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Effect of selective micronutrients on productivity of upland rice varieties

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The realization of optimal recommendations for the nutrient balance of upland rice is an excellent strategy to increase the productivity and sustainability of the production system, especially in soils with limiting conditions for cultivation. The objective of the study was to evaluate the behavior of upland rice cultivars (ANa 9005CL, ANa 8001, AN Cambará and BRS A502), by foliar fertilization (Maxi Zinc®, Booster® and Broadacre®) in the first year under dryland conditions in Vilhena-RO. The experimental design adopted was a randomized block design (BCT), with four cultivars and two levels of micronutrients and four repetitions, in a 4 × 2 factorial scheme. The production components evaluated showed statistically non-significant means for the foliar fertilizer factor, except for the number of spikes per panicle, for which there was a significant difference with an 8% increase in the cultivar ANA 8001 in relation to the other cultivars evaluated. Although the cultivar BRS A502 had fewer spikelets per panicle, the number of panicles per m^2 compensated for this and ensured statistical equality in yield. The cultivar ANa 8001 produced the best results in terms of productivity and physical quality of the grains, under the edaphoclimatic conditions of the region.

Key words: *Oryza sativa* L., rainfed, nutrition, production components, foliar fertilization.

INTRODUCTION

Rice (*Oryza sativa* L.), the third most important cereal crop after corn and wheat, feeds more than half of the world's population (Ramos et al., 2021). In Brazil, it plays a prominent role as it constitutes an important source of calories and proteins in people's diets (Fornasieri Filho and Fornasieri, 2006).

According to the National Supply Company (CONAB, 2020), rice is cultivated in almost every state in Brazil. An estimated data survey for the 2020/2021 harvested rice indicated that the national production was approximately

12 million tons in a total area of 1.72 million ha. It is also noteworthy that rice farming is predominant in the southern region of the country (10.8 million tons) (CONAB, 2020), where it occurs under irrigated conditions, while it is cultivated under rainfed conditions in the northern region (Ramalho, 2005). In the case of this region, rice is grown in acidic soils with a low water retention capacity, which is the case of sandy soils, implying the unavailability of nutrients to the plants (Silva et al., 2009).

Something aggravating is seen in the Southern Cone of Rondônia (SCRO), where spatial irregularities in rainfall distribution caused by changes in land use and cover (Khanna et al., 2017) have been altering the agricultural scenario of the main annual crops in this region (Andrea et al., 2018), including rice.

The municipality of Vilhena, an exponent of rice production in the SCRO, is located in a transition region between the Savanna and the Brazilian Amazon. The area is characterized by a clayey texture, with 64% clay, 16% silt, and 20% sand, although the soil has a low cation exchange capacity (CEC). Tropical regions, predominantly in Brazil, have more weathered soils, with a predominance of low activity clays and medium levels of organic matter. In this region the Latosols are highly weathered, with limitations in food production due to their low natural fertility (Lopes, 1996; Hunke et al., 2015), as they are acid soils with low availability of nitrogen, phosphorus, potassium, calcium, magnesium, zinc, boron and copper, with high aluminum saturation and high P fixation.

The farmer must pay attention to the characteristics of the sown cultivar, the amount of inputs, and the management techniques used in order for the rice crop to perform well and yield a high economic return (Xavier et al., 2021). Furthermore, it is still necessary to analyze its phenological and/or genotypic characteristics, as well as the soil edaphoclimate where it will be sown (Quevedo-Amaya et al., 2020; Sandhu et al., 2019).

There has been a decrease in the number of rice farmers in Brazil in recent years. However, it began to exhibit a high bias in its price in the second half of 2019 and with the entry into the core of the off-season, as there is a significant deficit between the country's supply and demand for grain (IPEA, 2020). This can be explained by the fact that a portion of farmers invest in soybean production rather than rice production due to the lower cost (Conceição et al., 2017; Júnior, 2019). In addition, weed infestations resistant to current methods of control (Rubin et al., 2014) and blast disease caused by the fungus *Magnaporthe oryzae* (Barr) Couch [anamorphic *Pyricularia oryzae* (Cav.)] (Prabhu et al., 2009) contribute to the difficulty of producers to remain in business.

Camargo et al. (2008), Dario et al. (2012), Marchezan et al. (2001), and Wei et al. (2012) investigated the possibility of increasing tillage productivity by including micronutrients in rice, but found no productivity increases. On the other hand, Mahmoodi et al. (2020), Nadeem and Farooq (2019), Phattarakul et al. (2012), and Prom-u-thai et al. (2020) obtained yield increments with the application of Zn. These different results are associated with the soil type and rice cultivation system in lowlands (flooded areas) and uplands (rainfed areas). According to Lahijani et al. (2020), deficiency of micronutrients, especially Fe and Mn, is a determining factor in reducing the productivity and quality of agricultural crops. Foliar sprays, according to these authors, are viable alternatives to rice culture for increasing yield rates due to the role of micronutrients in plant nutrition and enzyme activation.
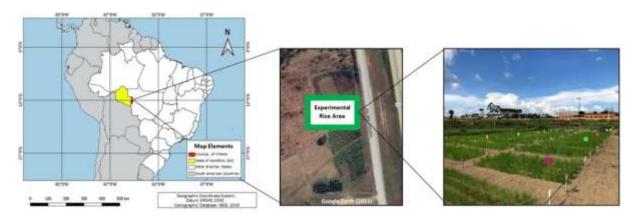
In acidic soils, Zn deficiency is common in upland rice (Fageria and Nascente, 2014). Plants lacking Zn during the early stages of development may have their development impaired and will hardly be able to reach their maximum genetic yield potential. It affects the maintenance of some enzymatic activities and the tryptophan synthetase enzyme, causing a decrease in cell volume and lower apical growth (Epstein and Bloom, 2006).

Molybdenum is not readily available in soils with low pH, and it may be one of the limiting factors to the biological fixation of atmospheric nitrogen concerning legumes and affecting the nitrate reductase enzyme activity in deficient leaves (Sundim et al., 2002; Guimarães et al., 2007). This can be proven in the works of Das Gupta and Basuchaudhuri (1977) and Fageria and Baligar (1997), who identified that foliar application of molybdenum with the addition of mineral nitrogen has a positive effect on the accumulation of dry mass in rice cultivar. Manganese is an element of vital importance for the development and growth of plants. Furthermore, it is involved with enzymes activated by cations and in the photosynthetic evolution of oxygen (Taiz and Zaiger, 2004).

Given the scarcity of research that verifies the effects of foliar fertilization based on the micronutrients Zn, Mo and Mn in rice cultivation in highlands, the present study aimed to evaluate the performance of some yield components and the productivity of four rice cultivars in Vilhena-RO, through the application of foliar fertilizer from three commercial products in the vegetative stage V5.

MATERIALS AND METHODS

The experiment was carried out in the experimental area of Faculdade Marechal Rondon – FARON (12°46'02"S 60°05'49"W and 588 m altitude), located in the municipality of Vilhena-RO, on the banks of the BR-364 road, in the CSRO (Figure 1), from November 2020 to March 2021. The soil is the Latossolo Vermelho-Amarelo distrófico type of clayey textural class (Godinho et al., 2009). According to Alvares et al. (2013), the climate of the region is tropical rainy (Am) with a well-defined dry season. The climatic data referring to the experiment period were obtained from the micrometeorological station located at FARON, adjacent to the

Figure 1. Location map of the experimental area in the FARON experimental field in Vilhena, RO.
Source: The authors.

Table 1. Chemical analysis of the soil in the experimental area before start of the experiment in the FARON experimental field in Vilhena, RO, 2020.

Depth	MO	pH	P resina	Zn	Cu	Fe	Mn	B	K	Ca	Mg	H+Al	SB	CEC
	g dm^{-3}	CaCl$_2$	--------------------mg dm^{-3}-------------------						--------------------cmol$_c$ dm^{-3}-----------------					
0-10 cm	21	4.9	2.7	1.2	0.7	42	2.2	0.09	0.02	0.2	0.1	4.2	0.32	4.5
10-20 cm	29	5.7	0.5	1.8	1.6	49	3.8	0.14	0.12	1.1	1.0	3.1	2.22	5.3

Depth = depth, MO = organic matter, SB = sum of bases, CEC = cation exchange capacity.

Table 2. Climatic and soil conditions when applying foliar fertilizer of micronutrients in upland rice, cultivars BRS A502, ANa 9005CL, ANa 8001, and AN Cambará, 2020/2021 crops in Vilhena-RO.

Application date	Air temperature (°C)	Relative humidity (%)	Wind speed (m s^{-1})	Soil moisture (m³ m^{-3})
Jan. 2nd 2021	26.8	71.6	0.1	0.380

experimental area where the present study was carried out.

The previous occupation was degraded pasture, and the soil was prepared with two passes of a leveling harrow before the installation of the experimental plots. Because it was the first agricultural year, the soil was chemically analyzed before rice sowing by collecting deformed samples (soil samples taken by modifying their natural structure) with augers at two depths (0-10 and 10-20 cm) (Table 1). Magnesian limestone (PRNT 86%) was applied 3.2 t ha^{-1} to raise the pH of the area, as well as to raise the soil base saturation to 60%. Limestone was applied manually in a homogeneous manner throughout the experimental area, and incorporation was done by harrowing, 30 days before rice sowing. The experimental design was randomized blocks, in a 4 × 2 factorial scheme, with factor 1 consisting of 4 certified cultivars (ANa 9005 CL, ANa Cambará, ANa 8001 and BRS A502) recommended and widely sown in the region, and factor 2 consisting of foliar fertilizer application and no foliar fertilizer application. Each experimental plot included five lines of 5 m in length, spaced at 0.45 m, and a seed density of 100 kg ha^{-1} (67 seeds per linear meter). The three central lines were used as a useful area to evaluate the characteristics of the cultivars, disregarding 0.5 m from each extremity and the two lateral lines,

obtaining 5.4 m^2 of useful area.

Fertilization was performed in the furrow, using 240 kg ha^{-1} of the fertilizer 04-24-12, following soil analysis and the recommendation protocol for rice cultivation under dryland conditions and clay soil of Rical - Rack Ind. e Com. de Arroz Ltda. In all cultivars, cover crop fertilization was performed with the formulation 20-00-20, 160 kg ha^{-1}, divided into two stages: the first done at the effective tillering, about 15 days after emergence (DAE), and the second applied at maximum tillering of the crop (vegetative stages V5 to V6), approximately 32 DAE.

Foliar fertilization occurred at 20 DAE (V4 stage), with a recommended application of 500 ml per hectare, obtaining 7.2 ml of the following products: Maxi Zinc® (zinc 50% w/w), Booster® (molybdenum + Zinc 5% w/w) and Broadracre Mn$^+$® (manganese 27% w/w). All foliar sprays performed, both for phytosanitary controls and foliar fertilization, were carried out with the aid of a 20 L manual backpack sprayer with a conical nozzle. The local climate and soil moisture conditions were ideal when applying the micronutrient foliar fertilizer (Table 2).

Cultural treatments were carried out whenever necessary, with weed control occurring through manual mowing without herbicide application for control. An application of 52.8 g ha^{-1} a.i. of the

insecticide based on Dinotefuran and Lambda-Cyhalothrin was carried out to control the attack of froghoppers (*Deois flavopicta*) at 47 DAE. In addition, 84 g p.a.i. ha^{-1} of fungicide based on Picoxystrobin and Cyproconazole for the preventive control of brown spot (*Bipolaris oryzae*) was applied at 58 DAE. In its from V5 to V6 stage, a sulfur deficiency was diagnosed, requiring the application of ammonium sulfate in the coverage at a dose of 80 kg ha^{-1}.

Manual harvesting was carried out using a cleaver at a cutting height of 15 to 20 cm above the ground when 90% of the panicles had the typical coloration of mature grains. The drying was then done in the shade, followed by the mechanized threshing. The harvest of the cultivar BRS A502 was carried out at 100 DAE; cultivars ANa 8001 and AN Cambará at 110 DAE and ANa 9005 CL occurred at 117 DAE.

The following characteristics were evaluated: number of panicles per m^2, determined by counting panicles in two linear meters in each plot; number of spikelets per panicle, obtained utilizing an average count of 15 panicles per plot; 1000 grains weight, performed by weighing three samples from each plot, each with 100 grains, and then multiplying by 10 (weight of 100 grains × 10); and productivity in t ha^{-1}, obtained by weighing the grains with husk from the useful area of the plots, correcting the humidity to 13% and converting it into t ha^{-1}.

The evaluation of the whole grain yield was performed in the RICAL classification laboratory. For such, a sample of 100 g of paddy rice grains was collected and a testing mill (Zaccaria), model PAZ-1-DTA, was used for 1 min and 15 s; then, the burnished (polished) grains were weighed and the values found were considered as yield of benefit, with data in percentage. Afterwards, the burnished (polished) grains were placed in the "trieur" at 5 and the separation of the grains was processed, for 60 s; the grains that remained in the "trieur" were weighed and the value obtained was considered as yield of whole grains and the rest, broken grains, both expressed in percentage. The experimental data were submitted to individual and joint analysis of variance, applying the F-test. The joint analysis was performed under conditions of homogeneity of residual variances. The Tukey test was applied at a 5% probability for comparisons between treatment means. All analyses were performed using the AgroEstat statistical software (Barbosa and Maldonado Junior, 2015).

RESULTS AND DISCUSSION

The results show that there was no statistical difference between the levels (with and without) of the foliar fertilization factor in the number of panicles per m^2 (NP), thousand-grain mass (TGM), percentage of whole grains (WG) and productivity (PROD). However, it was significant for the number of spikelets per panicle (NSP) (Table 3).

Concerning the variable NSP, it was observed that the application of foliar fertilizer promoted an increase of 8% for cultivar ANa 8001. These results are corroborated by Lahijani et al. (2020), who evaluated the effect of applying foliar fertilizers based on Fe, B, Zn, Cu, and Mn and also observed increases in NSP ranging from 92 (17%) to 159 (72%) in a study developed in Iran in an area with irrigated rice cultivation. According to Buzetti et al. (2006), the total number of spikelets is influenced by genetic factors and external conditions during the vegetative phase until five days before flowering, which is essential for achieving good crop yields.

When analyzing Table 3, it was discovered that the NP parameter was not influenced by the application of foliar fertilizers, resulting in no significant yields. However, only BRS A502 showed the highest NP when comparing this parameter between cultivars, significantly differing from the other cultivars. This can be explained by the genetic characteristics of this material since it has a high value for this parameter, as well as in relation to PROD for edaphoclimatic conditions in the Cerrado. According to Zayed et al. (2011), NP can be influenced by the form of application of micronutrients. The authors conducted a study in Egypt and discovered a 15% increase in NP compared to the control treatment (no application) when foliar fertilizer (a combination of Zn, Fe, and Mn) was applied via soil. In comparison, the increment of this parameter was only 8% via foliage. Additionally, Lahijani et al. (2020) highlight that foliar spraying of Fe, Zn, B, Cu, and Mn elements can delay plant metabolism procedures compared to soil application, which can compromise rice yields.

BRS A502 was one of the cultivars with the lowest NSP; however, it was the one with the highest NP 335.7 (32%), which was compensated in the TGM and PROD of this material. In addition, this result can be explained by the plants showing less sterility of spikelets and a greater amount of whole grains, allowing excellent productivity, as observed by Fageria et al. (1995).

It was noted that three of the four cultivars evaluated had a TGM of approximately 25.02 g, 9% higher than the cultivar ANa 8001, which average reached was 23.1 g. According to Boldieri et al. (2010), this slight variation of TGM is directly linked to the genetic characteristics of the evaluated cultivars. This observation is very important because, according to Fornasieri Filho and Fornasieri (2006), TGM is a stable varietal trait and is basically dependent on the husk size.

Concerning WG, there is a statistical difference between cultivars BRS A502, ANa 8001, and AN Cambará in relation to ANa 9005CL. It is approximately 10% lower for the last cultivar, implying a percentage of integers below that established by the company Agro Norte Pesquisa e Sementes Ltda. It is responsible for producing this cultivar, which establishes an acceptable range for this material between 61 and 70%. This may be associated with the time the grains remained in the field after complete physiological maturation, exposed to excess rain, solar radiation, and high temperatures, which caused changes in the moisture content of the grains and a low rate of whole grains (54.83%), as observed by Juliano and Duff (1991) and Smiderle and Pereira (2008).

A highlight regarding the yields of the cultivars studied is that all of them showed higher yields than those obtained by Agro Norte and EMBRAPA in their field experiments, which were carried out in the region covered by the FARON area. All productions are also higher than the state of Rondônia's average (4 t ha^{-1})

Table 3. Number of panicles per m² (NP), number of spikelets per panicle (NSP), thousand-grain mass (TGM), percentage of whole grains (WG), and productivity (PROD) of upland rice, cultivars BRS A502, ANa 9005 CL, ANa 8001 and ANa Cambará, with and without micronutrient foliar fertilization, 2020/2021 harvest, Vilhena-RO.

Foliar fertilization	NP	NSP	TGM (g)	WG (%)	PROD (t ha^{-1})
With fertilization	281.62[a]	127.65[a]	24.52[a]	58.31[a]	5.575[a]
Without fertilization	279.87[a]	117.68[b]	24.57[a]	58.26[a]	5.521[a]
Cultivar					
BRS A502	335.75[a]	96.46[c]	24.86[a]	59.43[a]	5.747[a]
ANa 9005CL	253.50[b]	103.44[c]	25.00[a]	54.83[b]	5.060[a]
ANa 8001	258.63[b]	166.70[a]	23.10[b]	59.64[a]	6.060[a]
ANa Cambará	275.13[b]	124.06[b]	25.21[a]	59.25[a]	5.325[a]
CV%	12.79	10.40	2.09	1.77	18.54

Means followed by the same letter in the column for each factor do not differ statistically by Tukey's test at the 5% probability level.

(CONAB, 2020). This consolidates the good adaptability of these cultivars to the soil and climate conditions of Vilhena. Even the soil presenting a pH value of 4.9, classified as high acidity (Table 1), did not interfere in PROD, as reported by Moro et al. (2013). The PROD seen in the ANa 9005CL cultivar should be observed with reservations, as there were attacks in three plots by wild animals natives from the forest located in the area adjacent to the experiment site. In addition, it should be noted that the plots affected by the attacks were located on the edge of the experiment, which facilitated the degradation of these experimental plots.

Even performing foliar fertilization at the stage V4, the cultivars presented results above the expected compared to the results of Agro Norte and EMBRAPA in their field experiments mentioned above. According to Garcia and Hanway (1976) and Rosolém and Boaretto (1989), the time when annual crops need to increase or maintain nutrient concentrations in the leaves is close to flowering and at the start of flowering for grain filling to prevail because root absorption of nutrients is practically zero at this stage. Therefore, if the application of foliar fertilizers were carried out at their phenological stage close to flowering and at the beginning of flowering, the cultivars used could have higher yields than those observed.

It is noteworthy that, for the experimental field conditions considered in the present work, the foliar fertilization with micronutrients performed in the vegetative stage (V4) in the production of upland rice did not influence the evaluated production components, except for NSP, which is in agreement with the results found by Andrade et al. (1997, 1998), Dynia and Moraes (1998), Marchezan et al. (2001), Camargo et al. (2008), Fang et al. (2008), Wei et al. (2012), Dario et al. (2012), and Maldonado Junior et al. (2013). Some differences in the results found in the literature can be attributed to the different locations where the field tests were conducted, particularly when considering the physical-chemical and water characteristics of the soil, as well as the local climate conditions, which vary from year to year in the various regions where rice sowing occurs. Furthermore, the form of application of the foliar fertilizer directly influences the physiological and phenological responses of rice subjected to either soil or foliar application (Marchezan et al., 2001). Nutritional deficiency is usually found in soils with a more sandy texture, which was not the case in the present work, once the soil was the Latossolo Vermelho-Amarelo distrófico type of clayey textural class.

Conclusion

The application of foliar fertilizers Maxi Zinc[®], Booster[®], and Broadracre[®] did not significantly affect the yield components, except for NSP and productivity of the evaluated rice cultivars. Under the region's edaphoclimatic conditions, the cultivar ANa 8001 produced the best results in terms of productivity and grain physical quality.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Alvares CA, Stape JL, Sentelhas PC, Gonçalves JLM, Sparove KG (2013). Köppen's climate classification map for Brazil.

Meteorologische Zeitschrift 22(6):711-728.

Andrade WEB, Souza AF, Carvalho JG (1997). Limitações nutricionais para a cultura do arroz irrigado em solo orgânico da região Nordeste Fluminense. Revista Brasileira de Ciência do Solo 21(3):513-517.

Andrade WEB, Souza AF, Carvalho JG (1998). Deficiências nutricionais no arroz irrigado em sucessão ao feijoeiro em solo de várzea. Pesquisa Agropecuária Brasileira 33(7):1129-1135.

Andrea MCS, Boote KJ, Sentelhas PC, Romanelli TL (2018). Variability and limitations of maize production in Brazil: potencial yield, water-limited yield and yield gaps. Agricultural Systems 165:264-273.

Barbosa JC, Maldonado Junior W (2015). AgroEstat: Sistema para análises estatísticas de ensaios agronômicos. Jaboticabal. FCAV/UNESP 396 p.

Boldieri FM, Cazetta DA, Filho DF (2010). Adubação nitrogenada em cultivares de arroz de terras altas. Revista Ceres 57(3):421-428.

Buzetti S, Bazanini GC, Freitas JG, Andreotti M, Arf O, Sá ME, Meira FA (2006). Respostas de cultivares de arroz a doses de nitrogênio e do regulador de crescimento cloreto de clormequat. Pesquisa Agropecuária Brasileira 41(12):1731-1737.

Camargo ER, Marchesan E, Avila LA, Silva LS, Rossato TL, Massoni PF (2008). Manutenção da área foliar e produtividade de arroz irrigado com a aplicação de fertilizantes foliares no estádio de emborrachamento. Ciência Rural 38(5):1439-1442.

Companhia Nacional De Abastecimento (CONAB) (2020). Acompanhamento da safra brasileira de grãos, 2º levantamento safra 2020. Brasília: Conab. Retrieved on December 05, 2020 from: https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos

Conceição LFC, Pinto LB, Cuadra SV, Almeida IR, Steinmetz S (2017). Variáveis meteorológicas e crescimento de arroz irrigado. Journal of Environmental Analysis and Progress 2(3):220-226.

Dario GJA, Dario ISN, Vazquez GH, Peres AR (2012). Adubação foliar na fase reprodutiva do arroz irrigado. Revista Brasileira de Agrociência 18(1-4):68-80.

Das Gupta DK, Basuchaudhuri P (1977). Molybdenum nutrition of rice under low and high nitrogen level. Plant and Soil 46:681-685.

Dynia FF, Moraes JFV (1998). Calagem, adubação com micronutrientes e produção de arroz irrigado e feijoeiro em solo de várzea. Pesquisa Agropecuária Brasileira 33(6):831-838.

Epstein E, Bloom AJ (2006). Nutrição mineral de plantas, princípios e perspectivas. 2ª edição. Traduzido por NUNES MET. Londrina: Planta 404 p.

Fageria NK, Baligar VC (1997). Response of common bean, upland rice, corn, wheat and soybean to soil fertility of an Oxisol. Journal of Plant Nutrition 20(10):1279-1289.

Fageria NK, Ferreira E, Prabhu AS, Barbosa Filho MP, Filippi MC (1995). Seja o doutor de seu arroz. Piracicaba: Potafos 20 p.

Fageria NK, Nascente AS (2014). Management of Soil Acidity of South American Soils for Sustainable Crop Production 128:221-275.

Fang Y, Wang L, Xin Z, Zhao L, An X, Hu Q (2008). Effect of Foliar Application of Zinc, Selenium, and Iron Fertilizers on Nutrients Concentration and Yield of Rice Grain in China. Journal of Agricultural and Food Chemistry 56(6):2079-2084.

Fornasieri Filho D, Fornasieri JL (2006). Manual de cultura do arroz. Jaboticabal: Funep 589 p.

Garcia LR, Hanway JJ (1976). Foliar fertilization of soybeans during the seed-filling period. Agronomy Journal, 68(4):763-769.

Godinho VPC, Utumi MM, Brogin RL, Oliveira SJM (2009). Estimativa do custo de produção de soja, em plantio direto, em Vilhena, RO, safra 2008/2009. Porto Velho: Embrapa Rondônia. 4 p.

Guimarães SL, Baldani JI, Baldani VLD, Jacob-Neto J (2007). Adição de molibdênio ao inoculante turfoso com bactérias diazotróficas usado em duas cultivares de arroz irrigado. Pesquisa Agripecuária Brasileira 42(3):393-398.

Hunke P, Roller R, Zeilhofer P, Schröder B, Mueller EN (2015). Soil changes under different land-uses in the Cerrado of Mato Grosso, Brazil. Geoderma Regional 4:31-43.

Instituto De Pesquisa Econômica Aplicada (IPEA) (2021). Ipea aponta causas da alta no preço do arroz. Retrieved on November 03, 2021 from: https://www.ipea.gov.br/portal/index.php?option=com_content&view=article&id=36755&Itemid=3

Juliano BO, Duff, B (1991). Rice grain quality as an emerging priority innational rice breeding programs. In. Internacional Rice Research Institute. Rice grain marketing and quality issues. Manila: IRRI. pp. 55-64.

Júnior SRGS (2019). Arroz em casca natural. In. Perspectivas para a agropecuária. Companhia Nacional de Abastecimento, Brasília: Conab. (1):28-41.

Khanna J, Medvigy D, Fueglistaler S, Walko R (2017). Regional dry-season climate changes due to three decades of Amazonian deforestation. Nature Climate Change 7(3):200-204.

Lahijani AD, Mosavi AA, Moballeghi M (2020). Effects of micronutrientes foliar application on rice (Oryza sativa L. cv. Shiroodi) morphological traits, yield and yield components. International Journal of Agricultural and Biologic Enginering 13(1):217-223.

Lopes AS (1996). Soils under Cerrado: A Success Story in Soil Management. Better Crops International 10(2):9-15.

Mahmoodi B, Moballeghi M, Aftekhari A, Neshaie-Mogadam M (2020). Efects of Foliar Application of Liquid Fertilizer on Agronomical and Physiological Traits of Rice (Oryza sativa L.). Acta Agrobotanica 73(3):1-12.

Maldonado Junior OP, Mendes RT, Pacheco LCPS, Pelá A, Pelá GM (2013). Influência da calagem e do fósforo na eficiência da adubação foliar com zinco em arroz de terras altas. Revista Agrotecnologia 4(2):1-16.

Marchezan E, Santos OS, Avila LA, Silva RP (2001). Adubação foliar com micronutrientes em arroz irrigado, em área sistematizada. Ciência Rural 31(6):941-945.

Moro E, Crusciol CAC, Cantarella H, Nascente AS, Moro AL, Broetto F (2013). Acidez do solo afetando concentração de micronutrientes, atividade da enzima nitrato redutase e produtividade em plantas de arroz de terras altas. Semina: Ciências Agrárias 34(6):3397-3410.

Nadeem F, Farooq M (2019). Application of Micronutrients in Rice-Wheat Cropping System of South Asia. Rice Science 26(6):356-371.

Phattarakul N, Rerkasem B, Li LJ, Wu LH, Zou CQ, Ram H, Sohu VS, Kang BS, Surek H, Kalayci M, Yazici A, Zhang FS, Cakmak I (2012). Biofortification of rice grain with zinc through zinc fertilization in different countries. Plant Soil 361:131-141.

Prabhu AS, Filippi MC, Silva GB, Lobo VLS, Morais OP (2009). An unprecedented outbreak of rice blast on a newly released cultivar BRS Colosso in Brazil. In. WANG GL, VALENT B. Advances in genetics, genomics and control of rice blast. Amsterdam: Springer Science pp. 257-267.

Prom-U-Thai C, Rashid A, Ram H, Zou C, Guilherme LRG, Corguinha APB, Guo S, Kaur C, Naeem A, Yamuangmorn S, Ashraf MY, Sohu VS, Zhang Y, Martins FAD, Jumrus S, Tutus Y, Yazici MA, Cakmak I (2020). Simultaneous Biofortification of Rice With Zinc, Iodine, Iron and Selenium Through Foliar Treatment of a Micronutrient Cocktail in Five Countries. Plant Science 11:589835.

Quevedo-Amaya YM, Beltrán-Medina JI, Hoyos-Cartagena JA, Calderón-Carvajal JE, Barragán-Quijano E (2020). Selection of sowing date and biofertilization as alternatives to improve the yield and profitability of the F68 rice variety. Agronomía Colombiana, 38(1):61-72.

Ramalho AR, Utumi MM, Godinho VPC (2005). Cultivares de arroz de terras altas indicadas para Rondônia – período 2004/06. Porto Velho: Embrapa Rondônia 10 p.

Rosolém CA, Boaretto AE (1989). Adubação foliar. In. Simpósio Brasileiro de Adubação Foliar. 2. 1987, Botucatu, SP. Anais... Campinas: Fundação Cargill 2:513-545.

Rubin RS, Agostinetto D, Manica-Berto R, Fraga DS, Tarouco CP (2014). Resistência de biótipos de arroz-vermelho aos herbicidas imazapyr + imazapic e alternativas de controle. Revista Ceres, 61(5):660-667.

Sandhu N, Yadaw RB, Chaudhary B, Prasai H, Iftekharuddaula K, Venkateshwarlu C, Annamalai A, Xangsayasane P, Battan KR, Ram M, Cruz MTS, Pablico P, Maturan PC, Raman KA, Catolos M, Kumar A (2019). Evaluating the Performance of Rice Genotypes for Improving Yield and Adaptability Under Direct Seeded Aerobic Cultivation Conditions. Frontiers in Plant Science 10:1-15.

Silva EA, Soratto RP, Adriano E, Biscaro GA (2009). Avaliação de cultivares de arroz de terras altas sob condições de sequeiro em Cassilândia, MS. Ciência Agrotecnologia 33(1):298-304.

Smiderle OJ, Pereira PRVS (2008). Épocas de colheita e qualidade fisiológica das sementes de arroz irrigado cultivar BRS 7 TAIM, em Roraima. Revista Brasileira de Sementes 30(1):74-80.

Sundim MFCAM, Alves JM, Baldani VLD, Goi SR, Jacob Neto J (2002). Respostas de cultivares de arroz à aplicação de molibdênio e diferentes fontes de nitrogênio. Agronomia 36(1-2):56-61.

Taiz L, Zeiger E (2004). Fisiologia vegetal. 3. ed. Tradução de SANTARÉM ER. Porto Alegre: Artmed 719 p.

Wei Y, Shohag MJI, Yang X, Yibin Z (2012). Effects of Foliar Iron Application on Iron Concentration in Polished Rice Grain and Its Bioavailability. Journal of Agricultural and Food Chemistry 60(45):11433-11439.

Xavier AIS, Arbage AP, Silva MR, Ribas GG, Meus LD, Santos GAA, Streck NA, Zanon AJ (2021). Economic and productive analysis of irrigated rice crops using a multicase study. Pesquisa Agropecuária Brasileira 56:1-12.

Zayed BA, Salem AKM, El Sharkawy HM (2011). Effect of different micronutrient treatments on rice (*Oriza sativa* L.) growth and yield under saline soil conditions. World Journal of Agricultural Sciences 7(2):179-184.