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Soybean yield under potassium fertilization in a protected environment

Produtividade da soja sob adubação potássica em ambiente protegido

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ABSTRACT
Most of the areas explored in Brazil with soybean cultivation are in tropical regions, where soil formations with a high degree of weathering and low levels of nutrients predominate. Therefore, the objective was to verify soybean yield under different doses of potassium in a dystrophic Yellow Latosol soil. The experiment was carried out in a greenhouse at the Center for Agricultural and Environmental Sciences, at the Federal University of Maranhão, from March to June 2017. The design was completely randomized with five treatments and five replications, totaling 25 plots. The treatments were 0 kg ha^{-1}, 50 kg ha^{-1}, 100 kg ha^{-1}, 200 kg ha^{-1}, and 300 kg ha^{-1} of K_2O, using potassium chloride as a source. The soybean cultivar used was FT4183IPRO, and the results obtained were submitted to the Shapiro-Wilk test to verify normality, the Levene test to verify homogeneity, and the analysis of variance by the F test, when significant the test was used. Tukey, at 5% probability for comparison of means. Potassium fertilization only had a significant effect on MSPA, in which there was also a high correlation between this variable and the grain quantity variable and yield with grain quantity and grain weight. Since the low productivity was due to the poor dispersion of the fertilizer in the pots, causing salinity to the environment.

Key words: Mineral fertilizer; Greenhouse, Glycine Max

RESUMO
A grande parte das áreas exploradas no Brasil com o cultivo da soja estão situadas em regiões tropicais, onde predominam formações de solos de elevado grau de intemperismo e com baixos níveis de nutrientes. Portanto, objetivou-se verificar a produtividade da soja sob diferentes doses de potássio em solo Latossolo Amarelo distrófico. O experimento foi realizado em casa de vegetação no Centro de Ciências Agrarias e Ambientais, da Universidade Federal do Maranhão, no período de março a junho de 2017. O delineamento foi inteiramente casualizado com cinco tratamentos e cinco repetições, totalizando 25 parcelas. Os tratamentos foram 0, 50, 100, 200 e 300 kg ha^{-1} K_2O, tendo como fonte o cloreto de potássio. A cultivar de soja utilizada foi a FT4183IPRO, e os resultados obtidos foram submetidos ao teste de Shapiro-Wilk para verificação da normalidade, ao teste de Levene para verificar a homogeneidade e à análise de variância pelo teste F, quando significativo utilizou-se o teste Tukey, a 5% de probabilidade para comparação das médias. A adubação potássica só apresentou efeito significativo na MSPA, no qual observou-se também alta correlação dessa variável com a variável quantidade de grãos, e da produtividade com quantidade de grãos e peso dos grãos. Sendo que a baixa produtividade foi devido à má dispersão do adubo nos vasos, ocasionando salinidade ao meio.

Palavras-chaves: Adubo mineral; Casa de vegetação, Glycine Max

1 INTRODUCTION

The soybean has become one of the most consumed legumes in the world due to its high nutritional content for human and animal food. Brazil is the largest exporter and the second largest world producer of soybean, according to the National Supply Company (CONAB, 2020), harvest in the period of 2019/20 had a production of 123.249 million tons, 7.1% higher than the previous crop.

In Brazil, a large part of the areas explored for the cultivation of soybean are located in regions of the tropical climate, that is, in these regions soils with a high degree of weathering and low levels of nutrients predominate, making it necessary to apply potassium in the soil by fertilizer (Silva & Lazarini, 2014).

The proper management of nutrients in the soil efficiently provides nutrients necessary for the development of plants, as well as in the chemical composition of seeds (Sedyaama, 2016; Zambiazzi et al., 2017). The deficiency of potassium in the soil manifests visible symptoms in the physical structure of the plant, causing the production of lighter seeds, affects the yield of the crop, which results in lower and less productive plants in the subsequent cycle (Pádua et al., 2010).

Potassium (K) is the second most required nutrient in soybean cultivation, being an important enzymatic cofactor and the main cation responsible for the control of internal osmotic potential, which acts free in plant tissue (Taiz & Zeiger, 2004; Santos et al., 2015). Potassium chloride (KCl) is the main source of K used in grain-producing crops in Brazil, as it is easily solubilized in water, releasing the K^+ ion with low adsorption strength to soil colloids (Raij, 1991).

Petter et al., (2014) concluded in their experiment that potassium doses influence the yield and vigor of soybean seeds grown in the Cerrado of Piauí, with the best results being verified with the application of 80 kg ha^{-1} to 95 kg ha^{-1} of K_2O. Leal et al. (2015) evaluated soybean yield with different doses of potassium chloride coated or not with polymers, concluding that the maximum grain yield was with the dose of 100 kg ha^{-1} of K_2O.

Studies on the influence of fertilization of crops under different edaphoclimatic conditions are important for expanding areas and sustainable fertilizer recommendations. Therefore, the objective was to evaluate soybean yield under different doses of potassium in a dystrophic Yellow Latosol.

2 MATERIAL AND METHODS

The experiment was carried out between March and June 2017, under greenhouse conditions, at the Agricultural and Environmental Sciences Campus of the Federal University of Maranhão, Chapadinha municipality, located at latitude 03 ° 44 ′ 27 ′ ′ South and longitude 43 ° 18 ′ 44 ′ ′ West, with an altitude of 110 m, state of Maranhão.

The experimental plot consisted of plastic pots containing 10 kg of soil, classified as dystrophic Yellow Latosol (Embrapa, 2013) with the following chemical characteristics of the soil in the 0-20 cm layer: pH in CaCl2 = 5.0; M.O = 15 g kg^{-1}; P = 21.1 mg dm^{-3}, and S = 9.08 mg dm^{-3}, K = 0.2, Ca = 1.73, Mg = 0.76, H + Al = 3.10, Al = 0, CTC = 5.79, SB = 2.69 cmolc dm^{-3}, V = 46.5, and m = 0%; and Cu = 0.23, Fe = 352.83mg dm^{-3}, Mn = 6.94, and Zn = 1.3 mg dm^{-3}.

The experimental design used was completely randomized (DCR), with five treatments and five repetitions, totaling 25 plots. The treatments were the doses of 0 kg ha^{-}, 50 kg ha^{-}, 100 kg ha^{-}, 200 kg ha^{-}, and 300 kg ha^{-1} of K2O, in the form of potassium chloride. The soybean cultivar used was FT4183IPRO, with three seeds sown per pot. Then thinning was carried out, leaving only one plant per pot.

The variables evaluated were: pod length (TV, in cm), number of pods per plant (QV), number of grain per pod (QG), grain yield (PG), dry mass of the roots (MSPR), aerial part dry mass (MSPA), plant height (ALT), stem diameter (DC), and weight corrected for moisture content of 13% (PC).

The data obtained went through the Box-Cox transformation estimated and applied as proposed by Hawkins & Weisberg (2017) and submitted to the Shapiro-Wilk test to verify normality. To verify the homogeneity of the variances, the Levene test was applied, since one of the hypotheses of the regression analysis of variance is that the variances are the same for the analyzed category.

Pearson's correlation analysis was performed to verify possible interactions between variables and thus observe possible effects of one on the other, the magnitude of the coefficients was interpreted by the Dancey & Reidy (2006) classification, which points to weak, values 0, 10 to 0.30; moderate from 0.40 to 0.60; and strong from 0.70 to 1.

The results obtained were also submitted to analysis of variance by the F test. The Tukey test at 5% probability was used to compare the means when the cultivar factor was significant. When necessary, the models were adjusted to improve the values of the standard error and the coefficient of determination. All tests were conducted at a 5% level of significance with the aid of the AgroEstat software (Barbosa & Maldonado, 2015).

3 RESULTS AND DISCUSSION

Table 1 shows the variables related to crop growth with potassium fertilization. In which the data obtained were rejected by the Shapiro-Wilk and Levene tests, thus expressing normality and homogeneity.

Table 1. Variables used to analyze soybean growth

Treatments	Variable			
	DC(cm)	MSR(g)	MSPA(g)	ALT(cm)
0	5.20	0.48	4.14A	21.93
50	5.44	0.57	6.20AB	29.20
100	4.49	0.62	4.39AB	19.30
200	5.58	0.71	8.01B	29.26
300	5.48	0.78	6.92AB	29.00
Mean	5.26	0.63	6.04	26.05
Test F	2.38^{NS}	2.12^{NS}	3.73^{*}	3.15^{NS}
P Shapiro−Wilk	0.16	0.80	0.37	0.52
P Levene	0.92	0.74	0.67	0.52
CV (%)	1.57	50.52	28.64	19.40

Averages followed by the same letter in the column do not differ by the Tukey test at 5%. NS = Not significant, * = Significant at 5% by the F test, CV = Coefficient of variation, DC = steam diameter, MSR = dry mass of the roots, MSPA = aerial part dry mass, and ALT = plant height.

We observed a significant effect ($p < 0.05$) when comparing the means, only on the dry mass of the aerial part of the soybean in different potassium doses (Figure 1). However, the 200 kg ha^{-1} dose differed only from the control treatment.

Potassium is a fundamental macronutrient for plant development, with direct influences on the physiological reactions existing in it, it is a nutrient that collaborates with quality factors such as size, shape, color, and vigor.

The data showed homogeneity and normality, therefore, models were adjusted to the dry mass of the aerial part and the root part with the different doses of potassium using a linear equation (Figures 1 and 2). The angular coefficient has a positive line, so it can be seen that as the dosage of potassium fertilization increases, there is an increasing increase in the biomass of the plant.

Figure 1 - Relationship between the dry mass of the aerial part and KCl doses

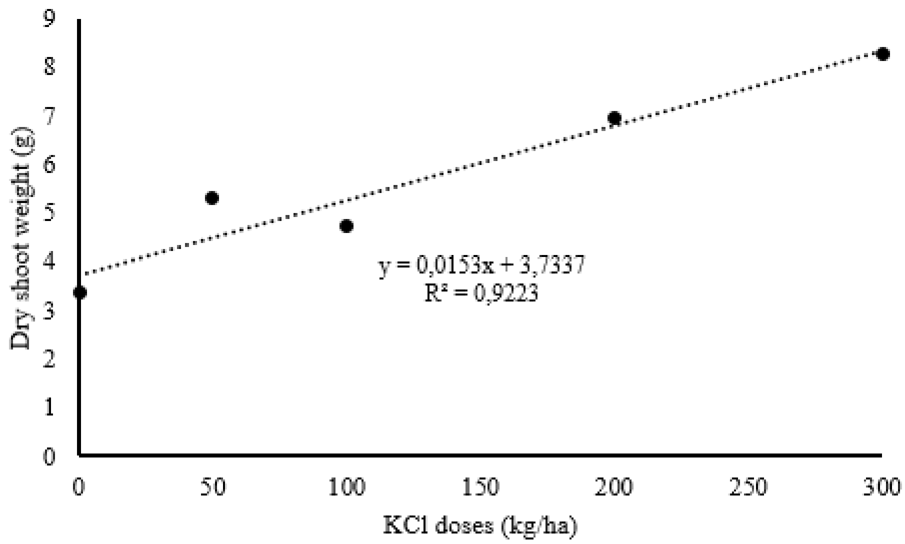
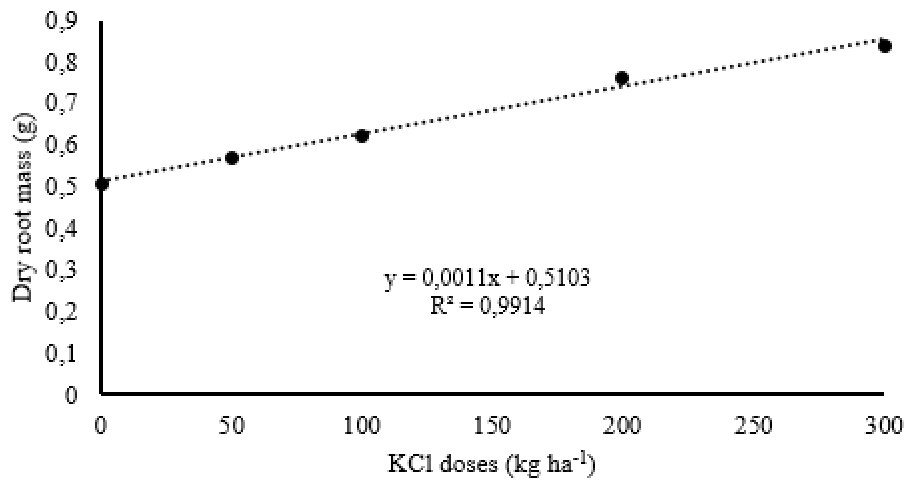


Figure 2 - Relationship between the dry mass of the root and the KCl doses



Catuchi et al. (2012) observed similar relationships in the development of plants to the effect of potassium supplementation having responses proportional to the applied levels, a consequence attributed to the K dynamics promoted through osmotic adjustments, higher photosynthetic rate, and cell expansion in plants.

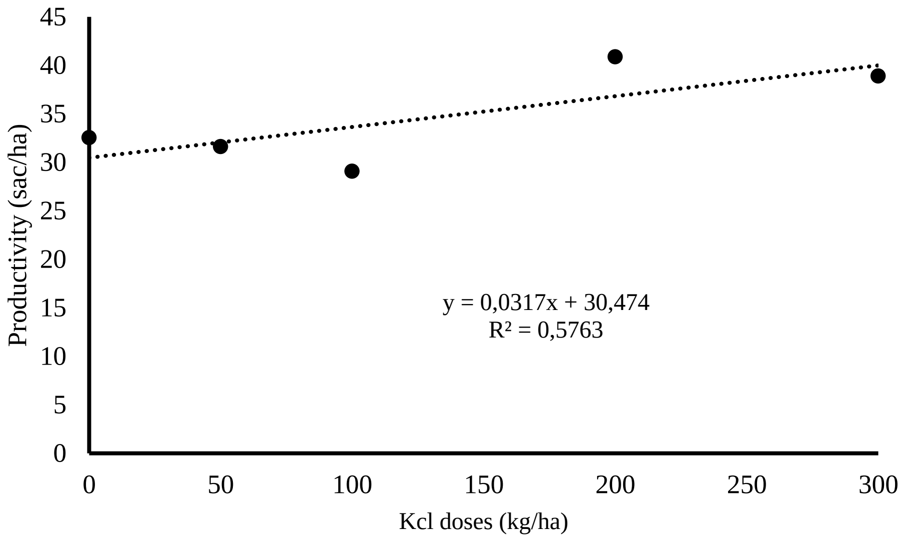
Table 2 shows the results found in the evaluation of production variables in which they presented normal and homogeneous data. Thus, a model (Figure 3) was adjusted using a linear regression between the yield and the different fertilizer doses used, in which, they presented a positive slope determining an increasing line (Figures 1 and 2)

Table 2: Soybean production variables in different potassium doses

Treatments	Variable				
	TV (cm)	QV	QG	PC(g)	PG (sac ha^{-1})
0	3.55	32.00	58.50	8.28	32.84
50	3.76	32.20	61.00	7.92	31.43
100	3.66	26.25	49.75	5.30	21.08
200	3.84	42.60	72.60	8.38	33.25
300	3.71	27.50	63.25	7.80	30.95
Mean	3.71	32.60	61.55	7.59	30.13
Test F	1.46^{NS}	2.40^{NS}	1.39^{NS}	0.98^{NS}	0.98^{NS}
PShapiro−Wilk	0.10	0.90	0.62	0.44	0.44
PLevene	0.61	0.55	0.80	0.11	0.11
CV (%)	15.49	29.90	27.03	39.17	39.00

Averages followed by the same letter in the column do not differ by the Tukey test at 5%. NS = Not significant. * = Significant at 5% by the F test, CV = coefficient of variation, TV = pod length, QV = number of pods per plant, QG = number of grain per pod, PC = weight corrected for moisture content of 13%, PG = grain yield.

Figure 3 - Relationship between the soybean yield and the KCl doses



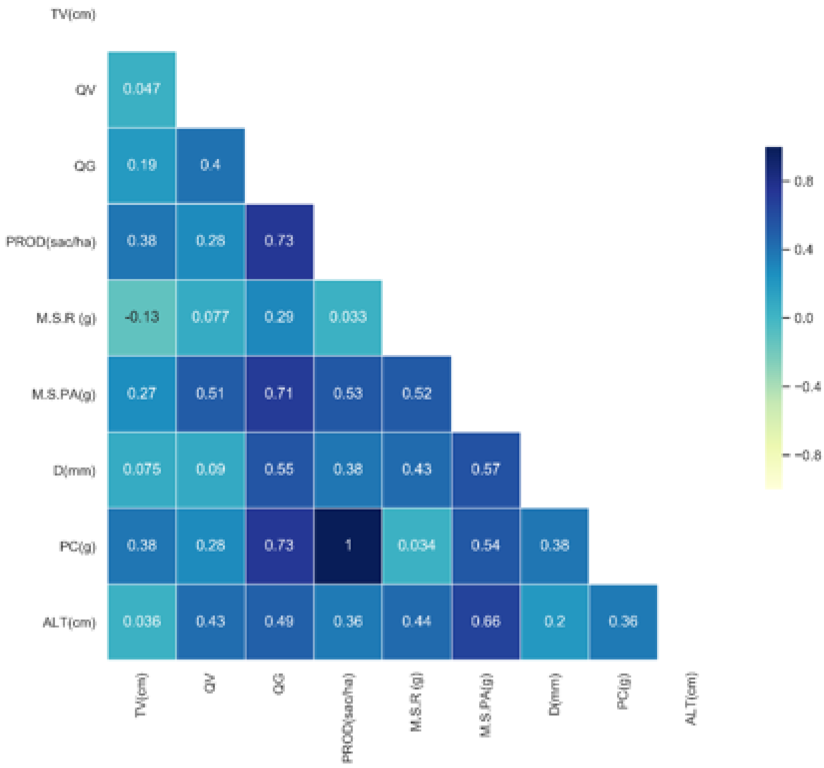
We observed in the adjusted linear model that for each 1 kg of KCl added in fertilization, there is an increase of 0.0317 sac ha^{-1} in the soybean yield. Complementing this information, it is also observed that, if this fertilization had not occurred, the yield would have been 30.474 sac ha^{-1}, according to the model presented.

The interactions present between the variables can be analyzed using Pearson correlation, thus, express the effect of one variable on another (Figure 4). In this way, it can be noted that MSPA has a strong correlation with QG, proportionally, that is, the higher the concentration of biomass in the plant, the greater the quantities of grains provided by it.

MSPA has a low correlation with TV, indicating no response action from one variable over the other. With the other variables, there was a moderate degree of correlation.

QG and PC demonstrated a relationship with PG. In which they are directly linked to the calculation of yield because the greater the number of grains per plant and the better the climate and soil conditions, the percentages of soybean yield are higher.

Figure 4 – Heatmap of soybean morphological variables.



Legend = TV = pod length, QV = number of pods per plant, QG = number of grain per pod, PROD = grain yield, MSPR = dry mass of the roots, MSPA = aerial part dry mass, ALT = plant height, DC = stem diameter, and PC = weight corrected for moisture content of 13%.

It can be taken into account that the possible handling location, in this case, the pots, as an aggravating factor for low yield, influenced by the poor dispersion of the fertilizer, causing salinity in the medium, thereby forming wilted pods with low quality in the grains.

Most fertilizers are salts when applied close to the seeds, thus impairing their germination. This is because the concentration of salts in the soil solution is higher than that of the seed (DESAI et al., 2004; TAVARES et al., 2013).

Tavares et al. (2013) found that the increase in the concentration of the K_2SO_4 and KCl salts in the crop, in a toxic way, was responsible for the reduction in the number of seeds per plant. Similar results were obtained by Mateus et al. (2007), whose seeds of Brachiara Brizantha in contact with the KCl salt had their germination reduced.

4 CONCLUSIONS

Potassium fertilization at a dosage of 200 kg ha^{-1} had a significant effect on the dry mass of the aerial part (MSPA). A high correlation was also observed with MSPA and QG, and between PG with QG and PC.

The soybean has low yield due to poor dispersion of the fertilizer in the pots, causing salinity in the medium, thereby forming wilted pods with low quality in the grains.

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