AGRONOMY SCIENCE AND BIOTECHNOLOGY

RESEARCH ARTICLE

Nutritional management in soybean crop for high yields using organomineral fertilizers

Luiz Leonardo Ferreira[1], Ivan Ricardo Carvalho[2,*], Dilmo Tailan Tombini Amaral[1], Marilaine de Sá Fernandes[1], Roselaine Lage Fonseca Prado[1], Núbia de Souza Carrijo[1], Andresley Joaquim da Silva[1] and Murilo Vieira Loro[3]

[1]Universidade em Mineiros, Goiás, GO, Brazil. [2]Regional University of the Northwest of the State of Rio Grande do Sul, Rua do Comércio, 3000, Universitário, Ijuí, RS, Brazil, CEP 98700-000. [3]Federal University of Santa Maria, Santa Maria, RS, Brazil. *Corresponding author, E-mail: carvalho.irc@gmail.com

Citation: Ferreira, L. L., Carvalho, I. R., Amaral, D. T. T., Fernandes, M.S., Prado, R. L. F., Carrijo, N. S., Silva, A. J., & Loro, M. V. (2022). Nutrition management in soybean crop for high yiels using organomineral fertilizers. *Agronomy Science and Biotechnology*, 8, 1-15 https://doi.org/10.33158/ASB.r153.v8.2022

Received: October 6, 2021.
Accepted: December 10, 2021.
Published: March 16, 2022.

English by: Luiz Leonardo Ferreira.

ABSTRACT

The objective of this work was to evaluate the performance of soybean cultivars as a function of the application of organomineral fertilizer via foliar, to obtain high yields. The study was conducted at the municipality of Mineiros-GO, Brazil. The soil is classified as neosol quartzeneic ortic typical, with medium texture. The experimental design was a 5x3 factorial, totaling 15 treatments, corresponding to five doses of Potamol Plus® (0, 0.25, 0.5, 0.75 and 1 L ha^{-1}) and 3 cultivars of (M7739, M8372 and TMG7062) in 4 replications. The data obtained was submitted to the assumptions of the statistical model, verifying the normality and homogeneity of the residual variances, as well as the additivity of the model, for these were performed single and multivariate analyzes. The analysis of variance showed that the cultivar factor was significant for all variables. Significance was also observed in the dose factor for APR, LUG, LQG, REN, LDG, GTP and GCP. Interaction between factors (C x D) occurred in APR, LUG, LDG, LQG, LTG, GTP and GCP. Potamol Plus® organomineral fertilizer applied foliar at 30 (50%) and 45 (50%) days after sowing did not increase the productive performance of soybean cultivars M7739, M8372 and TMG7062. The cultivars M7739 and TMG7062 presented high yields (yield ≥ 70 bag ha^{-1}).

Keywords: Leaf fertilization, *Glycine max*, micronutrient, linear correlation, canonical correlation, amino acids.

INTRODUCTION

Soybean farming for high yields requires knowledge and applied cultural practices, following the logic of plant development and the basic principles of plant physiology. The potential of the soybean crop is defined by the efficiency in the interpretation of the solar energy and the relation of the lower volume of straw to the maximum production of grains. Excess leaves, or plants, determine the inability of the lower canopy to intercept solar radiation, reducing liquid photosynthesis and grain production (Hipolito & Borges, 2017).

Soy is the most cultivated grain crop in Brazil (Barbosa et al. 2022; Ferreira et al. 2022a; Ferreira et al. 2022b). Its grains, sources of nutrients such as nitrogen, phosphorus and potassium (Loro et al., 2021; Treter et al. 2022), and rich in proteins, are used for human and animal food. In recent years, yields have increased as a result of the use of new technologies and the increasing professionalization of rural producers (Trentin et al., 2013). In order to obtain a better yield in soybean cultivation, producers adopt different management alternatives to promote the increase in their crops, among the alternatives is the use of foliar fertilization (Oliveira et al., 2017).

The foliar fertilization of micro or macro nutrients compounds is gaining more and more space because of its solubility power, and its main objective is to supply the plants, their nutritional needs through a fast absorption, providing the nutrients when really needed, and in this way avoid or correct deficiencies.

Solid organic products such as avian litter, cattle manure, urban waste and sugarcane by-products have already been the subject of other studies seeking to increase soil fertility. However, when it comes to fertilizing the soil in large areas such as the soybean crop in the midwest, an enormous organic volume is demanded annually, and almost no such need is ever attended, either by the area of cultivation or even by the biological consumption withdrawn in the grain harvest and high microbial decomposition.

In the desire to produce more and more, by spending less and reducing harm to the environment, strategies such as foliar fertilization with products classified as organomineral, can be a differential, when well positioned. This can be applied in isolation or even accompany activities that are of broad spectrum by the producers as the interventions of fungicide, insecticide or even herbicide. This makes it even more viable by reducing operating costs.

Benefits such as reduction of plant stress due to climatic factors or phytotoxicity by phytosanitary products, elevated systemic resistance induced, foliar retention potential, reduced floral abortion, and grain filling are some of the benefits proposed by organomineral products applied via foliar to the crop soy. However, few scientific reports prove or elucidate such benefits. Mambrin et al. (2020) showed that the supplementation in the bean crop promoted superior performance for dry mass of pods, grains, number of grains and grain yield. Silva et al. (2020) revealed that the positive effect of biostimulants depends on climatic conditions, and that the return in productivity does not guarantee the feasibility of the application.

In organomineral fertilizers, nutrient essences such as Molybdenum (Mo), Nitrogen (N), cobalt (Co) and Potassium (K) are usually present. For Possenti and Villela (2010), Mo is of great relevance for the action of the enzyme nitrate reductase. Moraes et al. (2008), emphasizes the efficacy of the method of biological fixation of N, allied to Co; as well as Mo (Sfredo & Oliveira, 2010). The K by its amplitude in interconnecting the internal and external medium, through the osmotic control of opening and closing of the stomata and lenticels, without directly binding to the organic compounds acting mainly as catalytic agent.

It is known that, in practice, foliar fertilization is a complement to the fertilization done in the soil for the crops. Thus, incorporation via foliar fertilization with organic substances may supplement soil supply at certain stages of growth (Gazola et al., 2014), and the use of these substances may be a strategy to prevent the undesirable effects of glyphosate soybean cultivation (Zobiole et al., 2011).

However, data on the efficiency of the application of organomineral fertilizers in the soybean crop are very scarce. Therefore, it is necessary to carry out more scientific work to fill the deficiency of information on the subject. These studies are of interest especially when associated with the different genetic materials of this crop. Therefore, the objective of this work was to evaluate the performance of soybean cultivars as a function of the application of organomineral fertilizer via foliar, to obtain high yields, superior to seventy sacks per hectare.

MATERIAL AND METHODS

Description of the environment

The study was conducted at the Luiz Eduardo de Oliveira Sales Experimental Farm in the municipality of Mineiros-GO, located at the geographic coordinates of 17 ° 34'10 '' South latitude and 52 ° 33'04 '' West longitude, with average altitude of 760 m. The average temperature is 22.7 °C, the average annual rainfall is 1695 mm occurring mainly in spring and summer. The predominant climate is warm, semi-humid and notably seasonal, with rainy summer and dry winter, being classified as "Aw" (Köppen and Geiger, 1936). The soil is classified as neosol quartzeneic typical orthicus, with medium texture, topography smoothly wavy to flat and good drainage.

Experimental design

The experimental design used was randomized blocks organized in a 5x3 factorial scheme, totaling 15 treatments, corresponding to five doses of Potamol Plus® (0, 250, 500, 750 and 1000 ml ha^{-1}) and 3 cultivars of (M7739, M8372 and TMG7062) in 4 replications, totaling 60 experimental units, where each unit was composed of 4 lines of 4 meters in length spaced every 0.5 m. The populations were 288,000, 222,222 and 445,000 plants ha^{-1}, respectively.

Potamol Plus® is an organomineral fertilizer class A. It is recommended for foliar application, which has in its constitution (water soluble nitrogen (N): 7.0, potassium oxide (K_2O) soluble in water: 2.3 molybdenum (Mo) soluble in water: 2.0, and organic carbon: 11.5).

Conduction of the experiment and evaluated parameters

Before offsetting up the experiment, soil samples were collected and analyzed in the 0-20 cm surface layer, with the following characteristics: hydrogen potential 4.1; phosphorus 3 in mg dm^{-3}; potassium 0.6, calcium 5, magnesium 3, aluminum 4, potential acidity 29, base sum 8.6, cation exchange capacity 37.6 and base saturation 22.94 in mmolc dm^{-3}; clay 80, silt 30 and sand 890 in g dm^{-3}. The analyzes were carried out at the UNIFIMES Soil Chemistry and Fertility Laboratory, according to the methodology of EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária [Embrapa], 2009).

Soil preparation was carried out using plowing and harrowing. Sowing was performed on 10/28/2016 with manual seed distribution, and fertilization with 300 kg ha^{-1} of NPK mineral fertilizer in formula 07-25-25 was performed simultaneously in the furrow. The doses of the organomineral fertilizer were fractionated and applied foliar at 30 (50%) and 45 (50%) days after sowing. Pest control was performed 30 days after sowing with glyphosate at the concentration of 1.5 L ha^{-1}. At 45 days after planting, application with Epoxiconazole 0.5 L ha^{-1}; and at 60 days after planting Fluxapiroxade and Piraclostrobin at the dose of 0.3 L ha^{-1}. For these, a constant pressure 2.0 bar (CO_2) cone-type sprayer was used, applying a syrup volume of 335 L ha^{-1}, during the mild daytime hours, with an average ambient temperature of 25ºC, relative humidity air above 60% and winds below 5 km h^{-1}.

The variables were measured in ten plants per plot after harvest on February 18, 2017. Plant height (ALP) in cm, height of the first reproductive branch (APR) in cm, total number of vegetables per plant (NLP) in unid plant-1, vegetables with one grain (LUG) in unit plant^{-1}, vegetables with two grains (LDG) in unit plant^{-1}, vegetables with three grains (LTG) in unit plant^{-1}, vegetables with four grains (LQG) in unit plant^{-1}, total number of grains per plant (GTP) in unit plant^{-1}, number of commercial grains per plant (GCP) in unit plant^{-1} and grain yield (REN) in bag of 60 kg ha^{-1}. The data obtained weas submitted to the assumptions of the statistical model, verifying the normality by Shapiro Wilk test and homogeneity of the residual variances by the Bartlett test.

Afterwards, the analysis of variance was carried out in order to identify the interaction between the soybean cultivars x doses of the organomineral fertilizer, where the description of the variables were performed as a function of the latter, and the polynomial regression was performed, observing the significance of the F test. After they were dismembered to the simple effects by Tukey's means clustering test, 5% probability. Subsequently, the variables were submitted to a linear correlation with the purpose of understanding the association tendency, and their significance was based on a probability of 5% by the t-test. Furthermore, a network of phenotypic correlations was generated to better understand the dynamics of associations. After which the biplot canonical variable variable method was used to visualize the joint variability of treatments and the multivariate trends. The analyzes were performed at the Rbio and R interface (Bhering, 2017).

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance showed that the cultivar factor (C) was significant for all the variables analyzed ($p \leq 0.01$), a significance was also observed in the dose factor (D) for APR, LUG, LQG, REN ($p \leq 0, 01$), LDG, GTP and GCP ($p \leq 0.05$). Interaction between factors (C x D) occurred in APR, LUG, LDG, LQG ($p \leq 0.01$), LTG, GTP and GCP ($p \leq 0.05$) (Table 1). These results corroborate with those found by Rossi et al. (2012); Moraes et al. (2008); Gazola et al. (2017); Dourado Neto (2012); and Nakao et al. (2014).

There was no adjustment of the models tested for ALP and ALP in factor D and in the interaction C x D, in addition to REN, for the latter (Table 1), as proposed by Diesel et al. (2010), where the application of fertilizer via foliar in the soybean crop, did not present significance for the analyzed agronomic variables.

Table 1. Summary of analyzes of variance (calculated F and CV (%)) for plant height (ALP), height of the first reproductive branch (APR), total number of vegetables per plant (NLP), vegetables with one grain (LUG), two-grain vegetables (LDG), vegetables with three grains (LTG), vegetables with four grains (LQG), total number of grains per plant (GTP), number of grains per plant (GCP) and grain yield (REN). Mineiros-GO, UNIFIMES, Brazil, 2019.

Factors	GL	ALP	APR	NLP	LUG	LDG	LTG	LQG	GTP	GCP	REN
Cultivar (C)	2	99.02**	181.67**	20.35**	22.65**	59.06**	13.99**	580.64**	62.62**	36.97**	18.87**
Dose (D)	4	1.14ns	8.09**	1.43ns	15.72**	2.98*	4.29**	10.83**	3.47*	2.62*	8.21**
C x D	8	1.62ns	4.59**	0.60ns	17.99**	2.99**	2.96*	17.47**	2.55*	2.61*	1.99ns
Block	3	5.23**	0.19ns	0.36ns	3.39*	0.76ns	1.73ns	1.14ns	0.73ns	0.60ns	0.07ns
CV (%)		6.77	7.29	17.86	49.08	11.97	16.88	23.98	9.78	12.68	13.46

** significant at 1% probability by F test; * significant at 5% probability by F test; ns not significant at 5% probability by the F test.

Breakdown of the interaction

The disintegration of the C x D interaction revealed that the cultivar M8372 showed the highest averages among the other cultivars for all doses in the APR, LUG, LDG, LTG, LQG, GTP and GCP characteristics (Table 2), demonstrating the high degree of adaptability and management. Argues that the presence of organic compounds in foliar fertilizer formulations exert a chelating effect on the absorption of macro and micronutrients, storing more protein in the seeds, promoting better commercial grains.

According to Dourado Neto (2012), high yields of soybeans require high amounts of N, which can be achieved especially from symbiotic fixation, however, there is a possibility that the efficiency of this biological process will be hampered by micronutrient deficiency, especially Co and Mo. Elements present in organomineral fertilizers. Nakao et al. (2014), showed that the micronutrient Mo is essential for the soybean crop, mainly in the BNF process.

The characteristics of ALP, NLP and REN represented the main effects of the study. In this, high yield was only provided by cultivar TMG7062 with 77.39 sc ha^{-1} (REN ≥ 70 bag ha^{-1}), followed by cultivars M7739 68.13 bag ha^{-1} and M8372 59.44 bag ha^{-1} (Table 3). Dourado Neto (2012) verified that the application of Mo via foliar promoted significant increases in crop yield with increases of up to 240 kg ha^{-1}. The results of the experiment demonstrated that foliar fertilization with organomineral fertilizers interferes in the yield and physiological quality of soybean seeds, increasing up to the dose of 800 g ha^{-1} of Mo (Nakao et al., 2014). Picolli et al. (2009), when analyzing the application of amino acid products in the wheat crop, concluded that these products allowed significant gains in grain yield and also benefited the crop in adverse climatic conditions, such as water deficit.

Research by Gazola et al. (2017) stated that yield of cultivars is associated with the characteristics of each genetic material and the treatment to which they are submitted. Preliminary study by others autors showed that the application efficiency of Mo in the soil is low due to its adsorption with the organic matter and the Fe iron and Al aluminum oxides. However, its application through foliar fertilization can increase the application efficiency by contributing to increase yield.

Table 2. Breakdown of the interaction Cultivar x Dose to the height of the first reproductive branch (APR), vegetables with one grain (LUG), vegetables with two grains (LDG), vegetables with three grains (LTG), vegetables with four grains), total number of grains per plant (GTP) and number of commercial grains per plant (GCP). Mineiros-GO, UNIFIMES, Brazil, 2019.

Doses	APR (cm)			//	LUG (unit planta^{-1})			//	LDG (unit plant^{-1})		
	TMG7062	M7739	M8372		TMG7062	M7739	M8372		TMG7062	M7739	M8372
0	9.51 B	9.07 B	11.10 A		6.47 B	10.36 B	61.55 A		23.12 B	31.97 A	36.46 A
250	9.12 B	9.42 B	13.83 A		8.92 A	19.99 A	12.67 A		23.52 B	33.00 A	32.83 A
500	9.52 B	10.57 B	15.05 A		6.20 A	16.20 A	8.13 A		21.10 B	30.90 A	26.90 AB
750	9.62 B	9.15 B	13.90 A		4.90 A	9.17 A	9.55 A		20.17 C	26.62 B	35.69 A
1000	9.57 B	8.70 B	13.83 A		6.60 A	8.72 A	10.82 A		22.52 B	27.22 B	35.96 A
	LTG (unit plant^{-1})			//	LQG (unit plant^{-1})			//	GTP (unit plant^{-1})		
0	29.55 A	30.62 A	25.40 A		0.20 B	0.15 B	0.61 A		105.40 B	164.37 A	163.36 A
250	22.42 B	28.20 AB	31.56 A		0.22 B	0.02 C	0.93 A		117.92 B	161.45 A	183.00 A
500	23.27 B	30.37 B	40.51 A		0.15 B	0.02 B	1.36 A		142.17 B	160.92 AB	183.70 A
750	19.70 A	24.00 A	27.43 A		0.20 B	0.05 B	1.51 A		137.46 B	145.52 B	188.50 A
1000	25.35 B	27.45 AB	35.00 A		0.17 B	0.00 B	1.33 A		124.05 B	136.07 B	171.97 A
				//	GCP (unit plant^{-1})			//			
0					88.50 B	132.95 A	140.75 A				
250					115.93 A	134.42 A	134.70 A				
500					124.07 B	136.30 AB	159.35 A				
750					104.47 B	111.00 B	169.17 A				
1000					99.30 B	118.45 B	148.55 A				

Means followed by the same horizontal letters do not differ statistically from each other, by the Tukey test, at 5% probability.

This is what the study by Ribeiro et al. (2014) sought to verify the benefits of the application of biofertilizer in the yield of soybeans found that the use of treatment enriched with Co and Mo promoted yields close to that found in the experiment of this work of 69.84 bag 60 kg ha^{-1} with foliar application in V6, differing from the control treatment 47.02 sc ha^{-1}, in 32.83% with the dose of 0.20 L ha^{-1}. Rossi et al. (2012) points out that the application of fertilizer via foliar at doses between 45 and 56 g ha^{-1} had a positive influence on yield components. For Prado et al. (2016), organomineral fertilizer improves the growth, development, mineral nutrition and yield of soybeans.

The doses of the organomineral fertilizer did not influence the means of ALP. These study contrast with works wich showed evidence that the use of foliar fertilization in soybean with 0.2 L ha^{-1} promoted a greater increase of ALP. The same effect was found by Valenti et al. (2015) where the fertilizer application via foliar, promoted better increases in the ALP of the soybean plants. The fertilizer concentration also did not influence the NLP and REN of the soybean cultivars.

Table 3. Averages for the main effects plant height (ALP), total number of vegetables per plant (NLP) and yield (REN). Mineiros-GO, UNIFIMES, Brazil, 2019.

Cultivars	ALP (cm)	NLP (unit planta^{-1})	REN (bag ha^{-1})
TMG7062	69.39 c	53.29 b	77.39 a
M7739	75.86 b	68.13 a	69.86 b
M8372	92.53 a	76.84 a	59.44 c

Means followed by the same vertical letters do not differ statistically from each other, by the Tukey test, at 5% probability.

Regression analysis

A significant effect was observed on the interaction (C x D) of the organomineral fertilizer, whose results in polynomial regressions can be observed (Figure 1 and Table 4) for the variables APR, LUG, LDG, LQG, LTG, GTP and GCP. Quadratic and cubic effects were reported for cultivars TMG7062 and M7739 (Table 4), respectively for APR (Figure 1A). The cultivar M8372 was the only one that presented interaction for the LUG (Figure 1B), LDG (Figure 1C) and LQG (Figure 1E) characteristics with cubic regression (Table 4).

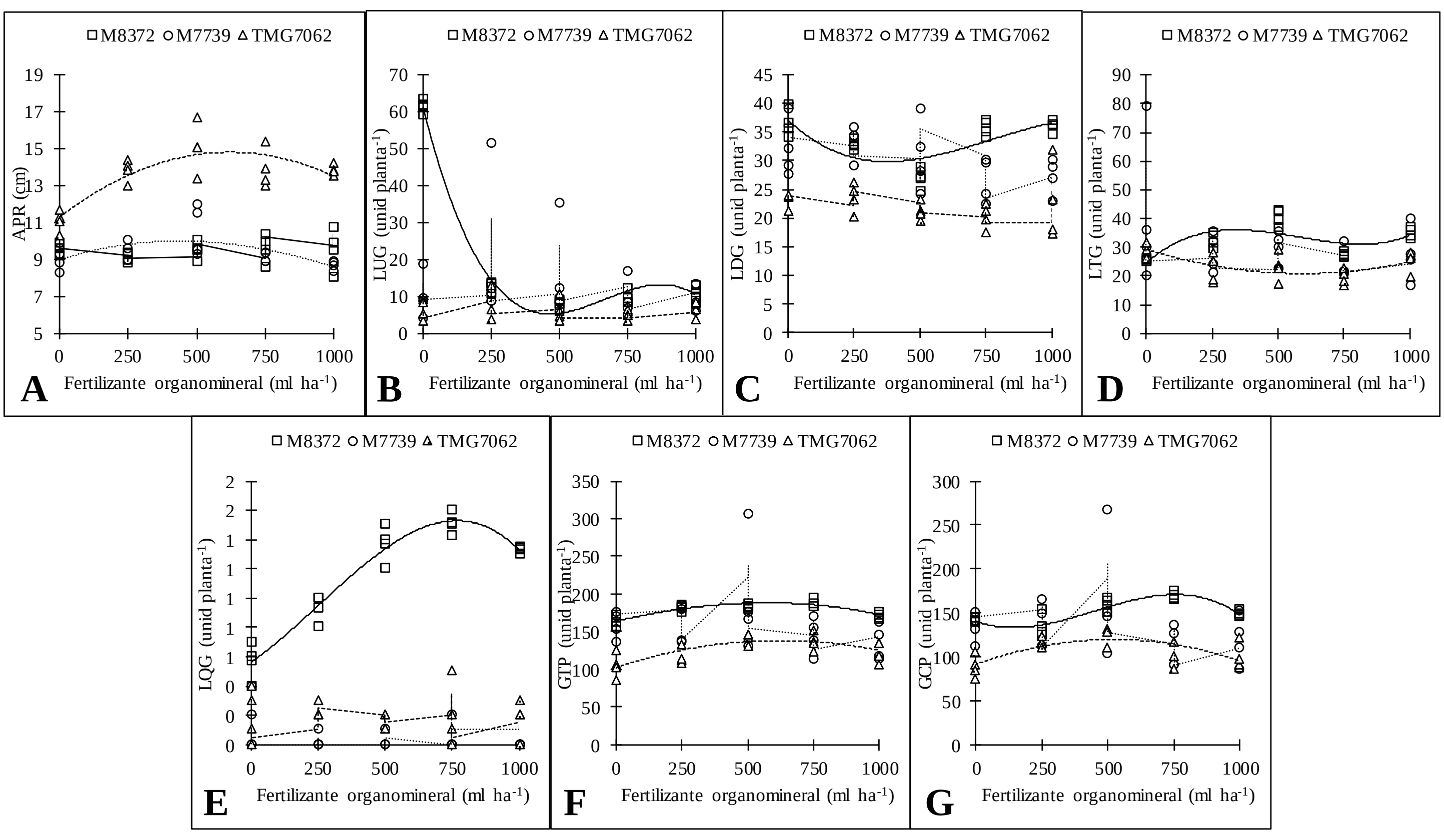

Figure 1. Height of first reproductive branch (APR) (A), vegetables with one grain (LUG) (B), vegetables with two grains (LDG) (C), vegetables with three grains (LTG) (G), number of commercial grains per plant (GCP) (G), of soybean cultivars when submitted to the application by foliar of organomineral fertilizer. UNIFIMES, Mineiros, GO, Brazil. 2019.

Characteristics of LTG (Figure 1D), GTP (Figure 1F) and GCP (Figure 1G) showed variations in the doses of organomineral fertilizer in cultivars TMG7062 and M8372. The increments were proposed in a quadratic model for the first and cubic for the second, in the respective characteristics (Table 4), the same already being elucidated by Rossi et al. (2012) in foliar fertilization with organomineral fertilizer. The study by Moraes et al. (2008) evidences that the Mo used by foliar translocates to the nodules and to the grains in the granulation stage, potentializing the GTP. Gazola et al. (2017), explains that the application of organomineral fertilizer can influence the efficiency of nitrogen fertilization, since the regulation of N absorption by the roots is explained by the proteolytic activity that releases amino acids in the leaves, which in turn are translocated to grains.

Table 4. Equations and R2, for the variables of APR, LUG, LDG, LTG, LQG, GTP and GCP of soybean cultivars. Mineiros-GO, UNIFIMES, Brazil, 2019.

Cultivar	Variable	
	Equation	R^2
//	Height of first reproductive branch APR (cm)	
TMG7062	$9.401071429-0.000178571^{ns}x+0.000000429^{ns}x^2$	0.02
M7739	$9.075000000-0.011625000x^{ns}+0.000084183^{ns}x^2+-0.000000147^{*}x^3$	0.45
M8372	Y average: 12.43	-
//	Vegetables with one grain LUG (unit plant^{-1})	
TMG7062	y average: 7.37	-
M7739	y average: 15.70	-
M8372	$61.09132143-0.29079607^{**}x+ 0.00047731^{**}x^2 -0.00000024^{**}x^3$	0.98
//	Vegetables with two grains LDG (uni plant^{-1})	
TMG7062	y average: 23.00	-
M7739	$33.12-0.00635^{*}x$	0.23
M8372	$36.4675+ 0.05300333^{**}x -0.00044974^{**}x^2+0.00000083^{**}x^3$	0.87
//	Vegetables with three grains LTG (unit planta^{-1})	
TMG7062	$29.30285714-0.02859286^{**}x+0.00002414^{*}x^2$	0.39
M7739	y average: 30.240	-
M8372	$25.4 -0.0814^{**}x+0.00071527^{**}x^2-0.00000134^{**}x^3$	0.91
//	Vegetables with four grains LQG (unit planta^{-1})	
TMG7062	y average: 0,20	-
M7739	y average: 0,10	-
M8372	$0.6046428571+ 0.0010428571^{*}x+ 0.0000019971^{ns}x^2-.0000000023^{**}x^3$	0.95
//	Total number of grains per plant GTP (unit planta^{-1})	
TMG7062	$102.4860714+ 0.1151284^{**}x -0.0000924^{**}x^2$	0.53
M7739	y average: 168.175	-
M8372	$163.3675+ 0.1955625^{**}x-0.0006911^{*}x^2+ 0.0000010^{*}x^3$	0,81
//	Number of commercial grains per plant GCP (unit planta$^{-1)}$	
TMG7062	$91.14835714+0.11029414^{**}x -0.00010624^{**}x^2$	0.47
M7739	y average: 137.11	-
M8372	$140.3228571-0.1050095^{*}x\ 0.0004389^{**}x^2-0.0000003^{**}x^3$	0.79

** significant at 1% probability by F test; * significant at 5% probability by F test; ns not significant at 5% probability by the F test.

Analysis of canonical variables

The canonical correlation was used, which assumes that characters do not only show a linear trend in pairs, and it is possible that not only a single trait influences the main attributes of this species, but two or more characters (Vergara et al., 2021). The first canonical variable accounted for 92.2% of the total data variation, observing that the GTP, GCP and NLP variables showed similarities of magnitude to each other, besides the influence of ALP by cultivar M8372. According to the eigenvalues, the REN (-0.7116) presented a contrast with the other variables APR (0.6065), GTP (0.7377), GCP (0.7810), ALP (0.8393) and NLP (0.8367), emphasizing that the last two variables contributed most to the influence of organomineral fertilizer on soybean cultivars (Figure 2).

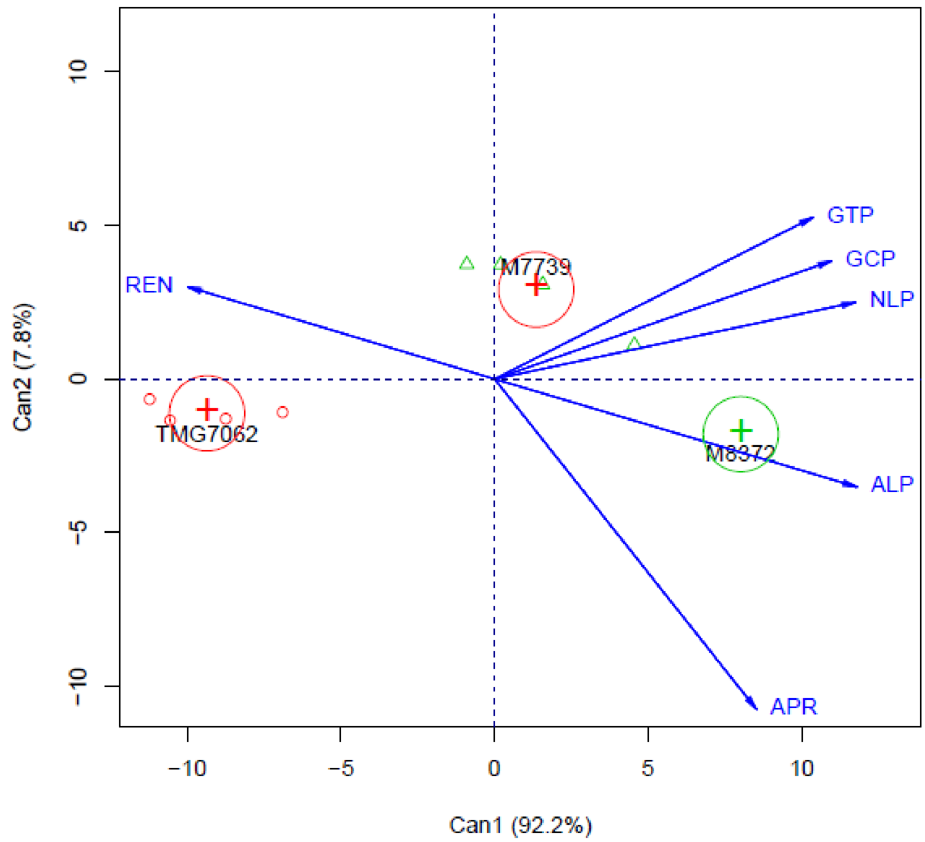

Figure 2. Analysis of canonical variables of plant height (ALP), height of first reproductive branch (APR), total number of vegetables per (NLP) plant, total number of grains per (GTP) plant, number of commercial grains per (GCP) plant and yield (REN), of soybean cultivars. Mineiros-GO, UNIFIMES, Brazil, 2019.

The cultivar TMG7062 showed high REN in comparison to the others (Figure 2). Santos et al. (2012), evaluating the genetic divergence, through multivariate techniques, verified that the first two canonical variables explained approximately 80% of the total variance found, which allows to explain satisfactorily the manifested variability among the evaluated genotypes. Martins Filho et al. (2015) using the technique of canonical variables also identifies the variables of greater importance in the variance of their data.

Simple correlation

Understanding the linear correlation between characters is essential to obtain efficient responses that can be used in indirect selection to enhance some trait (Nardino et al., 2016). According to the Pearson correlation test, the pairs of attributes whose correlations were high (0.6-1), medium (0.31-0.59) and low (0.1-0.3) had positive and negative, indicating increasing and decreasing function among the variables. Thus, scientific consistency was observed for the following positive correlation pairs: 1) ALP x APR (r = 0.4833**), 2) ALP x NVQ (r = 0.7827**), 3) ALP x NTG r = 0.6449**), 4) ALP x NGC (r = 0.6563**) 5) APR x NVQ (r = 0.8917**) and 6) NTG x NGC (r = 0.9269**). For these pairs, the correlations were direct and positive, indicating that the ALP is directly linked with the components of soybean yield (Table 5). Dalchiavon and Carvalho (2012).

Table 5. Simple correlation matrix among agronomic traits of soybean cultivars submitted to foliar application of Potamol Plus®. UNIFIMES, Mineiros, GO, Brazil, 2019.

	ALP	APR	NLP	LUG	LDG	LTG	LQG	GTP	GCP	REN
ALP	1									
APR	0.7833**	1								
NLP	0.6225ns	0.5016ns	1							
LUG	0.2566ns	0.0463ns	0.1642ns	1						
LDG	0.5424ns	0.4031ns	0.5464ns	0.4247ns	1					
LTG	0.4334ns	0.3645ns	0.4156ns	-0.0405ns	0.2668ns	1				
LQG	0.7827**	0.8917**	0.4578ns	0.0408ns	0.4444ns	0.3189ns	1			
GTP	0.6449**	0.4528ns	0.5153ns	0.1947ns	0.5279ns	0.2056ns	0.4286ns	1		
GCP	0.6563**	0.4457ns	0.5065ns	0.2035ns	0.4827ns	0.2071ns	0.4353ns	0.9269**	1	
REN	-0.2389ns	-0.3009ns	0.0379ns	-0.3114ns	-0.3349ns	-0.0184ns	-0.3723ns	-0.2087ns	-0.1280ns	1

Significance: * 5% probability; ** 1% probability; ns: not significant.
Variables: plant height (ALP), height of first reproductive branch (APR), total number of vegetables per plant (NLP), vegetables with one grain (LUG), vegetables with two grains (LDG), vegetables with three grains (LTG), vegetables with four grains (LQG), total number of grains per plant (GTP), number of commercial grains per plant (GCP) and Yield (REN).

The REN did not present a correlation with the other variables analyzed (Table 5), different from that reported by Zuffo et al. (2018), indicating a positive and significant association between grain REN and other variables. The authors commented that the correlation coefficient measures only the linear relationships, but there may be high determination among the variables of the nonlinear type. Pearson's correlation coefficient is used to express the degree of association between two numerical variables (Zuffo et al., 2018). Evidencing the correlation between characters facilitates the identification of promising genotypes and makes it possible to use their results for an indirect selection (Carvalho et al., 2015).

In general, the correlations between the morphological characters LQG, ALP and APR showed a significant correlation with a high positive magnitude among them, with a higher intensity between ALP and APR. Positive correlation was also diagnosed between GTP and GCP. The other correlations were not significant (Figure 3).

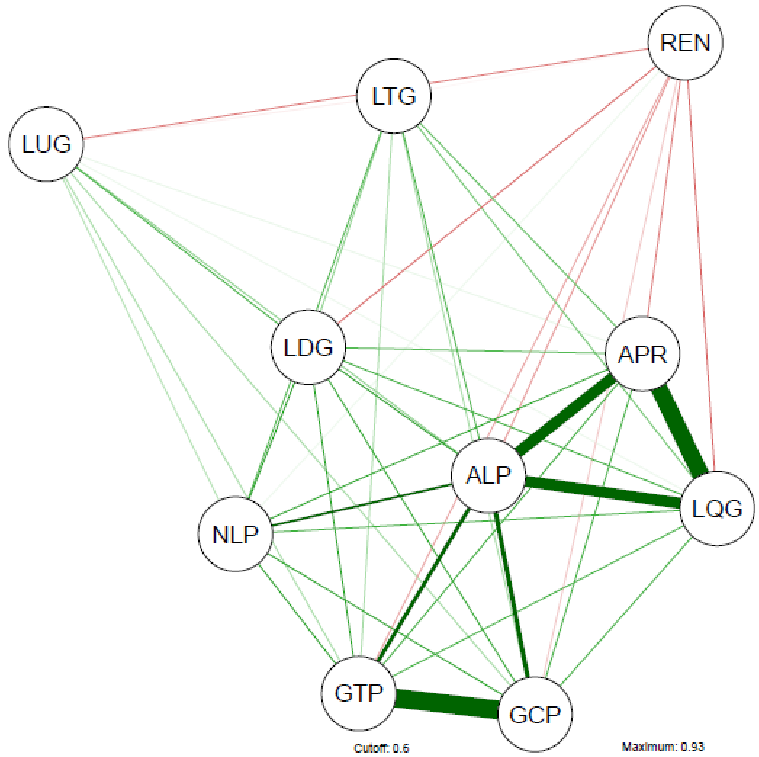

Figure 3. Network of phenotypic correlations of characteristics of soybean cultivars. The red lines represent negative correlations and the green ones represent positive corrections. The line thickness is proportional to the magnitude of the correlation. Plant height - ALP, height of first reproductive branch (APR), total number of vegetables per plant (NLP), vegetables with one grain (LUG), vegetables with two grains - LDG, vegetables with three grains (LTG), vegetables with four grains (LQG), total number of grains per plant (GTP), number of commercial grains per plant (GCP) and yield (REN). Mineiros-GO, UNIFIMES, Brazil, 2019.

Comparing the results obtained by the multivariate analysis and the results obtained by the Tukey grouping method, it can be verified that there was good agreement between the two methods in the constitution of the groups. The method used and the statistical procedure adopted allowed to differentiate the soybean cultivars in a short period of time (Texeira et al., 2008). As well as the interaction among the analyzed variables.

CONCLUSIONS

Potamol Plus® organomineral fertilizer applied foliar at 30 (50%) and 45 (50%) days after sowing did not increase the productive performance of soybean cultivars M7739, M8372 and TMG7062.

The cultivars M7739 and TMG7062 presented high yields (yield ≥ 70 bag ha^{-1}), and could be indicated for cultivation in the region of Southwest Goiania, more precisely in the municipality of Mineiros.

Plant height exerts a strong effect on soybean yield components, demonstrating the importance of multivariate analysis in the assay.

REFERENCES

Barbosa, D. D. A., Gargioni, E., Barbosa, G., Molinari, D. C., Fuganti-pagliarini, R., Regina, S., … Mertz-, L. M. (2022) Activated charcoal added to tissue culture media increases genotype-dependent biomass production in soybean. *Agronomy Science and Biotechnology*, 8, 1–11. https://doi.org/10.33158/ASB.r156.v8.2022

Bhering, L. L. (2017) Rbio: A tool for biometric and statistical analysis using the R platform. *Crop Breeding and Applied Biotechnology*, *17*(2), 187–190. https://doi.org/10.1590/1984-70332017v17n2s29

Carvalho, I. R., Souza, V. Q., Nardino, M., Follmann, D. N., Schmidt, D., & Baretta, D. (2015) Correlações canônicas entre caracteres morfológicos e componentes de produção em trigo de duplo propósito. *Pesquisa Agropecuaria Brasileira*, *50*(8), 690–697. https://doi.org/10.1590/S0100-204X2015000800007

Dalchiavon, F. C., & Carvalho, M. P. (2012) Correlação linear e espacial dos componentes de produção e produtividade da soja. *Semina: Ciencias Agrarias*, *33*(2), 541–552. https://doi.org/10.5433/1679-0359.2012v33n2p541

Diesel, P., Silva, C. A. T., Silva, T. R. B., & Nolla, A. (2010) Molibdênio e cobalto no desenvolvimento da cultura da soja Molybdenum. *Revista Agrarian*, *3*(8), 169–174.

Dourado Neto, D., Dario, G. J. A., Martin, T. N., Silva, M. R., Pavinato, P. S., & Habitzreiter, T. L. (2012) Adubação mineral com cobalto e molibdênio na cultura da soja. *Semina: Ciências Agrárias*, *33*(0). https://doi.org/10.5433/1679-0359.2012v33supl1p2741

Embrapa - Empresa Brasileira de Pesquisa Agropecuária. (2009) *Manual of soil analysis methods*. Brasília, DF: Embrapa. https://www.embrapa.br/soja/cultivos/soja1/dados-economicos

Fernandes, F. A., Arf, O., Binotti, F. F. S., Romanini Junior, A., Sá, M. E., Buzetti, S., & Rodrigues, R. A. F. (2005) Foliar molybdenum and nitrogen in common bean cultivated in the no - tillage system. *Acta Scientiarum*. Agronomy, 27 (1), 7-15. https://www.cabdirect.org/cabdirect/abstract/20053197160

Ferreira, D. F. (2011) Sisvar: a computer statistical analysis system. *Ciência e Agrotecnologia*, *35*(6), 1039–1042. https://doi.org/10.1590/s1413-70542011000600001

Ferreira, L. L., Carvalho, I. R., Lautenchleger, F., Martins, T. S., Carvalho, P. R. V., Amaral, G. C. L., … Loro, M. V. (2022a) Soybean seedling performance in diferente seed treatments. *Agronomy Science and Biotechnology*, *8*, 1–11. https://doi.org/10.33158/asb.r149.v8.2022

Ferreira, L. L., José, Â., Carvalho, I. R., Fernades, M. D. S., & Lautenchleger, F. (2022b) Correlations and canonical variables applied to the distinction of soybean cultivars in a tropical environment. *Agronomy Science and Biotechnology*, *8*, 1–12. https://doi.org/https://doi.org/10.33158/ASB.r146.v8.2022

Gazola, D., Zucareli, C., & Silva, R. R. (2017) Foliar application of amino acids as a supplement to nitrogen fertilization in wheat cultivars. *Scientific Journal,* 45(2): 182-189.

Gazola, D., Zucareli, C., & Silva, R. R. (2017) Aplicação foliar de aminoácidos como suplemento à adubação nitrogenada em cultivares de trigo. *Científica*, *45*(2), 182. https://doi.org/10.15361/1984-5529.2017v45n2p182-189

Hermes, E. C. K., Nunes, J., & Nunes, J. V. D. (2015) Influência do bioestimulante no enraizamento e produtividade da soja. *Revista cultivando o saber*, Edição Especial, 33-42.

Hipolito, J. L., & Borges, W. L. B. (2017) Nutritional and hormonal management of soybean crop for high yields. *Revista Nucleus*, 27-34.

Köppen, W., & Geiger, R. (1936) *Handbook of Climatology*. Berlin: Gebrüder Borntraeger.

Loro, M. V., Carvalho, I. R., Silva, J. A. G., Moura, N. B., Hutra, D. J., & Lautenchleger, F. (2021) Artificial Intelligence and Multiple Models Applied To Phytosanitary and Nutritional Aspects That Interfer in the Physiological Potential of Soybean Seeds. *Brazilian Journal of Agriculture - Revista de Agricultura*, *96*(1), 324–338. https://doi.org/10.37856/bja.v96i1.4258

Mambrin, R. B., Sausen, D., Moura, D. S., Carvalho, I. R., Szareski, V. J., & Lautenchleger, F. (2020) Selection of bean lineages regarding the use and response to phosphorus available in nutrient solution. *Research, Society and Development*, 9(11), 1-23. e3999118850-e3999118850.

Martins Filho, S., Sediyama, C. S., Cruz, C. D., Sediyama, T., & Gomes, J. L. L. (2015) Canonical variables in the evaluation of soybean resistance (*Glycine max* (L.) Merrill) to *Cercospora sojina* Hara. *Revista Ceres*, 39(221).

Moraes, L. M. F., Lana, R. M. Q., Mendes, C., Mendes, E., Monteiro, A., & Alves, J. F. (2019) Redistribution of molybdenum applied by foliage at different times in the soybean crop. *Ciência e Agrotecnologia*, 32(5): 1496-1502.

Nakao, A. H., Vazquez, G. H., Oliveira, C. O., Silva, J. C., & Souza, M. F. P. (2014) Foliar application of molybdenum in soybean: effects on yield and physiological quality of the seed. *Encyclopedia Biosphere*, 10(18): 343-352.

Nardino, M., Baretta, D., Carvalho, I. R., Follmann, D., Konflanz, V. A., Souza, V. Q., Oliveira, A. C., & Maia, L. C. (2016) Correlações fenotípica, genética e de ambiente entre caracteres de milho híbrido da Região Sul do Brasil. *Revista Brasileira de Biometria*, 34(3), 379-394.

Oliveira, C. O., Pinto, C. C., Garcia, A., Bettiol, J. V. T., Sá, M. E., & Lazarini, E. (2017) Produção de sementes de soja enriquecidas com molibdênio. *Revista Ceres*, *64*(3), 282–290. https://doi.org/10.1590/0034-737X201764030009

Picolli, E. S., Marchioro, V. S., Bellaver, A., & Bellaver, A. (2009) Application of amino acid based products in wheat. *Cultivating Knowledge*, 2(1): 141-148.

Possenti, J. C., & Villela, F. A. (2010) The effect of molybdenum applied by foliar spraying and seed treatment on the physiological potential and roductivity of soybean seeds. *Revista Brasileira de Sementes*, *32*(4), 143–150. https://doi.org/10.1590/s0101-31222010000400016

Prado, M. R. V. S., Weber, O. L., Moraes, M. F., Santos, C. L. R., & Tunes, M. S. (2016) Fertilizante organomineral líquido contendo substâncias húmicas em soja cultivada sob estresse hídrico]. *Revista Brasileira de Engenharia Agricola e Ambiental*, *20*(5), 408–414. https://www.scopus.com/inward/record.uri?eid=2-s2.0-84964889688&doi=10.1590%2F1807-1929%2Fagriambi.v20n5p408-414&partnerID=40&md5=47e26415398b543c7b282a7d1570374e

Ribeiro, F. C., Silva, J. I. C., Silva, E. L., Erasmo, E. A. L., & Alves, J. B. P. (2014) Response of soybean cultivar MSOY 8766 RR submitted to the application of fertilizers via seed treatment and foliar via at different times. *Cultivating Knowledge*, 7(2): 163-175.

Rossi, R. L., Silva, T. R. B., Trugilo, D. P., & Cristina, A. (2012) Leaf fertilization with molybdenum in soybean crop. *Journal of Agronomic Sciences*, 1(1), 12-23.

Santos, E. R., Barros, H. B., Ferraz, E. C., Cella, A. J. S., Capone, A., Santos, A. F., & Fidelis, R. R. (2012) Divergência entre genótipos de soja, Cultivados em várzea irrigada. *Revista Ceres*, *59*(6), 755–764. https://doi.org/10.1590/s0034-737x2011000600012

Sfredo, G. J., & Oliveira, M. C. N. (2010) *Soybean: molybdenum and cobalt.* Londrina: Embrapa Soja*,* Documentos / Embrapa Soja, 322.

Silva, J. A. G., Mamann, Â. T. W., Scremin, O. B., Carvalho, I. R., Pereira, L. M., Lima, A. R. C., … Norbert, L. (2020) Biostimulants in the Indicators of Yield and Industrial and Chemical Quality of Oat Grains. *Journal of Agricultural Studies*, *8*(2), 68. https://doi.org/10.5296/jas.v8i2.15728

Texeira, L. R., Braccini, A. L. E., Sperandio, D., Scapim, C. A., Schuster, I., & Viganó, J. (2008) Avaliação de cultivares de soja quanto à tolerância ao estresse hídrico em substrato contendo polietileno glicol. *Acta Scientiarum - Agronomy*, *30*(2), 217–223. https://doi.org/10.4025/actasciagron.v30i2.1731

Trentin, R., Heldwein, A. B., Streck, N. A., Trentin, G., & Da Silva, J. C. (2013) Subperíodos fenológicos e ciclo da soja conforme grupos de maturidade e datas de semeadura. *Pesquisa Agropecuaria Brasileira*, *48*(7), 703–713. https://doi.org/10.1590/S0100-204X2013000700002

Treter, R. J., Carvalho, I. R., Hutra, D. J., Loro, M. V., Cavinatto, M., Lautenchleger, F., & Sfalcin, I. C. (2021). Symptoms and interrelationships of macro and micronutrients available for soybean. *Agronomy Science and Biotechnology*, *8*, 1–15. https://doi.org/10.33158/asb.r150.v8.2022

Vergara, R., Carvalho, I. R., Gadotti, G. I., Soares, V. N., Szareski, V. J., Loro, M. V., … Villela, F. A. (2021) Canonical correlation and agronomic performance of quinoa (*Chenopodium quinoa* Willd). *Revista Brasileira de Agropecuária Sustentável*, 11(1), 252-258.

Zobiole, L. H. S., Oliveira, R. S., Constantin, J., & Biffe, D. F. (2011) Prevention of RR soybean injuries caused by exogenous supply of aminoacids. *Planta Daninha*, *29*(1), 195–205. https://doi.org/10.1590/S0100-83582011000100022

Zuffo, A. M., Ribeiro, A. B. M., Bruzi, A. T., Zambiazzi, E. V., & Fonseca, W. L. (2018) Correlations and track analysis in soybean cultivars grown at different plant densities. *Agronomic Culture: Journal of Agricultural Sciences*, 27(1): 78-90.