Seeding densities and productivity of rice cultivars in the West Border of Rio Grande do Sul State, Brazil[1]

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Abstract - The objective of this work was to study the influence of different seeding rates and cultivars over flooded rice yield at the west border of Rio Grande do Sul State. The experimental design was a randomized blocks with four replicates. The treatments were arranged in factorial scheme 4 x 3, in which factor A was the seeding rate (40, 60, 80 and 100kg ha^{-1}) and B the cultivars (BR-IRGA 409, Olimar and Puitá Inta-CL). The increase in seeding rate from 40 to 100 kg ha^{-1} reduces linearly the tilled number, filled, total grains for panicle and number of panicle per m^2. The greater rice grains yield in cultivars Olimar and Puitá Inta-CL is obtained in seeding rate of 66 and 77 kg ha^{-1} respectively. On the other hand, the yield of cultivar BR-IRGA 409 was not influenced by seeding rate. The yield grain was greater in cultivar Puitá Inta-CL, except with the seeding rate of 80 kg ha^{-1}, in which it was the second most productive cultivar.

Key words: *Oryza sativa*. Plant population. Genotype. Yield

Densidade de semeadura e produtividade de cultivares de arroz na Fronteira Oeste do Estado do Rio Grande do Sul, Brasil

Resumo - O objetivo deste trabalho foi estudar a influência de densidades de semeadura e cultivares na produtividade de arroz irrigado por inundação na Fronteira Oeste do Rio Grande do Sul. O delineamento experimental foi em blocos causalizados, com quatro repetições. Os tratamentos foram arranjados em esquema fatorial 4 x 3, onde o Fator A foi composto pelas densidades de semeadura (40, 60, 80 e 100 kg ha^{-1}) e o B pelas cultivares (BR-IRGA 409, Olimar e Puitá Inta-CL). O aumento na densidade de semeadura de 40 a 100 kg ha^{-1} reduz linearmente o número de perfilhos por planta, o número de grãos cheios e total por panícula e o número de panículas por m^2. A maior produtividade de grãos de arroz para a cultivar Olimar e Puitá Inta-CL é obtida na densidade de semeadura de 77 e 66 kg ha^{-1}, respectivamente, e a produtividade da cultivar BR-IRGA 409 não é influenciada pela densidade de semeadura. A produtividade de grãos é superior na cultivar Puitá Inta-CL, exceto na densidade de semeadura de 80 kg ha^{-1}, em que esta é a segunda cultivar mais produtiva.

Palavras-chave: *Oryza sativa.* População de plantas. Cultivares. Rendimento

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Introduction

Rice (*Oryza sativa* L.) is one of the main crops in economic, dietary, social and cultural importance in many countries worldwide. In Brazil, 70% of rice production comes from the Southern region, the states of Rio Grande do Sul (RS) with 61% and 9% in Santa Catarina (SC), where rice is irrigated and the highest productivities are obtained. In RS, the West Border stands out as the region that most produces rice, especially in Uruguaiana city, followed by Itaqui (SOSBAI, 2010).

Despite having the largest area planted with irrigated rice, RS needs technologies to achieve higher productivities, especially in the West Border. Among these, the spatial distribution of rice plants in a field is an easy to perform management practice. Appropriate spatial arrangement of the plants and densities promotes more uniform occupation of space, reducing intraspecific competition and favoring the use of environmental factors, such as solar radiation, and inputs, which contributes to of grain productivity increase (PESKE et al., 2004). Moreover, the correct spatial arrangement facilitates weed management, since there is the need to control these species in the rice crop, and sowing in the densities recommended by the research for each cultivar may reduce the use of herbicides, which is the most commonly used control method in rice fields (AGOSTINETTO et al., 2010).

Franco et al. (2011) verified that in the density of 150 kg ha^{-1} of seeds, the cultivars BRS Atalanta and BRS Pelota produced lower number of grains per panicle, smaller panicles and higher number of panicles per square meter, due to higher competition among the plants, compared to the density of 90 kg ha^{-1}. In the lower density, there was a higher number of panicles per plant, reflecting the higher tillering capacity of plants in low sowing densities. However, there was no difference in grain productivity when increasing sowing density. Mariot et al. (2003) also did not found any difference in rice grain productivity when sowing densities varied from 50 to 200 kg ha^{-1} for the cultivars BR-IRGA 410 and IRGA 417. Lima et al. (2010) verified that irrigated rice, cultivar IAC 102, independently of the contribution from the main stem and the tillers, due to increases in sowing density, from 100 to 600 seeds m^{-2}, did not show any difference in grain productivity because of densities, due to the plasticity that exists between rice production components, in which there is a compensation effect.

Some studies have shown that densities from 100 to 200 kg ha^{-1} of rice seeds increased the initial population of plants and the number of stems and panicles per area unit in relation to lower densities without, however, resulting in increased grain productivity for different cultivars (SOUSA et al., 1995; MARIOT et al., 2003, LIMA et al., 2010). Nevertheless, genotype and edaphoclimatic conditions interfere with productivity components and grain productivity (WU et al., 1998). In dryland rice, increased productivity was obtained at a density of 81 rice seeds per meter, compared to 50 and 110 seeds per meter, in which the number of panicles m^{-2} was the maximum (CARVALHO et al., 2008).

The plant stand established in a rice field is a key factor to achieve high productivity, so a low initial density of plants can compromise it, because secondary or tertiary tillers produce panicles with fewer grains. Moreover, excessive amounts of plants can cause lower productivity by the occurrence of diseases due to less penetration of sunlight within the community of plants, together with the stimulus to lodging. Therefore, low plant density as well as high density can negatively impact the yield potential of an irrigated rice cultivar. The ideal population for most cultivars range from 150 to 300 plants m^{-2} (SOSBAI, 2010).

Studies indicate that between 600-800 panicles per m^2 are needed to obtain high productivity, which is obtained with 100 to 120 kg ha^{-1} of seeds (SOSBAI, 2010). This quantity of seeds can also be reduced if management conditions are adequate, the seeds have excellent quality and high performance, are treated (fungicides, insecticides, hormones), well distributed in the soil and have adequate moisture for germination. The use of low seed density allows the producer to save money, obtain seeds with better quality and lower production costs (MENEZES et al., 2004).

The seeding density recommended by research for Rio Grande do Sul, for conventional cultivars in conventional and minimum tillage systems is 80 to 120 kg ha^{-1} of viable seeds (SOSBAI, 2010). However, there are few studies on environmental conditions and cultivars at the West Border of RS.

Rice grain productivity, in addition to being influenced by the spatial distribution, is related to management and cultivar or even to the adaptation of the genotype to the seeding region.

In this context, there are still cultivars that are most valued by industry for the excellent qualities of the grain. Among these, stands the cultivar BR-IRGA 409, launched in 1979 in a partnership between the Empresa Brasileira de Pesquisa Agropecuária (Brazilian Agricultural Research Corporation, Embrapa) and the Instituo Rio Grandense do Arroz (Rio Grandense Rice Institute, IRGA), because of its high productivity, resistance to pathogens and good milling productivity (SOSBAI, 2010).

Another decisive factor when choosing the rice cultivar is the increasing infestation of red and black rice that led to the development of biotypes that are tolerant to herbicides used to control these weeds. The products used to control weedy rice belong to the chemical group of imidazolinones, which act on the enzyme acetolactate synthase (ALS). This technology was called Clearfield® system, being the cultivar Puitá Inta-CL of the second generation launched in 2008, resistant to the herbicides imazethapyr + imazapic and imazapic + imazapyr (ALS inhibitors), intensively cultivated in the RS (SOSBAI, 2010).

Although numerous cultivars are available on the market, rice farmers imported the cultivar Olimar from Uruguay, which has good size and good grain productivity. This cultivar is spreading through the region with high productivity densities and grain quality.

In the West Border of RS, cultivars BR-IRGA 409, Puitá Inta-CL and Olimar are the most widely cultivated due to its adaptation to the region, productivity and quality of harvested grain.

The production per unit area constitutes a determining factor in economic return for the support of farmers. Each cultivar should be related to an appropriate population for maximum productivity performance. Intraspecific competition determines in each cultivar the population of plants that provides higher performance and better utilization of available resources (WU et al., 1998; AGOSTINETTO et al., 2010).

Rice farmers in the West Border are reducing seed density to amounts lower than 100 kg ha^{-1}. However, more information is needed about the main varieties of irrigated rice grown in flooded system in this region, which is the leading producer of this commodity in Brazil.

The objective of this work was to study the influence of seeding densities and cultivars on the productivity of flooded rice in West Border of RS.

Material and Methods

The experiment was conducted in Itaqui, RS, during the agricultural year 2010/11, in the geographical coordinates 29º 11' 24" S and 56º 32' 38" W, at 95 m of altitude. The soil was classified as Haplic Plinthosol (EMBRAPA, 2013).

The experimental design was in randomized blocks, with four replications. The treatments were arranged in a 4 x 3 factorial, in which factor A was composed of seeding densities (40, 60, 80 and 100 kg ha^{-1}) and B by cultivars (BR-IRGA 409, Olimar and Puitá Inta-CL.) The experimental units consisted of 3 m wide by 5 m long plots, containing 13 lines of rice.

The soil was prepared with conventional tillage system with plowing and harrowing before sowing. The seeds were sown on October 15, 2010 at a 0.17 m spacing between rows. Fertilization was 150 kg ha^{-1} of MAP (monoammonium phosphate) at sowing, 150 kg ha^{-1} of KCl (potassium chloride) applied 30 days after sowing and 150 kg ha^{-1} of urea in two aerial applications, being the first of 80 kg ha^{-1}, 20 days after germination and before the entry of water (11/20/2010) and the second of 70 kg ha^{-1}, before rice flowering. Fertilization was performed according to the recommendations for irrigated rice (SOCIEDADE…, 2004).

Evaluations included the number of tillers per plant at 60 days after emergence, number of sterile, full and total grains per panicle, in 10 panicles per plot and number of panicles in an area of 0.25 m^2. Grain productivity was determined in an area of 2 m^2 per plot when the grains have reached 22% humidity, being then corrected to 13%.

The results were subjected to analysis of variance by F test, and being significant to the quantitative factor, regression analysis was performed and the Tukey test for qualitative comparison of means at 5% level of probability.

Results and Discussion

The number of tillers decreased linearly with increasing sowing density from 40 to 100 kg ha^{-1}, for the three cultivars (Figure 1A). This is due to intraspecific competition, since the greater the number of individuals in the same area, the greater the competition for available resources in the environment, causing a reduction of tillering. In rice there is plasticity, in which a competitive and compensatory effect between the tillers and the productivity components promotes stability of grain productivity to a particular genotype in a population range of plants (WU et al., 1998). Lima et al. (2010) found in rice cultivar IAC 102 that the increase of sowing density from 200 to 600 seeds m^2 decreases tillering and leads to greater participation of the main stems, however not resulting in increased productivity due to the plasticity of the rice plants, which provides the adjustment of productivity components. The reduction of tillering with increasing seed density was observed in several studies (SOUSA et al., 1995; MARIOT et al., 2003; MARZARI, 2005; AGOSTINETTO et al., 2010, LEE et al., 2010).

According to Peske et al. (2004), rice fields with better seed distribution enable a better use of soil nutrients and sunlight by plants, factors which influence the production. As the seeding density is increased, the number of tillers per plant tends to decrease, and the number of stems per square meter does not suffer major changes.

In the 40 kg ha^{-1} densities the cultivar Puitá Inta-CL tillered more, and at 60 and 80 kg ha^{-1} densities the cultivar BR-IRGA 409 tillered more compared to ‘Olimar’ and ‘Puitá Inta-CL’, which did not differ between themselves, and at the 100 kg ha^{-1} density there was no difference in the number of tillers among the varieties (Table 1).

Increasing rice seeding density starting from 60 kg ha^{-1} resulted in an increase in the number of sterile grains in the three cultivars (Figure 1B). Similar results were obtained in other studies such as Mariot et al. (2003), Marques (2005) and Lima et al. (2010), who found that increasing the density of plants per m² decreases spikelet fertility. The increase in sterile grain per panicle at higher seeding densities is related to intraspecific competition, in which plants compete for resources such as light, nutrients, CO_2 and water available in the environment, with lower production of photoassimilates and filled grains (RIEFFEL NETO et al., 2000).

The number of total and filled grains per panicle decreased as seeding density increased from 40 to 100 kg ha^{-1} (Figure 1C, D), corroborating the results found by Mariot et al. (2003). Increasing seeding density promoted highest number of seedlings, stems and panicles per unit area and cause reduction in the number of grains per panicle because the competition that exists among plants, which reduces the photosynthetic activity and results in less accumulation of photoassimilates per plant, generating deficit to different plant organs (CANELLAS et al., 1997).

The cultivar Puitá Inta-CL, in all densities, showed a higher number of total and filled grains, followed by ‘Olimar’ and ‘BR-IRGA 409’ (Table 1). The cultivar BR-IRGA 409 had fewer filled grains in all seeding densities.

The number of rice panicles decreased linearly with increasing seeding density in the three cultivars and with greater intensity in the cultivar BR-IRGA 409, from 416 to 249 panicles per m^2, in seeding density of 40 and 100 kg ha^{-1}, respectively (Figure 2A). This highlights the importance of using tillering in rice to obtain greater number of panicles per area, confirming results obtained by Sousa et al. (1995) and Carvalho et al. (2008).

Sousa et al. (1995) found that at low rice seeding densities the compensation capacity is associated with increased number of panicles per area and there is an increase in productivity per panicle. On the other hand, Marzari (2005) found that there is a reduction in the number of panicles with increased density until reaching a minimum, then, with increasing density, there is an increase in the number of panicles, but there is a reduction in the number of grains per panicle. In studies of Lima et al. (2010) with the rice cultivar IAC 102, there was an increase in the number of panicles per m^2 with an increase in seeding density. However, for the evaluated cultivars, it was found a decrease in the number of panicles and number of grains per panicle with increasing seeding density for three of them, suggesting that they have different behaviors in relation to seeding density.

Regarding the cultivars, for the number of panicles per area, it was observed that ‘Puitá Inta-CL’ had the highest value, ‘Olimar’ was an intermediate and ‘BR-IRGA 409’ had the smaller value (Table 2). The higher number of panicles of ‘Puitá Inta-CL’ occurs mainly because it is a modern cultivar, with high productivity rates compared to ‘BR-IRGA 409’ and ‘Olimar’.

Grain productivity was not different in the seeding rate from 40 to 100 kg ha^{-1} for the cultivar BR-IRGA 409 (Figure 2B). Cultivars Olimar and Puitá Inta-CL showed a quadratic behavior, with higher productivities at 77 and 66 kg ha^{-1} seeding densities, respectively. In these densities, grain productivity of the cultivars Olimar and Puitá Inta-CL were 10,250 and 10,769 kg ha^{-1} respectively, and above the state average of 6,452 kg ha^{-1} (SOSBAI, 2010).

According to Peske et al. (2004), in rice fields with better seed distribution, there is a better plant development, because they use the available resources in the environment as nutrients, light, CO_2 and water, more efficiently what influences how the cultivars can express all their productive potential. At appropriate densities, there is less competition between plants, and the crop will provide photoassimilates to grain filling and less for the maintenance of a large amount of green mass, resulting in higher grain productivity.

The higher productivities in the cultivars Olimar and Puitá Inta-CL were obtained at densities below the recommended, 80 to 120 kg ha^{-1} (SOSBAI, 2010), and used in the West Border of Rio Grande do Sul, which is 100 kg ha^{-1}. This allows to infer that it is necessary an optimal seeding density and that, when the density is very high, there is a decrease in the number of panicles per area and number of grains per panicle formed, reflecting in a decrease in productivity for these two cultivars. According to Donald (1963), competition between plants at high densities can be so severe that a considerable number of plants can end up not surviving, and many are harmed by intraspecific competition with consequent reduced individual productions.

For cultivars BR-IRGA 410 and IRGA 417 increasing from 50 to 200 kg ha^{-1} seeding density resulted in no significant difference in productivity, in different soil and climatic conditions (MARIOT et al., 2003). These results found for the cultivar BR-IRGA 409, which showed no difference in productivity in the seeding density that ranged from 40 to 100 kg ha^{-1}. In this context, it is also necessary to consider that the answer to the density varies according to place of cultivation and genotype, according to Counce (1987), which explains why the cultivar BR-IRGA 409 do not show any response to seeding densities. Valério et al. (2009), studying wheat genotypes, found that in those who had high tillering lower seeding densities provide better productivities.

The cultivar Puitá Inta-CL showed higher grain productivity compared to the others, except for the 80 kg ha^{-1} density, in which it was the second most productive, after 'Olimar' (Table 2). This is in accordance with the number of panicles per area, because the cultivar Puitá Inta-CL showed a higher number, in function of its characteristics.

Concluding this study, it was found that each cultivar has ideal seeding densities for growing and differentiated behavior in relation to the production components, as also discussed by Counce (1987) and Rieffel Neto et al. (2000). The cultivars Olimar and Puitá Inta-CL, densities smaller than 80kg ha^{-1} resulted in higher grain productivity. A high plant population does not ensure high productivities, because in this condition fewer panicles and grains per panicle are produced.

Conclusions

1. Increasing seeding density from 40 to 100 kg ha^{-1} linearly reduces the number of tillers per plant, the number of filled grains per panicle and the total number of panicles per m^2.
2. The highest productivities for the cultivars Olimar and Puitá Inta-CL are obtained in the 77 and 66 kg ha^{-1} seeding densities respectively, and the productivity of the cultivar BR-IRGA 409 is not influenced by seeding densities.
3. The cultivar Puitá Inta-CL shows a higher number of total filled grains per panicle, smaller number of sterile grains and higher number of panicles in densities 40 to 100 kg ha^{-1}.

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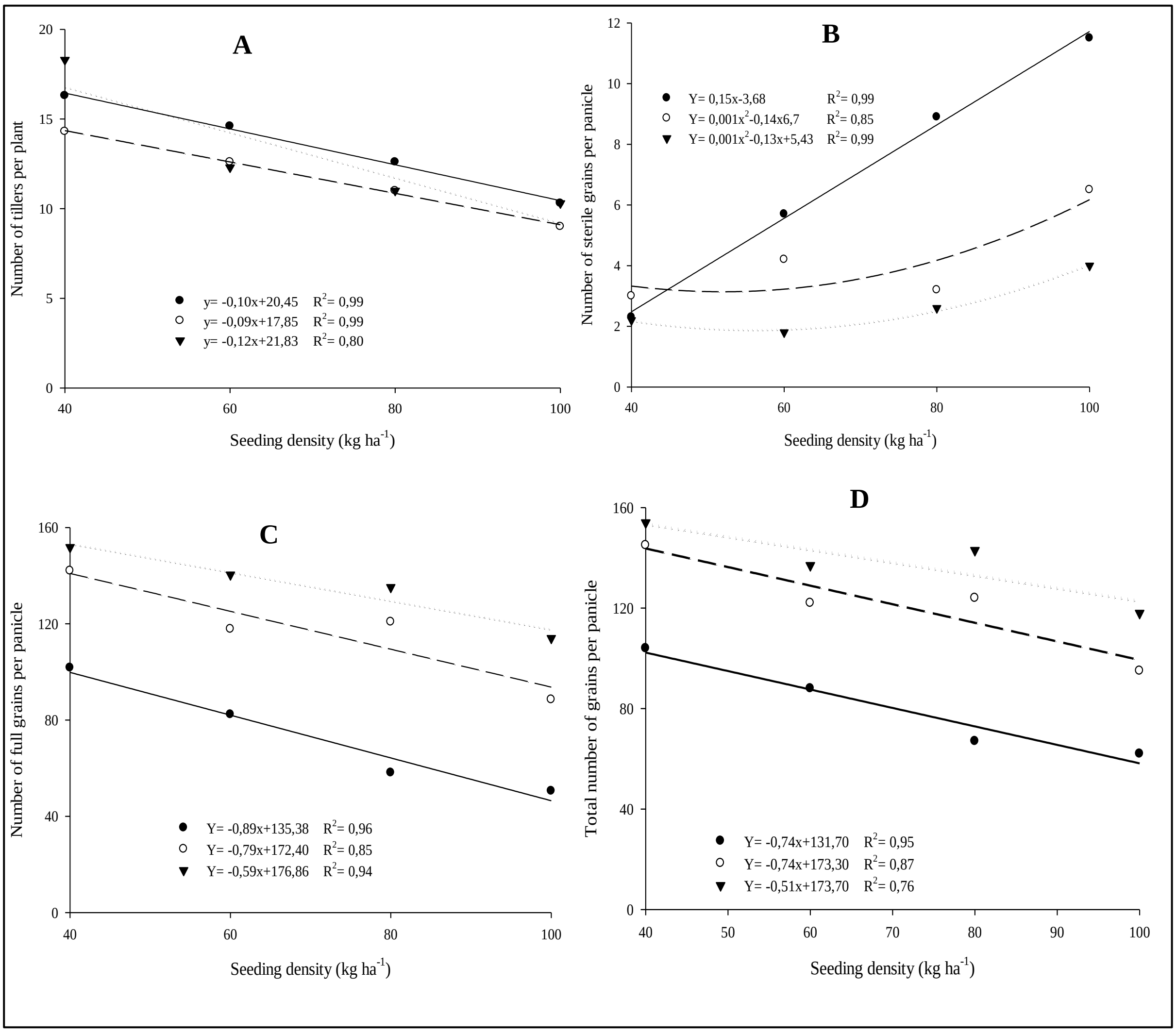

Figure 1 - Number of tillers per plant (A), number of sterile grains per panicle (B), number of full grains per panicle (C) and total number of grains per panicle (D) in function of seeding densities of the irrigated rice cultivars BR-IRGA 409 (●), Olimar (○) and Puitá Inta-CL (▼), Itaqui, 2014.

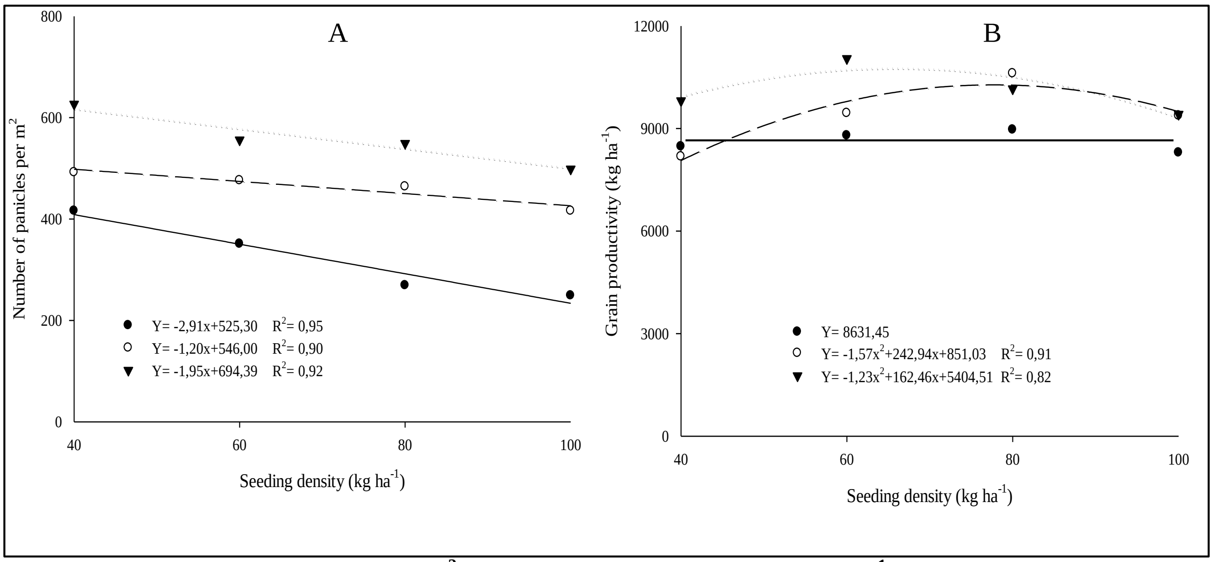

Figure 2 - Number of panicles per m^2 (A) and grain productivity (kg ha^{-1}) (B) in function of seeding densities of the irrigated rice cultivars BR-IRGA 409 (●), Olimar (○) and Puitá Inta-CL (▼), Itaqui, 2014.

Table 1 - Number of tillers per plant, sterile grains, full grains and total number of grains per panicle in the seeding densities and rice cultivars irrigated by flooding, Itaqui, 2014.

Cultivars	Seed densities (kg ha^{-1})				
	40	60	80	100	Mean
	Number of tillers per plant				
BR-IRGA 409	16 b	15 a	13 a	10 a	
Olimar	14 c	13 b	11b	10 a	
Puitá Inta-CL	18 a	12 b	11 b	10 a	
	Number of sterile grains per panicle				
BR-IRGA 409	2.3	5.7	8.9	11.5	7.1 a
Olimar	3.0	4.2	3.2	6.5	4.2 a
Puitá Inta-CL	2.2	1.8	2.6	4.0	2.6 b
	Number of full grains per panicle				
BR-IRGA 409	101.7 c	82.3 c	58.1 c	50.5 c	
Olimar	142.0 b	117.8 b	120.8 b	88.5 b	
Puitá Inta-CL	151.8 a	135.2 a	140.4 a	114.0 a	
	Total number of grains per panicle				
BR-IRGA 409	104.0 c	88.0 c	67.0 c	62.0 c	
Olimar	145.0 b	122.0 b	124.0 b	95.0 b	
Puitá Inta-CL	154.0 a	137.0 a	143.0 a	118.0 a	

*Means followed by the same lowercase letters in the column do not differ by Tukey test at 5% probability.

Table 2 - Number of panicles and grain productivity of irrigated rice in function of seeding densities and cultivars, Itaqui, 2014.

Cultivars	Densities (kg ha^{-1})			
	40	60	80	100
	Number of panicles (m^{2})			
BR-IRGA 409	416 b	351 c	269 c	249 c
Olimar	492 b	476 b	464 b	416 b
Puitá Inta-CL	627 a	556 a	549 a	499 a
	Grain productivity (kg ha^{-1})			
BR-IRGA 409	8.471 b	8.795 c	8.965 c	8.294 c
Olimar	8.178 c	9.449 b	10.610 a	9.377 b
Puitá Inta-CL	9.815 a	11.045 a	10.162 b	9.416 a

*Means followed by the same lowercase letters in the column do not differ by Tukey test at 5% probability.