FUNCTIONAL PLANT BREEDING JOURNAL

Scientific Journal. ISSN 2595-9433
Volume 5, Article n. 15, Jan/December
D.O.I. http://dx.doi.org/10.35418/2526-4117/v5a15
Received: 10/02/2023 - Accepted: 10/13/2023

AGRONOMIC PERFORMANCE OF LOCAL DRYLAND RICE VARIETIES OF THE FAR WEST OF SANTA CATARINA, BRAZIL

Rosenilda de Souza[1]*, Juliana Bernardi Ogliari[2], Otavio Rechsteiner Maghelly[2], Nuno de Campos Filho[2], Francisco Wilson Reichert Júnior[3], Tassiane Terezinha Pinto[4]

[1] Laboratório de Fitotecnia, Universidade Estadual do Norte Fluminense Darcy Ribeiro, Campos dos Goytacazes, Rio de Janeiro, Brasil;

[2] Departamento de Fitotecnia, Universidade Federal de Santa Catarina, Florianópolis, Santa Catarina, Brasil;

[3] Escola de Ciências Agrárias, Universidade de Passo Fundo, Passo Fundo, Rio Grande do Sul, Brasil;

[4] Departamento de Botânica, Universidade Federal de Santa Catarina, Florianópolis, Santa Catarina, Brasil.

** Corresponding author: rosenilda@pq.uenf.br.*

Abstract: Dryland rice varieties are conserved *in situ* on farm in the far west of the state of Santa Catarina, southern Brazil. The objective of this work was to evaluate the agronomic performance of 34 local dryland rice varieties from this region, which they represent four morphological groups. The experiments were carried out in two municipalities in Santa Catarina (Anchieta and Florianópolis), in complete randomized blocks design with four replications. The differences were significant ($p \leq 0.05$) for the effects of genotype, environment, and genotype x environment interaction, for the stem length variable. All other variables showed significant differences for the effects of genotype and interaction and not significant for the environment. Yield, stem length, number of tillers per plant, number of branches and grains per panicle ranged from 1,458.59 to 4,193.80 kg ha^{-1}, 69.2 to 113.1 cm, 2.5 to 4.0 tillers per plant, 8.5 to 10.2 branches and 75.9 to 97 grains, respectively. The highest yield values and stem length were obtained in Florianópolis. Resistance to lodging was greater in Anchieta, local of origin of the varieties. Yield, stem length and the number of grains showed dependence by the chi-square test ($p \leq 0.05$), in relation to the conservation time of the varieties by the farmers. Varieties grain medium to medium-elongated and color red, classified as special grains, obtained yields equivalent to the others. The local dryland rice varieties studied show differences in agronomic performance and stability, as well as potential for use as base populations in rice breeding programs.

Keywords: *Oryza sativa*, rice yield components, conservation *in situ* on farm.

Introduction

The cultivation of dryland rice has been carried out for several decades by family farmers from the western regions and slopes of the general mountain range of Santa Catarina, with production almost exclusively for self-consumption, occupying 60 hectares, with a production of

139 tons and yield of 2,317 kg ha^{-1}, in 2022 (EMBRAPA, 2023). In three decades, occurred a 99.8% reduction in dryland rice planted area, in the state (EMBRAPA, 2023). One of the reasons for the significant reduction in the planted area was the lower industrial quality, with great qualitative variation of the grains, in addition to the lower valuation of dryland rice (Soares et al., 2004). Besides, the genetic improvement and yields increases of the irrigated rice varieties made the yields and risks associated with rainfed cultivation less attractive for commercial production.

Although dryland rice has historical, social and food security importance for family farming, in Santa Catarina, currently, the state does not have any dryland rice cultivars recommended for cultivation (EPAGRI, 2021). However, there is a great diversity of local varieties grown in the dryland system in this region (Pinto et al., 2019), from seeds preserved by families of small-scale traditional farmers. One of the key traits for the definition of genetic diversity identified by Pinto et al. (2019) is the color of the whole grain. The authors identified fifteen varieties with a red or reddish color. Varieties of rice called “colored” tend to have a higher content of nutrients, compared to white rice and, therefore, should be valued for their beneficial properties to health (Kowsalya et al., 2022).

Local seeds tend to be vigorous materials and with adaptive advantages, due to the selection pressure offered by the agricultural ecosystem and the selection management of farmers, allowed more sustainable cultivation systems, less demanding on inputs (Ogliari et al., 2013). Local varieties tend to have high genetic variability and, although, in general, they do not have high productive potential, compared to improved varieties, they have greater stability and adaptation to environments with one or more factors limiting production (Brondani et al., 2006).

One of the main contributions to the *in situ* on farm conservation of these local varieties is the food security of rural families. Among the main use values pointed out by farmers in western Santa Catarina, are tradition, consumption habits, culinary quality for the preparation of local dishes and belief that these grains are healthier than commercial ones (Pinto et al., 2018), as they are more nutritious and freer from pesticides.

Besides, these local varieties can contribute to the expansion of the genetic base of rice cultivars in Brazil, as they reduce the genetic vulnerability of that crop, in addition to enabling the increase of their yields and agronomic quality (Abadie et al., 2005). In this sense, local varieties play an important role as a source of genes and characteristics for the development of new cultivars, although they have been the target of few efforts by formal breeding programs, especially in the southern region of the country, both in the commercial long pattern and in the special grains segment.

During the collection of germplasm for the construction of a national collection of rice by Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), the southern region contributed with eighty-nine rice local varieties (Abadie et al., 2005). However, additional efforts must be done to collect and characterize dryland rice germplasm adapted to milder temperatures (Burle et al., 2001), especially of far west region of Santa Catarina recognized as a microcenter of diversity of local dryland rice varieties (Pinto et al., 2019).

Based on this context, the objective of this work was to analyze and characterize the agronomic performance of local dryland rice varieties conserved by family farmers in the far west of Santa Catarina.

Material and methods

The local dryland rice varieties in the present study come from the municipalities of Anchieta and Guaraciaba, both located in the far west of Santa Catarina, in southern Brazil. They were collected in small-scale farms, between the years 2012 to 2014.

Of one hundred and twelve populations collected, Pinto et al. (2019) previously characterized sixty for morphological and phenological characters. Of these, thirty-four varieties of four distinct morphological groups, concerning the grain shape, the color of the husk and the whole grain, were included in the present study (Table 1). The varieties were selected according to the time of conservation by the farmer (prioritizing materials conserved for a longer time), the origin of the seed (as an indication of seniority in the region) and the Euclidean distance calculated by Pinto et al. (2019), based on thirty-one variables.

The varieties evaluated in the present study represent the genetic diversity of the sixty varieties for the characteristics number of tillers, stem thickness and panicle length, with precision greater than 95%, according to the calculation by variable of the maximum sampling error and population proportion from the mean and standard deviation data obtained by Pinto et al. (2019).

Five of the varieties evaluated present whole grains with red or reddish and medium or medium elongated grains, distinct from the commercial pattern of long thin grains, predominant in the Brazilian and world markets (Table 1).

Table 1. Dryland rice local varieties from the far west of the state of Santa Catarina, Brazil, grouped by morphological group, origin, cultivation time and usage values.

Variety [a]	Group	Grain shape	Husk color	Whole grain color	Origin	Time in property	City	Use values [b]
98	I	Long	Gold	Light brown	Heritage	19	Anchieta	Tradition
104	I	Long	Gold	Light brown	Neighbors	1	Anchieta	Culinary quality
7	II	Medium long	Straw color	Light brown	Neighbors	20	Guaraciaba	Good yield
12	II	Long	Straw color	Light brown	Syndicate	34	Anchieta	DCR
13	II	Long	Straw color	Light brown	FSS	10	Anchieta	Good yield
14	II	Medium long	Straw color	Light brown	Heritage	30	Anchieta	DCR
17	II	Long	Straw color	Light brown	Heritage	5	Anchieta	Resistant
20	II	Long	Straw and Gold	Light brown	Neighbors	13	Anchieta	Good yield
22	II	Medium long	Straw color	Light brown	Heritage	15	Guaraciaba	Culinary quality
24	II	Medium long	Straw color	Light brown	Neighbors	6	Anchieta	Good yield
34	II	Medium long	Straw color	Light brown	Neighbors	2	Guaraciaba	Culinary quality
35	II	Long	Straw color	Light brown	Syndicate	20	Anchieta	DCR
42	II	Medium long	Straw color	Light brown	Heritage	5	Guaraciaba	Healthy
43	II	Medium long	Straw color	Light brown	Heritage	10	Guaraciaba	Culinary quality
50	II	Long	Straw color	Light brown	Heritage	8	Guaraciaba	Culinary quality
60	II	Medium	Straw color	Light brown	FSS	12	Guaraciaba	Tradition
61	II	Long	Straw color	Light brown	Heritage	20	Guaraciaba	Culinary quality
67	II	Long	Straw color	Light brown	FSS	10	Guaraciaba	Good yield
68	II	Long	Straw color	Light brown	FSS	20	Guaraciaba	Good yield
72	II	Medium long	Straw color	Light brown	FSS	1	Guaraciaba	Tradition
83	II	Long	Straw color	Light brown	Heritage	60	Guaraciaba	Culinary quality
84	II	Long	Straw color	Light brown	FSS	3	Guaraciaba	DCR
90	II	Medium long	Gold	Light brown	Heritage	2	Anchieta	Good yield
31	III	Medium long	Brown	Red	Epagri	6	Guaraciaba	Good yield
32	III	Medium long	Brown	Red	Epagri	8	Guaraciaba	Good yield
82	III	Medium long	Brown	Light brown	Heritage	17	Guaraciaba	Culinary quality
10	IV	Medium	Straw color	Red	Neighbors	20	Anchieta	Culinary quality
19	IV	Medium	Straw color	Red	Neighbors	20	Anchieta	DCR
29	IV	Medium long	Gold	Light brown	Neighbors	2	Anchieta	Good yield
41	IV	Medium	Straw color	Light brown	Heritage	25	Anchieta	Good yield
54	IV	Medium	Straw color	Light brown	FSS	11	Guaraciaba	Healthy
59	IV	Medium	Straw color	Red	Heritage	42	Guaraciaba	Culinary quality
71	IV	Medium long	Straw color	Light brown	FSS	12	Guaraciaba	Adapted to the region
103	IV	Medium long	Straw color	Light brown	Heritage	34	Anchieta	Culinary quality

[a] Identified by access-collection number; [b] Values of use of varieties, in the view of farmers, according to an interview carried out between 2012 and 2014 for the diagnosis of dry rice diversity in Anchieta and Guaraciaba; FSS: Farm supply store; Epagri: Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina; DCR: Dislikes commercial rice. Source: Adapted from Pinto et al. (2018).

As a statistical control was used the variety IPR117 (IAPAR/ PR), the only dryland material with commercial production and cultivation recommendation for the southern states of the country. IPR117 was developed by Instituto Agronômico do Paraná (IAPAR) based on the crossing of IAC 47 and IRAT146, for dryland farming conditions, within the scope of family farming and rotation with soy. It has long thin class grains and high processing yield, long cycle and mean yield of up to 3,500 kg ha^{-1}, in demonstrative areas (IAPAR, 2004).

The varieties were evaluated in experiments conducted in two environments in the state of Santa Catarina, with different altitudes, temperatures, rainfall and soils, seeking to allow estimates of genotype x environment and stability interactions. The first experiment was conducted in smallscale farm of the region of origin and collect of varieties, in the municipality of Anchieta (26º 30' 53.93" S; 53º 18' 44.97" W, in altitude of 717 m, and soil classified as cambisol, with wavy and rocky terrain). Anchieta is located in the south of Brazil, in the micro-region of the far west of Santa Catarina (IBGE, 2010), has a humid mesothermal climate (Köppen's Cfa), mean annual temperature of 17.8 °C, and annual rainfall around 1,700 to 2,000 mm. The second experiment was conducted at the Federal University of Santa Catarina (UFSC) Experimental Farm, in Florianópolis (27º41'06.28"S, 48º32'38.81"W, in altitude of 5 m and soil is classified as a typical hydromorphic quartzarenic). Florianópolis is located in Santa Catarina coast, sub-region of sub-tropical climate that is constantly humid, without a dry season, with hot summer and an mean annual temperature of 20.1 °C, and annual rainfall around 1,270 to 1,600 mm (IBGE, 2010).

The experiments were conducted in a complete randomized block design, with four replications. Each experimental unit was formed by four linear rows (3.0 m in length), at 0.34 m spacing between rows and containing fifty-five plants per linear, and a useful plot of 1.36 m^2, with approximately two hundred and twenty plants (approximate density of 1.6 million plants ha^{-1}).

The conduction of the experiments in the two sites followed the technology used by the farmers, with tractor preparation of the area, complete organic fertilization (from the soil analysis) in the planting with poultry manure and manual weeding and weeds to control the invasive plants. No pest or disease control was carried out.

The characters evaluated were yields, stem length, lodging resistance, tillering, number of branches per panicle, number of grains per panicle and shattering resistance (Bioversity, Irri and Warda, 2011). The yield was recorded from the total harvest of the central rows, at the stage of physiological maturity of the grains. After grains drying in an oven at 42º, the humidity was corrected to standardize 13% of the rice grain in husk and the yield converted into kg ha^{-1}. The stem length character was measured in centimeters between flowering and maturation, taking the height between the ground level and the base of the panicle insertion, in twenty random plants within the useful plot. The lodging resistance was recorded in scale at maturation, based on the degrees of lodging observed in 2 m of the two central rows, being (1) Very weak (all plants fallen); (3) Weak (most of the plants fallen); (5) Intermediate (most plants curved at about 45°); (7) Strong (most plants slightly curved at 20° from the vertical); (9) Very strong (all plants standing). The number of tillers per plant (unit) was evaluated between anthesis and maturation by counting the total number of tillers from twenty random plants in the useful plot. The number of branches per panicle and the number of grains per panicle (unit) was obtained from counting ten plants of the useful plot, at harvest. Shattering resistance was evaluated in twenty random plants from the useful plot at the time of harvest, being (1) Difficult (few or no grains removed), (2) Intermediate (25-50% grains removed), (3) Easy (> 50% grain removed).

The data were subjected to analyzes of homoscedasticity and, subsequently, to joint analysis of variance, tests of comparison of means, genotype x environment interactions and stability. The joint analysis was carried out according to the mixed mathematical statistical model, described by Searle et al.

(1992), with fixed effects for environments and random for genotypes and other effects

$$Y_{ijk} = \mu + G_i + {}^{B}/_{A_{jk}} + A_j + GA_{ij} + E_{ijk}$$

In which, Y_{ijk} is the phenotypic value of the i-th genotype in the j-th environment and in the k-th block; μ is the parametric general mean; G_i is the effect of genotype i (i = 1, 2, … ,35), B/A_{jk} is the effect of the k-th block in the j-th environment (k = 1, 2, … , 4); A_i is the effect of environment j (j = 1, 2); GA_{ij} is the effect of the interaction of the i-th genotype with the j-th environment; and E_{ijk} it is the effect of the experimental error associated with the Y_{ijk} observation.

The variables that showed significant differences between varieties and locations by the F test at the significance level of 5% probability ($p \leq 0.05$) were subjected to the Scott-Knott test at the same level of significance.

The chi-square test was used to analyze the independence between quantitative variables (yield, stem length, lodging resistance, tillering, number of branches per panicle, number of grains per panicle and shattering resistance) and the characteristics associated with varieties (morphological group, seed origin, cultivation time and usage values (Table 1), as well as identify any association between yield and grain shape ($p \leq 0.05$).

Phenotypic correlation analyzes were carried out, seeking to evaluate the possible relationship between yield, stem length and number of tillers among themselves and with the other variables. Regression analysis was performed for number of grains per panicle × number of branches and stem length x lodging, variables with a known cause and effect relationship.

The stability analyzes were performed by the traditional method (Yates and Cochran, 1938), with subsequent ordering of the varieties, depending on the mean position in relation to the seven variables collected. All statistical analyzes were performed with the computer software GENES (Cruz, 2013).

Results

The treatments showed significant differences for all variables studied in the joint variance analyzes. No association between any of the variables analyzed and the morphological group was detected and, therefore, the results will be presented and discussed for the set of varieties. For the stem length variable of the joint analysis, the differences were significant ($p \leq 0.05$) for genotypes, environments and interaction. All other characteristics showed significant differences ($p \leq 0.05$) for genotypes and interaction and not significant for environments

Yields ranged from 1,458.59 to 4,193.80 kg ha^{-1}, considering the two experimental sites (Table 2). Higher yields were obtained at the Experimental Farm, in Florianópolis.

Fourteen varieties (10, 13, 19, 20, 22, 31, 34, 43, 59, 61, 67, 68, 72 and 84) obtained yields statistically equivalent to the control, in Anchieta, on the upper level the mean comparison test (2,430.7 to 3,350.2 kg ha^{-1}). In Florianópolis, eleven varieties (10, 12, 13, 35, 50, 59, 67, 71, 83, 98 and 104) were equivalent to the control at the intermediate level and nine (17, 19, 29, 34, 41, 43, 68, 72 and 84) were statistically superior, registering yields of 3,516.1 to 4,193.8 kg ha^{-1}. Varieties 19, 34, 43, 68, 72 and 84 showed higher yields in both locations. Twelve treatments (12, 17, 19, 29, 41, 43, 50, 68, 72, 84, 98 and 104) showed significantly higher performance in Florianópolis. The varieties obtained greater stem length in Florianópolis, with stem length ranging from 69.0 to 97.1 cm, in Anchieta, and from 84.5 to 113.1 cm, in Florianópolis (Table 2).

For the number of tillers, the values ranged from 2.7 to 4.2, in Anchieta, and from 2.2 to 4.0, in Florianópolis (Table 2). Twenty-six varieties did not show significant differences between sites for the number of tillers by the joint analysis. The values ranged from 2.6 to 4.2 tillers per plant. There was no trend towards a greater number of tillers in a given location, even though the plants remain for a longer period in the phenological tillering phase, in Anchieta, due to the lower daily accumulation of degree-days (lower temperatures, mainly at night, due to the altitude difference).

The variable number of branches per panicle, on mean, was 9.11 in Anchieta and 9.25 in Florianópolis (Table 3). The number of grains per panicle varied from 75.9 to 96.4, in Anchieta, and from 73.6 to 94.1, in Florianópolis (Table 3). For shattering resistance (scale), there were no significant differences between locations for most varieties (24 varieties) (Table 3).

Table 2. Means and coefficients of experimental and genetic variation estimated by individual and joint analyses of variance applied to traits yield, stem length and tillering of dryland rice local varieties and one control treatment, in two environments, in the Santa Catarina state, Brazil.

Group	Variety	Yield (kg ha^{-1})			Stem length (cm)			Tillering (unit)		
		ANC	FLP	Mean	ANC	FLP	Mean	ANC	FLP	Mean
I	98	1737.58 bB	2980.37 bA	2358.98 b	79.1 bB	90.7 cA	84.90 b	3.2 bA	3.1 bA	3.2 a
I	104	1458.59 bB	3300.69 bA	2379.64 b	70.8 bB	100.4 bA	85.60 b	3.3 bA	3.2 bA	3.3 a
II	7	2104.20 bA	2677.07 cA	2390.64 b	87.9 aB	113.1 aA	100.50 a	3.2 bA	3.4 aA	3.3 a
II	12	2023.22 bB	3125.80 bA	2574.51 b	81.4 bA	83.6 cA	82.50 b	2.9 cA	2.2 bB	2.6 b
II	13	2963.08 aA	3164.69 bA	3063.89 a	84.6 aB	98.3 bA	91.45 b	3.1 bA	3.1 bA	3.1 a
II	14	1877.52 bA	2600.89 cA	2239.21 b	82.2 bB	96.8 bA	89.50 b	3.0 cA	2.9 b A	3.0 b
II	17	1899.69 bB	3528.93aA	2714.31 a	78.2 bB	97.2 bA	87.70 b	2.8 cB	3.4 a A	3.1 a
II	20	2879.80 aA	2021.16 cA	2450.48 b	83.5 bB	99.5 bA	91.50 b	2.9 cB	3.7 aA	3.3 a
II	22	2593.38 aA	1717.17 cA	2155.28 b	88.5 aA	88.5 cA	88.50 b	3.2 bA	3.3 aA	3.3 a
II	24	2158.22 bA	1799.79 cA	1979.01 b	79.4 bB	102.1 bA	90.75 b	3.4 bA	2.9 bB	3.2 a
II	34	3020.13 aA	3934.07 aA	3477.10 a	80.3 bB	91.5 cA	85.90 b	3.4 bA	3.5 aA	3.5 a
II	35	2152.85 bA	2988.94 bA	2570.90 b	75.9 bB	92.2 cA	84.05 b	3.0 cA	2.7 bA	2.9 b
II	42	1815.15 bA	2526.02 cA	2170.59 b	78.8 bA	89.3 cA	84.05 b	3.1 bA	3.1 bA	3.1 a
II	43	2563.15 aB	3716.24 aA	3139.70 a	97.1 aA	97.0 bA	97.05 a	3.3 bA	2.9 bA	3.1 a
II	50	1762.33 bB	2895.89 bA	2329.11 b	79.0 bA	102.8 bA	90.90 b	2.8 cA	2.9 bA	2.9 b
II	60	1715.24 bA	2076.12 cA	1895.68 b	77.1 bB	98.3 bA	87.70 b	3.2 bA	3.0 bA	3.1 a
II	61	2435.05 aA	2038.13 cA	2236.59 b	86.6 aB	99.1 bA	92.85 b	3.2 bA	3.4 aA	3.3 a
II	67	2543.16 aA	3124.24 bA	2833.70 a	80.6 bB	96.1 bA	88.35 b	3.1 bA	3.0 bA	3.1 a
II	68	2644.75 aB	4099.04 aA	3371.90 a	79.1 bB	98.7 bA	88.90 b	3.2 bB	3.8 aA	3.5 a
II	72	2430.70 aB	3789.74 aA	3110.22 a	80.9 bB	93.9 cA	87.40 b	3.3 bA	3.0 bA	3.2 a
II	83	2238.77 bA	3117.14 bA	2677.96 b	78.9 bB	95.1 bA	87.00 b	2.7 cA	3.2 bA	3.0 b
II	84	2737.19 aB	4193.80 aA	3465.50 a	86.2 aB	100.9 bA	93.55 a	2.7 cB	3.7 aA	3.2 a
II	90	2181.24 bA	1890.67 cA	2035.96 b	90.9 aB	106.8 aA	98.85 a	3.1 bA	2.8 bA	3.0 b
III	31	2619.56 aA	2175.68 cA	2397.62 b	93.3 aB	106.6 aA	99.95 a	4.2 aA	3.0 bB	3.6 a
III	32	1836.39 bA	1752.91 cA	1794.65 b	91.3 aB	110.9 aA	101.10 a	3.2 bA	2.5 bB	2.9 b
III	82	1856.44 bA	1794.40 cA	1825.42 b	88.7 aB	106.2 aA	97.45 a	2.8 cA	3.0 bA	2.9 b
IV	10	3350.24 aA	2997.93 bA	3174.09 a	81.1bA	85.8 cA	83.45 b	3.2 bB	4.0 aA	3.6 a
IV	19	2541.09 aB	3727.32 aA	3134.21 a	81.9 bA	85.1 cA	83.50 b	3.1 bA	3.1 bA	3.1 a
IV	29	2206.48 bB	4181.14 aA	3193.81 a	82.8 bA	90.4 cA	86.60 b	3.0 cA	3.4 aA	3.2 a
IV	41	1866.03 bB	3516.12 aA	2691.08 a	73.7 bB	89.9 cA	81.80 b	3.3 bA	2.8 bA	3.1 a
IV	54	2108.75 bA	2695.04 cA	2401.90 b	74.7 bB	89.3 cA	82.00 b	2.6 bA	2.9 bA	2.8 b
IV	59	2537.04 aA	3352.88 bA	2944.96 a	79.3 bA	86.1 cA	82.70 b	3.2 bA	3.6 aA	3.4 a
IV	71	2304.12 bA	2947.31 bA	2625.72 b	78.3 bA	84.5 c A	81.40 b	3.5 bA	3.2 bA	3.4 a
IV	103	2330.76 bA	1789.53 cA	2060.15 b	75.5 bB	98.2 bA	86.85 b	2.7 cA	3.0 bA	2.9 b
Control	IPR 117	2674.32 aA	2942.38 bA	2808.35 a	69.0 bB	97.0 bA	83.00 b	2.9 cA	2.7 bA	2.8 b
Mean		2890.84	2297.75	2590.65	81.6	96.1	88.80 b	3.1	3.1	3.1
> MS/<Ms [a]		1.80		-	1.06		-	1.13		-
CV (%) [b]		23.39	24.90	24.46	8.20	7.00	7.65	11.98	11.21	11.60
Prob. F test [c]		0.00 **	0.01 **	-	0.00 **	0.00 **	-	0.00 **	0.06 **	-
Prob. F test G [d]		-	-	0.00 **	-	-	0.00 **	-	-	0.00 **
Prob F test E [e]		-	-	51.03 ns	-	-	0.03 **	-	-	100.00 ns
Prob F. test G x E [f]		-	-	0.00 **	-	-	0.013 **	-	-	0.00 **

ANC: Anchieta; FLP: Florianópolis; Values followed by vertical lower-case letters (genotypes) and values followed by horizontal capital letters (environments) did not show statistical differences in the Scott-Knotts test with 5% probability in the analysis of variance in the joint analysis of experiments; [a] Ratio between the largest residual mean square and the lowest residual mean square in the joint analysis of the experiments; [b] Coefficient of variation - values of the Anchieta and Florianópolis columns obtained from the analysis of individual variance by location, values of the joint column obtained from the joint analysis of experiments; [c] F test probability calculated from individual analysis, [d] F test probability for genotype, [e] environments and [f] genotype x environment calculated from the joint analysis; ** - significant at 1% in the F test; [ns] - not significant at 5% by the F test.

Table 3. Means and coefficients of experimental and genetic variation estimated by individual and joint analyses of variance applied to traits shattering resistance, number of branches, number of grains and lodging resistance of dryland rice local varieties and one control treatment, in two environments, in the Santa Catarina state, Brazil.

Group	Variety	Shattering resistance (scale)			Number of branches (unit/panicle)			Number of grains (unit/panicle)			Lodging resistance (scale)		
		ANC	FLP	Mean	ANC	FLP	Mean	ANC	FLP	Mean	ANC	FLP	Mean
I	98	1.6 cA	1.5 bA	1.6 a	9.3 aA	9.3 aA	9.3 a	85.8 bA	86.9 bA	86.4 a	9.0 aA	4.5 bB	6.8 a
I	104	1.8 cB	1.4 bA	1.6 a	9.3 aA	9 bA	9.2 a	85.5 bA	84.9 bA	85.2 a	9.0 aA	6.5 aB	7.8 a
II	7	1.2 aA	1.8 aB	1.5 a	9.7 aA	9bB	9.4 a	93.6 aA	80.5 cB	87.1 a	9.0 aA	1.5 bB	5.3 b
II	12	1.9 dB	1.1 cA	1.5 a	9.4 aA	8.5 bB	9.0 a	84.1 bA	76.4 cB	80.3 a	8.5 aA	8.5 aA	8.5 a
II	13	1.4 bA	1.4 bA	1.4 a	9.6 aA	9.5aA	9.6 a	93.2 aA	89.3 aA	91.3 a	9.0 aA	9.0 aA	9.0 a
II	14	1.5 cB	1.1 cA	1.3 a	9.3 aA	9.8aA	9.6 a	91.1 aA	92 aA	91.6 a	6.3 bB	9.0 aA	7.7 a
II	17	1.3 bA	1.2 cA	1.3 a	9.2 bA	9.1aA	9.2 a	87.0 bA	86.8 bA	86.9 a	9.0 aA	8.3 aA	8.7 a
II	20	1.4 bA	1.2 cA	1.3 a	9.0 bA	9 bA	9.0 a	82.9 bA	85.9 bA	84.4 a	9.0 aA	3.0 bB	6.0 b
II	22	1.3 bA	1.1 cA	1.2 a	9.5 aA	8.6 bB	9.1 a	91.1 aA	79.6 cB	85.4 a	9.0 aA	9.0 bA	9.0 a
II	24	1.2 bA	1.4 bA	1.3 a	9.5 aA	9 bA	9.3 a	89.9 aA	85 bA	89.9 a	9.0 aA	7.0 aA	8.0 a
II	34	1.1 aA	1.3 cA	1.2 a	9.5 aA	8.9 bB	9.2 a	89.9 aA	81.5 cB	85.7 a	9.0 aA	3.5 bB	6.3 b
II	35	1.4 bA	1.1 cB	1.3 a	9.0 bA	9.3 aA	9.2 a	86.1 bA	85.2 bA	85.7 a	7.5 bA	9.0 aA	8.3 a
II	42	1.4 bB	1.1 cA	1.3 a	9.2 bA	9.1 aA	9.2 a	85.1 bA	87 bA	86.1 a	9.0 aA	9.0 aA	9.0 a
II	43	1.0 aA	1.2 cA	1.1 a	10.2 aA	9 bB	9.5 a	96.4 aA	81.2 cB	88.8 a	9.0 aA	4.0 bB	6.5 b
II	50	1.3 bA	1.2 cA	1.3 a	9.4 aA	9.5 aA	9.5 a	90.1 aA	89.5 aA	89.8 a	7.7 bA	8.0 aA	7.9 a
II	60	1.1 aA	1.2 cA	1.2 a	8.8 bB	9.5 aA	9.2 a	84.4 bA	89.3 aA	86.9 a	8.5 aA	5.0 bB	6.8 a
II	61	1.1 aA	1.3 cA	1.2 a	8.4 bB	9 bA	8.7 a	84.4 bA	87.1 bA	85.8 a	9.0 aA	7.0 aA	8.0 a
II	67	1.6 cB	1.1 cA	1.4 a	8.8 bB	9.4 aA	9.1 a	80.4 bB	88.3 bA	84.4 a	7.0 bA	7.0 aA	7.0 a
II	68	1.1 aA	1.4 bA	1.3 a	9.1 bA	9.2 aA	9.2 a	89.2 aA	81.5 cB	85.4 a	9.0 aA	3.0 bB	6.0 b
II	72	1.4 bA	1.2 cA	1.3 a	9.6 aA	8.7 bB	9.2 a	89.9 aA	78.7 cB	84.3 a	9.0 aA	4.0 bB	6.5 b
II	83	1.2 bA	1.1 cA	1.2 a	10.1 aA	9.3 a B	9.7 a	97.2 aA	88.5 bB	92.9 a	9.0 aA	5.5 bB	7.3 a
II	84	1.1 aA	1.4 bA	1.3 a	9.2 bA	8.6 bA	8.9 a	87.8 aA	82.1 cB	85.0 a	8.5 aA	5.0 bB	6.8 a
II	90	1.1 aA	1.2 cA	1.2 a	9.4 aA	9.4 aA	9.4 a	90.1 aA	86.8 bA	88.5 a	8.5 aA	4.0 bB	6.3 b
III	31	1.1 aA	1.6 bB	1.4 a	8.8 b	9.6 aA	9.2 a	85.2 bA	90.5 aA	87.9 a	8.0 bA	7.5 aA	7.8 a
III	32	1.1 aA	1.2 cA	1.2 a	8.7 bB	9.6 aA	9.2 a	84.5 bA	91.1 aA	87.8 a	9.0 aA	7.5 aA	8.3 a
III	82	1.2 bA	1.2 cA	1.2 a	8.9 bB	9.9 aA	9.4 a	82.5 bB	94.1 aA	88.3 a	8.0 bA	6.5 aA	7.3 a
IV	10	1.3 bA	1.2 cA	1.3 a	9.2 bA	9 bA	9.1 a	89.2 aA	81.3 cB	85.3 a	7.7 bA	3.0 bB	5.4 b
IV	19	1.1 aA	1.1 cA	1.1 a	9.3 aA	8.9 bA	9.1 a	87.5 aA	81.5 cA	84.5 a	9.0 aA	2.5 bB	5.8 b
IV	29	2.1 eB	1.1 cA	1.6 a	9.7 aA	9.3 aA	9.5 a	89.7 aA	84.6 bA	87.2 a	9.0 aA	8.5 aA	8.8 a
IV	41	1.2 bA	1.1 cA	1.2 a	9.2 bA	8.6 bA	8.9 a	87.1 bA	80.0 cB	83.6 a	9.0 aA	4.5 bB	6.8 a
IV	54	1.3 bA	1.4 bA	1.4 a	9.6 aA	9.8 aA	9.7 a	91.7 aA	92.9 aA	92.3 a	9.0 aA	9.0 aA	9.0 a
IV	59	1.1 aA	1.3 cA	1.2 a	9.3 aA	8.6 bB	9.0 a	87.9 aA	78.8 cB	83.4 a	9.0 aA	6.5 aB	7.8 a
IV	71	1.1 aA	1.6 aB	1.4 a	9.3 aA	8.2 bB	8.8 a	88.2 aA	73.6 cB	80.9 a	9.0 aA	5.0 bB	7.0 a
IV	103	1.5 cB	1.2 cA	1.4 a	9.0 bA	8.8 bA	8.9 a	86.1 bA	84.5 bA	85.3 a	9.0 aA	6.0 aB	7.5 a
Control	IPR 117	1.1 aA	1.1 cA	1.1 a	8.8 bA	9 bA	8.9 a	75.9 bA	81.5 cA	78.7 a	9.0 aA	7.0 aA	8.0 a
Mean		1.3	1.3	1.3	9.3	9.1	9.2	87.7	84.8	86.3	8.6	6.1	7.4
> MS/< Ms [a]		1.18		-	1.07		-	1.58		-	4.13		-
CV (%) [b]		13.11	15.04	14.11	4.71	4.81	4.76	4.79	5.84	5.35	5.91	18.85	12.84
Prob. F Test [c]		0.00**	0.00**	-	0.00**	0.04**	-	0.00**	0.00**	-	0.00**	0.02**	-
Prob. F Test G [d]		-	-	0.00**	-	-	0.00**	-	-	0.00**	-		0.00**
Prob F. test E [e]		-	-	63.81 [ns]	-	-	60.03 [ns]	-	-	52.30 [ns]	-		50.80 [ns]
Prob F. test G x E [f]		-	-	0.00**	-	-	0.00**	-	-	0.00**	-		0.00**

ANC: Anchieta; FLP: Florianópolis; Values followed by vertical lower-case letters (genotypes) and values followed by horizontal capital letters (environments) did not show statistical differences in the Scott-Knotts test with 5% probability in the analysis of variance in the joint analysis of experiments; [a] Relationship between the largest residual mean square and the lowest residual mean square in the joint analysis of the experiments; [b] Coefficient of variation - values of the Anchieta and Florianópolis columns obtained from the analysis of individual variance by location, values of the joint column obtained from the joint analysis of experiments; [c] F test probability calculated from individual analysis, [d] F test probability for genotype, [e] environments and [f] genotype x environment calculated from the joint analysis; ** - significant at 1% in the F test; [ns] - not significant at 5% by the F test.

The chi-square test ($p \leq 0.05$) identified dependency between the variables yield, stem length and number of grains with the time of conservation and cultivation of the seeds by the farmers (obtained by Pinto et al. (2018) and showed in Table 1), indicating a tendency of varieties conserved less time to be more productive and to present a smaller plants size.

Diverging from the general trend, varieties 10, 19, 31, 32, with red or reddish whole grain color, were positioned at the highest level of yield, in Anchieta, by the mean comparison test (between 2,537.04 to 3,350.24 kg ha^{-1}). These varieties are among those that have been preserved the longest in the region and have characteristics that indicate the absence of formal genetic breeding (presence of awns and hairy leaves) (Pinto et al., 2019).

Regarding the joint analysis, variety 19 stood out in terms of yield and, at the same time, positioned itself in conjunction with variety 54, among the ten most stable in the mean stability ranking (Table 4). The association between the number of grains and the time of conservations showed that the varieties preserved the longest present a greater number of grains. Still using the chi-square test, no association between yield and grain shape was identified.

Although no significant direct correlations were found between yield and the other variables, positive and significant moderate correlations were observed, from 0.40 to 0.50, between stem length x number of branches per panicle and stem length and the number of grains per panicle, components that contributed to the achievement of greater yield, in Florianópolis, by the joint analysis of the experiments. The regression between number of grains per panicle and number of branches obtained a high coefficient of determination, around 95.31%.

In the stability analysis, whose mean ranking of the ten most stable varieties is presented in Table 4, stood out variety 13 (more stable in shattering resistance, number of tillers and resistance to lodging and the third most stable in yield) and the variety 19 (second most stable for number of tillers, fourth for shattering resistance and fifth for stem length). None of the varieties in group III (31, 32 and 82) ranked among the ten most stable varieties for the analyzed characteristics.

As expected, the most stable varieties were not the most productive in each location and together in both environments. Five varieties (13, 54, 42, 50 and 90) showed mean stability superior to the statistical control (Table 4).

Table 4. Mean ranking of the ten most stable dryland rice local varieties in Anchieta and Florianópolis, by morphological group, variable and mean ranking, in two environments, in the Santa Catarina state, Brazil.

Group	Variety	YD	SL	NT	SR	NB	NG	LG	Mean ranking
II	13	3	15	1	1	4	12	1	1
IV	54	14	14	20	3	11	7	1	2
II	42	17	9	5	28	6	9	1	3
II	50	25	32	10	7	8	3	7	4
II	90	5	22	21	7	1	11	26	5
I	98	28	12	7	18	3	6	25	6
IV	19	27	5	2	4	15	20	33	7
II	22	22	2	3	17	30	31	1	8
II	35	19	20	16	25	13	4	12	9
II	14	16	17	6	31	16	5	19	10

YD: Yield; SL: Stem length; NT: number of tillers; SR: Shattering resistance; NB: number of branches; NG: number of grains; LG: lodging resistance.

Discussion

The mean yield obtained in the present study was compatible with the traditional dryland varieties yield in Brazil and to those achieved by Gonçalves et al. (2013) (from 1,050 to 3,050 kg ha^{-1}), in experiments in the far west of the State, under conditions similar to the present study. Gmach et al. (2018), working with nine local varieties of the same origin, has also obtained yields similar, between 1,190 to 4,106 kg ha^{-1}. Despite lower yield compared to improved modern varieties, part of the varieties should be considered as special grains, resulting in better remuneration to farmers.

Gmach et al. (2018) obtained heights between 78 and 105 cm, similar to the estimates obtained in this study and compatible with those usual for local or traditional dryland varieties. The length of the stem assumes importance as it relates to the height of the plant and, consequently, with the photosynthetic capacity and competition with weeds. On the other hand, high stem lengths, characteristic of local or traditional rice varieties, increase the probability of lodging of the plants (Arf et al., 2015), which corroborates the achievement of superior data on lodging resistance in Anchieta where the varieties showed smaller stem length.

The number of grains per panicle in the present study was lower than those obtained by Alvarez et al. (2012), from 92 to 151 grains per panicle, working with improved commercial dryland rice varieties. Number of tillers, number of panicle branches and number of grains per panicle are considered important yield components for rice (Marchezan et al., 2005). The genetic variability present within the local varieties of this study is sufficient to justify individual selection of plants, with subsequent testing of progenies to improve these characteristics, especially for the number of tillers.

Shattering resistance is relevant in the production of dryland rice of local varieties, considering the harvesting methods used by family farmers in the far west, which involve partial harvesting of mature grains or cutting the entire plant and drying in the sun, before storage. Varieties with less shattering resistance will tend to result in greater losses to farmers.

Higher yield, in Florianópolis, may have indirectly occurred due to the larger plant length reached in this location. A total of 25 varieties showed significantly higher stem length in Florianópolis, with the magnitude of the length differences reaching 29.6 cm for variety 104 (Table 2). The coefficient of determination for the regression, calculated between stem length and lodging resistance, was 72.40%, indicating a moderately high cause-effect relationship between these variables. However, the greater length of the stems of the plants, in Florianópolis, resulted in lower resistance to lodging for 18 varieties and, consequently, with apparent losses in the quality of the grains and greater susceptibility to bird attacks, due to the easier landing of birds in the lodged plots. More than half of the treatments showed statistically different values in the joint analysis for lodging resistance between the two locations, always with higher resistance values for Anchieta.

Likewise, Cargnin et al. (2008), working with the twenty-five most widely used dryland rice genotypes in the country between the 1950s and 2000s, obtained significant differences ($p \leq 0.01$) for genotypes, environments and genotype x environment interaction, for the stem length. With respect of yield, these authors have also found significance for the environments, differently from the present work. For the same authors, the behavior variation of rice varieties tends to be more accentuated in dryland conditions, in which the cultivation is dependent on the environmental conditions, mainly on the water regime of each location. The observation of the stability of local dryland rice varieties allows us to infer about their expected mean behavior outside the original environment.

The local dryland rice varieties of the far west of Santa Catarina have the potential to be widely used in research and breeding programs, mainly related to the market of special grains for gourmet use, such as varieties in groups III and IV, with medium to medium-elongated grains and red (10, 19, 31, 32 and 59) and light brown colors (29, 41, 54, 71, 82 and 103).

In a previous study, Maghelly et al. (2020) evaluated the main parameters of processing yield of these local varieties of the far west of Santa Catarina. Benefit income, whole and broken grains ranged from 57.93 to 69.90%, 38.73 to 66.0% and from 3.40 to 22.15%, respectively. Fifteen local varieties (7, 12, 13, 14, 17, 22, 29, 34, 35, 54, 60, 72, 83, 84 and 98) reached values similar to those obtained by improved dryland rice varieties (Maghelly et al., 2020). Of these local varieties that stood out in the processing yield analysis, the varieties 29 and 54, belonging to group IV (with potential for classification as special grains), were positioned among those with better processing yield. The varieties classified as special grains tend to present higher income to the farmer and can be economically interesting, including those that showed level with intermediate levels of agronomic and industrial performance.

Values obtained for yields above 2,500 kg ha^{-1} for the ten most productive varieties, in Anchieta, and above 3,300 kg ha^{-1}, in Florianópolis, at levels similar or superior to those obtained by the statistical control, are promising for the maintenance of production for household self-consumption and the expansion of production to a local or regional market.

It is still necessary to carry out additional scientific studies to evaluate the biochemical composition of the grains, nutritional quality and sensory evaluations, correlating with agronomic data from the present study and with the use-values pointed out by farmers in Pinto et al. (2019), mainly in what refers to issues of nutritional and culinary quality, in the preparation of traditional dishes tipical from the region.

The varieties of dryland rice conserved in situ on farm in the far west of the state of Santa Catarina present genetic potential, both as base populations in rice breeding programs, and as an alternative for agroecological production and the market of organic products, due to their rusticity, stability and production capacity in systems with less external input. Furthermore, these local varieties can occupy a space in the market as colonial or traditional production of rural communities in Santa Catarina, within programs of rural tourism and appreciation of small-scale family farming.

Greater remuneration of the local rice grains can be pursued from the classification of varieties as special grains and commercialization in agroecological and organic market niches, in addition to incentive programs for small-scale family farming products.

Conclusion

The dryland rice varieties conserved *in situ* on farm in the far west of the state of the Santa Catarina show differences in agronomic performance and stability, as well as potential to be widely used in research and breeding programs, mainly with regard to the market of special grains.

Acknowledgment

To the team at UFSC's Experimental Farm for technical support, to Cooperanchieta for logistical support, and the family of farmer Rosa Uliana, for the assignment of the experimental area and assistance in conducting the experiment.

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