AGRONOMY SCIENCE AND BIOTECHNOLOGY

RESEARCH ARTICLE

Triple superphosphate provides high yields of soybean genotypes in the Brazilian Cerrado

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ABSTRACT

Soybean is currently the main crop in national agribusiness. Phosphorus is a limiting nutrient in obtaining high yield, especially in the soil conditions of the Brazilian Cerrado. Thus, the objective was to analyze the effect of triple superphosphate doses on the yield of soybean genotypes under Cerrado conditions. The study was conducted in Mineiros, GO, Brazil. A randomized block design was used, in a 4x5 factorial scheme, corresponding to four soybean genotypes (AS3680, NA5909, NA7337 and TMG1180), in five levels of phosphorus (0, 100, 200, 300 and 400 kg ha^{-1} of P_2O_5) using Triple Superphosphate (41% P_2O_5 and 9% Ca), in 4 repetitions. The variables related to yield were evaluated at 146 days after sowing. Statistical analyzes were performed on the R Core Team (2019). The study revealed a significant interaction ($p \leq 0.05$) between soybean genotypes and phosphate doses, in addition to the significance ($p \leq 0.05$) in the main effects. The regressions were adjusted and estimated with optimal points close to 100 kg ha^{-1} of P_2O_5 for the different characters. Positive and negative correlations and their trends were considered among the variables for each soybean genotype, in addition to grouping the interaction of factors. The characters with the greatest contribution to raising yield levels were the thousand grain mass, plant stand and pods per plant. Using triple superphosphate as a phosphate source, it is recommended to grow the AS3680 genotype, which showed the highest yield (91.57 bag ha^{-1}) with a dose of 95.65 kg of P_2O_5 ha^{-1}, corresponding to 21.57% increments in yield.

Keywords: Correlations, phosphating, phosphorus, *glycine max* (L.), linear association, soil.

INTRODUCTION

Brazil has numerous agricultural products with significant strategic value in our economy, such as ethanol and sugar, coffee, meat and leather, products of bovine, swine and poultry origin, fruit and forest products. However, soybean [*Glycine max* (L.) Merrill] is currently the main national agribusiness commodity. In addition, it represents the most produced grain in the world. Its growth in Brazil is evidenced, where in the last 20 years the production practically quadrupled in the country. The production estimate for the 2019/2020 harvest is 125 million tons, in a grown area of around 36 million hectares (Companhia Nacional de Abastecimento [CONAB], 2020).

In the Brazilian agricultural scenario, the Cerrado has been known as a very poor chemical soil. However, with the emergence of inputs capable of correcting changes in pH and mineral deficiencies, soybean growing became possible in the region (Sousa et al., 2016). In terms of nutrition, phosphorus (P) is one of the chemical elements of high relevance, and even limiting for increasing soybean yield. According to study by Alcântara-Neto, Gravina, Silva-Souza, & Bezerra. (2010), one of the most important nutrients for grain production in the Cerrados region is P, given its low availability under natural conditions in this environment. However, when added via fertilization it provides benefits to the grower in the first year of growing. Since P can limit yield in Cerrado soils, it is necessary to use phosphate fertilizers (Broch & Ranno, 2012).

For the realization of an adequate nutrition of the soybean crop in soils of the Brazilian Cerrado, it is necessary to use high doses of phosphate fertilizers, due to the predominance of highly weathered soils, characterized by the low availability of nutrients to the plants (Santos et al., 2015). It is worth mentioning that in order to reach the maximum genetic potential of soybean cultivars, the low levels of P available in Cerrado soils are a limiting factor, which makes it necessary to raise them to ideal levels through phosphate fertilization (Gonçalves et al., 2010).

P is an integral component of important compounds in plant cells, including phosphate sugars, intermediates for respiration and photosynthesis, as well as the phospholipids that make up plant membranes, it is also a component of nucleotides used in the energy metabolism of plants (such as ATP) and DNA and RNA (Taiz et al., 2017). It decisively participates in the filling of soybeans, contributing directly to the increase in crop yield. Positive effects with phosphate fertilization are evidenced in recent studies with crops such as beans (Mambrin et al., 2021), lettuce (Ferreira et al., 2020), *Amaranthus cruentus* (Rosa et al., 2019) and potato (Sausen et al., 2021).

According to Oliveira et al. (2012), in order to obtain a better production in the soybean crop, the growers adopt several management strategies, in order to promote the increase of yield. Among the alternatives, the use of phosphate fertilizer is essential. Therefore, in view of the above, this study aimed to analyze the most efficient triple superphosphate dose for high yields in soybean genotypes under Cerrado conditions.

MATERIAL AND METHODS

The study was conducted at the Luís Eduardo de Oliveira Salles Experimental Farm, located in the countty of Mineiros, GO, Brazil. Geographically it is at 17º 58 ’S latitude and 45º 22’ W longitude and approximately 800 m altitude. Average temperature of 22.7 °C and average annual rainfall of 1695 mm, occurring mainly in spring and summer, from November to February. The experimental area is classified as Aw type (hot to dry) (Köppen and Geiger, 1936).

Soil analysis was performed in the 0-20 cm layer according to the methodology proposed in the (Empresa Brasileira de Pesquisa Agropecuária [EMBRAPA], 2009), verifying the following characteristics: hydrogen potential 5.7; calcium 3, magnesium 0.8, aluminum 0.2, hydrogen + aluminum 2, cation exchange capacity 5.9, in cmolc dm^{-3}; potassium 53, phosphorus 59, sulfur 1.7, boron 0.2, copper 1.4, iron 51, manganese 23, zinc 8.3, sodium 1.5, in mg dm^{-3}; clay 223, silt 50, sand 728, organic matter 20 and organic carbon 12, in g dm^{-3}. The soil was classified as a Quartzarenic Neosol (Entisol) (Embrapa, 2013).

The experimental design used was a randomized block, in a 4x5 factorial corresponding to four soybean genotypes (AS3680, NA5909, NA7337 and TMG1180), in five levels of phosphorus (0, 100, 200, 300 and 400 kg ha^{-1} of P_2O_5) using triple superphosphate (41% P_2O_5 and 10% Ca) as a nutritional source, in 4 repetitions, totaling 20 treatments and 80 experimental units, dimensioned with six rows spaced 0.5 m and 5 m long. Data collection was carried out on the four central lines. The main morpho-agronomic characteristics of soybean genotypes are shown in Table 1.

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

Genotype		Thousand grain mass (g)	Genetics	Maturity group	Growth habit	Cycle (days after emergence)
Common	Technical					
AS3680	AS 3680 IPRO	160	Agroeste	6.8	Indeterminate	114 to 118
NA5909	NA 5909 RR	159	Nidera	6.2	Indeterminate	110 to 125
NA7337	NA 7337 RR	171	Nidera	7.6	Indeterminate	111 to 121
TMG1180	TMG 1180 RR	136	TMG	8	Semideterminate	115 to 120

The soil tillage system was carried out with harrowing and plowing of the area on 10/07/2017. Sowing of the soybean genotypes was carried out on 10/8/2017, with 18 seeds distributed for NA7337 and TMG1180 (360,000 plants ha^{-1}), in addition to 15 seeds in the genotypes AS3680 and NA5909 (300,000 plants ha^{-1}) per meter in the furrow using a single-row planter and phosphate fertilizer in the sowing furrow, according to the treatment description. The crop treatments relevant to the control of weeds, pests and diseases, were carried out whenever necessary, using the best practices of integrated management.

The variables were analyzed at 146 days after sowing on 03/13/2018. It was determined: plant population (STD, unit per linear meter); plant height (PH, meter), and first reproductive node height (FRH, centimeter); pods with one grain (POG, %), pods with two grains (PTWG, %), pods with three grains (PTHG, %), pods with four grains (PFG, %), pods per plant (PPP, unit), and grains per plant (GPP, unit), by counting the pods. The values also determined were; thousand grain mass (TGM, grams), and yield (YI, bag ha^{-1}) by means of an analytical balance with four decimal places of precision, correcting the weight to 13% of grain moisture.

Then, the data obtained were submitted to the assumptions of the statistical model, verifying normality (Shapiro & Wilk, 1965) and homogeneity of variances (Steel et al., 1997). Afterwards, the analysis of variance was carried out in order to identify the differences between the main and simple effects of the sources of variation. Polynomial regression was also performed, analyzing the linear, quadratic models and to select the significant models that presented the highest correlation value with the means, observing the significance by the F test.

Subsequently, the variables were subjected to linear correlation in order to understand the association trend, with a significance level of 5% by the t test. The path analysis was performed from the phenotypic correlation matrix, considering 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, the path analysis was performed under multicollinearity, with subsequent adjustment of the k factor to the diagonal elements of the correlation matrix. Statistical analyzes were performed on the R Core Team (2019).

RESULTS AND DISCUSSION

The study revealed a significant interaction ($p \leq 0.05$), between the soybean genotypes and phosphate doses, in addition to the significance ($p \leq 0.05$) in the main effects. The average test described the qualitative factor attributing a yield greater than 90 bag ha^{-1} in the AS3680 genotype. The regressions were adjusted and estimated with optimal points close to 100 kg ha^{-1} of P_2O_5 for the different characters. Positive and negative correlations and their trends were considered among the characters for each soybean genotype, in addition to grouping the interaction of factors.

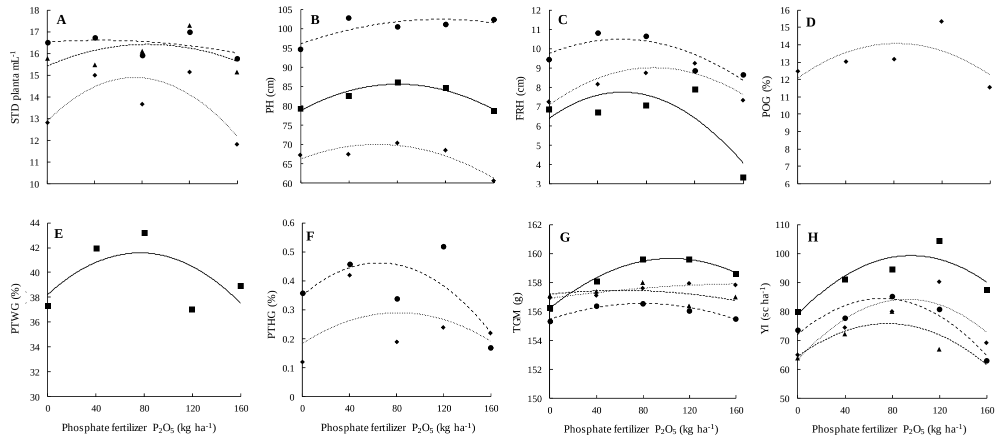
It was observed that the variables of stand (STD), height (PH) ($p > 0.05$), first reproductive node height (FRH), pods with one grain (POG), pods with two grains (PTWG), pods with four grains (PFG), thousand grain mass (TGM) and yield (YI) showed significance ($p \leq 0.01$) in the genotype x P doses interaction (Table 2). These results corroborate those obtained by Costa Leite et al. (2017). However, the results obtained in the present study differ from those verified by de Santos et al. (2015). The coefficient of variation was low to medium, enabling the test performed for all characteristics (Table 2) (Gomes, 2009). According to Batistella Filho et al. (2013), the components of soybean production, such as PPP, GPP and TGM are influenced by the dose of P and the edaphoclimatic conditions of the planting site. The study by Rosolem and Tavares (2006), indicate a high influence of phosphate fertilization on the floral setting in soybean plants, consequently influencing the number of pods per plant.

Table 2. Summary of analysis of variance (calculated MS and CV (%)) for 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 of soybean plants as a function of phosphate fertilization. UNIFIMES, Mineiros, GO, Brazil, 2020.

SV	DF	STD	PH	FRH	POG	PTWG	PTHG
GxP	12	1.5*	116.0*	2.1**	21.2**	95.2**	124.1
Genotypes (G)	3	116.8**	3968.7**	24.6**	388.9**	4297.1**	4052.6*
Phosphorus Concentration (P)	4	7.4**	68.0*	2.3*	15.1**	79.3**	96.5*
Blocks	3	0.4	127.3	2	0.3	0.3	1.5
Residue	57	0.4	88.6	0.6	0.6	2.3	2.7
CV%		4.78	11.55	9.85	6.3	3.09	4.42

SV	DF	PFG	PPP	GPP	TGM	YI
GxP	12	0.1**	254	1099.7	112.2**	1.9**
Genotypes (G)	3	0.4**	3850.4*	45042.5*	1782.2**	20.5**
Phosphorus Concentration (P)	4	0.1**	236.4*	1024.0*	857.5**	4.9**
Blocks	3	0.1	13.9	97.2	0.1	0.1
Residue	57	0.1	15.7	98.6	2.4	0.2
CV%		16.3	3.86	4.26	0.31	2.02

** significant at 1% probability by the F test; * significant at 5% probability by the F test.



Characters	Genotypes	Equations	R^2
STD	♦NA5909	$y = 10.116 + 0.054394^{*}x - 0.000368^{**}x^2$	0.79
	▲NA7337	$y = 15.419929 + 0.023529^{ns}x - 0.000139^{*}x^2$	0.91
	●TMG1180	$y = 16.5165 + 0.0041^{*}x - 0.000045^{**}x^2$	0.85
PH	■AS3680	$y = 78.788214 + 0.169227^{*}x - 0.001047^{**}x^2$	0.93
	♦NA5909	$y = 66.235283 + 0.119261^{*}x - 0.000939^{*}x^2$	0.87
	●TMG1180	$y = 96.090571 + 0.109471^{**}x - 0.000471^{*}x^2$	0.89
FRH	■AS3680	$y = 6.651214 + 0.016946^{ns}x - 0.000104^{*}x^2$	0.97
	♦NA5909	$y = 7.082214 + 0.044883^{ns}x - 0.00026^{**}x^2$	0.83
	●TMG1180	$y = 9.754143 + 0.024912^{**}x - 0.000211^{*}x^2$	0.97
POG	♦NA5909	$y = 12.079 + 0.04885^{ns}x - 0.000298^{*}x^2$	0.86
PTWG	■AS3680	$y = 38.1995 + 0.088688^{ns}x - 0.000581^{**}x^2$	0.94
PTHG	♦NA5909	$y = 0.187571 + 0.002515^{ns}x - 0.000015^{**}x^2$	0.87
	●TMG1180	$y = 0.3545 + 0.003425^{ns}x - 0.000027^{**}x^2$	0.85
TGM	■AS3680	$y = 156.193857 + 0.066582^{*}x - 0.000319^{*}x^2$	0.99
	♦NA5909	$y = 156.899714 + 0.011208^{*}x - 0.00003^{*}x^2$	0.91
	▲NA7337	$y = 157.185857 + 0.008832^{*}x - 0.000073^{*}x^2$	0.83
	●TMG1180	$y = 155.448357 + 0.02757^{*}x - 0.000171^{*}x^2$	0.92
YI	■AS3680	$y = 78.8065 + 0.428144^{*}x - 0.002238^{*}x^2$	0.89
	♦NA5909	$y = 63.026214 + 0.460052^{*}x - 0.002498^{**}x^2$	0.92
	▲NA7337	$y = 64.251 + 0,304638^{*}x - 0.002013^{**}x^2$	0.96
	●TMG1180	$y = 71.927429 + 0.353241^{*}x - 0.002495^{*}x^2$	0.89

Figure 1. Final stand STD (A), plant height PH (B), first reproductive node height FRH (C), pods with one grain POG (D), pods with two grains PTWG (E), pods with four grains PTHG (F), thousand grain mass TGM (G) and yield YI (H), of soybean genotypes as a function of phosphate fertilization. UNIFIMES, Mineiros, GO, Brazil, 2020.

The phosphorus fertilization dose of 81.47 kg of P_2O_5 ha^{-1} promoted a higher FRH in the AS3680 genotype, with an average of 7.01 cm. For the NA5909 genotype, it was obtained with 86.31 kg of P_2O_5 ha^{-1}, with an average of 8.17 cm. In TMG1180, it obtained 9.72 cm with the P dose of 59.03 kg of P_2O_5 ha^{-1} (Figure 1C). Silva et al. (2015) also observed elevation in FRH, where the additions of P provided an average of 9.2 and rising to 10.3 cm with the application of phosphate fertilizer. However, the results obtained differ from those observed by Alcântara-Neto. (2010) where FRH did not respond to phosphate fertilization. Regarding the POG percentage variable, there was a quadratic effect only for the NA5909 genotype, obtaining the percentage of 13.12% with the dose of 81.96 kg of P_2O_5 ha^{-1} (Figure 1D). According to a study by Perine et al. (2012) the characteristics number of grains per pod, per plant and thousand-grain mass, should receive greater emphasis in the selection of high yield soybean lines.

As for the percentage of PTWG, there was a quadratic effect only for the AS3680 genotype, with the percentage of 41.58% with the dose of 76.32 kg of P_2O_5 ha^{-1} (Figure 2E). In the study by Cavalli et al. (2016) there was no significant difference for the variable number of grains per pod. However, in this work it was possible to verify an expressive increase for grain per pod due to the use of increasing doses of P. The authors concluded that the increase in this variable is highly relevant, due to its direct interference in soybean yield.

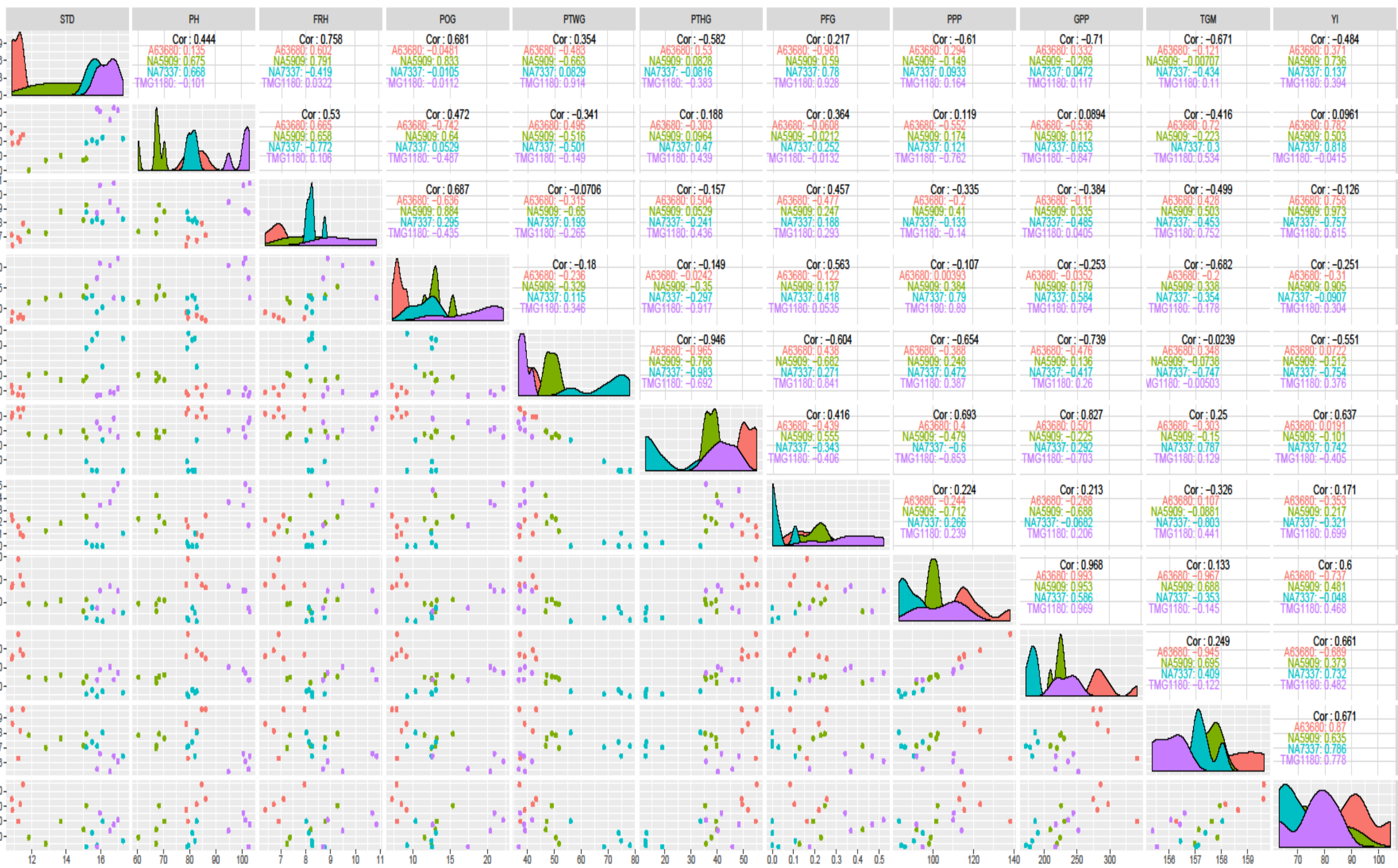


Figure 2. Phenotypic correlations of the general and categorical characteristics of the soybean genotypes (AS3680, NA5909, NA7337 and TMG1180) fertilized with phosphate fertilization. UNIFIMES, Mineiros, GO, Brazil, 2020. Variables: stand STD, plant height PH, first reproductive node height FRH, pods 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: Color ≥ 0.6 = significant at 1% probability by t test.

As for the percentage of PTHG, there was a quadratic effect only for the NA5909 genotypes, with 0.29% at the dose of 83.83 kg of P_2O_5 ha^{-1} and for the TMG1180 genotype 0.46% at the dose of 63.43 kg P_2O_5 ha^{-1} (Figure 2F). In the work carried out by Silva et al. (2015), the number of grains per plant showed a significant increasing linear response to the application of phosphate fertilizer P2O5, promoting an increase of approximately 20%. Similarly, Marin et al. (2015) observed a linear effect of supplying P to soybean plants for the percentage of PTHG. These results are contradictory, which strengthens the idea of developing research on the supply of phosphorus to the soybean crop, especially in the Cerrado Biome.

Quadratic effect was observed for all genotypes regarding TGM, where AS3680 obtained 159.67 g at a dose of 104.36 kg of P_2O_5 ha^{-1}. The NA5909 genotype showed an average of 157.95 g at a dose of 186.80 kg of P_2O_5 ha^{-1}. The TMG1180 genotype presented 159.57 g with a dose of 104.36 kg of P_2O_5 ha^{-1}, and the NA7337 genotype obtained 157.45 g with a dose of 60.49 kg of P_2O_5 ha^{-1} (Figure 2G). In the work carried out by Silva et al. (2015), results were observed close to the experiment where the TGM exhibited a quadratic response of the phosphate fertilizer with 222.83 kg ha^{-1}, with an average of 172.71 g. In a study by Santos et al. (2015) with the use of phosphate fertilizer, the average for the TGM was 169 g, increasing about 5.5% in relation to the control treatment.

In the present study, a quadratic effect was observed for all genotypes as to yield, where the AS3680 genotype showed a yield of 91.57 bag ha^{-1} for the dose of 95.65 kg of P_2O_5 ha^{-1}. The NA5909 genotype 75.64 bag ha^{-1} with the dose of 92.08 kg of P_2O_5 ha^{-1}, followed by the NA7337 genotypes with 69.30 sc ha^{-1} in the dose of 75.67 kg of P_2O_5 ha^{-1} and the TMG1180 genotype with 76.23 bag ha^{-1} in the dose of 70.79 kg of P_2O_5 ha^{-1}. Increments were of 20.48, 21.18, 11.53 and 12.9 bag ha^{-1}, respectively (Figure 3B). Peter et al. (2016) observed mean values of 77.03 bag ha^{-1} when applying phosphate fertilizer. However, Silva et al. (2015) had results below that found in the present experiment for the yield variable, showing a significant quadratic response to the application of doses of phosphate fertilizer of 222.83 kg of P_2O_5 ha^{-1}, where the yield was 49.95 bag ha^{-1}. The study by Marin et al. (2015) found that the application of phosphate fertilizer in the dose of 108.68 kg ha^{-1} of P_2O^5, contributed to the increase of the soybean crop yield in 71.92 bag ha^{-1}, showing the use of phosphate fertilizer in this component.

Correlations with Pearson's coefficients ($p \geq 0.6$) applied to the means of the soybean genotypes revealed 6, 7, 7 and 6 significant pairs for the genotypes AS3680, NA5909, NA7337 and TMG1180, respectively. Negative correlations were reported in the TGMxPPP, TGMxGPP and YIxPPP pairs in the AS3680 genotype, PTHGxPTWG in NA5909, PTWGxYI and PTWGxPTHG for NA7337 genotype and in the TMG1180 genotype, PTHGxPOG and PTHGxPTWG. The other significant correlations were positive (Figure 2). The correlations outline practical strategies for the grower regarding decision making to improve the characters of interest through their correlated peers.

Ibrahim et al. (2018) and Ferrari et al. (2018) have also reported such variations in phenotypic correlations of soybean. The degree of association between different characters can be determined by the correlation coefficient, which is an important statistical constant. For Guleria et al. (2019) it is essential to discover the influence of the characters on the yield, in order to give weight during the genetic selection, considering that it is very affected by the environmental irregularity. Categorically, significant positive and negative correlations were also reported (Figure 2).

The path analysis with the direct effects revealed that the elevation of the TGM, STD, FRW, PTHG, PPP and GPP averages, as well as the reduction of the PTWG, potentiate the increase in the yield of soybean genotypes. Similar results were evidenced by Meira et al. (2016) and Szareski et al. (2018) who also showed a contribution from the thousand-grain mass for soybean grain yield. Indirectly TGM, STD, PTHG, PPP and GPP, also had an influence on yield (Table 3). According to Silva et al. (2015), the increase in yield is explained by the increase in the production of pods per plant and in the thousand grain mass achieved with the application of increasing doses of phosphate fertilizer. According to Silva (2016), phosphorus plays an essential role in the metabolic processes of plants, from energy generation, nucleic acid synthesis, photosynthesis, glycolysis, respiration, phospholipid synthesis, enzyme activation and inactivation, redox reactions, signaling, carbohydrate metabolism and nitrogen fixation. In view of its fundamental importance, the lack of adequacy of soil phosphorus to the needs of the plant has the negative consequence of limiting its development and yield.

Table 3. 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 fertilized with phosphate fertilization. UNIFIMES, Mineiros-GO, Brazil, 2020.

Direct	Characters	TGM	STD	PH	FRH	POG	PTWG	PTHG	PFG	PPP	GPP
Direct effect	YI	0.97	0.68	-0.01	0.15	0.00	-0.12	0.11	0.00	0.44	0.34
Indirect effect	TGM		-0.67	-0.42	-0.50	-0.68	-0.02	0.25	-0.32	0.13	0.25
Indirect effect	STD	-0.46		0.30	0.52	0.46	0.24	-0.40	0.15	-0.42	-0.48
Indirect effect	PH	0.00	0.00		-0.01	0.00	0.00	0.00	0.00	0.00	0.00
Indirect effect	FRH	-0.07	0.11	0.08		0.10	-0.01	-0.02	0.07	-0.05	-0.06
Indirect effect	POG	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
Indirect effect	PTWG	0.00	-0.04	0.04	0.01	0.02		0.11	0.07	0.08	0.08
Indirect effect	PTHG	0.03	-0.06	0.02	-0.02	-0.02	-0.10		0.04	0.07	0.09
Indirect effect	PFG	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
Indirect effect	PPP	0.06	-0.27	0.05	-0.15	-0.05	-0.29	0.31	0.10		0.43
Indirect effect	GPP	0.09	-0.24	0.03	-0.13	-0.09	-0.25	0.28	0.07	0.33	
Total		0.62	-0.48	0.10	-0.13	-0.25	-0.55	0.64	0.17	0.60	0.66

Coefficient of determination R2: 0.95; K value used in the analysis: 2.21E-02; effect of the residual variable: 0.23; determinant of the correlation matrix between explanatory variables: 6.54E-06.

According to Cavalli et al. (2016) one of the nutrients that most limits the yield of agricultural crops in Brazil is P. This nutrient must be present in biological membranes, energy storage in photosynthesis and respiration that will be used in other processes, mostly in the form of ATP. On the other hand, low levels of P in the plant cause irreversible damage to the crop, such as reducing the amount and mass of grains per plant. According to a study by Costa Leite et al. (2017) increasing doses of phosphate fertilizer are able to exert significant influence on the variables plant height, number of pods per plant and yield in Brazilian Cerrado soil. According to the study by Alcântara-Neto. (2010), the yield of soybean plants shows an increase in the doses of P applied to the soil, where the yield reached was 2,614.7 kg ha^{-1} of soybeans, obtained with the dose of 94.8 kg of P_2O_5, showing the importance of phosphate fertilization in soybean crop.

Thus, the study brings innovations in the field of research demonstrating the efficiency of triple superphosphate as a phosphate source for the growing of soybeans, where the choice of genetic material is also crucial when it is desired to achieve high levels of yield. However, other works must be done using more or the same phosphate source, in order to better understand the dynamics of phosphorus in soy among the different types of soils and climatic and genetic conditions that prevail in the Brazilian cerrado agro-ecosystem.

CONCLUSIONS

It was observed that the characters with the greatest contribution to raising yield levels were the thousand grain mass, plant stand and pods per plant.

By using triple superphosphate as a phosphate source, it is recommended to grow the AS3680 genotype, which showed the highest yield (91.57 bag ha^{-1}) with a dose of 95.65 kg of P_2O_5 ha^{-1}, corresponding to 21.57% increments in yield.

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