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Influence of potassium on the quality of grains and seeds of flooded rice

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Abstract: Potassium (K) can influence the productivity and the physical and physiological qualities of grains and seeds of flooded rice, although its influence is not clear yet. Based on the necessity of more information, this work presents the evaluation of different stages of potassium application on rice grains' productivity, physical quality (whole grain and chalk kernel), and seed physiological quality (vigor and germination). A field experiment was conducted using a randomized block design consisted of control without application of K; a 100% of potassium dose applied at sowing; a 50% of potassium dose applied at sowing and the remaining 50% of potassium dose applied at the V3 stage; a 50% of potassium dose applied at sowing and the remaining 50% of potassium dose applied at V6 stage; and a 50% of potassium dose applied at sowing and the remaining 50% of potassium dose applied at V8 stage. The results show that potassium fertilization influences the physical quality of rice grains. When performed near to the reproductive stage, it can increase the percentage of whole grains and decrease the chalk kernel index. For producing seeds, all fertilization should be done up to the V3 stage to increase the seed vigor.

Keywords: potassium, rice, grains productivity, physical quality, physiological quality.

Influência do potássio na qualidade de grãos e sementes de arroz irrigado

Resumo: O potássio pode influenciar na produtividade e nas qualidades física e fisiológica de grãos e sementes de arroz irrigado, embora sua influência ainda não esteja clara. Com base na necessidade de maiores informações, este trabalho apresenta a avaliação de diferentes estágios de aplicação de potássio na produtividade de grãos de arroz, qualidade física (grãos integrais e índice de centro branco) e qualidade fisiológica das sementes (vigor e germinação). Os resultados demonstraram que a adubação potássica influencia a qualidade física dos grãos de arroz. Quando realizada próximo ao estágio reprodutivo, pode aumentar a porcentagem de grãos integrais e diminuir o índice de centro branco. Para a produção de sementes, toda adubação deve ser realizada até o estágio V3, a fim de aumentar o vigor das sementes.

Palavras-chave: potássio, arroz, produtividade de grãos, qualidade física, qualidade fisiológica.

Introduction

Potassium is an element with the highest demand for rice cultivation (Souza et al., 2015). The demand for potassium from irrigated rice is so or higher than that for nitrogen, reaches 51 kg of K_2O per ton of grain produced (Yoshida, 1981).

It can increase rice production because it influences the starch formation, sugar transfer, development of chlorophyll, grain formation, and weight gain, and root system development. Overall, the potassium acts positively on rice productivity components (Zaratin et al., 2004).

Anghinoni et al. (2013) cite that the response to potassium fertilization has always been positive, the magnitude of these responses and the productivity of irrigated rice varied and the grouping of soils according to the CTC classes pH7 can be an efficient way to improve calibration in the fertilizer recommendation for providing well-adjusted response curves.

Numerous studies have been carried out in the main rice regions in the southern region of Brazil. Usually, the results show no response in yield to the application of K under flooded soil conditions, even in soils with medium or low levels of available K and with relatively small increases in grain yield (Gomes; Magalhães Júnior, 2004). The available results indicate that the best application management is at sowing, as most of the potassium is absorbed in the vegetative phase, from tillering to panicle differentiation. Associated with this, fractionation can be a good strategy for better use, since it decreases the probability of nutrient losses. In addition, when potassium is placed in the sowing line, depending on the dose, there may be problems with salinity, and fractionation is recommended.

Because of this, information about potassium management during the rice cycle and its influence on rice grains' quality and on physiological characteristics of seeds are still scarce in the scientific literature.

Indeed, this information is important because the price paid to the producer depends on the physical quality of grains verified after processing. Furthermore, the percentage of whole grains is one of the most important parameters for the determination of commercial price (Sosbai, 2016). Based on this context, this work presents the evaluation of different stages of potassium application on rice grains productivity, physical quality (whole grain and chalk kernel), and seed physiological quality (vigor and germination).

Material and methods

A field experiment was performed in 2016/2017 and 2017/2018 agricultural crops at the "Instituto Rio Grandense do Arroz (IRGA)" located at Cachoeira do Sul (Brazil). The soil of the experimental area is classified as Ultisol soil (Soil US Soil Taxonomy Entisol), with the following physicochemical characteristics in the 0-20 cm depth: water pH = 5.2; phosphorus (P) = 4.0 mg dm^{-3}; potassium (K) = 95 mg dm^{-3} and organic matter (OM) = 10.9 g kg^{-1} and CTC_{pH7}= 4.7 cmolc dm^{-3}.The local climate is humid subtropical, classified as Cfa by the Köppen classification system. The average annual temperature and rainfall are 19.2 °C and 1,708 mm, respectively (Maluf, 2000).

The treatments consisted of phenological stages of potassium application following the scale proposed by Counce et al. (2000). The scale consisted of control without application (T1), a 100% of potassium dose applied at sowing (T2), a 50% of potassium dose applied at sowing and the remaining 50% of potassium dose applied at the V3 stage (T3), a 50% of potassium dose applied at sowing, and the remaining 50% of potassium dose applied at V6 stage (T4), and a 50% of potassium dose applied at sowing and the remaining 50% of potassium dose applied at V8 stage (T5). The potassium was spread on the soil and the total potassium (formula 00-00-60) dose used on each treatment was 135 kg/ha.

The area was sown with IRGA 424 RI, with a sowing density of 100 kg ha^{-1}, on October 25 and November 7 th, in the 2016/17 crop and 2017/18, respectively. The experiment consisted of a randomized complete block design with four replicates. Each experimental assay was composed of 18 rice lines of 5 m length and spaced 0.17 m. The area totalized 15.3 m^2 and all cultural treatments, such as weed, pests, and disease control, were carried out according to the technical recommendations for the culture of flooded rice in the South of Brazil (Sosbai, 2016).

Rice on a 4.75 m^2 area for each experimental assay was manually harvested, and the yield of grains was calculated, on 03/10/2017 and 03/21/2018, in the respective season. A portion of 100 g of rice and husks was selected, which was submitted to a model rice tester. The percentage of whole rice in each sample was determined. For the peeled samples (5 g), the average chalk kernel index was determined according to an international scale from zero to five (CIAT), where zero means a totally spotless grain and five means a grain wholly taken by chalk kernel.

Plant growth was quantified by the percentage of germination using Biochemical Oxygen Demand (BOD) camera incubation. Four replicates of 100 seeds from each treatment and seedling evaluations were performed at 7 and 14 days after sowing (DAS) according to the criteria established by the Brazilian Rules for Seed Testing (Brasil, 2009). At 7 DAS, the germinated plants were considered “vigor” and those germinated at 14 DAS were considered the “total percentage of germination”. The statistical analysis was performed using the Scott-Knott test at a 5% probability of error. The variable germination percentage (7 and 14 DAS) was transformed by the equation 1.

$$\text{yt} = \sqrt{y+1} \quad (1)$$

Where: yt is the transformed variable and y is the percent of germination.

Results and discussion

The responses after different potassium fertilization varied according to the agricultural year (Figure 1). In the 2016/2017 harvest, all quality parameters evaluated in the study were influenced by the stages of potassium application. The only exception was the grain yield. The parameter whole grain had an increase of 1.3% when applied near to the reproductive stage (V8). Zaranti et al. (2004) and Dann and Stevens (2017) reported the beneficial effects of potassium on the physical quality of rice grains, mainly due to its influence on grain filling. In this work, it is possible to increase up to 2% in the percentage of whole grains to the control without application. In the second harvest (2017/2018), this parameter was not influenced.

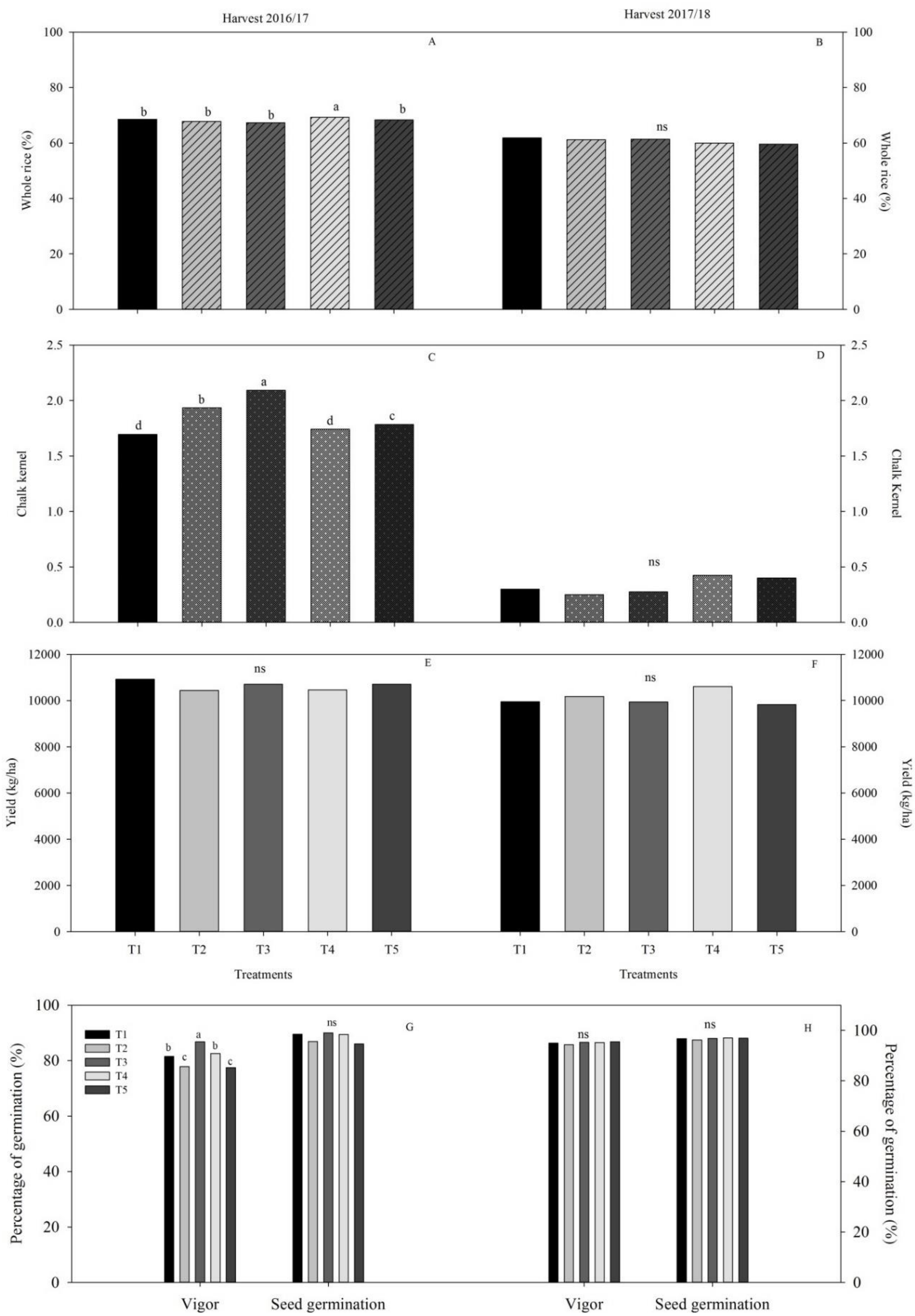

Figure 1. Influence of treatments on whole rice (%) (A and B), chalk kernel (C and D), rice yield (kg/ha) (D and E), and percentage of germination and vigor (G and H); ns: not significant.

In the application of 50% of potassium closer to the reproductive stage, the lowest chalk kernel index was found, from 2.09 when 50% fertilization was performed in V3 (T3) to 1.74 when it was performed in V8 (T5) or 1.69 with the absence of potassium application (T1). The negative influence of potassium on this index is mainly evidenced when all fertilization is done before flooding the area. In the second crop, this parameter was not influenced, even presenting a result four times smaller than the first year. Although the chalk kernel is influenced by genetic factors, this behavior most likely occurs because the index is also influenced by management and climatic factors. Climate changes are one of the main influences. The temperature increase when the grain is being filled induces a non-compacted arrangement between the starch granules and protein in the cells. Consequently, the air spaces diffract and diffuse the light, making the visual appearance as an opaque grain (Santos, 2012).

The results of this work corroborate with the findings reported by Wang et al. (2004). The authors recommended potassium application closer to panicle formation because the plant is able to increase the absorption and the proportion of potassium in the stage of elongation until flowering. It favors a higher number of full grains, lower gypsum index, and higher quality of grains. Despite the negative influence of potassium on grain quality, the application of 50% at sowing and 50% up to the V3 stage was the management with a higher influence on the vigor of seeds (Figure 1). In such a sense, the management should be modified depending on the purpose of the crop to be produced.

Despite the benefits of the physical quality of grains and the physiological quality of seeds, no significant differences were observed regarding the grain yield in both harvests. This behavior can be attributed to the spatial variation of potassium in the soil. According to scientific literature, potassium is an element with a high influence of soil mineralogy where flooded rice is cultivated. It can reach a spatial variation of 87.5% in the same area of cultivation (Leite et al., 2017). The absence of correlation between potassium available in the soil and grain yield has been attributed to factors such as the entry of potassium by irrigation water, the release of potassium from minerals (non-exchangeable or structural), and its increased diffusion. Therefore, the different forms of potassium present in the soil and in the soil solution can be a source of this nutrient to the plants in the short-term. Consequently, it could explain the differences or non-differences of the responses according to rice fertilization, especially the grain yield (Silva et al., 2015; Bui et al., 2019).

Conclusion

Potassium fertilization has an influence on the physical quality of rice grains. When carried out near to the reproductive stage, it can increase the percentage of whole grains and decrease the chalk kernel index. When the objective is to produce seeds, all fertilization should be done up to the V3 stage in order to favor the increase of seed vigor.

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