual agreement, the parties select seed producers that will be accredited for the multiplication and commercialization of seeds.

The seed production process is judicious and highly controlled. Genetic seeds are produced within Embrapa's Experimental Stations; basic seeds are produced by a partner seed producer authorized to do so by Embrapa and BASF; the First Certified Generation (C1) category is produced by one or two seed producers, and from these seeds Second Certified Generation (C2) seeds are produced by a much larger number of accredited producers chosen as described in the previous paragraph. Seeds of category C2 are made available to farmers for the production of grains that will be destined to the processing industry and finally to the consumer. According to estimates, cultivar BRS Pampa CL already occupies an area of approximately 100 thousand ha in production crops, which corresponds to 10% of the area under cultivation of this cereal.

REFERENCES

- CONAB - Companhia Nacional de Abastecimento (2022) **Acompanhamento da safra brasileira de grãos - Safra 2021/22 - sétimo levantamento**. Available at <<https://www.conab.gov.br/info-agro/safra/safra/graos/>>
- Magalhães Jr AM and Oliveira AC (2008) Arroz. In Barbieri RL and Stumpf ERT (eds) **Origem e evolução das plantas cultivadas**. Embrapa Clima Temperado, Pelotas, p. 186-208.
- boletim-da-safra-de-graos>. Accessed on April 18, 2022.


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Magalhães Jr AM, Streck EA, Aguiar GA and Facchinello PHK (2020) Industrial quality. In Oliveira AC, Pegoraro C and Viana VE (eds) **The future of rice demand: quality beyond productivity**. Springer Nature, Switzerland, p. 47-67.

Rangel PHN, Magalhães Jr AM, Fagundes PRR, Morais OP, Franco D, Colombari Filho JM, Torga PP, Nunes CD, Abreu AG, Petrini JA and Ferreira ME (2018) BRS A701 CL: a new irrigated rice cultivar adapted

to the clearfield® production system. **Crop Breeding and Applied Biotechnology 18**: 226-228.

Streck EA, Magalhães Jr AM, Aguiar GA, Facchinello PHK, Fagundes PRR, Franco DF, Nardino M and Oliveira AC (2018) Genetic progress in 45 years of irrigated rice breeding in southern Brazil. **Crop Science 58**: 1094-1105.

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