e-ISSN: 2177-5133
www.comunicatascientiae.com

Comunicata Scientiae 9(1): 70-80, 2018

DOI: 10.14295/CS.v9i1.1619

Article

Productive potential of upland rice under conventional and organic farming systems

Janice Regina Gmach[1] Cileide Maria Medeiros Coelho[2*], Círio Parizotto[3], Isaac Heberle[2], Heitor Amadeu Prezzi[2], André Tesser Mafioleti[4], Clovis Arruda Souza[2], David José Miquelluti[2]

[1]Federal Institute of Santa Catarina, São Miguel do Oeste, SC , Brasil
[2]University of the State of Santa Catarina , Lages, SC , Brasil
[3]Company of Agricultural Research and Rural Extension of Santa Catarina, Campos Novos, SC , Brasil
[4]University of Western Santa Catarina, Campos Novos, SC, Brasil
*Corresponding author, e-mail: cileide.souza@udesc.br

Abstract

This paper aimed to evaluate the genetic diversity of upland rice varieties, determine the components that contributes most to productivity and evaluate the yield of varieties grown in conventional and organic farming systems. The experiment was carried out during the 2011/2012, 2012/2013 and 2013/2014 crop years, with 11 local upland rice varieties (Agulha, Rosa 15, Mato Grosso, Gomes, Preto, Argentino, Kinsel, Camilo, Piriquito, Casca Roxa and Caipira) and two commercial varieties (Primavera and Cambará). Genetic diversity was observed among the varieties for all evaluated variables and the thousand grain weight was the character that contributed most to the divergence between varieties. The number of panicles m^{-2} was the yield component that presented the highest association with grain yield of varieties in organic farming systems. The average yield of the varieties was 2.303, 1.711 and 3.534 kg ha^{-1} for the seasons 1, 2 and 3 respectively, and the highest yields were obtained with earlier sowing and temperature during grains maturation about 20°C. The 'Piriquito', 'Argentino', 'Gomes' and 'Kinsel' varieties presented yield above 2.000 kg ha^{-1} for all seasons, in both systems, indicating better adaptation to the region of the study and can be indicated as the most promising for the crop under organic cultivation.

Keywords: characterization, genetic variability, path analysis

Introduction

The rice growth in Brazil has been realized in an upland and lowlands (Alvarez et al., 2012). The upland cultivation is the most representative when the number of states is taken in consideration, with higher production at the the midwest region of Brazil (EMBRAPA ARROZ E FEIJÃO, 2016).

In the Santa Catarina state, the upland rice can be produced throughout the state. Nowadays 400 ha are been cultivated, with the grain yield about of 1900 kg ha^{-1} (EMBRAPA ARROZ E FEIJÃO, 2016). This crop has been replaced by other crops, due to the low yield and profitability, mainly due to the lack of adopted varieties to these growing conditions.

The state is characterized by the predominance of family growers, and the rescue of local varieties represents an alternative for these growers, as well as studies that could identify productive varieties, with good quality and adapted to cultivation of the region, both under conventional and organic systems. The conventional farming system uses synthetic fertilizers and pesticides derived from non-renewable energy sources and is a non-sustainable production model. The organic system is based on specific production standards that establish sustainable structures from the social, ecological, and economic point of view.

Received: 22 October 2015
Accepted: 01 March 2017

Productivity is a complex character, resulting from the expression and association of different components, which should be considered in variety selection (Amorim et al., 2008). In rice, it is defined by the number of panicles per area, number of grains per panicle and grain weight (Marchezan et al., 2005). The variety yield also depends on the conditions offered for its development (Menezes et al., 2011), so the evaluation of the performance of the varieties based on only one year and one local of cultivation may be inefficient due to the variability of response to the local environmental conditions according to the years and growing seasons. In this way, the presence of interaction between the locations, years and seasons of cultivation is expected (Cargnelutti Filho et al., 2006).

It is known that there is great genetic diversity and different varieties cultivated in the world. However, the use of local varieties of rice is limited and has been replaced by improved cultivars with a smaller genetic base, limiting the use of biodiversity in a sustainable way.

Considering that the cultivation of local varieties provides the conservation of the genetic resources, it is necessary to study and characterize these materials according to the agronomic interests and climate influences in the different years of cultivation, making feasible the use by the growers of the region. The aim of this study was to evaluate the genetic diversity among upland rice varieties, determine the yield components that contribute most to productivity, and to evaluate the varieties yield in conventional and organic growing systems.

Material and Methods

The experiments were conducted during the following crop years: 2011/2012, 2012/2013 and 2013/2014 (vintages/harvests 1, 2 and 3 respectively), in upland conditions, at the Epagri Experimental Station – Campos Novos – SC. During the harvest 1, varieties under organic system were characterized and during the harvests 2 and 3, the organic and conventional systems were evaluated. The treatments consisted of 11 local varieties (Agulha, Rosa 15, Mato Grosso, Gomes, Preto, Argentino, Kinsel, Camilo, Piriquito, Casca Roxa and Caipira) and two comercial varieties (Primavera and Cambará).

For the organic cultivation, the organic fertilization was realized with poultry manure, in a similar amount as the region growers used to apply. During the first period of cultivation, 10 t ha^{-1} (dry bases) were used, being 5 t ha^{-1} after the incorporation of the winter cover, 1.7 t ha^{-1} at sowing and 3.3 t ha^{-1} on cover, at 50 days after emergence. During the second and thirty cultivations, 5 t ha^{-1} were applied, being 1.7 t ha^{-1} at sowing and 3.3 t ha^{-1} on cover. During the first year of growing, a higher amount was used to correct the lower soil fertility. Each ton of poultry manure provided 10 Kg of N, 30 KG of P and 16 kg of K to the soil. For the conventional system, the fertilization was realized considering a crop productive potential of 2.000 kg ha^{-1}, according to the soil analysis. For the first year of cultivation, 112 kg ha^{-1} of the formula 5-20-10 was used during sowing and 65 kg ha^{-1} of urea on cover at 50 days after emergence.

For the first year, the experiment was conducted under field conditions, in randomized blocks, with four repetitions. During the second and thirty years of cultivation, a completely randomized block design was used in the arrangement of subdivided plots with four repetitions per treatment. Conventional and organic systems were the main plots, while the varieties delimited the subplots. The experimental units were composed of four lines of 4 m in length, spaced 0.5 m. As a useful area, the two central lines were used, eliminating 0.5 m at each end. The sowing was manually performed with 100 grains m² of density, on 10/10/2011, 10/20/2012 and 10/09/2013.

For both systems, weed control throughout the experiment was performed manually whenever necessary. Due to the irregular distribution of rainfall in the municipality, irrigation was used, when necessary, through a fixed conventional sprinkler irrigation system with a precipitation of 8.0 mm hour^{-1}, providing a water depth of 16 mm.

The meteorological data of rainfall, maximum, average and minimum temperature, and relative humidity were collected during the experiment conduction at the Epagri Meteorological Station of Campos Novos - SC, located near the experimental area.

The evaluated agronomic characteristics were: number of tillers m²; plant height; panicle length; flowering; cycle; number of viable panicles m^2; number of grains per panicle; grain yield; thousand grains weight; percentage of filled grains per panicle. The plots were manually harvested according to difference stage of the cycle of each variety, considering 50% of the panicles with the mature grains.

In the obtained results, the normality and homogeneity of variances were evaluated. Based on the tests, it was necessary to apply the √ transformation to the variables emergence, tillering, flowering, cycle, number of viable panicles, panicles m^2, and number of grains per panicle. Also the arc-sine transformation was applied to the variable percentage of full grains. The results were submitted to variance analysis by the F´s test and the means of the varieties were compared using the Scott-Knott´s test, and among the cultivation systems by the Tukey´s test. The comparison of the yield of the local varieties with the commercial varieties was performed using the Dunnett´s test. In order to evaluate the degree of association of yield components and agronomic traits with productivity and to measure the relative importance of each variable on yield in the 1st crop year, path analysis was performed according to a causal diagram in two chains, where productivity was considered as the basic variable. In the first chain the components of the yield were considered as primary variables and in the second the other variables were considered as secondary variables. The varieties were grouped according to the Tocher optimization method, taking as a measure of dissimilarity the generalized distance of Mahalanobis and the relative importance of the characters was determined based on the Singh´s methodology (1981). The analyses were conducted with the aid of the GENES software (Cruz, 2008). For all performed tests, a minimum significance level of 5% was considered.

Results and Discussion

Experiment 1 – 1st crop year: characterization and productivity of upland rice varieties cultivated in organic system

The mean yield of the varieties was 2.303 kg ha^{-1}, higher than the mean yield achieved in the Santa Catarina State (1.400 kg ha^{-1}). Higher yields were observed for the varieties ‘Piriquito’ (4.106 kg ha^{-1}), ‘Argentino’ (3.638 kg ha^{-1}), ‘Gomes’ (3.367 kg ha^{-1}) and ‘Camilo’ (3.361 kg ha^{-1}) (Table 1). The mean yield was also higher than the observed by Gonçalves et al. (2011), with 17 local upland rice varieties at the west region of the Santa Catarina State, Brazil, where the mean observed was 1.720 kg ha^{-1}. It is possible that those differences were attributed to the additional irrigation applied in this present research. Other authors related that the occurrence of hydric deficiency during the flowering period resulted in lower grain yield, which is very important for higher upland rice yields (Guimarães et al., 2011) .

Most of the local varieties presented higher yield than the commercial ones, and only

Table 1. Agronomic characterization of upland 13 rice varieties under organic cultivation, Campos Novos, SC, Brazil, 2011/2012 crop year

Variety	TIL	HEI	PAL	CYC	NPM	PFG	TGM	Y
Agulha	74 b	78 c	21 b	191 c	107 c	80 b	25.3 h	1.216 d
Rosa 15	40 c	84 c	22 a	192 c	108 c	88 a	27.7 e	1.190 d
Mato Grosso	82 b	82 c	20 b	195 b	173 a	90 a	28.8 d	2.127 c
Gomes	117 a	102 a	22 a	186 d	161 b	89 a	30.4 c	3.367 a
Preto	123 a	102 a	22 a	185 d	199 a	84 b	24.1 i	2.087 c
Argentino	125 a	93 b	20 b	184 d	216 a	93 a	30.5 c	3.638 a
Kinsel	76 b	95 b	21 b	190 c	198 a	90 a	33.1 a	2.137 c
Camilo	100 a	105 a	23 a	203 a	149 b	86 b	32.5 b	3.361 a
Piriquito	100 a	95 b	20 b	180 d	237 a	93 a	30.2 c	4.106 a
Casca roxa	63 b	105 a	21 b	185 d	141 b	91 a	25.7 g	2.482 b
Caipira	68 b	85 c	22 a	190 c	156 b	87 a	27.2 f	2.728 b
Primavera	81 b	73 d	22 a	201 a	118 c	78 b	22.3 j	848 d
Cambará	46 c	70 d	22 a	206 a	101 c	51 c	21.6 k	654 d
Mean	84	90,2	21,7	192	159	85	27.7	2.303
CV (%)	12.2	5.82	4.39	1.41	10.1	6.82	0.64	21.5

TIL: number of tillers (tillers m^{-2}); HEI: plant height (cm); PAL: panicle lenght (cm); CYC: cycle (days); NPM: number of panicles (panicles m^{-2}); PFG: percentage of filled grains (%); TGM: Thousand grain weight (g); Y: yield (kg ha^{-1}); Means followed by the same letter, in column, are not different according to the Scott-Knott´s test at 5% of probability.

the varieties 'Agulha' and 'Rosa 15' were not different from the commercial varieties, which reinforces the adaptation of the local varieties as well as the edaphoclimatic conditions of the region of cultivation of the experiment. The less productive varieties ('Agulha' and 'Rosa 15') were the ones that presented the lowest values for the number of panicles m^2 and thousand grains weight, components that can influence the varieties yield.

The average cycle of the varieties was 192 days until harvest, with variations of 180 days ('Piriquito') up to 206 days ('Cambará') (Table 1). The characterization of the cycle of a rice variety is very relative, since this is an inherent characteristic of the variety, but can also be influenced by the environment (Menezes et al., 2011), such as water and nutritional stresses, temperature, solar radiation, among others.

Regarding plant height, based on the classification of Fonseca et al. (2007), the 'Agulha' variety and the commercial varieties 'Primavera' and 'Cambará' were classified as low size (mean height less than 80 cm). The varieties 'Gomes', 'Preto', 'Camilo' and 'Casca Roxa' as tall (mean height higher than 100 cm) and the other varieties as medium size (mean height of 80 to 100 cm) (Table 1). In the organic system, plant height may be an important feature, since tall plants have an advantage in competition with weeds, however, they are more prone to lodge (Fageria, 2007). Despite the observed diversity in size, no lodging problems were observed.

Thousand grain weight was the evaluated variable that presented the greatest diversity among the varieties. The 'Cambará' variety presented the lowest value (21.6g) and the 'Kinsel' the highest value (33.1g) (Table 1). Grain weight is one of the main agronomic variables related to grain yield (Ferrio et al., 2006). High diversity in this character in upland rice cultivars was also observed by Bonow et al. (2007).

According to Ribeiro et al. (2010) indirect selection in the primary components of grain production provides the identification of superior varieties. In addition, the nature of relations between characters, which correlate and indirectly influence of the yield, should be analyzed. However, simple correlation do not determine the relative importance of the direct and indirect influences of these variables on yield (Gondim et al., 2008), only the intensity and direction of the relationship between two or more variables (Yadav et al., 2011). Through path analysis it is possible to know in detail the influence of the characters involved in productivity (Silva et al., 2005).

Estimates of the phenotypic and genotypic correlation coefficients for the evaluated variables allowed the evaluation of the magnitude and direction of the influences of one variable on the other. After track analysis, the concordance of the phenotypic and genotypic correlations with yield (Y) for most of the variables was observed. As for the magnitudes, the genotypic correlations were superior to the phenotypic correlations, however with values of close magnitude, reflecting the small environmental influence on the association of the variables and demonstrating the greater effect of the genotype on the evaluated variables. Regarding the yield components, all variables presented a positive phenotypic and genotypic correlation with yield, as well as direct and indirect positive effects (Table 2). From the correlation estimation, it was observed that some components presented a greater favorable contribution.

The number of panicles m^{-2} (NPM) was the variable that presented higher values for phenotypic (0.782) and genotypic (0.841) correlations and the higher direct effect on Y

Table 2. Estimative of the phenotypic and genotypic correlation coefficients for direct and indirect effects of yield components of rice varieties produced in an organic system, Campos Novos, SC, Brazil, 2011/2012.

Variables	NPM		TGM		PFG	
Correlation	PHE	GE	PHE	GE	PHE	GE
DE on Y	0.481	0.564	0.328	0.288	0.158	0.131
IE via:						
NPM	-	-	0.286	0.360	0.322	0.403
TGM	0.194	0.183	-	-	0.233	0.215
PFG	0.106	0.093	0.112	0.097	-	-
Total	0.782	0.841	0.726	0.745	0.714	0.749

PHE: phenotypic correlation; GE: genotypic correlation; DE: direct effect; IE: indirect effect; Y: yield (kg ha^{-1}); NPM: number of panicles m^{-2}; TGM: thousand grain weight; [8]PFG: percentage of full grains.

(0.481 and 0.564 respectively), indicating that this component presented higher relation with Y and that varieties that resulted in higher NPM were the most productive ones.

For thousand grain weight (TGM), it was observed a phenotipic (0.726) and genotypic (0.745) correlation and positive direct effects, but with lower intensity (0.328 e 0.288 respectively). The percentage of filled grains (PFL) presented lower but positive correlation values (phenotypic: 0.714 and genotypic 0.749) and the lower values of direct effects (0.158 and 0.131, respectively). These results are in accordance with Krishnan & Surya Rao, (2005), who obtained similar results when evaluated 12 rice genotypes in three crop years, concluding the higher yield of certain genotypes is correlated with the higher number of panicles m-^{2} and to the higher proportion of grains with higher density, and also that these variables can be affected by the field growing environment.

According to Fageria (2007), the variation in productivity due to yield components is given by the following order: number of panicles per area> percentage of full grains> grains weight. The study of Jambhulkar & Bose (2014), Seesang et al. (2013) and Zahid et al. (2006), point out that for the increase of grain yield in rice genotypes, variables such as the number of grains per panicle and the thousand grains mass must be observed.

Different reports verified, during four harvests of rice production, that the thousand grains weight was the component of production with higher effect in increasing the crop yield, and the number of not filled panicles influenced most the reduction (Marchezan et al., 2005). Similar results were reported by Guimarães et al. (2008), with 5 rice cultivars, where the production of more productive cultivars was due to the increase of the harvest index and the grain weight, and the reduction of the panicle sterility.

Plant height (HEI) showed a high genotypic (0.756) and phenotypic (0.728) correlation with yield (Y), and higher direct effects (0.984 and 0.632 respectively), indicating that the varieties with higher HEI values were the most productive ones (Table 3). Jambhulkar & Bose (2014) concluded that this positive relationship of height and yield may depend on the genotype used, when evaluating 22 upland rice genotypes, observing positive association with plant height and yield. However, other authors, such as Tehrim et al. (2012) evaluating a group of 68 commercial and traditional rice varieties observed a negative correlation between plant height and grain yield.

According to Zia-Ul-Qamar et al. (2005) and Seesang et al. (2013) the number of productive tillers is one of the most important characteristics that should be considered for improving rice yield. Due to the emission of tillers, a compensation occurs between the rice plants, with adjustment in the plant density, number of tillers per plant and number of panicles per plant, so that the number of panicles and grains per area is constant (Guimarães et al., 2008, Fageria, 2007). Plants with high tillering capacity are able to use all available space and resources (Fageria, 2007). Akhtar al. (2011) and Agahi et al. (2007) identified through strong path analysis the association and direct effect of the number of tillers on the rice yield, as well as the number of filled grains per panicle and thousand grain mass.

Table 3. Estimative of the phenotypic and genotypic correlation coefficients for direct and indirect effects of components and cycle on the yield of rice varieties produced in an organic system, Campos Novos, SC, Brazil, 2011/2012.

Variables	TIL		HEI		PAL		CYC	
Correlation	PHE	GE	PHE	GE	PHE	GE	PHE	GE
DE on Y	0.268	0.243	0.632	0.984	-0.306	-0.728	0.018	0.511
IE via:								
TIL	-	-	0.150	0.151	-0.047	-0.039	-0.114	-0.109
HEI	0.355	0.611	-	-	0.092	0.138	-0.343	-0.535
PAL	0.054	0.119	0.044	-0.102	-	-	-0.151	-0.511
CYC	0.007	-0.229	-0.009	-0.277	0.009	0.358	-	-
Total	0.669	0.745	0.728	0.756	0.252	-0.272	-0.590	-0.644

PHE: phenotypic correlation; GE: genotypic correlation; DE: direct effect; IE: indirect effect; Y: yield (kg ha^{-1}); TIL: number of tillers m^{-2}; HEI: plant height (cm); PAL: panicle length (cm); CYC: cycle (days).

Experiments for the crop years 2 and 3: characterization and yield of upland rice varieties under conventional and organic cultivation

The mean yield of the experiment was 1.711kg ha^{-1} during the second year of production and 3.534 kg ha^{-1} during the third, values that are lower and above the observed during the variety characterization (2.303 kg ha^{-1}) (Table 4). The difference observed in the yield for the two harvests can be explained by the environmental conditions variation, mainly regarding temperature.

Steinmetz et al. (2006) affirm that air temperature is one of the most important climatic elements for the growth, development and productivity of rice cultivation. According to Steinmetz et al. (2006), the solar radiation and the air temperature during the reproductive phase are determinant to obtain high grain yields in the rice crop, and the optimum temperature is between 20 and 35°C during germination, 30 and 33°C during flowering and between 20 and 25°C for the grain maturation.

During the experiments for evaluation of the varieties, average temperatures were lower than the required by the crop. During the second crop year (2), the mean temperature in the sowing period until emergence was 19°C, from emergence to flowering of 21°C and from flowering to harvest was 18°C, and with registers with minimum temperature about 10°C. In this harvest, the grain yield was lower due to the high percentage of sterile panicles, caused by the occurrence of low temperatures during the grain filling phase. The varieties that presented the highest yields in the second crop year (2) were those with the shortest cycle and the highest percentages of full grains, due to the fact that in these varieties the period of filling grains occurred before the period when there was a higher occurrence of low temperature (Figure 01).

In third crop year (3), the mean temperature in the period from sowing to emergence was 17°C, from emergence to flowering 21°C and from flowering to harvest, 20°C. In this crop, even with the average temperature during grains filling below the optimum, it remained about 20°C (Figure 01). Seeding was carried out 11 days before when compared to the crop year 2, which may have contributed to the higher productivity of the varieties due to the advanced cycle, so that grain filling and maturation occurred with higher temperatures (near the ideal - 20°C), resulting in a higher percentage of full grains (PFG) and grain weight (GM).

Comparing the producing years (2 and 3), it was observed that the anticipation of sowing date and the occurrence of higher and more stable temperatures contributed to the reduction of varieties cycle and the grain yield increase. In the two harvests the varieties presented similar sowing-flowering period (FLO) (125 and 122 days respectively). The difference observed in the cycle occurred during the period of grain filling until maturation, since the occurrence of lower temperatures causes the reduction in grains dry matter accumulation, in the filling period and slower maturation. This was similar to that observed by other authors, where the grain formation and filling period occurred between 30 and 40 days, with little influence of the cultivar cycle (SOSBAI, 2012).

In addition to being influenced by climatic conditions, yield is mainly a consequence of the association of different income components, as verified in different years. In the third crop year (3), where yields were higher, the varieties presented the highest NPM (number of panicles m^2: 196), the highest TGW (thousand grain weight: 28.9g) and also high PFG (percentage of full grains: 84%). In the 2^{nd} year of production (2), when the lowest yield was obtained, the varieties produced higher NPM (180), high TGW (27.7g) and the lowest PFG (51%), being the last one the component that limited the varieties yield, which was caused by the occurrence of low temperatures during grain filling. The thousand grain weight and the percentage of full grains are the main characteristics for yield of the rice crop (Fageria, 2007).

At the first crop year (1), a lower yield was observed due to the lower NPM (159), variable with high association with these varieties yield. NPM was limited by the lower tillering of the varieties in this crop, which is reduced with lower temperatures. In addition, the weeds development is more accelerated and may cause competition with the crop, causing losses in productivity, which was not observed in this experiment.

The plants presented a mean height of 98 cm (ranging from 79 to 109 cm) during the 2nd cycle, and of 96 cm (ranging from 86 to 107 cm) during the 3rd cycle (Table 4), and in both crop years the average was higher than the observed for the first crop year (1: 90 cm) (Table 1). Even with plants with higher height, it was not observed problems with lodging.

As already observed in the varieties characterization, the thousand grain weight (TGW) was the characteristic that presented greater diversity between the varieties in the two harvests. In the second year of production, the

Table 4. Agronomic characterization of 13 upland rice varieties under conventional (CO) and organic (OR) system of production. Campos Novos, SC, Brazil, 2012/2013 and 2013/2014 crop years.

Variety	EME			TIL		HEI		PAL		FLO		CYC	
Harvest	2		3	2	3	2	3	2	3	2	3	2	3
System	CO	OR											
Agulha	88aA	90aA	88a	248[a]	252a	95c	91c	22a	21b	128c	123d	184a	173[a]
Rosa 15	84aB	96aA	72b	264[a]	208b	113a	100b	22a	21b	124c	118e	174c	165b
Mato Grosso	70cB	86aA	79a	232b	242a	88d	95c	20b	22a	124c	118e	174c	164b
Gomes	84aA	91aA	85a	229b	207b	109a	102b	21a	23a	120d	118e	168d	156c
Preto	79bA	75bA	89a	268a	261a	108a	107[a]	21a	22a	136b	130a	173c	166b
Argentino	65cB	78bA	87a	217b	188b	94c	90c	20b	20b	117d	118e	170d	148d
Kinsel	68cB	87aA	80a	241b	198b	93c	92c	20b	21b	118d	118e	170d	148d
Camilo	78bA	86aA	84a	258a	223b	102a	100b	21a	20b	139a	132a	187a	172[a]
Piriquito	73cB	90aA	82a	271a	234a	97c	92c	20b	21b	120d	119a	168d	158c
Casca Roxa	79bA	80bA	73b	211b	206b	108a	107[a]	22a	20b	133b	128b	173c	165b
Caipira	90aA	92aA	81a	281a	221b	97c	98b	21a	22a	127c	124c	180b	165b
Primavera	89aA	93aA	79a	253a	233a	87d	90c	22a	22a	120d	118e	181b	169[a]
Cambará	76cB	95aA	66b	251a	216b	79e	86c	20b	23a	124c	120e	187a	168b
Mean	79	88	80	247	222	98	96	21	22	125	122	176	163
CV	10.0	5.81	7.88	7.41	8.34	6.82	5.65	4.87	10.4	1.62	0.73	1.15	1.85

EME: emergence (plants m-²); TIL: number of tillers (tiller m-²); HEI: plant height (cm); PAL: panicle length (cm); FLO: flowering (days); CYC: cycle (days). Averages followed by the same lowercase letter in the column are not different according to Scott-Knott´s test at 5% of probability; averages followed by the same capital letter within the same variable, in the line, are not different according to the Tukey's test at 5% probability.

Table 5. Agronomic characterization of 13 upland rice varieties under conventional (CO) and organic (OR) system of production. Campos Novos, SC, Brazil, 2012/2013 and 2013/2014 crop years.

Variety	NPM		NGP		PGC		MMG				PRD		
Harvest	2	3	2	3	2	3	2		3		2	3	
System							CO	OR	CO	OR		CO	OR
Agulha	176b	189a	166[a]	135b	47c	79c	27.7eA	26.2hB	27.6fA	26.1gB	1.419c[2]	3.719aA[2]	3.711aA[2]
Rosa 15	192a	224a	138b	122c	48c	84c	27.3fA	27.2gA	29.9dA	26.8fB	[1]1.957b[2]	4.176aA[2]	3.729aA[2]
Mato Grosso	175b	197a	129b	117c	63b	90b	27.7eB	28.7fA	30.0dA	28.9eB	[1]1.795b[2]	3.423bA	[1]3.454aA
Gomes	181b	208a	126b	129c	71b	86b	35.1aA	33.7aB	33.2bA	29.2dB	[1]2.271a[2]	3.234bA	3.644aA[2]
Preto	165b	211a	141b	99d	31d	83c	22.5jA	21.9jB	28.8eA	27.0fB	907d	2.531cA	[1]2.349cA
Argentino	166b	176a	104c	123c	77a	93a	32.7bA	32.6bA	32.6cA	32.1fB	[1]2.301a[2]	3.395bB	4.069aA[2]
Kinsel	193a	191a	100c	118c	78a	93a	32.7bA	32.2cB	33.5bA	32.7bB	[1]2.408a[2]	3.310bB	3.939aA[2]
Camilo	157b	162a	165[a]	116c	49c	87b	31.7cA	30.3dB	34.8aA	35.2aA	1.292c[2]	3.857aA[2]	3.983aA[2]
Piriquito	217a	214a	107c	102d	70b	80c	29.7dA	29.8eA	33.6bA	30.6cB	[1]2.722a[2]	3.780aA[2]	3.906aA[2]
Casca roxa	154b	174[a]	161[a]	113c	53c	92a	24.1hA	21.1lB	26.4gA	24.7hB	[1]1.858b[2]	3.640aA[2]	[1]2.438cB
Caipira	172b	190[a]	168[a]	140b	48c	81c	26.9gA	26.1hB	28.2eA	28.2eA	[1]1.679b[2]	3.989aA[2]	4.140aA[2]
Primavera	206a	224[a]	189[a]	159a	18e	69d	23.0iB	24.3iA	23.5hB	24.0iA	1.008d	3.521bB	4.211aA
Cambará	198a	192[a]	192[a]	160a	16e	72d	21.6lA	21.3lB	22.4iA	21.7jB	631d	2.504cA	2.962bA
Mean	180	196	142	126	51	84	27.9	27.4	29.6	28.3	1.711	3.468	3.580
CV (%)	8.16	11.2	8.54	7.99	9.39	6.47	0.51	0.76	0.92	1.18	24.5	13.2	9.12

NPM: number of panicles per meter (panicles m-²); NGP: number of grains per panicle (grain panicle-¹); PFG: percentage of full grains (%); TGW: thousand grain weigh (g); Y: yield (kg ha-¹). Averages followed by the same lowercase letter in the column are not different according to Scott-Knott´s test at 5% of probability; averages followed by the same capital letter within the same variable, in the line are not different according to the Tukey's test at 5% probability. [1]Different from the commercial variety – 'Primavera' – according to Dunnet´s test at 5% of probability. [2]Different from the commercial variety – ' Cambará, according to Dunnett´s test at 5% of probability.

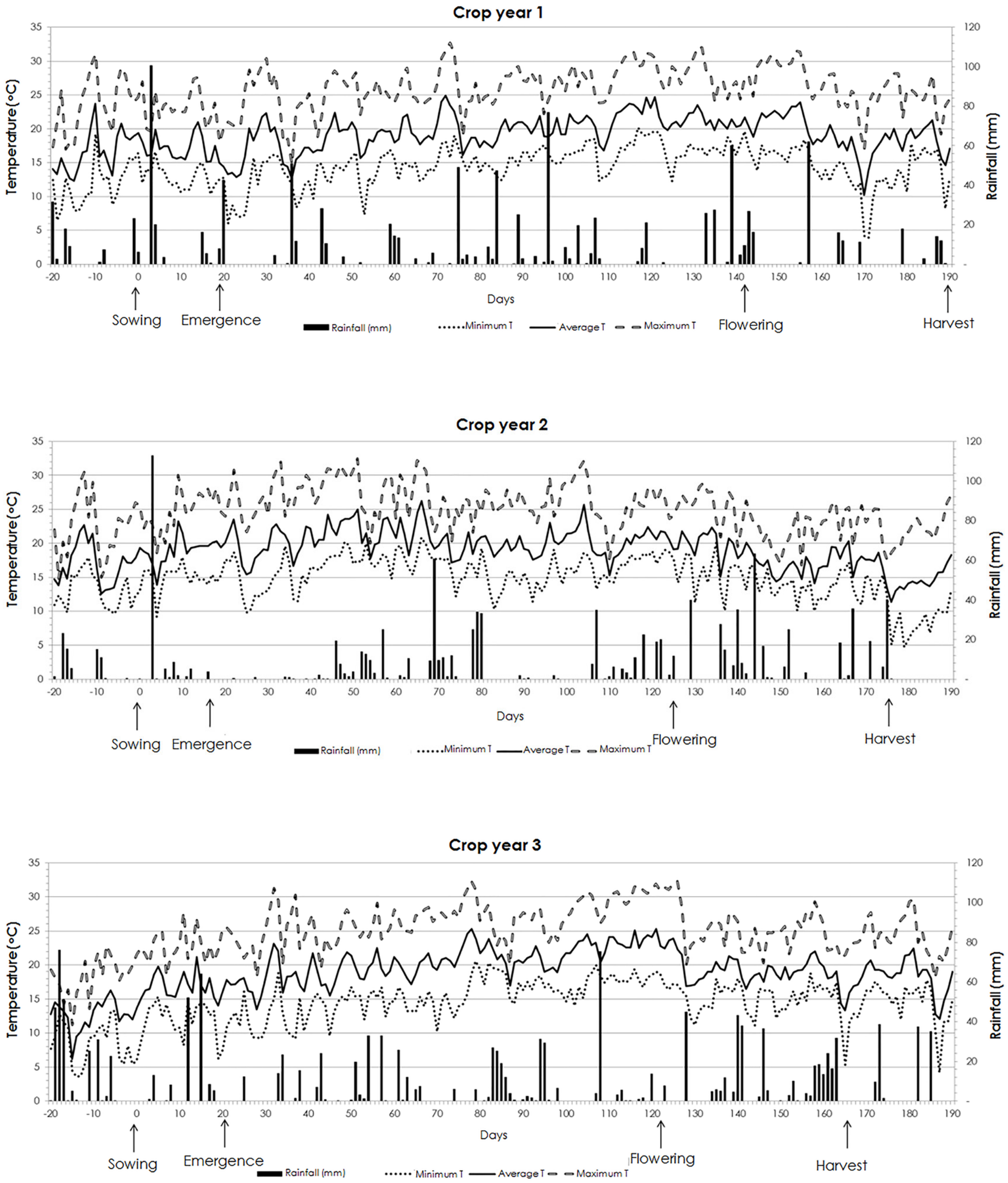

Figure 1. Daily maximum, average and minimum temperatures (°C) and rainfall (mm) registered at the EPAGRI meteorological station, Campos Novos, SC, Brazil, from sowing to harvest of the crop years 2011/2012 (1), 2012/2013 (2) and 2013/2014 (3).

varieties averaged 27.7 g and the 'Gomes' variety produced heavier grains in the two cropping systems and during the third year of production, the average TGM was 28.9 g and the 'Camilo' variety presented the highest values, differing from the 1st harvest, when the higher TGM was observed in the 'Kinsel' variety (Table 4).

Regarding the varieties, it was observed that the 'Piriquito' variety presented higher yields for the years of production and cropping systems. The varieties 'Gomes', 'Argentino' and 'Kinsel' presented higher yields during the 2nd year of production, with adverse environmental conditions and with higher productivity when compared to commercial varieties during the same year, probably due to the greater rusticity of the cited materials. The varieties 'Agulha', 'Rosa 15', 'Camilo' and 'Caipira' presented good productive potential in both cropping systems during the 3rd crop year, with favorable environmental conditions.

In order to verify the relative contribution of each variable to the genetic dissimilarity, by the method proposed by SINGH (1981), it was identified variability among the evaluated characters, being the TGM the character that presented the greater variation, and greater contribution to the divergence between the varieties, for both harvests and systems of cultivation.

By cluster analysis using the Tocher optimization method, the varieties were separated into distinct groups, according to the crop and cropping system (Table 5). For the 2nd year of production, all varieties showed different behavior in the different cropping systems. However, during the 3rd year of production, the varieties 'Caipira', 'Mato Grosso' and 'Rosa 15' (group 1) presented similar behavior in both cropping systems. In relation to the cultivation systems, the varieties 'Piriquito' (group 2), 'Primavera' (group 3) and 'Cambará' (group 3) presented similar behavior in conventional cultivation, and the varieties 'Caipira' and 'Rosa 15' (group 1) for the organic cultivation in the two crop years.

The local evaluated varieties presented satisfactory yield for both evaluated systems of production, showing their potential in the evaluated region. Although the varieties presented good levels of productivity, a high variability was observed in the two harvests, caused mainly by the climatic conditions. The sowing time was one of the factors that influenced most the varieties yield due to the sensitivity of the plant to adverse environmental factors, especially regarding air temperature. Thus, sowing must be carried out in a moment that allows the coincidence of the filling and maturation phases of grains with periods of low probability of occurrence of low temperatures.

The agronomic performance of the local varieties was efficient when grown in an organic system of production, which favors its maintenance and its high promising potential use, demonstrating a high genetic contribution to the evaluated agronomic variables. As it is an autogamous species, there are strong indications that within the population there is already genetic stability, and also because it has already undergone a selection process, realized by growers.

Table 6. Grouping by the Tocher optimization method of 13 upland rice varieties grown in organic and conventional systems. Campos Novos, SC, Brazil, 2012/2013 and 2013/2014 crop years.

Group	Harvest 2		Harvest 3	
	Conventional	Organic	Conventional	Organic
1	Argentino, Kinsel, Camilo	Agulha, Caipira, Rosa 15	Agulha, Caipira, Preto, Mato Grosso, Rosa 15	Argentino, Kinsel, Piriquito, Gomes, Mato Grosso, Caipira, Rosa 15
2	Rosa 15, Caipira, Agulha, Mato Grosso, Piriquito	Argentino, Kinsel, Gomes	Argentino, Kinsel, Gomes, Piriquito	Agulha, Primavera, Casca roxa, Preto
3	Primavera, Cambará, Preto, Casca roxa	Mato Grosso, Piriquito, Camilo	Primavera, Cambará	Cambará
4	Gomes	Preto, Casca roxa, Cambará	Casca roxa	Camilo
5		Primavera	Camilo	

Conclusions

1. There is genetic diversity between varieties for all evaluated variables.

The thousand grain weight was the variable that influenced most the divergence between the varieties.

3. The number of panicles m^{-2} is the yield component that contributed most to the varieties grain yield under organic system of cultivation, indicating that this is an important characteristic when choosing varieties aiming the yield increase.

4. The varieties, 'Piriquito', 'Argentino', 'Gomes' and 'Kinsel' presented yields higher than 2,000 kg ha^{-1} for all evaluated crop years and systems of production.

5. Most of the varieties presented higher yield when compared to the average yield of rainfed rice produced in the Santa Catarina State, Brazil (1,400 kg ha^{-1}) in organic and conventional systems. The highest yields were obtained in the crops with earlier sowing and temperatures during grain maturation about 20°C.

Acknowledgments

To CNPq for the financial support (Call 58, grant n° 563920/2010-6). To FUMDES for the scholarship for the first author. To the National Council of Scientific and Technological Development (CNPq), for the 'PQ2' scholarship for the 2nd and 7nd authors. To the Santa Catarina State Foundation for the research and innovation support (FAPESC n° 10.043/2012-9) and PAP-FAPESC-CP 04/2014 2015 TR 649/FAPESC TR653-2017 for the financial support.

References

Agahi, K., Fotokian, M.H., Ezatollah, F. 2007. Correlation and Path Coefficient Analysis for Some Yield-Related Traits in Rice Genotypes (Oryza sativa L.). *Asian Journal of Plant Sciences* 6: 513-517.

Akhtar, N., Nazir, M.F., Safdar, A., Asif, T., Rehman, M.E., Rabnawaz, M., Mahmood, A. 2011. Estimation of Heritability, Correlation and Path Coefficient Analysis in Fine Grain Rice (*Oryza sativa* L.). *Journal of Animal and Plant Sciences* 21: 660-664.

Alvarez, R.C.F., Crusciol, C.A.C., Nascente, A.S., Rodrigues, J.D., Habermann, G. 2012. Gas exchange rates, plant height, yield components, and productivity of upland rice as affected by plant regulators. *Pesquisa Agropecuária Brasileira* 47: 1455-1461.

Amorim, E.P., Ramos, N.P., Ungaro, M.R.G., Kiihl, T. A.M. 2008. Correlações e análise de trilha em girassol. *Bragantia* 67:307-316.

Bonow, S., Von Pinho, E.V.R., Soares, A.A., Siecola Junior, S. 2007. Caracterização morfológica de cultivares de arroz visando a certificação da pureza varietal. *Ciência e Agrotecnologia* 31: 619-627.

Cargnelutti Filho, A., Ribeiro, N. D., Jost, E. 2006. Número necessário de experimentos para a comparação de cultivares de feijão. Ciência Rural, Santa Maria 36: 1701-1709.

Cruz, C.D. 2008. *Programa Genes - Diversidade Genética*. Universidade Federal de Viçosa, Viçosa, Brasil. 278p.

EMBRAPA ARROZ E FEIJÃO. 2016. Dados conjunturais da produção de arroz (*Oryza sativa* L.) no Brasil (1986 a 2015): área, produção e rendimento. Santo Antônio de Goiás: Embrapa Arroz e Feijão, Disponível em: <http://www.cnpaf.embrapa.br/socioeconomia/index.htm>. Acesso em: 24 out. 2016.

Fageria, N.K. 2007. Yield Physiology of Rice. Journal of Plant Nutrition 30:843-879.

Ferrio, J.P., Alonso, N., Voltas, J., Araus, J.I. 2006. Grain weight changes over time in ancient cereal crops: Potential roles of climate and genetic improvement. Journal of Cereal Science 44:323-332.

Fonseca, J.R., Castro, E. da M. de, Morais, O.P. de, Soares, A.A., Pereira, J.A., Lobo, V.L. da S., Resende, J.M. 2007. Descrição morfológica, agronômica, fenológica e culinária de alguns tipos especiais de arroz (Oryza sativa L.). <http://www.cnpaf.embrapa.br/transferencia/informacoestecnicas/publicacoesonline/seriedocumentos_210.pdf>. Acesso em 10 out. 2014.

Gonçalves, G.M.B., Souza, R., Cardozo, A.M., Lohn, A.F., Canci, A., Guadagnin, C.A., Ogliari, J.B. 2011. Análise da diversidade de variedades locais de arroz de sequeiro do Oeste de Santa Catarina. *Cadernos de Agroecologia* 6:1-4.

Gondim, T.C.O., Rocha, V.S., Sediyama, C., Miranda, G.V. 2008. Análise de trilha para componentes do rendimento e caracteres agronômicos de trigo sob desfolha. *Pesquisa Agropecuária Brasileira* 43:487-493.

Guimarães, C.M., Stone, L.F., Neves, P.C.F. 2008. Eficiência produtiva de cultivares de arroz com divergência fenotípica. *Revista Brasileira de Engenharia Agrícola e Ambiental* 12:465-470.

Guimarães, C.M., Stone, L.F., Oliveira, J.P., Rangel, P.H.N., Rodrigues, C.A.P. 2011. Sistema radicular do arroz de terras altas sob deficiência hídrica. *Pesquisa Agropecuária Tropical* 41:126-134.

Jambhulkar, N.N., Bose, L.K. 2014. Genetic Variability and Association of Yield Attributing Traits With Grain Yield in Upland Rice. *Genetika* 46:831-838.

Krishnan, P., Surya Rao, A.V. 2005. Effects of genotype and environment on seed yield and quality of rice. *Journal of Agricultural Science* 143:283-292.

Marchezan, E., Martin, T.N., Santos, F.M., Camargo, E.R. 2005. Análise de coeficiente de trilha para os componentes de produção em arroz. *Ciência Rural* 35:1027-1033.

Menezes, B.R.S., Moreira, L.B., Lopes, H.M., Pereira, M.B. 2011. Caracterização morfoagronômica em arroz vermelho e arroz de sequeiro. *Pesquisa Agropecuária Tropical* 41:490-499.

Ribeiro, N.D., Cargnelutti Filho, A., Poersch, N.L., Rosa, D.P. 2010. Critério de seleção indireta para a produtividade de grãos em feijão. *Ciência Rural* 40:986-989.

Seesang, J., Sripicchitt, P., Somchit, P., Sreewongchai, T. 2013. Genotypic Correlation and Path Coefficient for Some Agronomic Traits of Hybrid and Inbred Rice (*Oryza sativa* L.) Cultivars. *Asian Journal of Crop Science* 5: 319-324.

Silva, S.A., Carvalho, F.I.F., Nedel, J.L., Cruz, P.J., Silva, J.A.G., Caetano, V.R., Hartwig, I., Sousa, C.S. 2005. Análise de trilha para os componentes de rendimento de grãos em trigo. *Bragantia* 64:191-196.

Singh, D. 1981. The relative importance of characters affecting genetic divergence. The Indian Journal of Genetic and Plant Breeding 36: 237-245.

SOSBAI. Sociedade Sul-Brasileira de Arroz Irrigado. 2012. *Arroz irrigado: recomendações técnicas da pesquisa para o Sul do Brasil*. SOSBAI, Pelotas, Brasil. 176 p.

Steinmetz, S., Silva, S. C. da, Santana, N. M. P. de. 2006. Clima. In: Santos, A. B., Stone, L. F., Vieira, N. R. de A. *A cultura do arroz no Brasil*. Embrapa arroz e Feijão, Santo Antônio de Goiás, Brasil. p. 117-160.

Tehrim, S., Pervaiz, Z.H., Mirza Y., Rabbani, A., Masood, S. 2012. Assessment of Phenotypic Variability in Rice (*Oryza Sativa* L.) Cultivars Using Multivariate Analysis. *Pakistan Journal of Botany* 44:999-1006.

Yadav, S.K., Pandey, P., Kumar, B., Suresh, B.G. 2011. Genetic Architecture, Inter-relationship and Selection Criteria for Yield Improvement in Rice (*Oryza sativa* L.). *Pakistan Journal of Biological Sciences* 14: 540-545.

Zahid, M.A., Akhter, M., Sabar, M., Manzoor, Z., Awan, T. 2006. Correlation and path analysis studies of yield and economic traits in basmati rice (*Oryza sativa* L.). *Asian Journal of Plant Sciences* 5: 643-645.

Zia-Ul-Qamar, Cheema, A.A., Ashraf, M., Rashid, M., Tahir, G.R. 2005. Association Analysis of Some Yield Influencing Traits in Aromatic and Non Aromatic Rice. *Pakistan Journal of Botany* 37:613-627.