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Times of Application of Boron in Irrigated Rice Genotypes in Tropical Varzeas

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Abstract

Boron is an important micronutrient for all vegetables, being part of several metabolic functions within cells. Rice stands out as a staple food for more than half the world's population and requires small amounts of boron. The objective of this study was to evaluate the effect of boron application at different times in the culture of irrigated rice in the conditions of the floodplains in the Southwest of the State of Tocantins. The experiment was installed at Fazenda Santa Rita, municipality of Lagoa da Confusão-TO in the 2015/2016 harvest, in bands, with a randomized block design, in a 4 x 4 factorial scheme, with 4 repetitions. The dose of 3.0 kg ha $^{-1}$ of boron was applied, in the form of borax, via leaf, in four seasons. Were four lowland rice cultivars (IRGA-424, IRGA-424 RI, IRGA-425, and IRGA-426) were used.

Keywords: micronutrient; Oryza sativa; productivity.

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The characteristics evaluated were plant height, number of panicles, spikelet sterility, the mass of one hundred grains, grain yield, whole grains, and grain yield. Boron resulted in higher productivity. The highest yields were achieved with borate fertilization at 60 and 75 days after emergence. The genotypes IRGA-424 RI and IRGA-425 proved to be more efficient in the use of boron, is recommended at any time of application of the micronutrient.

1. Introduction

Micronutrients are of great importance for the development of a plant, being present in the main metabolic functions within the cells and causing great losses in productivity in the absence of them [1]. Boron is an important micronutrient for all vegetables, being part of meristematic growth, cell wall structure, cell membrane function, auxin transport, carbohydrate metabolism, and nucleic acid synthesis [2]. According to reference [3], there is a direct relationship between the supply of boron and the pollen production capacity, as the element affects microsporogenesis, germination, and particularly the development of the pollen tube. It is a little mobile element in the structure of most plant species and its deficiency occurs in growing tissues, characterized by the overgrowth and curling of the leaves, while the symptoms of toxicity appear first in the apexes and margins of old leaves, through chlorosis [4]. Rice (*Oryza sativa* L.) stands out as a staple food for more than half of the world population. It is grown on all continents, playing a strategic role in the economic and social aspects [5]. In Brazil, it is grown in floodplains and highlands, with its irrigated cultivation contributing approximately 68% of Brazilian production and occupying about 31% of the area cultivated with this cereal [6]. According to reference [7], the national yield of irrigated rice in the 2017/18 crop reached 7.339 kg ha^{-1}, 3,7 % lower when compared to the previous crop. In the Tocantins, productivity was 5.400 kg ha^{-1}, 8,7% less compared to the previous harvest, and 26,4% less than national productivity. The production of irrigated rice in the State takes place in the Vale do Javaés, considered the largest continuous area for gravity irrigation in the world. Because of the productive potential presented by the State due to the large areas suitable for the cultivation of irrigated rice, it is necessary to adapt the fertilizer to be used. The culture of rice requires small amounts of boron, and the decision to apply adequate doses of the micronutrient is vital for increasing its productivity [3], requiring caution because the range of deficiency and toxicity is quite narrow [8]. Besides, determining the appropriate time for application of nutrients, including boron, can be fundamental for increasing its efficiency and the grain yield of the crop [3], since the plant has a difference in speed absorption of nutrients during its cycle. Given the above, the objective was to evaluate the effect of the application of boron at different times on the culture of irrigated rice in the conditions of the floodplains in the Southwest of the State of Tocantins.

2. Material and Methods

The experiment was installed at Fazenda Santa Rita, municipality of Lagoa da Confusão -TO (10 ° 47'22 " S, 49 ° 37'50 " W, 186 m altitude), in the 2015/2016 crop year, in bands, with a randomized block design, in a 4 x 4 factorial scheme, with 4 repetitions. The dose of 3.0 kg ha^{-1} of boron was applied, in the form of borax, via leaf, in four seasons (0. Absence of boron application, being, therefore, considered the control; 1. application of boron in coverage - 25 days after emergence; 2. application of boron in coverage - 60 DAE; 3. application of boron 75 DAE). There were four lowland rice cultivars used (IRGA-424, IRGA-424-RI, IRGA-425, and IRGA-426).

The result of the chemical and physical analysis of the soil in the 0-20 cm layer before the installation of the experiment was: pH in $CaCl_2$ = 4,9 ; M.O (%) = 3,5 ; P (Mel) = 19,4 mg dm $^{-3}$; K = 210 mg dm $^{-3}$; Ca + Mg = 3,6 cmol dm $^{-3}$; B = 0,28 mg dm $^{-3}$; Zn = 3,7 mg dm $^{-3}$; Cu = 0,4 mg dm $^{-3}$; Fe = 95,3 mg dm $^{-3}$; Mn= 10,5 mg dm $^{-3}$; H + Al = 3,4 cmol dm $^{-3}$; Al = 0,1 cmol dm $^{-3}$; SB = 3,9 cmol dm $^{-3}$; V = 54%; 350,0 g kg $^{-1}$ of sand; 120,0 g kg $^{-1}$ of silt and 530,0 g kg $^{-1}$ of clay. The sowing and covering fertilization were carried out according to the recommendation of the soil analysis and in the sowing fertilization, the dose of 300 kg ha $^{-1}$ of the formulated 4-20-20 was used. The cover fertilizations were carried out using 100 kg ha^{-1} of ammonium sulfate, close to the effective tillering, 70 kg ha $^{-1}$ of 30-0-20, in the phase of floral differentiation, and 60 kg ha^{-1} of urea, in the flowering stage. Phytosanitary treatments were carried out with products duly recommended for the crop, according to the schedule adopted by the producer. Weed control was performed with herbicide application (Butyl-Cialofop 180 gl^{-1} + Basagran 600 gl^{-1}, 2, and 1.5 l of p.c. ha^{-1}, respectively). Control with fungicides was performed using Tricyclazole 750kg^{-1} + Tebuconazole 200 gl^{-1}. Along with the application of herbicide, 0,2 l ha^{-1} of methoxyfenozide insecticide 240gl^{-1} was applied and, together with the fungicide applications, 0.3 l ha^{-1} of sphenolvalerate insecticide 40 gl^{-1} were applied.

3. Results and Discussion

The experimental data were subjected to analysis of variance, with the application of the F test. To compare the treatment means, the Tukey test was used at 5% probability, using the computational application [9]. Means followed by the same letters, uppercase in the columns and lowercase in the rows, do not differ by Tukey's test at 5% probability. There was no statistical difference between the averages for cultivars and for the time of application of boron regarding the number of panicles (Table 1). This characteristic is defined between the stages of germination and the beginning of panicle development [3] and is directly related to the number of tillers formed in the plant, so boron was not able to influence rice tillering. As for the number of grains per panicle (Table 1), a difference between the periods of the application was expected since boron is linked to plant reproduction. There is no difference between the cultivars IRGA-424, IRGA-425, and IRGA-424 RI, which had the highest averages. There was a significant difference depending on the rice cultivar for spikelet sterility (Table 1). The s cultivating s IRGA 424-RI and 425-IRGA are sat the s most es averages, while IRGA IRGA-424 and-426 showed the lowest average. It is observed that, except for IRGA-425, the application of boron showed a tendency to reduce the sterility of spikelets. During the reproductive period, temperatures above 35◦C can cause spikelet sterility [10], which may explain the difference between cultivars since they show different responses to environmental conditions and the occurrence of high temperatures in the growing region. Boron can improve stomatal opening, affecting the efflux of potassium ions from the guard cells in the epidermal strips [11], that is, even in stressful temperature conditions, as occurs in the region where this work is grown, boron can increase the plant's capacity to deal with this environmental stimulus. There was no significant difference for 100 grain mass depending on the rice cultivar and the time of boron application (Table 2). P ode inversely relates the number of grains per panicle with the mass thereof, because the smaller the number of drains the more photoassimilate will be directed to the filling of the grains [12].

Table 1: Average of plant height characteristics (cm), number of panicles, number of grains per panicle, and spikelet sterility (%) of four rice cultivars, grown under different boron application times.

Genotypes	Plant height				
	Time of application				
	0	1	2	3	Average
IRGA-424	92,8	93,3	94,9	96,6	94,4 A
IRGA-426	86,1	88,3	85,0	88,6	87,0 B
IRGA-424 RI	92,8	93,3	91,0	93,5	92,7 A
IRGA-425	89,6	90,6	94,0	90,0	91,0 A
Average	90,3 a	91,4 a	91,2 a	92,2 a	
	Number of panicles				
	Time of application				
	0	1	2	3	Average
IRGA-424	162,8	146,5	159,8	151,8	155,2 A
IRGA-426	168,5	205,3	160,5	127,8	165,5 A
IRGA-424 RI	213,0	173,8	189,3	168,5	186,1 A
IRGA-425	195,8	163,5	165,0	150,8	168,8 A
Average	185,0 a	172,3 a	168,6 a	149,7 a	
	Number of grains per panicle				
	Time of application				
	0	1	2	3	Average
IRGA-424	101,5	107,4	112,1	109,7	107,7 A
IRGA-426	92,2	104,3	91,1	98,9	96,6 B
IRGA-424 RI	102,1	94,5	96,5	107,3	100,1 AB
IRGA-425	110,8	98,3	110,5	109,8	107,3 A
Average	101,7 a	101,1 a	102,6 a	106,4 a	
	Sterility of spikelets				
	Time of application				
	0	1	2	3	Average
IRGA-424	10,0	9,1	9,3	8,0	9,1 B
IRGA-426	8,1	7,3	9,0	7,9	8,0 B
IRGA-424 RI	15,5	13,0	11,6	12,3	13,1 A
IRGA-425	7,7	10,4	9,3	11,1	9,6 AB
Average	10,3 a	9,9 a	9,8 a	9,8 a	

Means followed by the same letters, uppercase in the columns and lowercase in the rows, do not differ by Tukey's test with 5% probability.

Means followed by the same letters, uppercase in the columns and lowercase in the rows, do not differ by Tukey's test at 5% probability. As for the percentage of whole grains (Table 2), when there was no application of boron, the cultivars with the highest percentages were IRGA-424 RI and IRGA-425. The cultivar IRGA-424 RI also stood out when the application occurred at 25, 60 and 75 DAE, while IRGA-426 obtained the lowest average in the three conditions. It is noted that the use of boron did not increase the averages for the evaluated cultivars. The quality of the rice grain is a fundamental factor for its commercialization, since whole and flawless grains have a higher market value [13]. Therefore, the cultivar IRGA-424 RI is the most recommended for this characteristic. Also, later applications do not increase the characteristic of the aforementioned cultivar. It has an average of 100 days for flowering, so it can be said that it is efficient in using boron to increase the quality of grains in the earliest application. According to reference [8], boron is important in the formation of the cell wall, more specifically in the synthesis of components, such as pectin, cellulose, and lignin, and in the transport of carbohydrates. Although there was no increase in the percentage of whole grains due to the interaction of the cultivar with the time of application of boron, it is noted that there are significant differences, highlighting the importance of boron for the characteristic.

Table 2: Averages of the characteristics mass of 100 grains (g), whole grains (%), grain yield (%), and grain yield (kg ha $^{-1}$) of four rice cultivars, grown under different application times boron.

Genotypes	Mass of 100 grains				
	Time of application				
	0	1	2	3	Average
IRGA-424	2,58	2,64	2,62	2,41	2,56 A
IRGA-426	2,66	2,72	2,73	2,69	2,70 A
IRGA-424 RI	2,57	2,60	2,70	2,75	2,65 A
IRGA-425	2,57	3,39	2,67	2,61	2,81 A
Average	2,59 a	2,84 a	2,68 a	2,61 a	
	Whole grains				
	Time of application				
	0	1	2	3	Average
IRGA-424	55,4 Ba	58,3 Ba	56,6 ABa	56,7 Ba	56,7
IRGA-426	54,6 Ba	53,2 Ca	55,1 Ba	56,6 Ba	54,9
IRGA-424 RI	61,6 Aab	64,5 Aa	59,7 Ab	60,9 Aab	61,7
IRGA-425	59,5 Aa	56,5 BCa	58,6 ABa	57,9 ABa	58,1
Average	57,8	58,1	57,5	58,0	
	Grain yield				
	Time of application				
	0	1	2	3	Average
IRGA-424	71,7	72,3	71,3	71,5	71,7 AB
IRGA-426	72,3	72,3	72,4	72,1	72,3 A
IRGA-424 RI	71,0	72,4	71,7	71,5	71,7 AB
IRGA-425	71,1	71,1	71,5	71,0	71,2 B
Average	71,5 a	72,0 a	71,7 a	71,5 a	
	Grain productivity				
	Time of application				
	0	1	2	3	Average
IRGA-424	6.051,5 ABc	8.691,2 Aa	5.842,6 Cc	7.022,1 Ab	6.901,8
IRGA-426	5.639,7 Bbc	5.522,1 Cc	6.522,1 Ba	6.128,7 Bab	5.953,1
IRGA-424 RI	5.492,7 Bc	5.801,5 Cbc	6.077,2 BCab	6.643,4 ABa	6.003,7
IRGA-425	6.242,6 Ab	7.095,6 Ba	7.125,0 Aa	6.838,2 Aa	6.825,4
Average	5.856,6	6.777,6	6.391,7	6.658,1	

Means followed by the same letters, uppercase in the columns and lowercase in the rows, do not differ by Tukey's test with 5% probability.

The ambient air temperature during grain filling can drastically affect the quality and yield of whole grains [13], which may explain the stability of the averages for the characteristic. The cultivar IRGA-426 was the only one to differ significantly from IRGA-425 for the characteristic yield of rice grains (Table 2). The whole grain yield is an extremely important parameter to determine the commercial value of the rice culture, meaning the number of whole grains that is obtained after the industrial processing of rice grains [14]. Regarding the productivity of rice grains (Table 2), it appears that with the borate application carried out at 25 DAE, the cultivar IRGA-424 presented the highest average, while IRGA-424 RI and IRGA-426 presented the lowest averages and did not differ significantly. As for application at 60 DAE, the cultivar IRGA-425 showed the highest grain yield, while IRGA-424 had the lowest average. When boron application occurred at 75 DAE, the cultivars IRGA-424, IRGA

424 RI, and IRGA-425 reached the highest averages and did not differ significantly, while IRGA-426 obtained the lowest average. It is observed that the application of boron results in an increase in grain yield for all cultivars. The increase in grain yield was most noticeable when the borate application occurred at 60 and 75 DAE. The cultivars used to present an average of 60 days for the beginning of the reproductive stage, which may explain the higher averages of grain products in the mentioned application periods, as according to reference [15] boron has low mobility in the phloem, being more available to the plant. Still, according to reference [16] the borate application via foliar increases the boron contents in the reproductive parts. The influence of boron on the pollen grain fertilization process and the growth of the pollen tube are also determining factors for increasing grain production [17].

4. Conclusion

Boron resulted in higher productivity; the highest yields were achieved with borate fertilization at 60 and 75 DAE; the genotypes IRGA-424 IR and IRGA-425 proved to be more efficient in the use of boron, is recommended at any time of application of the micronutrient.

References

[1]. CORCIOLI, G.; BORGES, J.D.; JESUS, R.P. Deficiência de macro e micronutrientes em mudas maduras de Khaya ivorensis estudadas em viveiro. Cerne, v. 22, n. 1, p. 121-128, 2016. http://dx.doi.org/10.1590/01047760201622012085.

[2]. XAVIER, C.V.; NATALE, W. Influência do boro no teor, acúmulo e eficiência nutricional em porta-enxertos de caramboleira. Revista Brasileira de Ciências Agrárias, v. 12, n. 1, p. 6-13, 2017. http://dx.doi.org/ 10.5039/agraria.v12i1a5409

[3]. LEITE, R.F.C.; SCHUCH, L.O.B.; AMARAL, A.S.; TAVARES, L.S. Rendimento e qualidade de sementes de arroz irrigado em função da adubação com boro. Revista brasileira de sementes, v. 33, n. 4, p. 785-791, 2011. http://dx.doi.org/10.1590/S0101-31222011000400021

[4]. PAVINATO, P.S.; AGUIAR, A.; CASTRO, G.S.A.; CRUSCIOL, C.A.C. Boro em arroz de terras altas cultivado em solução nutritiva. Bragantia, v. 68, n. 3, p. 743-751, 2009. http://dx.doi.org/10.1590/S0006-87052009000300022.

[5]. BORDIN, L.C.; CASA, R.T.; MARCUZZO, L.L.; BOGO, A.; ZANCAM, R.L. Efeito da aplicação de fungicidas no controle de doenças foliares de arroz irrigado e sua relação com o rendimento industrial. Summa Phytopathologica, v. 42, n. 1, p. 85-88, 2016. http://dx.doi.org/10.1590/0100-5405/2012.

[6]. LOPES, M.B.S.; SILVA, F.R.; ZELLMER, V.A.; ALVES, P.M.; FIDELIS, R.R. Adubação potássica na cultura do arroz em solos arenosos de várzea tropical. Brazilian Journal of Applied Technology for Agricultural Science, v. 9, n. 3, p. 27-33, 2016. 10.5935/PAeT.V9.N3.03

[7]. CONAB - Companhia Nacional de Abastecimento. Acompanhamento da safra brasileira de grãos 2017/18, décimo levantamento. Disponível em: <https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos/item/download/21088_8ca248b277426bb3974f74efa00abab6>. Acesso em: 09 ago 2018.

[8]. BRUNES, A.P.; MENDONÇA, A.O.; OLIVEIRA, S.; LEMES, E.S.; LEITZKE, I.D.; VILLELA, F.A.

Produção, qualidade e expressão isoenzimática de semente de trigo produzidas sob diferentes doses de boro. Revista Brasileira de Biociências, v.14, n.3, p. 137-144, 2016.

[9]. FERREIRA, D.F. SISVAR: um programa para análises e ensino de estatística. Revista Symposium, v. 6, n. 2, p. 36-41, 2008.

[10]. WALTER, L.C.; STRECK, N.A.; ROSA, H.T.; FERRAZ, S.E.T.; CERA, J.C. Mudanças climáticas e seus efeitos no rendimento de arroz irrigado no Rio Grande do Sul. Pesquisa Agropecuária Brasileira, v. 49, n. 12, p. 915-924, 2014. http://dx.doi.org/10.1590/S0100-204X2014001200001.

[11]. REHMAN, A.U.; FAROOQ, M.; RASHID, A.; NADEEM, F.; STUERZ, S.; ASCH, F.; BELL, R.W.; SIDDIQUE, K.H.M. Boron nutrition of rice in different production systems. A review. Agronomy for Sustainable Development, v. 38, n. 3, p. 1-24, 2018. https://doi.org/10.1007/s13593-018-0504-8

[12]. PERIN, A.; GONÇALVES, É.L.; FERREIRA, A.C.; SALIB, G.C.; RIBEIRO, J.M.M.; ANDRADE, E.P.; SALIB, N.C. Uso de promotores de crescimento no tratamento de sementes de feijão carioca. Global Science and Technology, v. 9, n. 3, p. 98-105, 2016.

[13]. LONDERO, G.P.; MARCHESAN, E.; PARISOTTO, E.; COELHO, L.L.; ARAMBURU, B.B.; FLORES, C.S.; SILVA, A.L. Qualidade industrial de grãos de arroz decorrente da supressão da irrigação e umidade de colheita. Irriga, v. 20, n. 3, p. 587-601, 2015. https://doi.org/10.15809/irriga.2015v20n3p587

[14]. GARCIA, N.F.S.; ARF, O.; PORTUGAL, J.R.; RODRIGUES, M.; PENTEADO, M.S. Rendimento e qualidade de grãos de arroz de terras altas em função de doses e modos de inoculação com Azospirillum brasilense. Enciclopédia Biosfera, v. 11, n. 21, p. 1653-1651, 2015.

[15]. OLIANI, D.; TEIXEIRA, C.M.; BONILHA, M.A.F.M.; CASSIA, M.T. Adubação foliar com boro e manganês na cultura do feijão. FAZU em Revista, n.8, p. 9-14. 2011.

[16]. LEMISKA, A.; PAULETTI, V.; CUQUEL, F.L.; ZAWADNEAK, M.A.C. Produção e qualidade da fruta do morangueiro sob influÊncia da aplicação do boro. Ciência Rural, v.44, n.4, p. 622-628, 2014. http://dx.doi.org/10.1590/S0103-84782014000400008.

[17]. LIMA, M.L.; CARDOSO, F.R.; GALANTE, A.H.A.; TEIXEIRA, G.C.S.; TEIXEIRA, I.R.; ALVES, S.M.F. Fontes e doses de boro na qualidade de sementes de feijão-comum e mamona sob consórcio. Revista Caatinga, v. 26, n. 4, p. 31-38, 2013.