GRAIN YIELD OF UPLAND RICE AS AFFECTED BY POTASSIUM RATES FERTILIZATION AND INOCULATION OF THE DIAZOTROPHIC BACTERIA *Serratia* spp.

Marta Cristina Corsi de Filippi [1]; Adriano Stephan Nascente[2]; Anna Cristina Lanna[3], Mabio Chrisley Lacerda[4]

Palavras-chave: *Oryza sativa*, Rhizobacteria, growth promoter

INTRODUCTION

For upland rice plants, K is essential for growth and development and is extracted from soils in large amounts, such as 245 kg ha^{-1} (FAGERIA et al., 2011). The principal role of K in plants is the osmotic potential regulation, acts in the transporter machinery present in the cell membrane of root tissues, increases of root development in rice (CLOVER; MALLARINO, 2013) and accumulates in the shoots (CRUSCIOL et al., 2016). Although K is required in great amounts, there is an increasing wish to increase crop grain yield with a significant reduction of fertilizer and pesticides (BASHAN et al., 2014), once this reduction is environmentally friendly and yield efficient.

In this sense, adopting Plant Grown Promoting Rhizobacteria (PGPR) is one practice that can reduce the negative environmental impact caused by excess chemical fertilizers and agrochemicals, playing an important role in sustainable agriculture (VEJAN et al., 2016). These bacteria are basic components of food webs and play crucial and unique roles in the agricultural production system (ANEES et al., 2010). Research focusing on the use of rhizobacteria in rice crops selected promising rhizobacteria isolates which stood out mainly due to their increased biomass production and disease resistance (FILIPPI et al., 2011). These rhizobacteria was tested under greenhouse conditions and showed that *Serratia* ssp, strain BRM 32114, promoted an increase in gas exchange, nutrients accumulation and biomass production, which differed from the control (untreated plants) in the upland rice plants (NASCENTE et al., 2017). However, there is still no information under field conditions combining upland rice plant, rhizobacteria and potassium fertilization, especially in the Tropical region. Therefore, the objective of this study was to determine the effect of the rhizobacteria *Serratia* spp., strain BRM 3214, and doses of K at sowing fertilization on upland rice by yield components and grain yield under no-tillage systems in a Tropical Region.

MATERIAL AND METHODS

The experiments were conducted at Capivara Experimental Station of Embrapa Rice and Beans, located at Santo Antônio de Goiás, GO, Brazil, 16º28'00"S and 49º17'00"W coordinates, and at 823 m of elevation. The climate is Tropical Savanna and is considered Aw according to its Köppen classification. There are two well-defined seasons: a usually dry season from May to September (autumn/winter) and a wet season from October to April (spring/summer). The average annual rainfall is between 1500 and 1700 mm, and the average annual temperature is 22.7°C, ranging annually from 14.2 °C to 34.8 °C. During the period of this study, the temperature and the amount of rainfall data were recorded.

The experimental soil is classified as a clay loam (kaolinitic, thermic Typic Haplorthox) acidic

[1] Embrapa Arroz e Feijão, GO-462, km 12 - Zona Rural, Santo Antônio de Goiás - GO, 75375-000, cristina.filippi@embrapa.br.
[2] Embrapa Arroz e Feijão, adriano.nascente@embrapa.br.
[3] Embrapa Arroz e Feijão, anna.lanna@embrapa.br.
[4] Embrapa Arroz e Feijão, mabio.lacerda@embrapa.br.

soil.

Trials were conducted in rainfed conditions using the cultivar 07SEQCL441 CL (resistant to the Imazapyr + Imazapic herbicide). Trials were arranged in a complete randomized block in a 4x2 factorial scheme with four replications, during two growing seasons (2015/16 and 2016/17) in different areas. The plots had the dimension of 3.5 m x 6 m. The usable area of the plot was composed of the four central rows of rice, disregarding one row of each side of the plot and 0.50 m to each side of the rows in each plot. The treatments consisted of combining four broadcasted K_2O doses (0, 20, 40 and 60 kg ha^{-1} as potassium chloride) at the time of sowing with or without BRM 32114 applied by seed (microbiolization) and sprayed at plant/soil in the field at the 7 and 15 DAS (days after sowing). BRM 32114 isolate belongs to the Microorganism Culture Collection at the Embrapa Rice and Bean Research Center, with KX378746 GenBank code.

BRM 32114 bacterial suspension was prepared with water, from cultures that had been growing for a 24-hour period on solid medium 523 (KADO; HESKETT, 1970), at 28 °C, and the concentration was set in a spectrophotometer to A540 = 0.5 (108 UFC). Rice seeds were immersed in the bacterial suspension, during 24 hours under constant agitation at 25 °C, and control seeds (no bacteria) were immersed only in water, during 24 hours, in the same conditions. Soil pulverization was done at 7 days and plant pulverization at 15 days after rice sowing in all plots with rhizobacteria, with bacterial suspension prepared as described above, in the same concentration (108 UFC), at 600 l ha^{-1}, with a costal atomizer.

Cover crops were desiccated with a glyphosate application (1.8 kg ha^{-1} acid equivalent) 30 days before sowing of the upland rice. The sowing was performed mechanically using 200 seeds per m2 of rice. The seeds were sown on December 15th, 2015 and on November 23rd, 2016. Seven days before the sowing of the rice, the seed microbiolization was carried out. Rice plant emergence occurred five days after sowing for both growing seasons. Cultural practices were performed according to standard recommendations for a rice crop to keep the area free from weeds, diseases and insects.

Rice harvest was carried out by hand after physiological maturity of the grains in the usable area of each plot. Plots were evaluated for the number of panicles m^{-1}, which was determined by counting the number of panicles within 1.0 m of one of the rows in the useful area of each plot; number of grains per panicle, which was determined by counting the number of grains in 10 panicles random sampled in the usable area and divided by 10; the mass of 1000 grains, which was randomly evaluated by collecting and weighing 1000 grains from each plot, corrected to 13% of water content; and the grain yield, which was determined by weighing the harvested grain of each plot, corrected to 13% of the water content and converted to kg ha^{-1}.

For statistical analysis, the SAS Statistical Software was used. In the qualitative factor (with or without BRM 32114), data was subjected to an analysis of variance, and when the F test proved significant, the data was compared by a Tukey test at $p<0.05$. In the quantitative factor (K rates), results were submitted to regression analysis when $p<0.05$. The K rates, use of rhizobacteria (BRM 32114) and year were considered as fixed effects.

RESULTS AND DISCUSSIONS

In our trials, we describe an exceptional grain yield increase promoted by BRM32114 under field conditions independently of K doses (Table 1). These results corroborate our results found under greenhouse conditions. During researches performed at Embrapa Rice and Beans, *Serratia* spp., strain BRM 32114, was identified as IAA, cellulase and siderophores producer, resistance inducer, photosynthetic rate, root development, dry matter and uptake/accumulation nutrients enhancer in rice shoots, (NASCENTE et al., 2017; SPERANDIO et al., 2017).

Our results show that K rates (20, 40 and 60 kg ha^{-1}) presented no effect on the evaluated parameters. This is probably because in both growing season the K content in the soil was very high (101.3 mg dm^{-3} and 97 mg dm^{-3} in 2015/16 and 2016/17, respectively) (SOUSA; LOBATO, 2004). So, the soil with 0 kg ha^{-1} of K did not show any deficiency or unbalanced evidence. Corroborating this information, Zaratin et al. (2004) observed that K fertilization provided increases in the yield components of rice grains in Cerrado Oxisol with K content in the soil of 82 mg dm^{-3}. This value is 20% lower than the values found in our areas.

Table 1. Potassium rates and Serratia spp. isolated BRM 321114 with or without inoculation in rice seeds as affecting plant biomass (PB), number of panicles per plant (NPP), number of grain per panicle (NGP), mass of 1000 grains (1000M) and grain yield (GY) of upland rice. Santo Antônio de Goiás, growing season 2015/2016 and 2016/2017.

Factors	PB	NPP	NGP	1000M	GY
Serratia	g m^{-2}	Unit	unit	g	kg ha^{-1}
With	222 a	81 a	121	23.17	3792 a
Without	206 b	73 b	124	22.98	3174 b
Growing season					
2015/2016	186 b	76	116 b	23.06	2513 b
2016/2017	243 a	78	130 a	23.09	4453 a

* Means followed by the same letter do not differ by Tukey test.

Many species classified as PGPRs have been studied in order to try to include them in cropping systems. So, many of these PGPRs have already been commercialized, such as the genus *Pseudomonas*, *Bacillus*, *Enterobacter*, *Klebsiella*, *Azobacter*, *Variovorax*, *Azospirillum*, and *Serratia* (AHEMAD; KIBRET, 2012). Our research seems promising and showed that using biodiversity (microorganism collected from the rhizosphere of upland rice) could bring many benefits to the crops systems. In this sense, using upland rice treated with beneficial microorganism could contribute to improve the profitability of the crop for the farmers, since the tested rhizobacterium provided advantages to the plant, independently of the high K level in soil. The use of microbial for integrated nutrient management for rice production could is the way to a sustainable agriculture. It turns to be an environmentally friendly alternative to chemical fertilizer for upland rice production as well as seems to enhance the soil fertility and health.

CONCLUSION

The use of Rhizobacterium *Serratia* spp., strain BRM 32114, in soil with high level of K, provided increases in number of panicles per plant, number of grains per panicle and grain yield of upland rice;

Grain yield of rice treated with Rhizobacterium *Serratia* spp. isolated BRM 321114 was 16.3% higher than no treated plants;

The use of bioagent was effective to provide better plant upland rice growth/development under field conditions and showed promising to be incorporated into crop systems.

ACKNOWLEDGMENT

To Embrapa Rice and Beans for supporting this research and to CNPq to the award in research production for the first and second author.

REFERENCES

AHEMAD, M.; KIBRET, M. Mechanisms and applications of plant growth promoting rhizobacteria: current perspective. Journal of King Saud University, v.26, n.1, p.1-20, 2014. http://dx.doi.org/doi:10.1016/j.jksus.2013.05.001

ANEES, M.; EDEL-HERMANN, V.; STEINBERG, C. Buildup of patches caused by *Rhizoctonia solani*. Soil Biology and Biochemistry, v. 42, p. 1661-1672, 2010.

BASHAN, Y.; DE-BASHAN, L.E.; PRABHU, S.R.; HERNANDEZ, J. P. Advances in plant growth-promoting bacterial inoculant technology: Formulations and practical perspectives. Plant and Soil, v. 378, p. 1–33, 2014.

CLOVER, M.W.; MALLARINO, A.P. Corn and soybean tissue potassium content response to potassium fertilization and relationships with grain yield. Soil Science Society of America Journal, v. 77, p. 630–642, 2013.

CRUSCIOL, C.A.C.; FERNANDES, A.M.; CARMEIS FILHO, A. C.; ALVAREZ, R.C.F. Macronutrient uptake and removal by upland rice cultivars with different plant architecture. Revista Brasileira de Ciencia do Solo, v. 40, p. 1-16, 2016.

FAGERIA, N.K.; BALIGAR, V.C.; JONES, C.A. Growth and mineral nutrition of field crops. 3rd ed., Boca Raton: CRC Press. 2011.

FILIPPI, M. C. C.; SILVA, G. B.; SILVA-LOBO, V. L.; CÔRTES M. V. C. B.; MORAES, A. J. G.; PRABHU, A. S. Leaf blast (*Magnaporthe oryzae*) suppression and growth promotion by rhizobacteria on aerobic rice in Brazil. Biological Control, v.58, n.2, p.160-166, 2011.

KADO, C. J.; HESKETT, M. G. Selective media for isolation of Agrobacterium, Corynebacterium, Erwinia, *Pseudomonas* and *Xanthomonas*. Phytopathology, v.60, n.6, p.969-976. 1970.

NASCENTE, A. S.; FILIPPI, M. C. C.; LANNA, A. C.; SOUZA, A. C. A.; LOBO, V. L S.; SILVA, G. B. Biomass, gas exchange, and nutrient contents in upland rice plants affected by application forms of microorganism growth promoters. Environmental Science and Pollution Research, v.24, n.3, p.2956-2965, 2017a.

SPERANDIO, E. M.; VALE, H. M. M.; REIS, M. S.; CORTES, M. V. C. B.; LANNA, A. C.; FILIPPI, M. C. C. Evaluation of rhizobacteria in uplant rice in Brazil: growth promotion and interaction of induced defense responses against leaf blast (*Magnaporthe oryzae*). Acta Physiologiae Plantarum, v.39, n.1, p.258-270, 2017.

VEJAN, P.; ABDULLAH, R.; KHADIRAN, T.; ISMAIL, S.; BOYCE, A. N. Role of Plant Growth Promoting Rhizobacteria in Agricultural Sustainability—A Review. Molecules, v. 573, p. 1-17, 2016.

ZARATIN, C.; SOUZA, S. A.; PANTANO, A. C.; SÁ, M. E; ARF, O; BUZETTI, S. Effects of four potassium doses on six sprinkler irrigated rice upland cultivars. II. Outcome of grain processing. Científica, v. 32, p. 115–120, 2004.