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Tolerance to drought in rice cultivars in Southern Cerrado area from Tocantins state, Brazil

Thiago Gledson Rios Terra[1], Tarcísio Castro Alves de Barros Leal[1], Paulo Hideo Nakano Rangel[2], Hélio Bandeira Barros[1] and Antonio Clementino dos Santos[1*]

*[1]Programa de Pós-graduação em Produção Vegetal, Universidade Federal do Tocantins, BR 153, km 112, 77804-970, Araguaína, Tocantins, Brazil. [2]Empresa Brasileira de Pesquisa Agropecuária, Santo Antonio de Goiás, Goiás, Brazil. *Author for correspondence. E-mail: clementino@uft.edu.br*

ABSTRACT. The rice is large-scale cultivated in a wide range of edaphic and climatic conditions, compounding an alternative source for the increase in food production worldwide. The present study assessed the traits related to productivity, in rice genotypes under conditions of irrigation and water stress, in Gurupi municipality, Southern region from Tocantins state. We evaluated agronomic attributes (number of tillers and panicles, number of grains per panicle and productivity), besides the index of drought sensitivity. The selection of superior genotypes and traits that may serve for the differentiation among the genotypes in this stress condition is essential to create more tolerant materials. Among the most productive genotypes, we highlight the 'Quebra Cacho' that besides presenting relatively high productivities for both culture conditions, also presented a low index of drought sensitivity, ratifying itself as one of the most productive ones and adapted to this culture condition. The number of tillers by square meter did not present differences among the genotypes in both environmental conditions, but in some cases, there was a decrease under the condition of water stress. The number of grains per panicle evidenced great variation between the environments, with a decrease under the stress condition.

Key words: water stress, index of drought sensitivity, yeld, *Oryza sativa* L.

RESUMO. Tolerância à seca de cultivares de arroz no Cerrado do Estado do Tocantins, Brasil. O arroz é cultivado em larga escala de condições edafoclimáticas e se constitui em forte alternativa para o aumento da produção de alimentos no mundo. O objetivo deste trabalho foi avaliar caracteres relacionados à produtividade, em genótipos de arroz, em condições de irrigação e de estresse hídrico, no município de Gurupi, região Sul do Estado do Tocantins. Foram avaliados atributos agronômicos (número de perfilhos e panículas, número de grãos por panículas e produtividade), além do Índice de Susceptibilidade à Seca. A seleção de genótipos superiores e de caracteres que possam servir para diferenciação entre os mesmos nessa condição de estresse é fundamental para criação de materiais mais tolerantes. Dentre os genótipos mais produtivos pode-se destacar o 'Quebra Cacho' que, além de apresentar produtividades relativamente altas para ambas as condições de cultivo, apresentou também o Índice de Susceptibilidade à Seca baixo, firmando-se como um dos mais produtivos e adaptados a esta condição de cultivo. O número de perfilhos e de panículas por metro quadrado não apresentaram diferenças entre os genótipos em ambas as condições ambientais, havendo, em alguns casos, diminuição na condição de estresse hídrico. O número de grãos por panícula mostrou grande variação entre os ambientes, havendo diminuição na condição deste estresse.

Palavras-chave: estresse hídrico, índice de susceptibilidade à seca, produtividade, *Oryza sativa* L.

Introduction

Rice is a hydrophilic species, cultivated in more than 148 million hectares in varying temperatures and water regimes. The largest production and consumption of rice occurs in Asia, representing more than 90% of world production, and in all producing countries, the rice is the staple diet, providing from 50 to 80% of daily calories for the population of the region (MACLEAN et al., 2002).

Recently, some locals have presented decline in yield by environmental factors. The rice is the culture with the higher potential of yield increase, becoming an important alternative to fight hunger that plagues the world. About 13% of the rice are cultivated in uplands, without accumulation of water on the surface, and are always influenced by the water during its development (BABU et al., 2003), and may affect the stability and production in these regions.

The water stress causes several alterations in the plant, as the reduction in the opening of stomata, reduction of CO_2 absorption, negative effects on photosynthetic rate, negative effects on the vigor and plant height, decreased fertility of pollen grains and, among other, reduced productivity (BOTA et al., 2004). According to Santos et al. (2008), water deficiency reduces the nutrient absorption, decreasing productivity and causing damages to rice farmers, and fluctuations in production from year to year.

Tropical regions present high seasonality of rainfalls, frequently with periods of excess of water and others, with deficiency (WREGE et al., 2001). According to Nguyen et al. (1997), the physiological mechanisms of tolerance to drought are related to the following factors: the moderate use of water by the plant; the control of water loss by the leaves; the ability of roots to explore deeper soil layers; the higher ratio of root and aerial part; the decrease in volume of the cells; the increase of concentration of the protoplasts; the decrease in the leaf size; the energy dissipation in the leaf; the serosity and thickness of leaf cuticle; the angle of leaf slope; the stomatal behavior; the accumulation of metabolites, and dehydration resistance of the cells. Rice is not quite efficient in preventing water loss by the leaves because, among other factors, presents little cuticular wax (FUKAI; COOPER, 1995).

The selection of superior genotypes may be hindered by the lack of information about these individuals under condition of water stress. In accordance to Fischer and Maurer (1978), Lazar et al. (1995), Ouk et al. (2006) and Pantuwan et al. (2002), the use of the index of drought sensitivity (IDS) may be effective in the selection of individuals superior under condition of water stress, thereby repairing grain yield under this type of stress, ensuring that the selected genotypes may have traits of tolerance to drought.

Regarding the importance of choice of rice cultivars tolerant to drought, the present study aimed to evaluate the traits related to productivity, in rice genotypes, under conditions of irrigation, in accordance to the culture needs, and water stress, in Gurupi municipality, Southern region from Tocantins state.

Material and methods

The experiment was developed at the Experimental Station, belonging to Universidade Federal do Tocantins, in the University Campus from Gurupi municipality – Tocantins state, between June and December 2007, located about 287 m altitude. The mean annual temperature is around 26°C, relative humidity of 68.5%, and mean annual rainfall about 1,400 mm.

The local soil is classified as dystrophic yellow latosol, with sandy clay loam texture and pH of 5.5 (Table 1). We evaluated ten (Tables 2 and 3) material of rice in randomized complete block design, with three repetitions, in two situations of irrigation: without stress, according to the culture needs indicated by Stone and Silveira (2004), and under water stress.

Table 1. Results from the soil analysis of experimental area (February 2007).

Soil analysis										
M.O	pH	P(mel.)	K	Ca	Mg	Al	H + Al	Sand	Silt	Clay
(%)	$CaCl_2$	mg dm^{-3}	cmol$_c$ dm^{-3}					g kg^{-1}		
4.75	5.5	0.3	0.097	2.36	0.38	0.25	2.3	562.5	127.5	310

In the experimental area, with previous use by typical cerrado vegetation, around 90 days before the sowing, we cut down the vegetation, and ten days later, liming was done, trying to raise the pH, according to indication from Ribeiro et al. (1999) for the cultivation of upland rice, through the application of dolomitic limestone. The sowing was performed in conventional system, with two heavy disking, and a light disking or leveling. The fertilization was carried out at the time of sowing, using 12; 90; 48 and 20 kg ha^{-1} of N, P_2O_5, K_2O and zinc sulfate, respectively. We accomplished two coverage fertilizations: the first around 20 days after sowing, and the second around 90 days after sowing, with 45 kg ha^{-1} of N in each application in the form of urea.

The plots were compounded by four lines with 3 m length and spaced 0.35 m, with an average of 80 seeds per meter. We applied in pre-emergence, 0.75 kg ha^{-1} (A.I.) of the oxadiazon herbicide, using a tractor with spray (flat-fan nozzle type). At 75 days after sowing, we applied a mixture of the fungicides Triciclazol (Bin 0.3 kg ha^{-1} A.I.) and trifloxystrobin + propiconazole (Stratego 0.05 kg ha^{-1} A.I.) to control rice blast (bruzone), through motorized backpack sprayer.

The water table was provided without distinction between the environments, where previously there was no stress, until the 35 days after emergence, through an irrigation system compounded by a self-propelled set and cart with sidebars. There were, in the exit of nozzle sinks, pressure regulating valves to maintain constant and homogeneous water level during the application, and to minimize experimental error. After this period, we placed for the treatment with stress, the half of water supplied for the treatment without stress. The irrigation schedule was adjusted according to evapotranspiration, with the aid of tensiometers put at strategic locations throughout the area, whose porous capsule was 0.15 m deep in the soil. The soil water tension used in the experiment was 0.035 MPa, as described by Stone and Silveira (2004), and in these conditions, there was stress.

Prior to the harvest time, we counted in 1 m of row from each plot, the number of tillers and number of panicles, which served as traits related to production. We also collected in each plot, ten panicles in order to have: the number of filled grains, the number of empty grains, and the weight of 100 grains. The grains were weighed in an accurate balance of 0.002 g. With the amount of filled and empty grains, it was possible to estimate the percentage of sterile grains or spikelets, in both environments. For this, we used the following equation: SS = (EG x 100) ÷ TG, where: SS = spikelet sterility, EG = number of empty grains, and TG = total number of grains. We also measured, during the harvest time, ten plants by plot, taking as basis the ground and the apex of the panicle to determine the plants height at each experimental unit.

The index of drought sensitivity (IDS) was calculated according to Fischer and Maurer (1978), in order to know the superiority of genotypes under stress condition, caused by water deficiency. The formula used to calculate this index was as follows: IDS = (1- (Yce/Yse))/(1-(Mce/Mse)), where: Yce = production of genotype under stress, Yse = production of genotype without stress, Mce = mean of genotypes under stress and Mse = mean of genotypes without stress. For data analyses, we used Genes Software (CRUZ, 1998).

Results and discussion

According to the results, we may state that there was variation among cultivars in established water conditions, for most variables.

The number of tillers and panicles per square meter, and the number of grains per panicle is listed in Table 2.

Regarding the number of tiller per square meter in both environments, we did not detect difference among the cultivars. Nevertheless, we observed lower number of tiller in the cultivars 'Quebra Cacho', 'Santo Américo' and 'Paulista', when cultivated under drought stress, but no difference when considering other materials.

In the same way, with respect to the number of panicle per square meter, we did not observe difference among cultivars in both environments. However, the materials 'Quebra Cacho', 'Muruim Branco', 'Santo Américo', 'Paulista' and 'BRS Sertaneja' presented lower number of panicles when submitted to water stress. Kumar et al. (2008) also found lower number of panicles in different rice cultivars when exposed to water stress.

Table 2. Number of tillers per square meter, number of panicles per square meter and number of grains per panicle in two environmental conditions: without drought stress and with drought stress, evaluated in 2007, in Gurupi municipality – Tocantins state.

Cultivars	Number of tillers m^{-2}		Number of panicles m^{-2}		Number of grains $panicle^{-1}$	
	S.E.*	C.E.**	S.E.*	C.E.**	S.E.*	C.E.**
'Quebra Cacho'	244Aa	157Ba	215Aa	123Ba	124Ad	100Abc
'Bico de Rola'	231AA	153Aa	170Aa	115Aa	162Aabcd	95Bbc
'Muruim Branco'	274Aa	197Aa	223Aa	131Ba	203Aa	161Ba
'Santo Américo'	311Aa	151Ba	236Aa	113BA	155Abcd	78Bc
'Paulista'	279Aa	184Ba	234Aa	154Ba	129Acd	97Bbc
'Puteca'	246Aa	174Aa	193Aa	141Aa	128Acd	81Bc
'Branquinho'	279Aa	229Aa	210Aa	194Aa	115Ad	75Bc
'BRS Sertaneja'	286Aa	216Aa	253Aa	180Ba	173Aabc	87Bbc
'Arroz Comprido'	244Aa	219Aa	199Aa	185Aa	121Ad	59Bc
'Agulhinha Tardio'	239Aa	210Aa	196Aa	142Aa	199Aab	135Bab
CV (%)	18.94	20.48	21.21	24.92	11.08	20.17

Means followed by the same capital letter in the line, and lower case in the row, are not statistically different between themselves, at 5% significance, by Tukey test. *Environment without water stress. **Environment with water stress.

The number of grains per panicle was one of the production components that presented wide range among materials, both within each environment as between the environments, except for 'Quebra Cacho', which was among the lowest sterility, under both conditions and did not present significant difference between the environments.

The cultivar 'Quebra Cacho' despite producing lower number of tillers and panicles per square meter was quite relevant among the most productive. Such observation may be associated to a redirection of photoassimilates, which would be to produce more tillers, grain filling, reflecting in low sterility of spikelets, under both conditions (Table 3).

Spikelet sterility, weight of 100 grains and productivity are presented in Table 3.

The spikelet sterility was other factor that presented differences between the treatments, emphasizing higher sterility in the environment under stress. Fukai et al. (1999) reported that the spikelet sterility is a process sensitive to drought and is directly reflected in the capability of materials to keep the water potential in leaves. The cultivars with lower water potential in leaves, around flowering under stress, reached higher sterility.

The weight of grains was also affected in most cultivars within each environment. Cultivars with no difference between the environments were more efficient in the translocation of photoassimilates to the grains, which may present higher harvest rates.

Table 3. Number of grains per panicle, sterility of spikelet and weight of 100 grains, in two environmental conditions: without drought stress and with drought stress, evaluated in 2007, in Gurupi municipality, Tocantins state.

Cultivars	Sterility (%)		Weight of 100 grains (g)		Yeld (kg ha^{-1})	
	S.E.*	C.E.**	S.E.*	S.E.*	S.E.*	S.E.*
'Quebra Cacho'	23.60Aa	37.11Ab	2.92Ac	2.69Abc	4,143Aab	2,414Ba
'Bico de Rola'	18.48Ba	52.19Aab	2.99Abc	2.60Bbc	3,776Aabcd	1,490Bab
'Muruim Branco'	30.32Aa	43.40Aab	2.22Ade	2.23Ac	2,495Abcd	1,271Bab
'Santo Américo'	21.00Ba	51.23Aab	3.45Aab	3.22Aa	3,376Aabcd	943Bab
'Paulista'	15.70Ba	35.64Ab	3.52Aa	2.69Bbc	4,076Aabc	864Bab
'Puteca'	23.60Ba	60.10Aab	3.51Aa	2.54Bbc	3,205Aabcd	743Bb
'Branquinho'	17.09Ba	60.73Aab	3.72Aa	2.91Bab	3,033Aabcd	600Bb
'BRS Sertaneja'	27.76Ba	63.32Aab	3.26Aabc	2.34Bc	4,490Aa	450Bb
'Arroz Comprido'	36.29Ba	81.57Aa	2.70Ad	2.39Bbc	2,481Acd	214Bb
'Agulhinha Tardio'	42.56Ba	80.06Aa	1.74Ae	1.43Bd	2,395Ad	14Bb
CV (%)	9.07	17.59	2.78	9.47	22.12	49.7

Means followed by the same capital letter in the line, and lower case in the row, are not statistically different between themselves, at 5% significance, by Tukey test. *Environment without water stress. **Environment with water stress.

We may observe that the genotypes were statistically different amongst themselves ($p < 0.05$), and also between the environments, presenting a reduction in productivity when subjected to water stress, as recorded by Jongdee et al. (2006), Kumar et al. (2008), Ouk et al. (2006) and Wade (1999), examining other rice cultivars. We may also observe that the cultivar 'Quebra Cacho' presented a productivity upper to 2.4 t ha, when exposed to water stress. In turn, the cultivar 'Agulhinha Tardio' had an extremely low yeld under this condition (14.29 kg ha^{-1}), denoting its great susceptibility to drought.

In the Figure 1, we may observe the yeld of each studied cultivar, in the environment under stress and its respective IDS, according to Fischer and Maurer (1978).

Some cultivars presented a relatively low index of drought sensitivity, and may present morphophysiological traits that contribute to drought tolerance in rice, and that may be used in genetic improvement programs for this purpose (OUK et al., 2006; PANTUWAN et al., 2002).

We emphasize that superior genotypes should present a low IDS, and a relatively satisfactory yeld, in both environments, since depending on the environmental condition, with or without water stress; the selected genotype must provide good harvest rates. Such condition is easily observed in the genotype 'Quebra Cacho', which presented low IDS (0.56), associated to high yeld (2,414 kg ha^{-1}), when cultivated under water stress, distinguishing itself as the genetic material most tolerant to this condition. Despite significant technological innovations, the Brazilian agronomic research continues with several challenges, regarding the rice and the search for solutions to problems related to this crop, an important point in the mission of paddy field research in Brazil (NOSSE et al., 2008).

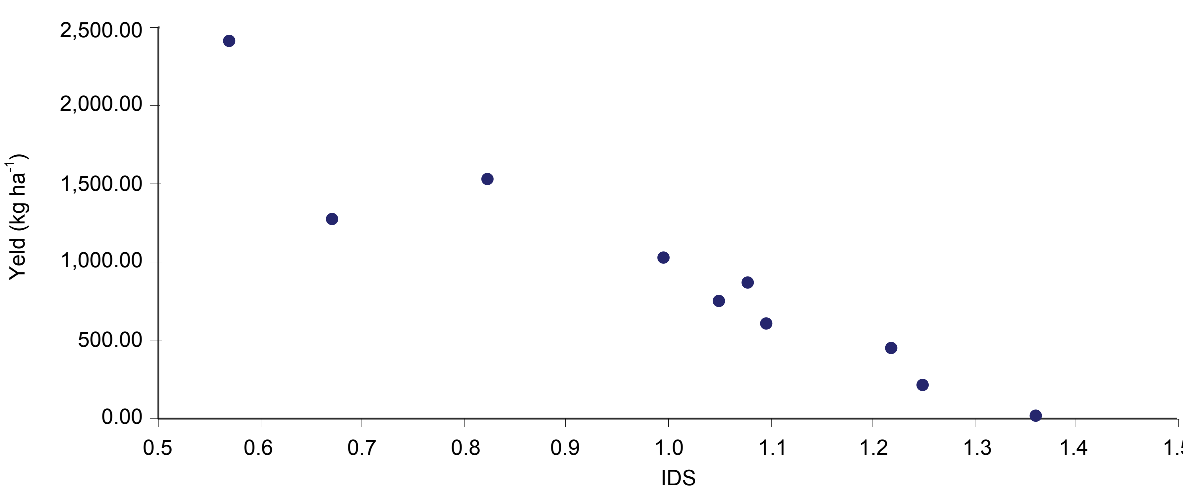

Figure 1. Index of drought sensitivity – IDS (FISCHER; MAURER, 1978) and yeld under drought stress (kg ha^{-1}), in different rice cultivars in Gurupi municipality – Tocantins state, between June and December 2007.

Conclusion

In general, a great variability was observed among the rice cultivars studied, with prominence of 'Quebra Cacho', among the most productive that simultaneously evidenced the lower index of drought sensitivity, and may present morphophysiological traits for drought tolerance.

The spikelet sterility presented large variation among cultivars, with trend to higher sterility under water stress condition. Therefore, this variable may serve as differentiating among cultivars most tolerant for this condition of water stress.

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