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RESEARCH PAPER

Performance of rice hybrids determined by different planting arrangements

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Abstract

E. da S. Goulart, L.O.B. Schuch, L.V.M. de Tunes, and J.F. Vieira. 2015. Performance of rice hybrids determined by different planting arrangements. Cien. Inv. Agr. 42(1): 75-83. The practices and techniques used in irrigated rice to improve performance include optimal plant density and the best arrangement of the plants in an area. This study aims to evaluate the performance and plasticity in the yield and grain quality of three rice hybrids using different row spacing. The field experiments were conducted during the 2010/2011 season in rice crops in Capão do Leão, Viamão and Uruguaiana in the state of Rio Grande do Sul, Brazil. Three different sowing arrangements were evaluated, *i.e.*, row spacing of 17 cm, 34 cm, and 17 cm alternated with 34 cm, which corresponded to densities of 40, 20 and 32 kg ha^{-1}, respectively. The experimental design used was randomized blocks with subdivided plots replicated three times considering each location as a replication. Yield and grain quality were evaluated. The grain yield and grain quality components of the rice hybrids were not affected by the planting arrangements. The performance of the hybrids demonstrates their plasticity to compensate for lower densities resulting from different distances between planting rows. Therefore, with respect to seeding rates and row spacing for these hybrids, the amount of seed sown per area can be reduced compared with current recommendations. This will result in a cost reduction that can make this technology more attractive and ensure it is widely used in commercial rice fields.

Key words: Irrigated rice, *Oryza sativa* L., plant densities, row spacing.

Introduction

Rice (*Oryza sativa* L.) belongs to the family Poaceae and is one of the most important cereal crops in the world. In Brazil, rice is cultivated over an area of 2.4 million hectares and annual production is approximately 11.9 billion tons (CONAB, 2013). Rio Grande do Sul is the largest rice producer in the country, with 61.5% of the national production and a cultivated area of approximately 1.1 million hectares in the 2012/13 crop season. The average yields in the 2012/2013 crop season were higher than 7.4 t ha^{-1}. In certain situations, the genetic yield potential of rice cultivars and management practices can result in yields that exceed 10 t ha^{-1}.

Reducing seeding rates is a management practice that provides better exploitation and utilization of available resources, such as water, light and

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nutrients. Lower seeding rates allow better interception of sunlight, greater tillering potential, and a crop that can express its full development potential. Low crop densities may provide better crop development and increased productivity due to greater photosynthetic area. This technique makes crops more resistant to environmental stresses, pests and disease attacks. Furthermore, stems tend to be thicker and stronger, which increases resistance to lodging (Luzzardi *et al*., 2005).

Research performed by Schuch (2001) showed that crop productivity is a function of the ability of a crop to transform incident solar energy into organic products through the process of photosynthesis and their subsequent allocation to different plant parts. This author stated that the amount of solar radiation intercepted by a crop is related to leaf area. Leaf area is dependent on plant density; therefore, plants should be arranged equidistantly from each other in the field.

The recommended seeding rate for irrigated rice in a conventional system varies according to the region and cropping system. The typical range is between 80 and 120 kg of seeds per hectare (SOSBAI, 2012) and depends mainly on the cultivar, planting date and soil type.

The commercial rice hybrids in Brazil have the potential to reduce the planting density to approximately 40 to 50 kg ha^{-1} (EPAGRI, 2005). The recommended seeding rate of 50 kg ha^{-1} does not negatively influence the performance of the hybrids, and some studies suggest that it is possible to further reduce this rate (Luzzardi *et al*., 2005). Compared with the average yields and different crop densities that have been observed in conventional rice systems, low plant densities in hybrids are being positively exploited to maintain an economic and productive balance.

Some research studies that have been conducted on rice hybrids and varieties have indicated the possibility of decreasing plant density using different distances between rows (Souza *et al*., 1995; Fagundes *et al*., 1998; Rieffel-Neto *et al*., 2000; Shrirame *et al*., 2000; Obulamma and Reddeppa, 2002; Mariot *et al*., 2003; Höfs *et al*., 2004; Xian-Qing *et al*., 2009). This is an important way to reduce the amount of seed sown per area compared with the current recommendations. In addition, the use of this technology can reduce production costs, making this method more attractive and consequently, the most widely used in commercial irrigated rice crops. Therefore, this study aims to evaluate the performance and plasticity in the yield and grain quality of three rice hybrids using different row spacing.

Materials and methods

The experiments were performed in commercial rice crop fields during the 2010/2011 crop season, in the Municipality of Viamão (North Coast), Uruguaiana (West Border) and Capão do Leão (Southern region) of the Rio Grande do Sul, Brazil. The geographic coordinates are 31º45’46’’ S, 52º29’02’’ W for Capão do Leão (altitude of 21 m), 30º04’5’’ S, 51º01’22’’ W for the city of Viamão (altitude of 9 m) and 29º45’18’’ S, 57º05’16’’W for Uruguaina (altitude of 66 m).

Three hybrids were used: QM Arize 1003 (midcycle), Arize QM 1010 (mid/late cycle) and Arize Prime (early/mid-cycle). Three sowing arrangements that corresponded to 17-cm, 34-cm and 17-cm skip-row (*i.e*., 17 cm alternated with 34 cm) spacings were tested. The arrangements of these plants did not change the density of seeds within a row, which was equivalent to a sowing density of 40 kg ha^{-1}. After sowing, arrangements with 17, 34 and 17/34 cm corresponded to population densities of 40, 20, and 32 kg ha^{-1}, respectively.

The experiments were conducted at three different sites. The soils classes were haplic planosols in Capão do Leão and Viamão, and Argiluvic chernosol in Uruguaina. The climate of the regions according to the Köppen climate classification is fundamental type CFA, characterized as humid subtropical, with hot summers and no dry season. Capão do Leão, Uruguaina and Viamão have mean annual temperatures of 17.8 ºC, 19.5 ºC and 19.6 ºC, mean annual rainfall of 1,439 mm, 1,114 mm and 1,347 mm and mean annual solar radiation of 14.4, 15.2 and 15.9 MJ m^{-2} day^{-1}, respectively. The same fertilizer, doses and timing of nitrogen application, and chemical treatment for controlling pests and diseases was used in the management of the experiments at all locations. After tillage, prior to the desiccation of the vegetation before rice was planted, glyphosate was applied (1,440 g ha^{-1}). At the S3 stage (needle point), a second application of glyphosate (1,440 g ha^{-1}) was performed, and irrigation occurred soon after herbicide application.

Post-emergence herbicide was applied to control narrow and broad leaf weed species in rice using the Sonora (Iharabras S/A Chemical Industries of Sorocaba, SP, Brazil) product (bispyribac-sodium) at a dose of 0.125 L ha^{-1} and Gamit (FMC Agricultural Products, Campinas, SP, Brazil) (Clomazone 360 g L^{-1}) at a dose of 0.3 L ha^{-1}; the herbicides were dissolved in Aureo brand (Bayer CropScience, Belford roxo, RJ, Brazil) vegetable oil and applied at flow rates of 100 L ha^{-1} and 0.5 L ha^{-1}, respectively. The products were applied using a CO_2 pressurized sprayer (Herbicat brand, HB PES 003 model, Catanduva, SP, Brazil).

Fertilization was performed based on the interpretation of the soil analysis; 400 kg ha^{-1} of granular 5-20-20 fertilizer was applied at planting using a furrow seeder. In addition, two applications of nitrogen were conducted; the first application occurred 15 days after emergence at the V3 stage (three-leaf rice) and the second after the differentiation of floral primordia. A total of 220 kg ha^{-1} of nitrogen was applied, of which 70% was applied in the first season and 30% in the second season.

Seed distribution at the three study sites was conducted using a SEMINA II experimental seeder. The seeds of commercial hybrids (Arize QM 1003, QM 1010 and Arize Arize Prime) were previously treated with Gaucho FS insecticide (Bayer CropScience, Belford roxo, RJ, Brazil) (imidacloprid) at a dose of 0.8 L 100 kg^{-1} seeds, Standak (BASF) (fipronil) at a dose of 0.2 L 100 kg^{-1} seeds and Derosal Plus fungicide (Bayer CropScience, Belford roxo, RJ, Brazil) (carbendazim+thiram) at a dose of 0.2 L 100 kg^{-1} of seeds.

The productivity, grain yield and commercial quality of the grains were analyzed. Sampling was conducted by measuring grain moisture in the field. The evaluations were performed every 2 days at the same time, and the grains used were collected from the edges of the plots using a portable device (Platinum brand) that measured grain moisture content (H-10 model). The crop was harvested mechanically; the grain moisture content at harvest was approximately 20-23% for all cultivars and locations.

A 3-kg grain sample was collected from each plot. From this sample, a 500-g subsample was used for the determination of impurities and a 50-g subsample was used for the determination of moisture using a universal tester (Gehara brand). The remainders of the samples were dried in a dryer (Bandeirante brand) at a temperature of 40 °C until a 13% moisture content was reached. One kilogram of each sample was collected and stored in airtight plastic containers. Then, the samples were identified and forwarded to the Laboratory of Analysis of Grains, Bayer S/A for the analysis of commercial grain quality such as the percentage of chalk grains, white belly, belly, chalk area of grains, broken grains, whole grains free from defects and total milling yield.

A sample of 100 g of paddy rice was collected and processed for one minute using a rice mill (model MT, Suzuki) to determine the percentage of whole grains, broken grains and total milling yield. After polishing, the grains were weighed and this value was regarded as the total milling yield, which was expressed as a percentage. The percentage of total milling grains was calculated by adding the percentage of whole grains and broken grains. Subsequently, polished grains were placed in a number two ‘‘trieur’’ and grain separation was processed for thirty seconds. The grains that remained in the ‘’trieur” were weighed to calculate the yield of whole and broken grains, both expressed as a percentage.

A rice analyzer (model 521) was used to determine the percentage of chalk grains, white belly, belly, chalk area of grains, broken grains and whole grains free from defects. This machine is able to analyze rice samples and provide detailed information for each grain individually. A sample of 100 g of peeled rice was used; the sample was separated into different categories based on the proportion of grain chalkiness.

Rice grains were classified as chalk when more than 75% of the grain surface was chalk. Grains were considered belly when they showed a small white midpoint covering an area smaller than 33% of the grain surface, whereas the central white area of the grain surface of white belly grains was greater than 33% and less than 70%. The chalk area of the grains was calculated as the average ratio of the chalkiness area considering the surface of all grains in the sample (100 g). Whole grains free from defects were the grains that were completely translucent with no chalk.

The experiment was a randomized block with a split plot design with three replications. There was a border around the entire experiment, and this was implemented at all three locations. The hybrids QM Arize 1003, Arize QM 1010 and Arize Prime were the main plots and the planting arrangement was the subplot. Each subplot was composed of a different numbers of rows depending on the sowing arrangement used. Specifically, 26, 14 and 18 lines that were 10 m long corresponded to the 17-, 34- and paired 17- and 34-cm row spacings, respectively. Grains were harvested from the 17, 8 and 10 central lines of the plots with the 17- and 34- row spacings and 17- and 34-cm paired row spacings, respectively. The 50 cm at the ends of each line were not used for harvesting, resulting in useful plot areas of 26.01, 24.48 and 26.01 m^2 for the 17-, 34- and 17- and 34-cm paired row spacings, respectively.

The experimental data were subjected to analysis of variance and the effects of cultivar, spacing and location were evaluated by a comparison of means using the Tukey test at a 5% probability.

Results and discussion

There were no significant interactions between the cultivars and planting arrangements for any experimental variable. This indicated that the different rice hybrids showed similar performance when the plant distribution was changed in the field. Therefore, when analyzing the effect of planting arrangement, it appears that hybrid rice varieties did not differ in yield and no significant differences were observed at the 5% probability level based on the F test (Table 1).

The other commercial grain quality parameters shown in Table 1 indicate that the percentage of whole grains for the Arize Prime hybrid was higher by four percentage points compared with the other hybrids. However, with respect to the percentage of broken grains, Arize QM 1003 was higher than Arize Prime by two percentage points, while QM Arize 1010 did not differ from Arize Prime. These differences between hybrids are derived from intrinsic genetic characteristics because the Arize Prime hybrid normally has a higher percentage of whole grains and a smaller percentage of broken grains compared with the other hybrids (this has been observed under various conditions). The total milling yield, *i.e*., the sum of the percentages of whole grains and broken grains in a sample of 100 g of paddy rice, was high in the Arize Prime hybrid, which was at least two percentage points higher than Arize QM 1010. However, Arize QM 1003 was not significantly different from the other hybrids with respect to the percentage of total yield.

Table 1. Grain yield (kg/ha) and the percentage of whole grains, broken grains and total yield for the three planting arrangements and commercial rice hybrids in the 2010/2011 crop season.

Genotype/ planting arrangement	Grain yield ns[2] (kg ha^{-1})	Whole grains[1] (%)	Broken grains[1] (%)	Total milling yield (%)
Hybrid				
Arize Prime	11.771	59.26 a	8.00 b	67.25 a
Arize QM 1010	12.406	55.13 b	9.91 ab	65.04 b
Arize QM 1003	11.324	54.99 b	10.98 a	65.97 ab
Planting arrangement				
17 cm (ns[2])	11.729	56.06	9.99	66.08
34 cm (ns[2])	11.903	56.86	9.68	66.54
17/34 cm (ns[2])	11.869	56.44	9.21	65.66
Mean	11.834	56.45	9.63	66.08
C.V. (%)	12.7	5.5	23.1	2.0

[1]Means followed by different letters within a column for each factor differ at the 5% probability level based on the Tukey test.
[2]ns- not significant at 5% probability based on an F test.

The planting arrangements did not affect grain yield (Table 1). In addition, the planting arrangements did not affect the percentage of whole grains, broken grains or total milling yield despite the variation in spacing and seeding rate. Variations in spacing and the seeding rate possibly affect the uniformity of maturation because a reduction in the seeding rate results in a gradual increase in the number of tillers per plant that exhibit different phenological development. Similar to the results reported here, Crusciol *et al.* (1999) did not find a significant effect of row spacing or seeding rate on the whole grain yield or the yield value. These results disagree with the experiment conducted by Arf *et al.* (1996) who studied the effect of row spacing and population density in rice cultivars. These authors found significant effects resulting from an increase in the seeding rate, which increased the percentage of whole grains and reduced the percentage of broken grains. These contradictory results indicate that the effects of these factors may be dependent on the crop cultivars and environments in question.

The data presented in Table 2 show that sowing arrangements did not affect the percentage of chalk, white belly, belly, chalk area of grain or whole grains free from defects. The results show that the productivity and commercial quality components of the hybrid rice cultivars were not affected by sowing arrangements that involve changes in plant densities or the arrangement of the planting rows. Arf *et al.* (1996), Crusciol *et al.* (2000) and Hofs *et al.* (2004) studied the effect of row spacing and population density on the behavior of other rice cultivars and did not find a difference in grain yield with increasing planting density. The whole grain yield was not affected by variation in seeding rate.

These results contradict the hypothesis that lower plant populations can reduce the grain quality of rice. Lower plant populations result in abundant tillering and decrease the uniformity of grain ripening among tillers of different orders. Similarly, Canellas *et al.* (1997) expected that higher seeding rates would result in better milling yield, which was not confirmed experimentally.

The use of sowing arrangements involving density and line spacing did not affect the yield or grain quality of the rice hybrids, which shows the plasticity

Table 2. Aspects of grain quality of three commercial rice hybrids and three planting arrangements in the 2010/2011 crop season.

Genotype/sowing arrangement	Chalk ns[1]	White Belly ns[1]	Belly ns[1]	Chalk area of grains ns[1]	Whole grains free from defects ns[1]
			(%)		
Hybrids					
Arize Prime	0.70	7.66	3.51	14.45	46.69
Arize QM 1010	0.96	6.68	3.47	13.79	43.66
Arize QM 1003	0.84	6.09	3.44	12.64	43.54
Planting arrangement					
17 cm	0.81	7.45	3.93	13.63	45.58
34 cm	0.83	6.65	3.37	14.17	45.33
17/34 cm	0.86	6.32	3.09	13.07	44.99
Mean	0.83	6.81	3.47	13.62	44.63
C.V. (%)	47.1	30.7	27.5	13.8	7.9

[1]ns- not significant at 5% probability based on an F test.

of these hybrids to compensate for lower densities and distributions of planting rows. This suggests the possibility of changing the recommended seeding rates and row spacing for these hybrids. This will allow for a reduction in the quantity of seed sown compared with current recommendations, which will reduce production costs, making this technology more attractive and therefore ensure it is widely used in commercial rice fields.

This study provides preliminary information on the possibility of optimizing genetic resources and enabling the use of sowing arrangements that provide high yield potential and acceptable levels of commercial grain quality. High yield and quality can be achieved by reducing the seeding rate per area as well as by using different arrangements of planting rows while maintaining the density within the planting rows.

The grain yield measured in the Capão do Leão experiment was approximately two tons higher than that recorded in Uruguaiana and three tons higher than in the city of Viamão (Table 3). According to Schuch *et al.* (2000), these differences in productivity can be due to differences in the genetic materials adapting to the different environments, which may be reflected by high leaf area index and growth rates during the early stages of plant growth.

The yield of whole grains, which indicates the amount of whole grains, obtained after industrial processing is one of the most important parameters in determining the commercial value of rice (Oliveira *et al.*, 1998) and this parameter varied between the different localities. Rice grown in the municipality of Uruguaiana showed higher values and significant differences compared with rice grown in Viamão and Capão do Leão (Table 3). The rice grown in the municipality of Viamão showed a higher percentage of broken grains, whereas there was no difference in this parameter in the rice grown in the municipalities of Uruguaiana and Capão do Leão. The percentage of total milling yield was similar among all localities.

The percentage of chalk and white belly did not differ between the different localities. However, the percentage of rice belly grain was higher in Viamão and Capão do Leão compared with Uruguaiana (Table 4). The highest percentage of grain chalk area was measured in rice from Viamão and Uruguaiana, and the lowest value was observed in Capão do Leão.

Table 3. Grain yield and the percentage of whole grains, broken grains and total yield for each cultivation location of commercial rice hybrids sown at three row spacings in the 2010/2011 crop season.

	Grain yield	Whole grains	Broken grains	Total milling yield
Localities	(kg ha^{-1})	(%)		
Capão do Leão	13.529 a[1]	57.19 b	9.62 a	66.81 a
Uruguaiana	11.536 b	58.32 a	9.88 a	65.20 a
Viamão	10.437 b	53.87 b	12.39 b	66.25 a
Mean	11.834	56.46	9.63	66.09
C.V. (%)	11.7	6.2	24.2	2.3

[1]Means followed by different letters within a column differ at the 5% probability level based on the Tukey test.

Table 4. Aspects of grain quality for each growing site. Values are the average of three commercial rice hybrids in the 2010/2011 crop season.

	Chalk	White belly	Belly	Chalk area of grains	Whole grains free from defects
Localities	(%)				
Capão do Leão	0.67 a[1]	7.59 a	3.64 a	12.02 b	44.24 b
Uruguaiana	0.93 a	5.42 a	2.69 b	14.24 a	48.55 a
Viamão	0.91 a	7.52 a	3.86 a	14.63 a	41.11 b
Mean	0.84	6.84	3.40	13.63	44.63
C.V. (%)	41.4	28.7	26.6	14.0	7.6

[1]Means followed by different letters within a column differ at the 5% probability level based on the Tukey test.

With respect to the percentage of whole grains free from defects, Uruguaiana stood out from the other localities, with more than four percentage points above Capão do Leão and more than seven percentage points higher than Viamão.

Therefore, it appears that the hybrid rice showed different behavior for grain yield and certain parameters of grain quality depending on the growing site. For example, the municipality of Capão Leão had rice with a high percentage of belly grains and a high yield of whole grains. The municipality of Viamão had rice with a low percentage of whole grains and a relatively high percentage of broken grains. The municipality of Uruguaiana had rice with the lowest percentage of belly grains and a relatively high percentage of whole grains and grain chalk area. This variability can be attributed to climate differences between the three localities, particularly temperature and relative humidity during grain filling and the pre-grain harvesting period.

The results indicate that genetic factors may be exploited to maintain acceptable levels of yield potential and commercial quality of the grains provided the planting arrangements involving density and spacing between lines do not affect the performance of the irrigated rice hybrids.

This information can be exploited to increase the planted area using the same amount of seeds with the consequent reduction in production costs. This result was found for the hybrids studied although this should be confirmed for other flooded rice hybrids. It was also observed that hybrids respond to local growing conditions that interfere with grain yield and industrial quality. This indicates the need to develop adapted hybrids for different regions where irrigated rice is grown in Rio Grande do Sul.

In conclusion, the different planting arrangements tested did not affect the yield or grain quality of the rice hybrids. In addition, hybrid plasticity compensates for the plant arrangements using less seed, and much more flexibility is possible in the recommendations for seeding rates and row spacings for hybrid rice.

Resumen

E. da S. Goulart, L.O.B. Schuch, L.V.M. de Tunes y J.F. Vieira. 2015. Rendimiento de plantas híbridas de arroz en función de las diferentes modalidades de plantación. Cien. Inv. Agr. 42(1): 75-83. Las prácticas y técnicas utilizadas para el riego de arroz son para obtener un mejor rendimento dentro de ellas se, incluyen uma óptima densidad de siembra y la mejor disposición de las plantas en el area del cultivo. Este estudio tuvo como objetivo evaluar el rendimiento y la plasticidad, en el rendimiento y calidad del grano de tres híbridos de arroz con diferentes espacimento de líneas de siembra. El experimento de campo se llevó a cabo en la temporada de siembra de arroz entre 2010/2011 en las localidades de Capão do Leão, Viamão y Uruguaiana, en el estado de Río Grande del Sur, Brasil. Se evaluaron tres arreglos diferentes de siembra, incluyendo la distancia entre surcos que fue de 17, 34 y 17 cm, intercaladas con 34 cm, que corresponden, a las densidades de 40, 20 y 32 kg ha^{-1}, respectivamente. El delianeamento experimental utilizado fue de bloques completos al azar con parcelas subdivididas, con tres repeticiones, considerando cada lugar como la replicación. También se evaluó el rendimiento y la calidad del grano. Los resultados muestran que los componentes del rendimiento de grano y la calidad del grano de arroz híbrido no fueron afectadas por los arreglos de siembra. El rendimiento del arroz híbrido demuestra plasticidad para compensar densidades más bajas y en diferente distancia entre líneas de siembra. Esto permite que las recomendaciones para la densidad de siembra y la distancia entre surcos de estos híbridos, reducir la cantidad de semilla que se siembra por área en comparación con lo que se recomienda actualmente. Esto significa una reducción de costos que puede hacer de esta tecnología más atractivo y ampliamente utilizado en los campos de arroz comerciales.

Palabras clave: Arroz de riego, *Oryza sativa* L., densidades de siembra, distancias entre líneas.

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