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Use of blood residue as alternative source of phosphorus in sunflower (*Helianthus annuus* L.) cultivation

[*Utilização de resíduo de sangue como fonte alternativa de fósforo no cultivo de girassol (*Helianthus annuus *L.*)]

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ABSTRACT

The aim of this work was to increase the aerial part, biometry, and yield of achenes from sunflower plants on the effect of increasing doses of blood residue, as an alternative source of phosphorus (P), in a clayey-textured red Oxisol. The experimental design used was randomized blocks, with six treatments and four replications. The treatments consisted of five doses of blood residue (0, 6, 12, 24 and 48m^3 ha^{-1}) and a control treatment that received phosphate chemical fertilization, 80kg ha^{-1} of P_2O_5. The increasing doses of blood residue and chemical fertilization do not show disproportionality for P concentration in soil, leaf, plant height (PH), stem diameter (SD), chapter diameter (CD) and achene production. The analysis of the principal component (PC) revealed that the first PC presents the greatest accumulated variation (74%). Based on the first PC, the dose of 12m^{-3} ha^{-1} has greater influence for PH, SC, and CD. Due to the greater influence on the biometric characteristics of sunflower plants, the blood residue (12m^{-3} ha^{-1} = 98.4kg P ha^{-1}), can be used as an alternative source of phosphorus for the cultivation of sunflower in clayey oxisols.

Keywords: achenes production**,** aerial part biometry, inorganic fertilizer, organic fertilization, oxisols

RESUMO

Objetivou-se com este trabalho verificar biometria de parte aérea, rendimento de aquênios de plantas de girassol sobre o efeito de doses crescentes de resíduo de sangue, como fonte alternativa de fósforo (P), em um Latossolo vermelho de textura argilosa. O delineamento experimento utilizado foi o de blocos casualizados, com seis tratamentos e quatro repetições. Os tratamentos foram constituídos por cinco doses de resíduo de sangue (0, 6, 12, 24 e 48m^3 ha^{-1}) e um tratamento que recebeu a adubação fosfatada química, 80kg ha^{-1} de P_2O_5. As doses crescentes de resíduo de sangue e adubação química não demostram desproporcionalidade para a concentração de P no solo, folha, altura de planta (AP), diâmetro de caule (DC), diâmetro de capítulo (DCP) e produção de aquênios. A análise de componentes (CP) principais revelou que o primeiro CP apresenta maior variação acumulada (74%). Baseado no primeiro CP, a dose de 12 m^{-3} ha^{-1}exibe maior influência para AP, DC e DCP. Devido a maior influência sobre as características biométricas em plantas de girassol, o resíduo de sangue (12m^{-3} ha^{-1} = 98,4kg P ha^{-1}), pode ser utilizado como fonte alternativa de fósforo para o cultivo de girassol em Latossolos de textura argilosa.

Palavras chaves: adubação orgânica, biometria de parte aérea, fertilizante inorgânico, Latossolos, produção de aquênios

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INTRODUCTION

The cultivation of sunflower (*Helianthus annuus* L.) is of great importance to society, and due to good nutritional indices, it is used in human food (Franzen *et al*., 2019), and the extracted oil is used as biofuel (Dueso *et al*., 2018). At the same time, sunflower can be part of the diet of large ruminants (Polvisetet *et al*., 2020); it is a versatile species because good agronomic indices are measured in monoculture and intercropped systems (Cruvinel *et al*., 2017; Linhares *et al*., 2020).

Regarding nutritional management, sunflower plants have high nutrient absorption when compared to other agricultural crops. For the supply of phosphorus (P) the use 80 kg ha^{-1} of P_2O_5 is recommended (Campos *et al*., 2015).

Brazilian savannah (Cerrado) due to edaphoclimatic conditions, temperature, and adequate distribution of precipitation in the summer, associated with the sparsely moved relief, has a high potential for the cultivation of plants of high agronomic interest (Severiano *et al*., 2013). However, the chemical composition of the soil in these regions makes primary production challenging, as they have high levels of acidity, low concentration of macronutrients, especially low adsorption of P (Beck *et al*., 2018).

Conventional sources of essential nutrients are of industrial origin, and their acquisition value is influenced by market trends and dollar fluctuations, therefore, depending on the economic scenario, the investment made in chemical fertilizers will increase the operating costs of the production system. Therefore, to carry out economic and sustainable agricultural production in tropical climate environments, it is necessary to use alternative management techniques, such as the use of biofertilizers and/or organic waste (Emerenciano Neto *et al*., 2016; Leite *et al*., 2019; Biserra *et al*., 2020).

The use of waste from the refrigeration industry can be a great option, since it is possible to obtain high levels of essential nutrients (P), improve the chemical composition of the soil, due to the increase in organic matter; impacting good primary production rates (Silva *et al*., 2019).

Knowing the potential benefits of using this type of co-product, it is possible to suggest the following hypothesis: the supply of P through blood residues from the meat industry will promote the good development of sunflower plants and may replace conventional sources of phosphate fertilizer.

The aim of this work was to verify shoot biometry and yield of sunflower achenes on the effect of increasing doses of blood residue as an alternative source of P in a clayey red oxisol.

MATERIALS AND METHODS

The work was carried out on a school farm belonging to the State University of Goiás – West campus, located in the municipality of São Luís de Montes Belos - GO, (Lat.16º 32' 23.60” 'South, and long. 50º 25' 11.77" West and mean altitude of 542 meters). The experiment was implemented in February 2018 and conducted until June 2018.

According to Köppen’s classification, the climate is Aw, with an average temperature of 23.5ºC, ranging from 20.7ºC (June) to 25.0ºC (December). The average annual precipitation is 1,785mm, of which 87% concentrated between the months of October and March. The region has an average rainfall deficit of four months (Alvares *et al*., 2014).

Before the implementation of the experiment, the chemical and physical characterization of the soil in the 0-20 cm layer was carried out, with collecting of 15 simple samples at equidistant points. Subsequently, a composite sample was taken and sent to the laboratory. According to the method described by Miyazawa *et al*. (2009), the soil was classified as Dystrophic Red Latosol (Santos *et al*., 2018), with clayey texture (390, 320 and 290 g kg^{-1} of sand, silt, and clay, respectively). Regarding the chemical parameters, the results were: active acidity (pH, $CaCl_2$) of 5.0; 3.4, 0.7, 3.5, 0.102 e 7.7$cmol_c$ dm^{-3}, respectively from calcium (Ca), magnesium (Mg), potential acidity (H+Al), potassium (K), and exchange capacity cationic (CEC); 1.0mg dm^{-3} phosphorus (P) (Mehlich I); 16.0g kg^{-1} organic matter and 55.69% base saturation.

The experimental design was in randomized blocks, with six treatments and four replications. The treatments consisted of five doses of blood residue (0, 6, 12, 24, and $48m^3$ ha^{-1}) and a control treatment that received phosphate chemical fertilization, 80kg ha^{-1} of P_2O_5. Each plot measures 4 x 5m, totaling $20m^2$ of area.

The residue applied in the experiment plots was obtained through a partnership with private companies located in the municipality of São Luís de Montes Belos -GO. The analysis of residues was performed according to Miyazawa *et al*. (2009), with the following values being observed: nitrogen (N): 420mg dm^{-3}; P: 8200mg dm^{-3}; K: 1230mg dm^{-3}; Ca: 1200mg dm^{-3}; Mg: 160mg dm^{-3}; Na: 2940mg dm^{-3}; S: 526mg dm^{-3}; pH: 7.23 $CaCl_2$. From the residue analysis and nutritional recommendation according to Sousa (2004), residue doses were calculated: 0, 6, 12, 24 and $48m^3$ ha^{-1}, providing respectively P: 0; 49.2; 98.4; 196.8; 393.6kg ha^{-1} and chemical fertilization with 80kg ha^{-1} of P_2O_5.

The residue was applied once, manually, according to each treatment, two days before sowing. Sowing was performed manually, with a density of 50,000 plants ha^{-1}, equivalent to a spacing of 0.60m between rows and 0.2m between plants on the same row. Sunflower seeds were treated with insecticide CROPSTAR with active ingredient (Imidacloprid) and fungicide STANDAK TOP (Pyraclostrobin).

The cultivar used was Altis 99, a simple early cycle hybrid, with flowering between 50 to 58 days after emergence and harvesting point from 110 to 125 days, which can be used for oil or silage.

During the experiment, an insecticide application was made to eliminate the insect pest attack. For this, KESHET 25 EC (Deltamethrin) and KOHINOR 200 SC (Imidacloprid) were used. In addition, to avoid competition for nutrients and the growth of weeds, whenever necessary, manual weeding of the experiment was carried out.

The boron solution was applied 30 days after emergence, according to Sousa *et al*. (2004), and using 2.9% boric acid per 200 L ha^{-1}. Top dressing was carried out in all plots, except for the control, with 60kg ha^{-1} of K_2O through potassium chloride and 60kg ha^{-1} of N, using urea as a source.

Diagnostic leaf collection was carried out according to Oliveira (2004), with the removal of 2 leaves per plant, being 10 plants per plot. The collection was carried out 70 days after emergence, being at the beginning of flowering at the top of the plant. In the laboratory, the sampled leaves were washed in distilled water, and the material was weighed and placed in a forced air circulation oven at 65°C for 48 hours. The grinding was done in a Willey mill, and the material was stored in paper bags and sent for analysis.

For the soil evaluation, samples were collected, according to Sousa *et al*. (2004) and sent to the Plant Analysis Laboratory of the Department of Natural Resources of the Faculty of Agronomic Sciences UNESP - REGISTRO, SP.

The parameters evaluated according to the methodology used by Fernandes (2008) were: stem diameter, chapter diameter, plant height until head insertion and achene yield. Plant height was measured with a measuring tape. To obtain the stem diameter, a digital caliper was used. The chapters were harvested above the humidity (10 and 12%) recommended by Castro (2005). The humidity was adjusted to 11% to determine productivity per hectare, as humidity was below that recommended by Silveira *et al*. (2005).

Residual doses were submitted to the first ($Y_{ij} = \beta 0 + \beta 1 * X + \varepsilon_{ij}$) and second degree regression analysis ($Y_{ij} = \beta 0 + \beta 1 * X + \beta 2 * X^2 + \varepsilon_{ij}$); being chosen the model that exhibited a significant effect at 5%, and the higher coefficient of determination ($R^2 \geq 80\%$).

Data on the doses of blood residues and chemical fertilization were analyzed following a random block model ($Y_{ijk} = \mu + T_i + B_j + \varepsilon_{ijk}$). Y_{ijk}: observed value of dose i in block j repetition k; μ = general constant; T_i: effect of treatments (i = 0, 6, 12, 24, 48 m^3 ha^{-1} waste and 80 kg ha^{-1} of chemical fertilizer); B_j: block effect (j, k = I, II, II, and IV); ε_{ijk}: random error, associated with each observed value. After the procedures described above, when appropriate, Tukey's means comparison test was performed, considering a significance level of 5%.

Data were analyzed by main component: the data set was standardized; therefore, each descriptor had zero mean and unitary variation. This analysis allowed us to reduce the space of the original variables in a smaller set, preserving the maximum of the original data variability.

To perform the analysis of variance and regression, the ExpDes package was used (Ferreira *et al*., 2014). All statistical procedures were performed using software R version 4.0.0.

RESULTS AND DISCUSSION

Due to increasing doses of blood residue, P concentration values in soil and leaf, biometric data of aerial part and productivity of achenes, did not present adjustment for the linear and quadratic equations; this can be evidenced by the absence of a significant effect (P>0.05), associated with low values of the coefficient of determination (R^2 <60%) (Table 1).

Although there are other more rigorous methods to validate and recommend the accuracy of the predicted values of the equations studied in agricultural environments, this is already established in the literature: when low values of R^2 are estimated, they indicate that the model will promote low precision and accuracy estimates (Fernandes *et al*., 2012; Duarte *et al*., 2018). Therefore, for the described experimental scenario, it was not possible to make recommendations for P supply prediction equations using increasing doses of blood residue in sunflower crop, therefore, the suggestions for managing the use of residues will be through other tools statistics.

The increasing doses of blood residue and chemical fertilization do not show disproportionality for the concentration of P in the soil and leaf (P>0.05);, thus, it was possible to estimate a mean value of 7.75mg dm^{-3} and 2.07g kg^{-1}, respectively.

Table 1. Regression analysis for phosphorus concentration in soil and leaves, aerial part biometry and sunflower achene yield subjected to blood residue doses.

	Equation		R^2		P-value	
Variable	L	Q	L	Q	L	Q
Phosphorus in the soil (mg dm^{-3})	Y = 6.95	Y = 7.55	0.033	0.090	0.440	0.445
Phosphorus on leaf (g kg^{-1})	Y = 1.98	Y = 1.97	0.007	0.007	0.710	0.934
Plant height (cm)	Y = 1.29	Y = 1.33	0.029	0.065	0.470	0.561
Stem diameter (cm)	Y = 15.91	Y = 16.08	<0.001	0.001	0.983	0.987
Chapter diameter (cm)	Y = 13.98	Y = 14.18	0.055	0.068	0.318	0.544
Achenes production (kg ha^{-1})	Y = 192.70	Y = 177.15	0.048	0.108	0.352	0.377

L: Linear equation. Q: Quadratic equation. R^2: coefficient of determination. P-value: significant effect probability.

The sunflower cultivar Altis 99, regardless of the factors studied (organic fertilizer versus chemical fertilizer), presented low leaf P values, according to Ribeirinho *et al*. (2012), the appropriate range or sufficient level of diagnostic P on the sheet, should be between 3 and 5g kg^{-1}. Lower values warn that the plant has not received an adequate P limit. Therefore, in acidic soils, doses of blood residue are not able to increase the concentration of P for the cultivation of sunflower plants.

The doses of residue and chemical fertilization are similarity for the biometric variables of aerial part and production of achenes (P >0.05); therefore, the sunflower cultivar exhibited the following characteristics: plant height of 1.27m, diameter of stem of 1.63cm, chapter diameter of 13.72cm and achenes production of 214kg ha^{-1}.

The sunflower cultivar Altis 99 has a median height (1.20m) when compared to other cultivars and, to obtain good productivity indices for this genotype, the average diameter of the chapter should be approximately 21cm (Soares *et al*., 2020), in this way, less developed chapters, will imply a lower production of achenes, compromising the efficiency of the production system.

To verify the formation of treatment groups and the correlation and/or association between variables, principal component (PC) analysis is a very efficient technique. Thus, through two-dimensional analysis, six components (PCs) were generated. The results revealed that 93% of the variance accumulated in the data set is explained by the first and second PCs (Fig. 1). Despite this, the first PC has the highest accumulated variance (74%). Thus, due to the smaller contribution of the other PCs, it is recommended that they be disregarded, and the interpretation of results should be based on the PC with the greatest variance. (Oliveira *et al*., 2019; Gurgel *et al*., 2021; Rodrigues *et al*., 2021).

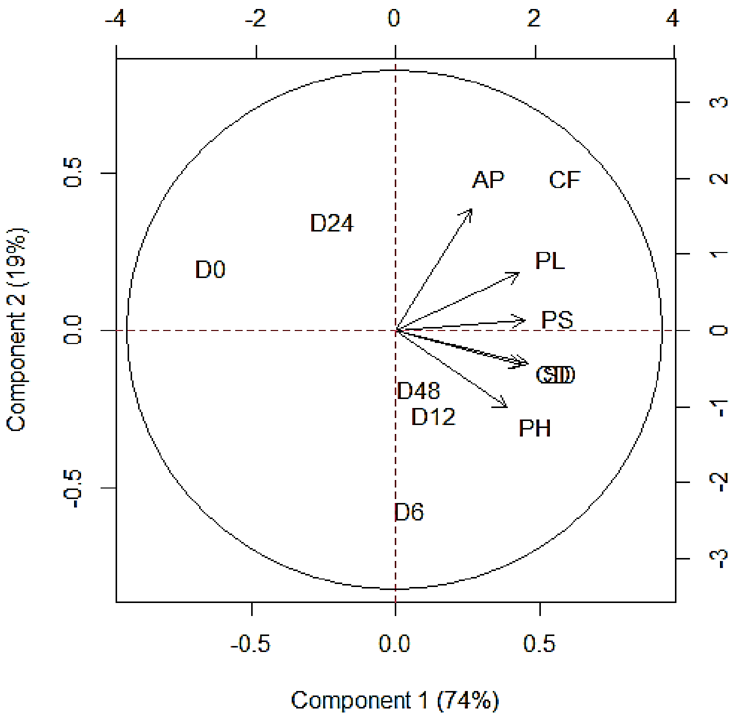

Figure 1. Biplot of the first and second main components of sunflower culture as a function of increasing doses of blood residue and chemical fertilizer. PS: Phosphorus in the soil. PF: phosphorus on leaf. PH: Plant height. SC: Stem diameter. CD: Chapter diameter. AP: Achenes production. Blood residue doses: D0: $0m^3 ha^{-1}$; D6: $6m^3 ha^{-1}$; D12: $12m^3 ha^{-1}$; D24: $24m^3 ha^{-1}$; D48: $48m^3 ha^{-1}$. CF: Chemical fertilization of 80kg ha^{-1} of phosphorus.

Based on the first PC, it is possible to verify that the treatments are evenly distributed: the residue doses 0 and $24m^{-3}$ ha^{-1} are not related to any analyzed variable, while the doses 6 and $48m^{-3}$ ha^{-1} show tendency to neutrality due to proximity of the zero axis. The high correlation observed between stem diameter and chapter, well as plant height, is associated with the dose of $12m^{-3}$ ha^{-1} (Fig. 1).

Although sunflower plants have adequate height, this does not mean that they have shown vigorous development, as the low values of stem diameter possibly reduced the rate of translocation of nutrients and photosynthesis products necessary for the good development of the inflorescence, negatively affecting the size of the chapters and production yield. In addition, plants with less developed stems are susceptible to windfall and other weather problems (Andrade *et al*., 2019).

Chemical fertilization is not related to biometric variables. However, it is associated with leaf P levels and achene production. The concentration of P in the soil is not correlated with any variable or associated with the tested sources of variation (Fig. 1).

The use of chemical fertilizers contains nutrient sources that are easily absorbed by the plant, and when their respective supply occurs properly, it affects significant increases in primary production (Soares *et al*., 2016, 2020).

The use of organic waste from slaughterhouses has potential as an alternative source of essential nutrients, as noted by Auler *et al*. (2020), the authors recommend its use in combination with mineral fertilizers in the proportion of 50% of the mixture.

However, the use of this residue without adding other sources of P is still questionable, due to the lack of associative effect with the production of achenes (Fig. 1). On the other hand, due to the association with variables related to the aerial part of sunflower plants, further studies are recommended to verify the potential of organic residues in agriculture.

CONCLUSION

Due to the greater influence on the biometric characteristics of sunflower plants, the blood residue ($12m^{-3}$ ha^{-1} = 98.4kg P ha^{-1}), can be used as an alternative source of phosphorus for the cultivation of sunflower in clayey oxisols. On the other hand, its effectiveness in producing achenes is still questionable. Thus, for future studies, aiming to obtain increases in the primary production indices in sunflower crop, together with the reduction in the use of inorganic mineral sources, it is recommended to verify the associative power of blood residue with chemical fertilizers.

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