












RESEARCH ARTICLE

Agronomic performance of soybean genotypes supplemented with micronutrients via leaf

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ABSTRACT

Foliar fertilization, mainly with micronutrients, is one of the tools most recommended by researchers and professionals to growers in order to correct nutritional imbalances in crops. This work aimed to evidence the agronomic performance of soybean genotypes supplemented via leaf with micronutrients and to identify the relationships between characters. The experimental design used was in randomized blocks in a 3x5 factorial scheme corresponding to three soybean genotypes ANTA82, CD2737 and N7902 and five concentrations of leaf supplement, Triplus Anuais[®] with its guarantees of phosphorus 2%, boron 3.4%, molybdenum 1 % and nickel 0.35%. The leaf supplement was applied in a single dose during pre-flowering (0, 300, 600, 900 and 1200 ml ha⁻¹). The variables were analyzed after the plants were harvested at the physiological maturation stage and the data were submitted to the assumptions of the statistical models. Analysis of variance was carried out with subsequent splitting with grouping of Scott-Knott means and polynomial regression models, in addition to simple correlation and path analysis, with grain yield as the main variable and the other variables as explanatory. The different performances of soybean genotypes were verified when submitted to foliar supplementation of micronutrients with adjustment of the most efficient dose for yield, through the regression curves. That supplementation via leaf with micronutrients in the pre-flowering phase was efficient for all soybean genotypes analyzed. However, it is worth mentioning the high yields obtained by the NS 7209 IPRO genotype at a dose of 514.23 ml ha⁻¹. The selection of productive soybean genotypes can be performed indirectly by the number of legumes, grains per plant and the weight of a thousand grains.

Keywords: Correlations, *Glycine max*, Leaf nutrition, Savanna, path analysis, regression.

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INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) originating in China is the Fabaceae of greatest economic expression in the world. Since the domestication of soybeans, farmers and entrepreneurs have been interested in its large-scale production, aiming at profit and taking advantage of its great energetic, nutritious and commercial potential. Although soybean is not considered a staple food, it is one of the most important crops in the world, mainly for the supply of protein and vegetable oil.

The 1970's were a milestone for the development of soybean in the country. The green revolution in agriculture made possible the emergence and dissemination of new seeds and agricultural practices that included mechanization, use of fertilizers and pesticides, which led to increased yield and, consequently, production. In the same decade, soybean gained great visibility in Brazil, causing great impacts on the economy and on the expansion of its growing areas to other regions, especially the cerrado (Alves and Tedesco, 2016).

Soybean represents one of the most consumed grains in Brazil, standing out as the agricultural crop that has grown the most in the last three decades. As a result, a favorable scenario is projected for soybean in world agriculture, both for growers and investors. This fact is due to the high profitability of this activity, however, it is worth mentioning that the factors of production must be observed according to the requirements of the crop, especially the nutritional one (Barbosa, 2018).

Brazil in the 2020/2021 crop season cultivated an area of approximately 38 million hectares of soybeans, and a production of around 135 million tons of the grain. Brazilian production is led by the states of Mato Grosso (27.3%), Paraná (16.3%), Rio Grande do Sul (14.5%), Goiás (9.9%), Mato Grosso do Sul (8.2%), Minas Gerais (4.4%) and Bahia (4.4%). Regarding yield, in this same season, Mato Grosso stood out with 32.30 million tons, Paraná with 19.17 million tons, Rio Grande do Sul with 17.15 million tons and Goiás with 11.78 million tons. These four states together accounted for 67.6% of the national production (Companhia Nacional de Abastecimento (Conab, 2021).

The increased demand for food and agricultural products makes the use of fertilizers more precisely inevitable, aiming at high grain yields. The use of fertilizers in agriculture provided a revolution in food production with a great positive impact on yield. Fertilizers are found on the market with different nutrients, chemical formulas and efficiency levels.

Among the factors of production that affect soybean crop yield, fertility stands out as essential for the establishment of the plant's productive potential. So nutrients are extremely important for the success of a crop. Both macronutrients and micronutrients play a role in the realization of several vital factors in the plant, associated with climatic conditions and water availability, which directly determine the germination, emergence, growth, development and production of soybean plants (Farias et al., 2009).

In order to raise the yield levels of soybean crops, new technologies are developed. Research with growth regulators and hormones associated with nutrients aims to accelerate the development of plants, which would result in increased yield (Silva et al, 2018a). Recent studies have shown positive effects of micro and macronutrient supplementation on several crops such as cassava (Bester et al., 2020), beans (Ferreira et al., 2021), oats (Silva et al., 2019), corn (Ferreira et al., 2021), soybean (Frota et al., 2021) and *Physalis peruviana* (Pedó et al., 2018).

In this context, foliar fertilization, mainly with micronutrients, is one of the tools most recommended by companies to rural growers in order to correct nutritional imbalances in crops. Nutritional balance is a key factor to obtain improved seed quality and, consequently, increases in soybean yield (Suzana et al., 2012). In view of the above, this work aimed to evidence the agronomic performance of soybean genotypes supplemented via leaf with micronutrients and to identify the relationships between characters.

MATERIAL AND METHODS

The study was conducted at the Luís Eduardo de Oliveira Salles Experimental Farm, located in the county of Mineiros, GO, Brazil. Geographically it is at 17° 58' S latitude and 45° 22' W longitude and approximately 800 m altitude. The experimental area is classified as Aw type (hot to dry) (Köppen and Geiger, 1936).

Soil analysis was carried out in the 0-20 cm layer according to the methodology proposed in the Empresa Brasileira de Pesquisa Agropecuária [Embrapa] (2009). The soil was classified as a Quartzarenic Neosol (Entisol) (Embrapa, 2013). The following characteristics were evaluated: hydrogen potential 5.7; calcium 3.0, magnesium 0.8, aluminum 0.2, hydrogen + aluminum 2.0, cation exchange capacity 5.9, in $\text{cmol}_c \text{dm}^{-3}$; potassium 53, phosphorus 59, sulfur 1.7, boron 0.2, copper 1.4, iron 51, manganese 23.0, zinc 8.3, sodium 1.5, in mg dm^{-3} ; clay 223, silt 50, sand 728, organic matter 20.0 and organic carbon 12.0, in g dm^{-3} .

The experimental design used was in randomized blocks in a 3x5 factorial scheme corresponding to three soybean genotypes (Anta82, CD2737 and N7902), and five doses of micronutrients via leaf supplement Triplus Anuais® (0, 300, 600, 900 and 1200 ml ha^{-1}), in 4 repetitions, totaling 15 treatments and 60 experimental units. Each plot was dimensioned with four rows spaced 0.5 m and 6 m long, totaling 3 m^2 . The main morpho-agronomic characteristics of the soybean genotypes were described in Table 1.

Table 1. Main morpho-agronomic characteristics of soybean genotypes. UNIFIMES, Mineiros-GO, Brazil, 2020.

Cultivar		Maturity group	Growth	Cycle (Days after emergence)
Commercial	Common			
ANTA 82	ANTA82	7.4	Semideterminate	127-132
CD 2737 RR	CD2737	7.3	Indeterminate	112-114
NS 7209 IPRO	N7902	7.3	Indeterminate	103-113

The soil preparation was carried out with harrowing and plowing the area at a depth of 20 cm. Sowing of soybeans occurred on November 15 of 2017, with 16 seeds distributed per linear meter in the furrow (population of 320,000 plants ha^{-1}). Simultaneously, 205 kg ha^{-1} of Phusium® was applied as a phosphate source. The top dressing was carried out on November 28 of 2017 applying 116 kg KCl ha^{-1} . As a foliar supplement of micronutrients, Triplus Anuais® was used with its guarantees of phosphorus 2%, boron 3.4%, molybdenum 1% and nickel 0.35%. The leaf supplement was applied in a single dose in the phenological phase R1: pre-flowering with the appearance of the first buds, using a cone-type 2.0 bar constant pressure (CO_2) knapsack sprayer, with a spray volume of 335 L ha^{-1} , in the mild hours of the day (7 - 9 am), with an mean ambient temperature of 25°C, relative humidity above 60% and

winds below 5 km h⁻¹. The cultural treatments necessary for the control of weeds, pathogens and insects were carried out whenever necessary, following the agronomic knowledge of the researchers.

The variables were analyzed after the harvest on March 28, 2018. To this end, it was determined: plant stand (STD) in unit per linear meter; plant height (PH) in meter, and first reproductive node height FRH in centimeter, with measuring tape; pods with one grain (POG) in %, pods with two grains (PTWG) in %, pods with three grains (PTHG) in %, pods with four grains (PFG) in %, pods per plant (PPP) in unit, and grains per plant (GPP) in unit, by counting the pods with the aid of a scientific calculator, determining the values; thousand grain mass (TGM) in grams, and yield (YI) in sc ha⁻¹, by means of a scale with four decimal places of precision, correcting the weight to 13% moisture of the grains.

The data were submitted to the assumptions of the statistical model, verifying normality (Shapiro and Wilk, 1965) and homogeneity of variances (Steel et al., 1997). Afterwards, the analysis of variance was carried out in order to identify the interaction between the soybean genotypes x leaf supplement, when verifying significant interaction these were broken down to the simple effects by the Scott-Knott means cluster test, at 5% probability.

Then, the description of the variables was performed according to the different doses of leaf supplementation, performing polynomial regression, testing the linear and quadratic models and, choosing the significant models, which will present the highest correlation value with the means, observing the significance of the F test. Subsequently, the variables were subjected to linear correlation in order to understand the trend of association, with the significance based on the t test.

The path analysis was performed from the phenotypic correlation matrix. It was considered YI as the dependent variable and STD, PH, FRH, POG, PTWG, PTHG, PFG, PPP, GPP and TGM as explanatory. The presence of high multicollinearity among the data was identified, and the path analysis was carried out under multicollinearity (Montgomery et al., 2021), with subsequent adjustment of the k factor to the diagonal elements of the correlation matrix. The analyzes were performed in the R Core Team (2020).

RESULTS AND DISCUSSION

The summary of the analysis of variance with mean square MS and significance by the F test, revealed significant interaction ($p \leq 0.05$) between soybean genotypes x leaf supplement in the variables of pods with one grain POG, pods with two grains PTWG, pods with three grains PTHG, pods with four grains PFG, pods per plant PPP, grains per plant GPP, thousand grain mass TGM and yield YI ($p \leq 0.01$) and for first reproductive node height FRH ($p \leq 0.05$). Changes in the means of soybean components using leaf supplementation were also reported by Batista et al. (2017), Silva et al. (2017), Hermes et al. (2015), and Silva et al. (2015).

The research demonstrates the different performances of the soybean genotypes when submitted to foliar supplementation with micronutrient and adjustment of the efficient dose for the yield, through the regression curves. The level of correlations between the characters was also described, observing the peer-to-peer relationship and their individual contributions to soybean grain yield.

In the break up of the interaction, it was observed that FRH in CD2737 obtained the highest means in all doses, reaching values of 6.08 cm. The same trend followed for POG in the ANTA82 genotype with an mean of 12.02 units, and in PTWG with the N7902 genotype, which stood out among the others with an mean of 51.77 units (Table 2). Results found in the works Batista et al. (2017), analyzed that for FRH there

was no interaction between the factors of foliar supplementation, however with different soybean genotypes. For Lemos et al. (2011) FRH is directly related to PH, in which these characteristics can be influenced by the environment or cultural practices and are strongly related to the genetic load of soybean genotypes.

Table 2. Summary of analysis of variance 'calculated MS and CV (%)' for STD stand, plant height PH, first reproductive node height FRH, pods with one grain POG, pods with two grains PTWG, pods with three grains PTHG, pods with four grains PFG, pods per plant PPP, grains per plant GPP, thousand grain mass TGM and yield YI of soybean genotypes supplemented via leaf. UNIFIMES, Mineiros-GO, Brazil, 2020.

SV	DF	STD	PH	FRH	POG	PTWG	PTHG	PFG	PPP	GPP	TGM	YI
G x LS	8	1.60 ^{ns}	0.00 ^{ns}	0.75*	17.25**	22.34**	26.19**	0.06**	65.14**	512.35**	199.63**	62.39**
Genotypes (G)	2	30.33**	0.14**	8.56**	46.78**	1413.24**	1250**	6.86**	926.38**	3395.16**	3601.28**	1527.59**
Leaf supplement (LS)	4	9.10**	0.00 ^{ns}	1.35**	18.21**	51.71**	82.52**	0.28**	442.13**	2849.16**	402.02**	310.88**
Blocks	3	0.61 ^{ns}	0.1**	0.78 ^{ns}	0.58 ^{ns}	1.78 ^{ns}	1.52 ^{ns}	0.02 ^{ns}	5.25 ^{ns}	36.45 ^{ns}	2.77 ^{ns}	6.82 ^{ns}
Error	42	0.95	0.00	0.34	1.16	2.36	2.74	0.02	5.75	38.26	10.20	13.86
CV	-	6.91	4.02	11.03	11.21	3.65	3.48	21.62	4.20	4.53	1.87	8.29

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

The most prominent genotype at all doses for variable PTHG was CD2737, reaching an mean of 54.60 units. And for the variable PFG to ANTA82 with results of 1.37 units (Table 2). A lower result was found in the study by Silva et al. (2018b) for PTHG with an mean of 28.68 units, however, with high means for PFG expressed in 4.77 units (Table 2). Variations in the number of grains per pod are attributed to genetic loads, climatic conditions and can be answered by products applied via leaves, with hormonal or even nutritional effects.

For the variables PPP, GPP, TGM and YI, the most prominent genotype was N7902, reaching the highest means in all doses compared to the others with mean values of 64.47 units, 148.52 units, 185.21 g and 54.18 sc ha⁻¹, respectively (Table 3). Values that corroborate the results obtained by Batista et al., (2017) when analyzing that the studied genotypes showed differences between them in the TGM and YI variables. It was observed that supplementation via leaf proved to be viable in soybean crop, achieving higher grain yields and providing greater profit in growing the crop. Satisfactory results were verified using foliar fertilizer, with a 10.2% increase in yield (Domingos et al., 2015). Ferreira et al. (2021), in a study with beans, showed a positive effect of foliar supplementation on productive traits. The increase in the number of grains per plant is one of the fundamental characteristics for increasing the yield of soybean, this increase can be obtained by a better nutritional supply of the soybean plant throughout its cycle (Fernandez et al., 2009).

The genotypes ANTA82 and N7902 did not show changes in their respective plant stands when submitted to foliar fertilizer doses, however CD2737 had the maximum plant stand at the dose of 540.50 ml ha⁻¹ with 14.87 plants per linear meter (Figure 1A). The plant height PH was not altered by the presence of leaf fertilizer, the means were: ANTA82 (0.96 m), CD737 (1.07 m) and N7902 (0.90 m) (Figure 1B).

For the first reproductive node height FRH, it was observed that CD737 did not change its means, however, ANTA82 and N7902 corresponded to the doses of 191.17 and 551.33 ml ha⁻¹, with heights of 4.61 and 5.12 cm, respectively (Figure 1C). The result of the experiment was below that found in the literature, such as the work carried out by Bertolin et al. (2010) who obtained through leaf fertilization at the soybean stage R1, the FRH of 15.67 cm. To perform mechanical harvesting, it is desirable that soybean genotypes that have a first reproductive node height equal to or greater than 10 cm and a plant height equal to or greater than 65 cm.

Table 3. Breakdown of the genotype x dose interaction for the first reproductive node height FRH, pods with one grain POG, pods with two grains PTWG, pods with three grains PTHG, pods with four grains PFG, pods per plant PPP, grains per plant GPP, thousand grains mass TGM and yield YI of soybean genotypes supplemented via leaf. UNIFIMES, Mineiros-GO, Brazil, 2020.

Dose	FRH			POG			PTWG		
	ANTA82	CD2737	N7902	ANTA82	CD2737	N7902	ANTA82	CD2737	N7902
0	4.40 B	6.35 A	4.27 B	8.67 B	10.38 A	7.50 B	41.23 B	36.95 C	49.49 A
300	4.83 B	5.90 A	4.82 B	10.52 A	8.06 B	4.97 C	37.61 B	35.62 B	47.94 A
600	5.76 B	6.60 A	5.33 B	10.71 A	11.16 A	9.37 B	36.58 B	32.80 C	49.40 A
900	5.12 A	5.43 A	5.21 A	13.81 A	6.33 C	10.77 B	38.33 B	39.02 B	55.97 A
1200	5.61 A	6.12 A	4.47 B	13.04 A	9.25 B	9.93 B	37.33 B	37.51 B	56.06 A
	PTHG			PFG			PPP		
0	48.56 B	52.06 A	42.99 C	1.53 A	0.59 B	0.00 C	45.69 B	41.95 C	61.98 A
300	50.45 B	58.65 A	43.57 C	1.40 A	0.75 B	0.42 C	53.50 C	57.54 B	67.27 A
600	51.22 B	55.44 A	40.96 C	1.47 A	0.59 B	0.27 C	55.84 C	67.94 B	74.25 A
900	46.77 B	54.03 A	33.21 C	1.08 A	0.60 B	0.04 C	50.81 C	57.37 B	61.03 A
1200	48.58 B	52.85 A	34.36 C	1.03 C	0.37 B	0.00 C	49.27 B	54.83 A	57.83 A
	GPP			TGM			YI		
0	110.99 B	101.88 C	145.96A	167.24 B	182.85 A	185.65 A	36.71 B	39.66 B	53.05 A
300	129.89 C	146.81 B	158.99A	160.82 B	165.01 B	185.02 A	39.15 C	45.34 B	55.23 A
600	135.9 B	166.96 A	172.36A	153.92 B	157.70 B	178.18 A	41.03 C	48.35 B	62.89 A
900	119.47 B	142.82 A	135.81A	156.77 C	178.37 B	185.19 A	38.13 B	52.55 A	50.12 A
1200	117.08 B	133.98 A	129.49A	155.15 B	155.94 B	192.02 A	29.04 B	32.94 B	49.61 A

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

POG showed an increasing linear effect for ANTA82 and N7902. CD2737 did not obtain significance with an mean of 8.42 (Figure 2A). In the study by Hermes et al. (2015) the use of bioregulators through foliar fertilization on soybeans promotes improvements in plant components, such as more uniform filling of grains and, consequently, higher yield. The N7902 showed an increasing linear behavior for PTWG (Figure 2B).

Approximate value was found in the, CD2737 obtained 55.59% PTHG with 548.59 ml ha⁻¹ of the foliar fertilizer, whereas N7902 had a linear decreasing behavior and ANTA82 was not significant (Figure 2C).

In Figure 2D ANTA82 showed a decreasing linear effect for PFG, however, N7902 and CD2737 found a normal quadratic effect with the doses of 413.50 and 191.17 ml ha⁻¹, respectively. Pods with only one grain is not a characteristic improved by geneticists, just as, for growers, in practice the mean is pods with 2.5 grains.

The study by de Batista et al., (2017), presented a significant result for the

application of leaf nutrition for soybean PH, reaching 122.8 cm when the product was applied at the flowering stage. According to the experiment by Hermes et al. (2015), found that the influence of bioregulators on soybean development induces the plant to greater growth, which promotes greater plant height. However, in the work of Bernardes et al. (2019), the molybdc leaf fertilization did not alter the PH and FRH of the soybean.

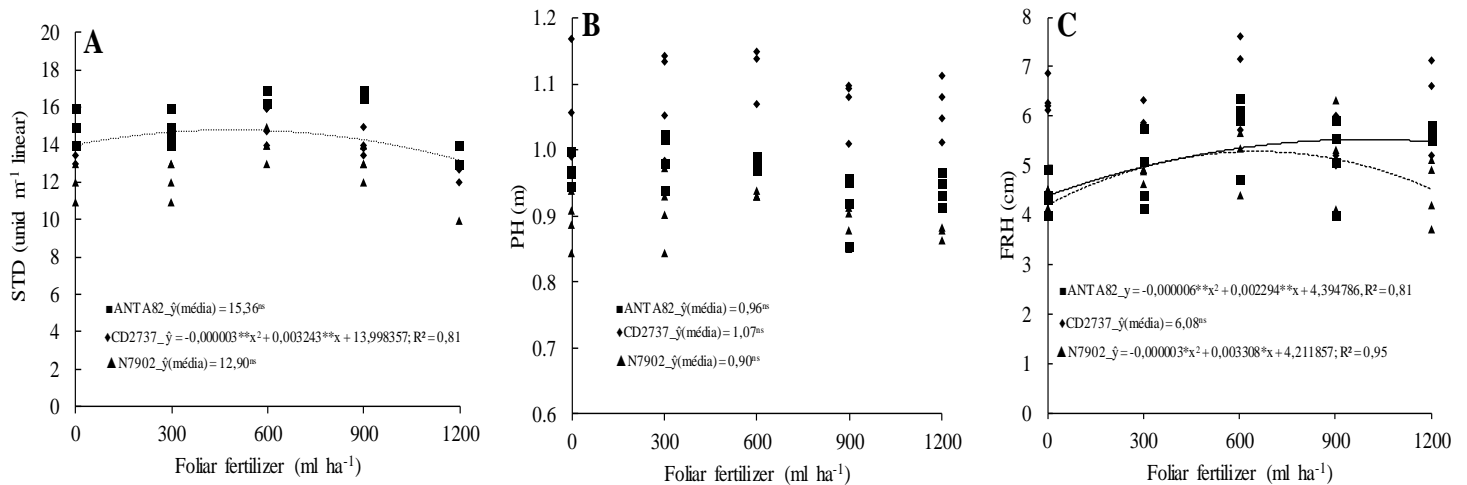


Figure 1. Stand STD (A), plant height PH (B) and first reproductive node height FRH (C), of soybean genotypes supplemented via leaf. UNIFIMES, Mineiros-GO, Brazil, 2020.

In the PPP, a quadratic effect was found for all genotypes, with peaks of 54.66, 64.72 and 69.85 PPP at doses 627.02, 700.72 and 509.27 ml ha⁻¹, in that order (Figure 2E). Corroborating with Silva et al. (2015), Malavolta et al. (2002), Bevilaqua et al. (2002) and Souza et al. (2008). Albrecht et al., (2011) emphasize that foliar supplementation with bioregulators promotes the development of plants as well as their soybean production components, promoting a significant increase in the crop's YI and PPP.

Maximum points were also observed in all genotypes for GPP, with ANTA82 (131.88 GPP - 602.10 ml ha⁻¹), CD2737 (160.79 GPP - 680.51 ml ha⁻¹) and N7902 (162.50 GPP - 469.13 ml ha⁻¹) (Figure 2F). Contradictory results are reported, probably due to the variation of gene expression, climate and methodologies applied in the field, thus, inferior results Crusciol (2013), equivalent to Bevilaqua (2002) and superior Seeds (2002), can be found in the literature with nutritional supplementation via leaf in soybean. The study by Silva et al. (2017) emphasizes that the use of a bioregulator through foliar fertilization contributes to the acceleration of the grain filling process, preventing yield losses.

In TGM, it was noted that the genotypes ANTA82, CD2737 and N7902 did not differentiate their means when fed via leaf, checking the values of 158.78, 167.97 and 185.21 g, respectively (Figure 2G). On the other hand, differences were also not seen by Malavolta et al (2002), Calonego (2011). Boaretto et al. (1997), who warn that often the non-significant results of TGM with Boron B in leaf supplementation, is attributed to the retention of the leaf cuticle or in the pectic layer of the cell wall, without realizing its metabolic function, thus overestimating the level of leaf B. However, Souza et al., (2008) reported significance under similar conditions of this work at TGM.

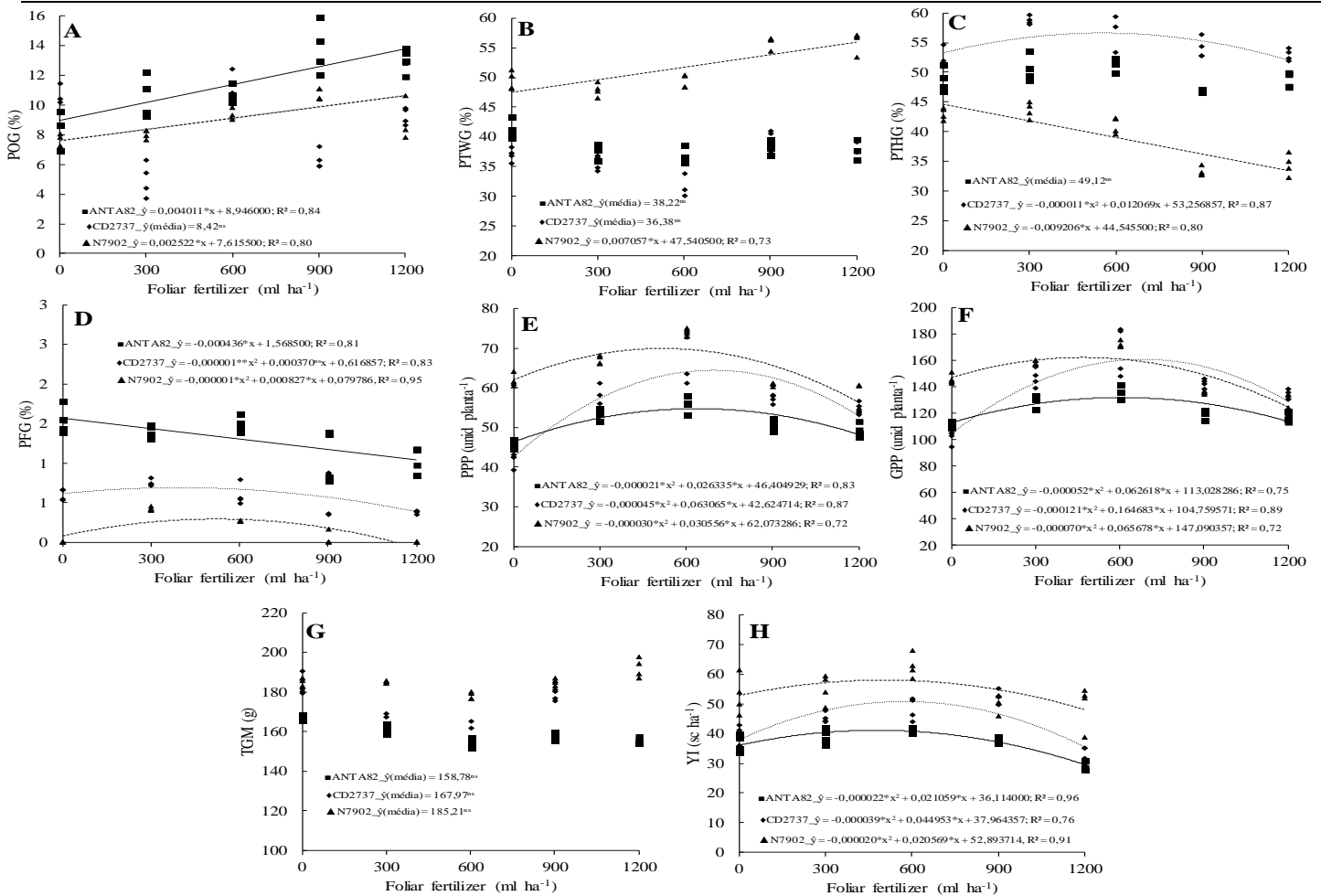


Figure 2. Pods with one grain POG (A), pods with two grains PTWG (B), pods with three grains PTHG (C), pods with four grains PFG (D), pods per plant PPP (E), grains per plant GPP (F), thousand grain mass TGM (G) and YI yield (H), of soybean genotypes supplemented via leaf. UNIFIMES, Mineiros-GO, Brazil, 2020.

The analyzes showed that all varieties expressed quadratic effects for YI. ANTA82 pointed a YI of 41.18 sc ha⁻¹ in response to a dose of 478.61 ml ha⁻¹, CD2737 RY of 50.92 sc ha⁻¹ in the dose of 576.32 ml ha⁻¹ and N7902 RY of 58.18 sc ha⁻¹ with the dose of 514.23 ml ha⁻¹ (Figure 2H). Similar data were found by Meschede (2004), Calonego (2011), Schon and Blevins (1990) and Rosolem et al. (2008). These results can be explained by Rosolem and Boaretto (1989), when stating that although the highest absorption speeds for most macronutrients occur during the R1 stage, R2 is in the post-flowering period. However, they may have a reduction in their assimilation. According to this fact and, together with the high rate of translocation in the xylem observed in the plant at this time, it generates a discussion about the efficiency of foliar fertilization in soybeans, often showing satisfactory results in relation to increased yield.

There were 33 significant correlations, 23 of which were negative. The highest magnitude was considered between PPPxGPP (0.97) and the lowest among PHxPOG (-0.26) (Figure 3). The large number of significant correlations portrays the level of interaction that exists between the characters, making it clear that there is a degree of plant balance, and that this is entirely dependent on decision making and the strategies to be adopted by the technician responsible for the crop, such as the adoption of genetics and foliar supplementation for soybean. Thus, Person's

coefficients can indicate improvement strategies for production systems, enhancing decision-making in increasing yield or reducing production costs of soybean crops.

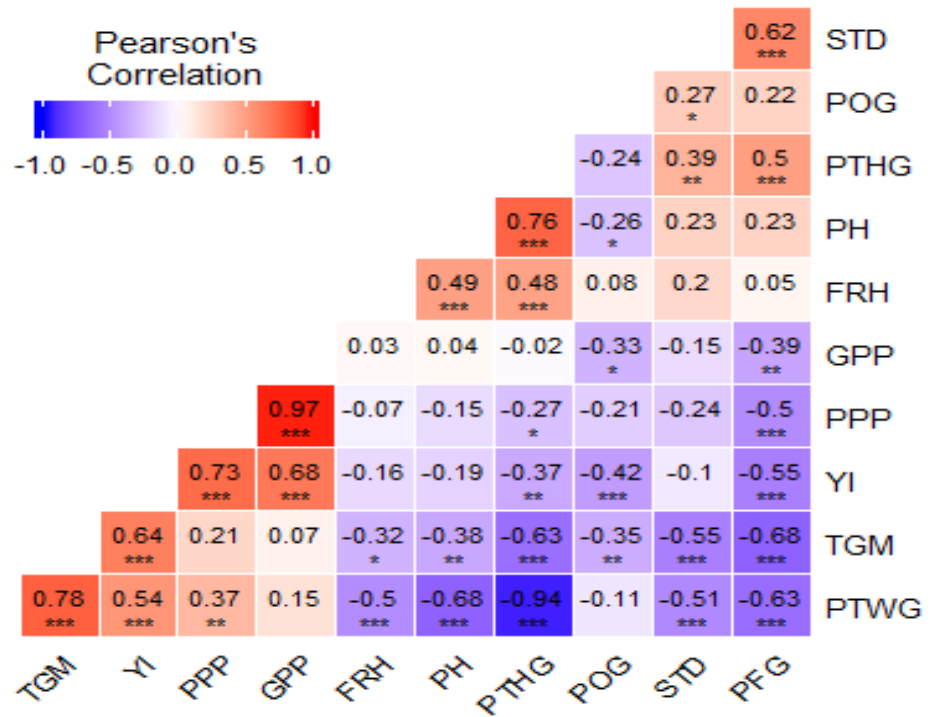


Figure 3. Simple correlation applied to soybean genotypes supplemented via leaf. UNIFIMES, Mineiros-GO, Brazil, 2020. Variables: stand STD, plant height PH, first reproductive node height FRH, pods with one grain POG, pods with two grains PTWG, pods with three grains PTHG, pods with four grains PFG, pods per plant PPP, grains per plant GPP, thousand grain mass TGM and yield YI. Significance: * 5%, ** 1% and *** 0.1 probability by t test.

Moderate multicollinearity was evidenced in the matrix of explanatory variables. However, it was decided to keep all the variables and use the correction by the constant k, thus observing weak multicollinearity. In decreasing order of magnitude, path analysis revealed a direct effect on the yield of the characters TGM, GPP, STD and PPP, the latter being negative. Similar results were also observed by Ferrari et al. (2018), in which the number of legumes per plant exhibited a direct and positive effect on grain yield. Technically, we can verify that the yield of soybean genotypes fertilized via leaf, can be increased mainly by the increase in TGM. Szarecki et al. (2016) evaluating foliar supplementation, also showed a contribution of the thousand-grain mass to soybean grain yield.

Some works contradict, as in Bernardes et al. (2018) with Zn, Nakao et al., (2018) using Zn and B and Bernardes et al. (2019) using Mo via foliar supplementation, did not diagnose influences on soybean grain yield. However, the results of this work point out that the joint foliar supplementation (phosphorus, boron, molybdenum and nickel) potentiated the grain filling providing an increase in the weight gain of the grains and consequently the yield (Table 4).

According to Domingos et al. (2015), compounds that have one or more nutrients are being used with great expressiveness in foliar fertilization. The act of replacing nutrients via the leaf is able to sustain the rate of photosynthesis for a longer period of time, promoting greater yield of soybeans.

Table 4. Estimates of the direct and indirect effects of the descriptive characters stand STD, plant height PH, first

reproductive node height FRH, pods with one grain POG, pods with two grains PTWG, pods with three grains PTHG, pods with four grains PFG, pods per plant PPP, grains per plant GPP and Thousand grain mass TGM on the yield YI of soybean genotypes supplemented via leaf. UNIFIMES, Mineiros-GO, Brazil, 2020.

Effect	Variable	STD	PH	FRH	POG	PTWG	PTHG	PFG	PPP	GPP	TGM
Direct effect	YI	0.35	0.00	-0.01	-0.10	0.00	0.00	0.02	0.40	0.31	0.72
Indirect effect	STD		0.10	0.10	0.14	-0.22	0.16	0.26	-0.09	-0.06	-0.24
Indirect effect	PH	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indirect effect	FRH	0.00	-0.01		0.00	0.01	-0.01	0.00	0.00	0.00	0.01
Indirect effect	POG	-0.04	0.03	-0.01		0.01	0.02	-0.03	0.02	0.03	0.04
Indirect effect	PTWG	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
Indirect effect	PTHG	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00
Indirect effect	PFG	0.01	0.00	0.00	0.00	-0.01	0.01		-0.01	-0.01	-0.01
Indirect effect	PPP	-0.11	-0.07	-0.02	-0.10	0.16	-0.12	-0.21		0.38	0.10
Indirect effect	GPP	-0.05	0.01	0.03	-0.11	0.06	-0.01	-0.13	0.30		0.04
Indirect effect	TGM	-0.50	-0.32	-0.33	-0.28	0.58	-0.46	-0.52	0.19	0.09	
Total		-0.33	-0.25	-0.24	-0.45	0.58	-0.41	-0.61	0.82	0.76	0.68

Determination coefficient R²: 0.97; K value used in the analysis: 2.21E-02; effect of the residual variable: 0.18; determinant of the correlation matrix between explanatory variables: 3.05E-06.

Thus, in order to achieve a good result of foliar fertilization, it is necessary, in addition to knowledge of the phenological stages of soybean and nutritional needs, it is necessary to determine the time of application of foliar fertilizer, as well as the best dose, with the aid of soil chemical analysis, leaf and visual diagnosis (Otto, 2016). Thus, as highlighted by Bernardes et al. (2019), the importance of technological advances in the knowledge of the nutritional requirements of soybean in the various production systems, provide an efficient management of the crop and increase in yield.

CONCLUSIONS

Supplementation via leaf with micronutrients in the pre-flowering phase was efficient for all soybean genotypes analyzed. However, it is worth mentioning the high yields obtained by the NS 7209 IPRO genotype at a dose of 514.23 ml ha⁻¹.

The selection of productive soybean genotypes can be performed indirectly by the number of legumes, grains per plant and the weight of a thousand grains.

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