CULTIVAR RELEASE

SCSBRS126 Dueto: irrigated rice variety resilient to cold and heat at reproductive stage

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Abstract: *SCSBRS126 Dueto is a late-maturing high yield performing cultivar released by Epagri/Embrapa/Udesc. It has high tillering capacity, but poor resistance to lodging, medium resistance to blast, with long, slender grains and good sensory/cooking traits, and it has lower sterility under cold stress at microsporogenesis/anthesis and under heat at anthesis.*

Keywords: Oryza sativa*, Extreme temperatures, Low and high temperatures, climatic changes*

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INTRODUCTION

Santa Catarina State is the second largest irrigated rice producer in Brazil, with a cultivated area of 148.290 ha (2020/2021 crop season), which represents 10.6% of Brazilian rice area (Padrão 2022). Grown in 93 municipalities in Santa Catarina, rice is concentrated on the South Coast (61.9%), followed by the Middle/Lower Itajaí Valley and North Coast region (25.2%), Upper Itajaí Valley (9.04%) and Coast Center (3.9%) (Padrão 2022). From this total area, 3.66% (5.476 ha) are above 400 m altitude, and this number reaches 8.08% (12.095 ha) if a limit above 300 m is considered. On the other hand, 78.05% of Santa Caratina´s rice fields are cultivated at altitudes from 0 to 50 m, and 11% below the 50 to 100 m range, with 2.63% from 100 to 150 m. There is no cultivation between 150 and 300 m. Altitude plays an important role in temperature, which is decisive for rice, and therefore it is an important point, since climate change is affecting temperatures.

Climate change increases the frequency of extreme temperatures, and these usually lead to yield reductions, which puts humanity in a serious dilemma, due to the challenge of at least doubling the production of food by 2050 (Liu 2013). The vulnerability of rice farming in southern Brazil to extreme temperature events puts the country's food security at risk. Low temperatures (Najeeb et al. 2021), as well as those that are too high (Ye et al. 2021), cause

sterility in rice, decreasing yield and consequently lowering the total production and final quality of this cereal.

Low temperatures particularly affect rice in Santa Catarina especially in periods when the rice plant is in the reproductive stage. When cold masses invade the state, especially the high altitude regions are at risk. There are studies indicating annual losses in rice production due to cold reaching 60-80% (Xiao and Chen 2021). In Brazil, temperatures between 15 and 19 ºC are considered to induce sterility in irrigated rice varieties (Sosbai 2018), with the most critical phase being microsporogenesis (R2) and anthesis (R4), the first one usually being considered the most sensitive of them (Rozzetto et al. 2015, Souza et al. 2017, Xiao and Chen 2021). Concerning the high temperatures, they reduce anther dehiscence and pollen fertility rates. Some data estimate that a 1 °C increase in the temperature would decrease rice yield by 10%, and rice can be affected at microsporogenesis and anthesis. Temperatures above 35 °C at the flowering stage are considered to be at a critical level that harms floret fertility and grain yield, which occasionally could cause up to 80% loss (Buu et al. 2021).

Different strategies can be used to increase rice tolerance to extreme temperatures, and one of them is phenotypic selection (Khan et al. 2019), despite the temperature being an unpredictable factor and therefore difficult to use as a selective agent in breeding programs. Nevertheless, progress has been achieved in obtaining cold resistant cultivars; for instance, in Hokkaido, Japan (Shinada et al. 2013) and also in high altitude sites in tropical regions of Kenya, selection for cold tolerance in reproductive stages in field experiments was described as successful (Samejima et al. 2020). There are results that indicate progresses, in a similar way, in the breeding program of Epagri (Santa Catarina State Agricultural Research and Rural Extension Agency) (Rozzetto et al. 2017, Souza et al. 2017, Stürmer et al. 2019).

Despite all the efforts and resources spent on gene identification for cold and heat tolerance, the use of marker assisted selection for cold tolerance in breeding has crucial barriers, related to the lack of consistency of the quantitative trait loci (QTLs) governing this trait for any given growth stage over different genetic backgrounds under different low-temperature stress conditions (Xiao and Chen 2021, Lv et al. 2019, Najeeb et al. 2021, Ye et al. 2021). Besides that, molecular mechanisms related to heat stress remain unknown, so some promising molecular technologies seem not to be able to deliver proper solutions, like the transgenic efforts for heat tolerance, which have failed to release any commercial cultivars in the last 20 years (Buu et al. 2021).

Therefore, still relies on conventional breeding the hope that we can cope with the challenges of climate change developing varieties that tolerate extreme temperatures (Ramalho et al. 2009). In this context, Epagri´s Rice Team, concerned with issues related to climate change, began in 2008 studies with tolerance to low temperatures in the reproductive stages, which was a demand from rice farmers of the High Itajaí Valley region.

PEDIGREE AND BREEDING METHOD

The SCSBRS126 Dueto (SC 806 inbreed line) is the 26th rice cultivar released by Epagri's Irrigated Rice Breeding Program for Santa Catarina, in partnership with Embrapa, with support of Udesc/CAV. The name "Dueto" alludes to the inter-institutional partnership between Epagri and Embrapa, in addition to referring to the dual aptitude of the new variety, which is tolerant to low and high temperatures in the reproductive stage. Its release is dedicated to Dr. Orlando Peixoto de Morais (in memoriam), from Embrapa Rice and Beans, and to M.Sc. Richard Elias Bacha, former scientist at Epagri. The new variety results from the cross between the IRGA 424 variety and the Embrapa line BRA040081 (BRS Pampa variety), which was carried out in 2008 by Embrapa Rice and Beans. The F1 was carried out in 2009 (Goianira/GO), at the Palmital Experimental Station (EEP) and the F2 generation was conducted at Epagri – Itajaí Experimental Station (EEI) (2009/10). In 2010/11 the F2:3 families were evaluated in the Family Observation Test (EOF) at the EEP and in the "F2:3 Field Trial" at the EEI, with five families being selected, which were advanced to the F2:4 Family Yield Test (ERF) and evaluated in the 2011/12 crop season in Alegrete (RS), Capão do Leão (RS), Santa Vitória do Palmar (RS), and Itajaí (SC), where the family CNAx16810-B-7-B stood out. The genotype was then kept under study only at Epagri, which took this family to the F5 level (2012/13), and later to F6 and F7 (2013/14 and 2014/15) at EEI, as SC 806 inbred line.

Posteriorly, supported also by phenotypic selection field trials in autumn-winter at the EEI, SC 806 was standing out as an interesting genotype, and after that was included in normal spring-summer crop season experiments at 600 m (Rio do Campo/SC, 2014/15 to 2015/16) and 500 m altitude (Mirim Doce/SC, 2016/17). The SC 806 line showed good performances at these high altitude sites, and it was advanced to the official Value for Cultivation and Use trials (VCU)

in 2017/18.

At the same time (2015 - 2020), experiments were carried out at the EEI in partnership with the Agroveterinary Center of the State University of Santa Catarina – Udesc/CAV, in a controlled growth chamber (Instalafrio; software Sitrad). These studies confirmed the resilience of SC 806 not only to low temperatures (15-17 ºC) but also to high temperatures (up to 38 ºC), which can be summarized by a lower sterility percentage when compared to other cultivars (Stürmer et al. 2019, Souza et al. 2022). However, SCSBRS126 Dueto only has intermediate cold tolerance in germination and vegetative stage.

TRAITS PERFORMANCE

The agronomic/morphological traits of the SCSBRS126 Dueto variety are given in Table 1. SCSBRS126 Dueto has a late maturing cycle in Santa Catarina (SC) (142-144 days), excellent tillering at low altitudes, modern type of plant, and upright, hairy but short leaves. It is susceptible to lodging in pre-germinated system at low altitudes (SC at ≤ 400m), and moderate susceptible at higher altitudes (≥ 400m), whereas no lodging was observed in direct seeding system in Rio Grande do Sul State (RS). The variety also has low shattering and moderate susceptibility to blast (*Pyricularia oryzae*),

Table 1. Morphological and agronomic traits of SCSBRS126 Dueto in VCU[3]/DHS[4] trials

Plant trait / descriptor		**Description or Code (MAPA[1] - IRRI[2])**
Leaf color	[1, 4]	Green (2)
Leaf pubescence	[1, 4]	Medium (3)
Auricle color	[1, 4]	Green (1)
Ligule color	[1, 4]	Green or colorless (1)
Flag leaf angle	[1, 4]	Upright (1)
Plant height (culm length)	[1, 3, 4]	87 cm at the DHE Trials (76 cm at VCU)
Culm width	[1, 4]	4.1 mm
Tillering angle	[1, 4]	Upright (1)
Internode color	[1, 4]	Light Green (1)
Anthocyanin node color	[1, 4]	Absent/Weak (1)
Panicle length	[1, 4]	25.7 cm
Type of panicle	[1, 4]	Intermediate (3)
Panicle exsertion	[1, 4]	Complete (1)
Shattering	[1, 4]	Intermediate (3)
Awns	[1, 4]	Present (0), but rare
Awns length	[1, 4]	------- (1) (≈ 1-2 mm)
Stigma color	[1, 4]	Green (1)
Lemma/Palea pubescence	[1, 4]	Medium (5)
Keel's color (flowering)	[1, 4]	Green (2)
Keel's color (maturing)	[1, 4]	Yellow (2)
Glume color (palea/lemma)	[1, 4]	Golden/straw (1)
Sterile lemmas color (glumes)	[1, 4]	Straw (1)
Cycle to maturity	[1, 3]	Late maturing (142 -144 Days)
Leaf blast	[1, 3]	Moderately resistant
Panicle blast	[1, 3]	Moderately resistant
Brown spot	[1, 3]	Moderately susceptible
Leaf Scald	[1, 3]	Moderately susceptible
Sheath rot	[1, 3]	Moderately susceptible
False smut	[1, 3]	Moderately susceptible
Iron toxicity tolerance	[2]	Moderately susceptible (5.7)
Tillering	[1, 3]	Very High
Lodging (≥ 400 m altitude)	[1, 3]	Moderately susceptible
Lodging (≤ 400 m altitude)	[1, 3]	Susceptible

[1] MAPA (Ministry of Agriculture, Livestock and Food Supply) (2008) Descritores mínimos de arroz; [2] SES/IRRI (Standard Evaluation System) (IRRI 2013) www.clrri.org/ver2/uploads/SES_5th_edition.pdf>; [3] VCU trials (Itajaí, Massaranduba, Mirim Doce, Turvo, in 2017/18 and 2019/20); [4] DHS - distinguishability, homogeneity, stability (MAPA) evaluations 2018/19 to 2020/21

brown spot (*Bipolaris oryzae*), false smut (*Ustilaginoidea virens*) and sheath rot (*Sarocladium oryzae*).

The SCSBRS126 Dueto showed an average yield of 10,290 kg ha^{-1} in the pre-germinated VCU trials in Santa Catarina during tree crop seasons, which is a competitive yield compared to Epagri´s best control cultivars (Table 2). The same good performance was reached by Embrapa in the VCU trials in Rio Grande do Sul under direct seeding system in dry soil (Table 2).

SCSBRS126 Dueto has long, slender translucent grains, with lower percentage of chalked grains and chalked grain area, with good milling quality for white milled rice (Table 3), which are desirable traits to become accepted for white milled as well as for parboiled rice. All the physical grain analyses were carried out with 100g rough rice samples dehulled and milled by the Testing Rice Mill Device Suzuki (Model MT.08 - Suzuki, Santa Cruz do Rio Pardo/SP) and then analyzed by the Image Rice Grain Scanner (Selgron, Blumenau/SC) at the Epagri's Rice Breeding Laboratory (Lamgen/EEI). The sensorial and cooking traits of SCSBRS126 Dueto are comparable or better than those of the control cultivars, since the grains show soft texture, good aroma and taste (Table 4) (Quality Laboratory of Urbano Agroindustrial - Jaraguá do Sul/SC, Brazil).

Table 2. Average grain yield (kg ha^{-1}) of SCSBRS126 Dueto in Santa Catarina compared to control cultivars, in 12 VCU trials: 4 locations, in three crop seasons (2017/2018 to 2019/2020) under pre-germinated system; and average grain yield (kg ha^{-1}) of SCSBRS126 Dueto in Rio Grande do Sul (RS) compared to control cultivars, in VCU trials at four locations, in two crop seasons (2020/2021 to 2021/2022) under direct seeding system in dry soil

Location SC	**Itajaí**			**Massaranduba**			**Mirim Doce**			**Turvo**			**Average[1]**
Crop season	**17-18**	**18-19**	**19-20**	**17-18**	**18-19**	**19-20**	**17-18**	**18-19**	**19-20**	**17-18**	**18-19**	**19-20**	
Cultivar													
SCSBRS126 Dueto	10.788	9560*	13.696	9.731	9.405	12.536	10.586	9.733	7.695	10.708	11.229	7820**	10.290a
SCS116 Satoru	10.673	10.334	11.975	7.358	8.504	11.194	7.689	9.160	8.839	10.625	7.197	9.347	9.408a
SCS122 Miura	12.265	11.233	14.175	8.543	8.332	10.337	8.779	10.037	9.241	10.042	7.918	8.909	9.984a

Location RS	**Alegrete**				**Uruguaiana**					**Capão do Leão**		**Sta Vitória do Palmar**	**Average[2]**
Crop season	**20-21**		**21-22**		**20-21**		**21-22**			**20-21**	**21-22**	**21-22**	
Cultivar	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	Trial1	Trial 2		Trial1	Trial 2	Trial 1	
SCSBRS126 Dueto	12.281	12.200	13.362	13.394	14.422	13.588	14.059	7.170	**	11.698	10.749	7.126	11667a
BRS Pampeira	11.284	11.394	13.226	12.809	15.703	12.238	13.761	8.718	**	10.696	10.223	7.582	11386a
BR-IRGA 409	10.700	10.556	9.899	10.295	10.803	9.984	11.211	12.827		9.716	8.898	6.624	9907b

[1, 2] Means with different letters are significantly different by Scott-Knott test at 1% probability (ANAVA by software GENES/UFV with [1] CV 8.5 % [2] CV 9.38 %). * Lodging; ** Underestimated due to birds attack

Table 3. Grain traits of SCSBRS126 Dueto milled rice grains at 3 years VCU's (2017/18 to 2019/20): Itajaí, Massaranduba, Mirim Doce and Turvo (SC – Brazil)

Trait	**Cultivar**		
	SCSBRS126 Dueto	**SCS116 Satoru**	**SCS122 Miura**
Total milled grains (%)[3]	67.94	66.10	66.95
Whole grains (%)[3]	60.01	56.72	58.65
Broken grains (%)[3]	7.93	9.38	8.30
Amylose content (%)[1]	24.28	24.87	25.00
Gelatinization temp.[1]	6.98	2.55	2.58
Grains chalked area (%)[3]	4.24	4.02	2.81
Chalked grains (%)[3]	6.66	6.95	5.08
Grain length (mm)[3]	7.09	7.13	7.24
Grain width (mm)[3]	1.99	2.16	2.09
Grain thickness (mm)[3]	1.73	1.72	1.70
Length-Width ratio[3]	3.56	3.30	3.46
Thousand grain weight[4]	27.75	28.5	27.9

[1] Embrapa/CNPAF (International Standard Method ISO 6647 2007); [2] Martínez C and Cuevas F (1989); [3] Analyzed with "Image" Scanner (Selgon) at LAMGEN (Rice Breeding Laboratory - Epagri) (Marschalek et al. 2017). [4] Analyzed at LAMGEN (Rice Breeding Laboratory - Epagri)

Table 4. Means of SCSBRS126 Dueto sensory traits of the grains (2017/2018 to 2019/2020)

	Texture	Color	Stickiness	Characteristic odor	Characteristic taste
SCSBRS126 Dueto	2.0	2.4	2.9	0.5	0.8
SCS116 Satoru	3.4	1.3	5.2	1.0	0.9
SCS122 Miura	3.2	1.8	5.2	0.8	0.9

ABNT (1998) NBR14140 sensory analysis - methodology - Quantitative descriptive analysis (QDA) - Food - Beverage. Available at https://www.abntcatalogo.com.br/norma.aspx?ID=004432>.

SCSBRS126 Dueto grains are suitable for parboiled rice and based on the laboratorial analysis the soaking time during the parboiling process should be preferably 6 hours at temperatures of 60 ºC (Certificate number 0421, 3/9/2020 - LabGrãos/UFPel– Pelotas/RS), which indicates a similar parboiling behavior as other main Epagri cultivars (hydration curve can be obtained by request to corresponding author).

Added to all this, the main trait to stress out is that SCSBRS126 Dueto has the ability to tolerate cold and heat during the reproductive stage for some days, which is demonstrated by lower sterility rates compared with control cultivars (daily temperatures of 15-17 °C and night ones of 10-12 °C or daily of ≥38 °C, during 3-4 days). This was proved under controlled stress trials and also validated by two natural field cold cases (Stürmer et al. 2019, Souza et al. 2022, Marschalek et al. 2023).

SCSBRS126 Dueto is recommended to rice farmers and industry for growing in Santa Catarina pre-germinated rice areas, specially over 400 m altitude, where the yield is competitive with those of other cultivars, and the risk of lodging is low, whereas the risks of sterility due to cold are lower than the ones expected in other cultivars. On the other hand, even for the low altitude areas in Santa Catarina, SCSBRS126 Dueto remains a good option for farmers to reduce the risks of losses due to low or high temperature events at reproductive stages, like the one reported by Eberhardt (2010). It is also recommended for the Rio Grande do Sul State, at least under direct seeding system in dry soil.

MOLECULAR BACKGROUND

The genetic profile of the variety SCSBRS126 Dueto was done at the Molecular Biology Laboratory (EEI) using 26 microsatellite rice markers, using Jaccard coefficient and UPGMA agglomerative coefficient using the software NTSYS-PC 2.1, and the SCSBRS126 Dueto similarity with the other Epagri´s varieties was about 27%. The new variety has an allele (203, for the RM-316) which is not shared with the other Epagri varieties. Similarity dendrogram including SCSBRS126 Dueto, its parents, and the most important Epagri varieties still cultivated can be obtained by request to the corresponding author.

FOUNDATION SEED PRODUCTION

SCSBRS126 Dueto is registered and protected at the Ministry of Agriculture, Livestock and Food Supply (MAPA) of Brazil (respectively 48358, 7/8/2021; 20230006, 9/20/2022 - 9/20/2037). Seeds are produced by Santa Catarina Irrigated Rice Seed Producers (Acapsa) for the 2023/2024 crop season.

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REFERENCES

Buu BC, Chan CY and Lang NT (2021) Molecular breeding for improving heat stress tolerance in rice: recent progress and future perspectives. In Hossain MA, Hassan L, Iftekharuddaula K Md, Kumar A and Henry R (eds) **Molecular breeding for rice abiotic stress tolerance and**

nutritional quality. Wiley Blackwell, Hoboken, p. 92-119.

Cruz CD (2006) **Programa Genes - Biometria**. Editora UFV, Viçosa, 382p.

Eberhardt DS (2010) Altas temperaturas afetam produtividade e qualidade do arroz irrigado do Estado. **Agropecuária Catarinense 23**: 12

Khan S, Anwar S, Ashraf MY, Khaliq B., Sun M, Hussain S, Gao Z, Noor H and Alam S (2019) Mechanisms and adaptation strategies to improve heat tolerance in rice. **Plants 8**: 508.

Liu QA (2013) The impact of climate change on plant epigenomes. **Trends in Genetics 29**: 503-505.

Lv Y, Hussain MA, Luo D and Tang N (2019) Current understanding of genetic and molecular basis of cold tolerance in rice. **Molecular Breeding 39**: 159.

Marschalek R, Oliveira DG, Souza NM, Fachinello PHK, Terres LR and Sangoi L (2023) Avaliação de tolerância a baixas temperaturas em genótipos de arroz irrigado (*Oryza sativa* L.) na fase reprodutiva em experimento a campo, durante evento climático espontâneo na safra 2019/2020. **Ciências Agroveterinárias 22**: 103-108.

Marschalek R, Silva MC, Santos SB, Manke JR, Bieging C, Porto G, Wickert E and Andrade A (2017) Image - Rice Grain Scanner: a three-dimensional fully automated assessment of grain size and quality traits. **Crop Breeding and Applied Biotechnology 17**: 89-97.

Martínez C and Cuevas F (1989) **Evaluación de la calidad culinária y molinera del arroz: Guía de estúdio**. CIAT, Cali, 95p.

Najeeb S, Mahender A, Anandan A, Hussain W, Li Z and Ali J (2021) Genetics and breeding of low-temperature stress tolerance in rice. In Ali J and Wani SH (eds) **Rice improvement: physiological, molecular breeding and genetic perspectives**. Springer, Metro Manila, p. 221-280.

Padrão G Arroz (2022) **Síntese anual da agricultura de Santa Catarina**. Epagri/Cepa, Florianópolis, p. 24-28.

Ramalho MAP, Silva GS and Dias LAS (2009) Genetic plant improvement and climate changes. **Crop Breeding and Applied Biotechnology 9**: 189-195.

Rozzetto DS, Marschalek R, Stuker H, Raimondi JV, Eberhardt DS and Knoblauch R (2015) Tolerância de genótipos de arroz irrigado submetidos a estresses por baixas temperaturas na fase reprodutiva. **Agropecuária Catarinense 28**: 61-66.

Samejima H, Kikuta M, Katura K, Menge D, Gichuhi E, Kimari J, Inukai Y, Yamauchi A and Makihara D (2020) A method for evaluating cold tolerance in rice during reproductive growth stages under natural low-temperature conditions in tropical highlands in Kenya. **Plant Production Science 23**: 466-476.

Shinada H, Iwata N and Fujin K (2013) Genetical and morphological characterization of cold tolerance at fertilization stage in rice. **Breeding Science 63**: 197-204.

Sosbai - Sociedade Sul-Brasileira de Arroz Irrigado (2018) **Recomendações técnicas da pesquisa para o sul do Brasil**. Sosbai, Cachoeirinha, 205p.

Souza NM, Marschalek R, Sangoi L and Stümer FW (2017) Spikelet sterility in rice genotypes affected by temperature at microsporogenesis. **Revista Agriambi 21**: 817-821.

Souza NM, Sangoi L and Marschalek R (2022) Tolerance of lowland rice (*Oryza sativa*) genotypes to heat stress at anthesis. **Agropecuária Catarinense 35**: 50-54

Stürmer FW, Marschalek R, Sangoi L and Souza NM (2019) Esterilidade de espiguetas e produção de grãos de genótipos de arroz irrigado submetidos a baixas temperaturas na microsporogênese. **Agropecuária Catarinense 32**: 57-61

Xiao N and Chen JM (2021) Molecular breeding for improving cold tolerance in rice: recent progress and future perspectives. In Hossain MA, Hassan L, Iftekharuddaula KMd, Kumar A and Henry R (2021) **Molecular breeding for rice abiotic stress tolerance and nutritional quality**. Wiley Blackwell, Hoboken, p. 120-130.

Ye C, Li X, Redoña E, Ishimaru T and Jagadish K (2021) Genetics and breeding of heat tolerance in rice. In Ali J and Wani SH (eds) **Rice improvement: physiological, molecular breeding and genetic perspectives**. Springer, Metro Manila, p. 203-219.