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Development of Cowpea *(Vigna unguiculata (L.) Walp.)* under Different Doses of Phosphorus in a Sandy Soil with and without Gypsum

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Cowpea is a crop of great socioeconomic importance in the North and Northeast regions of Brazil. In these regions, soils tend to be more acidic, causing greater difficulty in root development and absorption of nutrients available in deeper layers. Another limiting factor for the development of the

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culture is the inadequate management or even the non-use of phosphate fertilizers. In this context, the objective of the research was to evaluate the development of cowpea subjected to different doses of phosphorus, with and without the use of agricultural gypsum applied to a sandy soil surface. The experiment was carried out from February to June 2018, in a completely Randomized Complete Block Design (RCBD), Replicated four (4) times. The phosphorus dosages used were 0, 40, 80 and 120 kg ha - in soils with and without the use of gypsum. To verify the results, morphological and productivity parameters were analyzed. The best results were obtained at the dosage of 80 kg ha $^{-1}$ of phosphorus for treatment with gypsum and without gypsum. The values decreased with doses higher than 80 kg ha $^{-1}$ in all parameters analyzed.

Keywords: Phosphorus; soil management; fertilizing; gypsum; cowpea.

1. INTRODUCTION

Vigna unguiculata (L.) Walp., popularly known as cowpea, stands out for its socioeconomic importance for families in the North and Northeast regions of Brazil and has been expanding in the Center-West region [1]. Its main use is in the production of dry or green grains, green fodder, hay, silage, flour for animal feed, and also as green manure and soil protection [2].

Several factors can influence the low productivity of cowpea, among which the inadequate management of phosphate fertilization stands out [3]. Phosphorus is an essential element in plant metabolism, playing an important role in cell energy transfer, respiration and photosynthesis [4]. Among the nutrients, P is the on of the most important element that limits crop production in soils in the Cerrado region [5].

In order to obtain high productivity, a phosphate fertilization is necessary, which has generated a greater intensity of searches for doses and forms of use that are more adequate to the cultures and economically viable [6,7]. Another factor that can compromise productivity is the acidity of the subsoil in depth, an alternative to this problem, according to [8] is the use of gypsum on the surface. Gypsum is the main input for the correction of sodic or alkaline soils, acting in the removal of sodium, an element that degrades the soil structure, through calcium, an element that promotes the improvement of the structure [9].

Barros [10] verified a sharp increase in the percentage of germination and dry matter production in cowpea, with the application of gypsum incorporated into the soil, regardless of the granulometry used. In summary, there is a great possibility of increasing crop production with the use of gypsum. The effect is generally not spectacular, but persists for many years, thus being advantageous from an economic point of view [9].

In this context, the research aims to evaluate the development of cowpea (*Vigna unguiculata* (L.) Walp.) submitted to different doses of phosphorus, with and without the use of agricultural gypsum applied on sandy soil surface.

2. MATERIALS AND METHODS

2.1 Location, Characterization and Preparation of the Experimental Area

The experiment was carried out under field conditions in Araguatins - TO, more precisely in the village of Santa Tereza (Fig. 1). The municipality is a component of the Bicol do Papago mesoregion, located in the northern region of the country. It has approximate coordinates of 05º 0' 00'' S and 48º 07' 00'' W and an average distance of 612 km from the capital of the State of Tocantins, Palmas. The period for carrying out the work extended between March and June 2018.

The rainfall and temperature data during the experiment were obtained from the data system provided by the National Institute of Meteorology – INMET, at the Araguatins – TO meteorological station (Fig. 2).

According to the Koppel-Geiger classification, the climate of the region is of the Aw type, being characterized as a tropical climate with a dry winter season and rainy summer, with an average temperature of 28.5ºC and an average annual rainfall of 1500 mm [11].

To prepare the area, weeding was carried out using tools to remove debris and weeds present on the site. For chemical analysis (OM - Organic matter, P, K, Ca, Mg, Al, (Hal) (Table 1) and physical (Sand, Silt and Clay) (Table 2) Soil samples were collected at 0-20 and 20-40 cm depths.

2.2 Experimental Design and Treatments

The experimental design used was Randomized Complete Block Design (RCBD), with 4 replications and 8 treatments, totaling 32 plots 2.5 in length and 2m in width, totaling 5m². The experimental area had a spacing of 0.5m between plots, totaling an area of 224.25m². The experiment was implemented from March 2018 with the application of gypsum that took place 30 days before sowing.

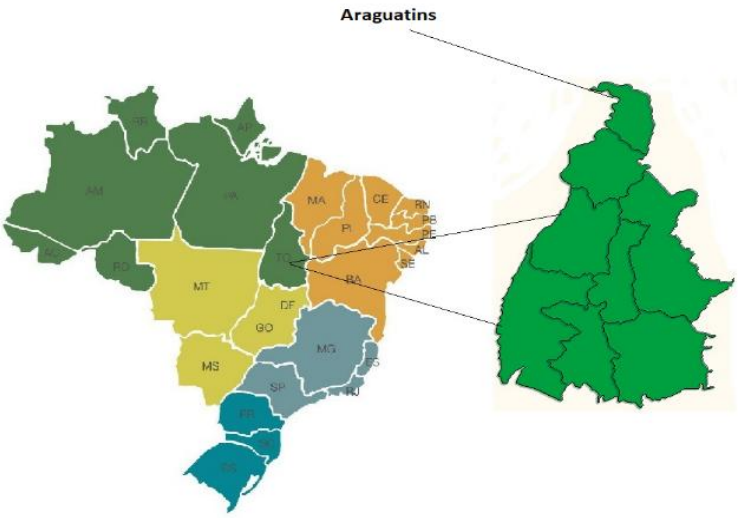

Fig. 1. Location of the municipality of Araguatins

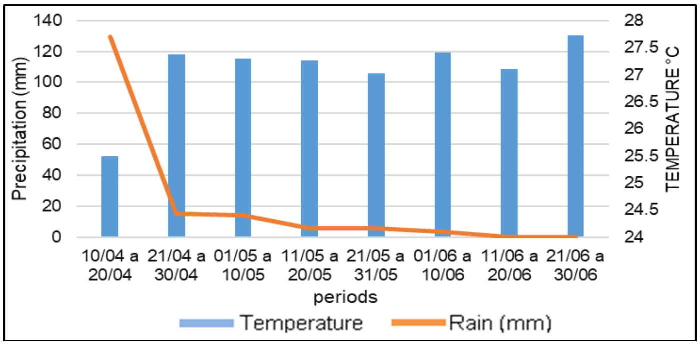

Fig. 2. Average temperature and precipitation data during the crop cycle

Table 1. Soil chemical analysis before project implementation

Dept h (cm)	pH (H_2O)	P	K	Her e	mg	Al	H+Al	s	T	V	MO
		mg/dm³				cmolc /dam³				%	%
0-20	4.6	2.20	15	0.3	0.1	0.7	1.65	0.44	2.09	20.99	1.44
20-40	5.2	2.20	21	0.9	0.5	1.2	1.98	1.45	3.43	42.34	0.36

Table 2. Physical analysis of the soil before project implementation

Dept h (cm)	Sand	Clay	silt
		%	
0-20	85.49	7.25	7.26
20-40	64.37	19.61	16.02

The treatments were T1 - Cowpea cultivation without gypsum and phosphorus (control); T2 - Cowpea cultivation without gypsum application + 40kg P_2O_5 ha $^{-1}$. T3 - Cowpea cultivation without gypsum application + 80kg P_2O_5 ha $^{-1}$. T4 - Cowpea cultivation without gypsum application + 120 kg P_2O_5 ha $^{-1}$. T5 - Cowpea cultivation with gypsum application + 0kg P_2O_5 ha $^{-1}$. T6 - Cowpea cultivation with gypsum application + 40kg P_2O_5 ha $^{-1}$. T7 -Cowpea cultivation with gypsum application + 80kg P_2O_5 ha $^{-1}$. T8 - Cowpea cultivation with gypsum application + 120kg P_2 O_5 ha $^{-1}$.

2.3 Conducting the Experiment (Fertilization and Sowing)

For soil correction and plot standardization, fertilizer dosages were defined according to soil analysis before sowing. The application of limestone and gypsum was performed manually 30 days before planting. Limestone was applied over the entire area and gypsum was applied according to the treatments, respectively 1.12 ton. ha^{-1} for dolomitic limestone and 0.21 ton. ha^{-1} for agricultural gypsum.

The NPK rates applied at the time of sowing were: 2 0 kg ha $^{-1}$ of nitrogen in the form of Ammonium Sulfate (NH_4). $2SO_4$ - 20% of N), 40 kg of K2O in the form of Potassium Chloride (KCl - 60% of K_2O) defined according to chemical (Table 1) and physical (Table 2) analyses, and for Phosphorus, P_2O_5 ha $^{-1}$ was applied as Single Superphosphate (SSP - 21% P_2O_5) defined according to the treatments described above. The plots consisted of 4 rows of two and a half meters in length with 10 plants each. The spacing used was 0.25m between plants and 0.5m between rows. For evaluations, the 5 central plants of each plot were considered, discarding the ends.

Sowing was carried out 30 days after application of limestone and gypsum. The study was carried out manually in pits, with a distance of 0.25 m. Planting fertilization and sowing of 3 seeds per hole were carried out, with thinning 10 days after emergence, leaving one plant per hole, reaching an approximate density of 80,000 plants. ha^{-1}. The cowpea cultivar used was BR 17 GURGUEIA, which has an indeterminate growth habit, branched size, globose leaves, purple flower color, yellowish dry pod color and greenish seeds, and also has an average cycle of d75 days, with initial flowering at 43 days after emergence [12].

Weed control was carried out according to the incidence and population of plants, using the mechanical method with the use of hoes and/or manual pulling. To control aphids, insecticide (EFORIA) was applied at the rate of 5ml/20L of water. To meet the water needs of the crop, irrigation was performed using a drip tape. Irrigation was carried out from the pod production phase in the morning on non-rainy days, to prevent the lack of water from interfering with grain yield. The harvest was carried out 68 days after sowing the plants. The pods of 6 plants were manually collected in the central lines within the useful area of each experimental plot.

2.4 Evaluated Variables

Morphological analyses were performed at 15, 25 and 40 days after plant emergence. For data collection, 5 plants were randomly chosen within the useful area of each plot, which were properly identified with visible color ribbons so that the following collections were carried out on the same plants.

The parameters analyzed were:

a) Plant height – obtained in centimeters with the aid of a tape measure. The measurement was performed from the base of the plant to the last extended leaf;
b) Stem diameter: It was performed using a universal caliper. The measurement was made in millimeters at a height of 5 cm from the base of the plants;

To analyze cowpea productivity components, pods were collected from six central plants in the useful area, from which 10 pods were counted and separated from each plot to evaluate the parameters. The methodology used was according to [13] for the evaluation of agronomic characteristics.

The evaluated parameters are described below:

a) Length of pods (CV in cm): Determined by the average measurement of 10 pods from each plot;
b) Number of pods per plant (NVP): Defined by dividing the total number of pods by the number of plants harvested in the useful area.
c) Number of grains per pod (NGV): Defined from the average of the grain count of the 10 pods used in the previous variable;
d) Grain weight per plant (PGP);
e) Grain yield (GR) per hectare (kg ha1): It was defined by multiplying the weight of

grains per plant (PGP) by the estimated density of 80,000 plants per hectare;

f) Weight of one hundred grains (PCG - g): After harvesting, the grains were all threshed and homogenized among themselves. Then, 100 grains were separated from each plot and weighed on a precision scale.

2.5 Statistical Analysis

The collected data were subjected to Analysis of Variance (ANOVA). The means were compared with each other using the Tukey test at the 5% probability level. Statistical tests were performed with the aid of the SISVAR 5.6 program and the graphs were prepared in Microsoft Excel.

3. RESULTS AND DISCUSSION

3.1 Morphological Parameters of Cowpea

For plant height, there were significant differences between the phosphorus doses in the treatments with the use of gypsum incorporated into the soil in the third collection (45 days after emergence) of data (Table 3).

Table 3. Average plant height (AP) in cowpea cultivar BR 17 GURGUEIA, submitted or not to gypsum application and different doses of phosphorus, with data at 15, 25 and 40 days after emergence (DAE). Aragua tins - TO, 2018

Trementes [(1)]	**AP (cm)**		
	15 DAE	**25 DAE**	**40 DAE**
1	20, 22 a	43.90 a	64, 63 a
2	21, 18 a	36, 75 a	56, 30 a
3	22, 17 a	42, 15 a	62.01 a
4	22, 41 a	37, 90 a	62.03 a
5	17, 96 a	30, 90 a	49, 63 b
6	21, 15 a	35, 87 a	60.00 a
7	23, 10 a	45, 25 a	69.02 a
8	20, 38 a	34, 80 a	57, 84 a
CV%	**18, 48**	**28, 99**	**19, 91**

*(1) 1: Cowpea cultivation without gypsum application + 0kg P_2O_5/ha ; 2: Cowpea cultivation without gypsum application + 40kg P2O5 ha^{-1} ; 3: Cowpea cultivation without gypsum application + 80kg P_2O_5 ha^{-1} ; 4: Cowpea cultivation without gypsum application + 120kg P_2O_5 ha^{-1} ; 5: Cowpea cultivation + Gypsum application + 0kg P_2O_5 ha^{-1} ; 6: Cowpea cultivation + Gypsum application + 40kg P_2O_5 ha^{-1} ; 7: Cowpea cultivation + Gypsum application + 80kg P_2O_5 ha^{-1} ; 8: Cowpea cultivation + Gypsum application + 120kg P_2O_5 ha^{-1} . *Means followed by the same lowercase letter, do not differ from each other, by Tukey's test at 5% probability. CV%= coefficient of variation*

In the first two collections, the different levels of phosphorus and the use of gypsum did not influence plant growth. However, they showed homogeneous growth in all plots and treatments. At 40 days after emergence (DAE) treatments with gypsum differed from each other, with greater height for treatment 7 (80kg.ha $^{-1}$). The plants presented a growth proportional to the increase of the phosphorus dosage until the dosage of 80kg.ha $^{-1}$, with a decrease in the dosage of 120kg.ha $^{-1}$.

Alves [14] found no statistically significant differences for plant height and stem diameter when growing cowpea under different gypsum dosages in a yellow latosol in Northeast Pará. In this context, regardless of the period of development, it is possible that more reaction time is required for the supply of calcium on the surface. As highlighted, the results were significant from 40 DAE. This fact can be justified by the longer time interval available for the action of gypsum on the soil.

For the variable stem diameter (Table 4), there was a significant difference in the second collection at a dosage of 80kg.ha $^{-1}$ of phosphorus, with a decrease in the stem measurement at the later dosage of 120kg.ha $^{-1}$, which highlights the dosage of 80kg.ha $^{-1}$ as the most suitable for obtaining a better stem diameter. In the third data collection, the control showed a significantly higher value than the other treatments, showing a low influence of gypsum on this parameter evaluated.

There was a significant difference in the second collection at a dosage of 80kg.ha $^{-1}$ of phosphorus, with a decrease in the stem measurement at the later dosage of 120kg.ha $^{-1}$, which highlights the dosage of 80kg.ha $^{-1}$ as the most suitable for obtaining better stem diameter. In the third data collection, the control showed a significantly higher value than the other treatments, showing a low influence of gypsum on this parameter evaluated.

The low action of gypsum can be justified by the high solubility presented by gypsum and the form of application may have favored excessive leaching, considering the high permeability of the soil used and the low water and nutrient retention according to [15].

Another possibility would be the amount of gypsum applied. According to [9], The amount of gypsum is based on soil evidence that is carried out at a depth of evidence that is carried out at a depth of 40 cm in the safe doses do not apply, but there are beneficial results.

Table 4. Average stem diameter (DC) in cowpea cultivar BR17 GURGUEIA, submitted or not to gypsum application and different doses of phosphorus, with data at 15, 25 and 40 days after emergence (DAE). Aragua tins - TO, 2018

Trementes	DC (mm)		
	15 DAE	25 DAE	40 DAE
1	3.98 a	6.22 a	7.77 b
2	4.21 a	5.6 a	7.06 a
3	4.56 a	5.77 a	7.33 a
4	4.59 a	6.12 a	6.77 a
5	3.48 a	5.3 a	6.2 a
6	4.4 a	6.21 a	6.92 a
7	4.63 a	7.42 b	7.76 a
8	3.83 a	6.08 a	6.6 a
CV %:	**17, 51**	**15, 76**	**13.05**

*(1) 1: Cowpea cultivation without gypsum application + 0kg P_2O_5 ha $^{-1}$; 2: Cowpea cultivation without gypsum application + 40kg P_2O_5 ha $^{-1}$; 3: Cowpea cultivation without gypsum application + 80kg P_2O_5 ha $^{-1}$; 4: Cowpea cultivation without gypsum application + 120kg P_2O_5 ha $^{-1}$; 5: Cowpea cultivation + Gypsum application + 0kg P_2O_5 ha $^{-1}$; 6: Cowpea cultivation + Gypsum application + 40kg P_2O_5 ha $^{-1}$; 7: Cowpea cultivation + Gypsum application + 80kg P_2O_5 ha $^{-1}$; 8: Cowpea cultivation + Gypsum application + 120kg P_2O_5 ha $^{-1}$. *Means followed by the same lowercase letter, do not differ from each other, by Tukey's test at 5% probability. CV%= coefficient of variation*

Another possibility would be the amount of gypsum applied. According to [9] the amount of gypsum recommended by official bodies, which are based on analyzes carried out at a depth of 40 cm in the soil, are safe and do not cause damage, but there is evidence that applying higher doses can bring advantageous results.

To prove this hypothesis, it is necessary to carry out a soil analysis at a depth greater than 50 cm to verify chemical barriers and corrective needs. In this context, considering that the dose of gypsum used in this research was based on chemical analysis of the soil, it may not have been sufficient to influence the morphological parameters of the crop.

3.2 Cowpea Yield

The averages obtained for yield parameters showed significant differences for P doses in almost all aspects evaluated, except for pod length (CV) and number of grains per pod (NGV). That is, gypsum and phosphorus do not significantly interfere with the increase or decrease of these two parameters.

Collaborating with these results, [16], evaluating different doses and forms of phosphorus application in a dystrocohesive yellow oxisol in Roraima, showed that there were significant differences for practically all parameters evaluated. Rosal [17], evaluating the interaction of zinc with the same doses of phosphorus in the present work, found a significant difference for PCG, NVP, and NVP in relation to phosphate fertilization. For the number of pods per plant (NVP), there was practically no interference of gypsum in the results obtained.

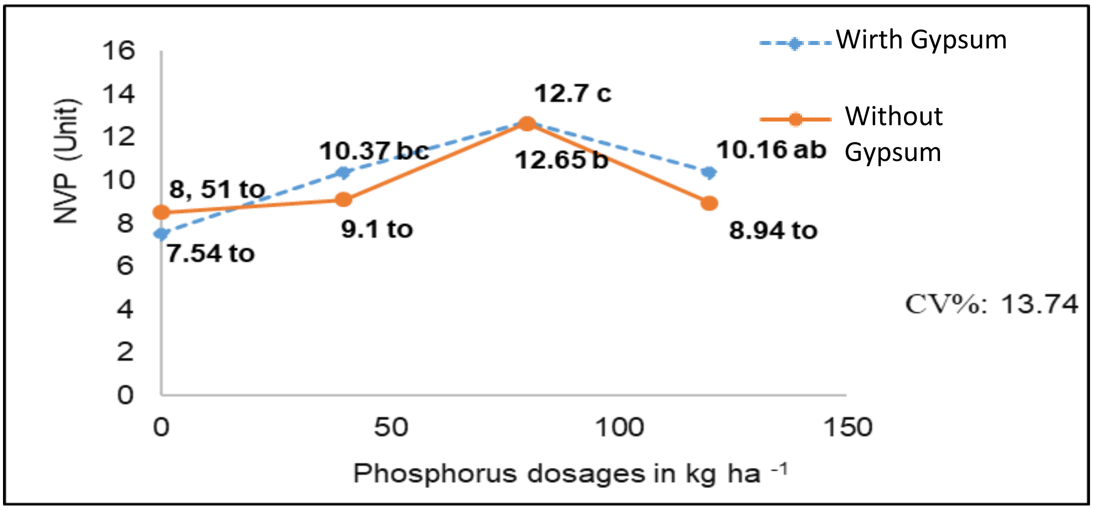

Fig. 3. Mean number of pods per plant (NVP) in cowpea cultivar BR 17 GURGUEIA, submitted or not to gypsum application and different phosphorus doses. Aragua tins - TO, 2018

According to Fig. 3, the productivity means did not differ significantly between treatments with gypsum application and without gypsum application, except at the rate of 40kg.ha $^{-1}$. It is possible to observe that the best results were obtained at the dosage of 80kg ha $^{-1}$.

The behavior of the lines in the graph showed a similarity for the plots with and without gypsum, with an increase in the number of pods up to the dose of 80kg.ha $^{-1}$ decreasing at higher doses. The maximum number of pods obtained was 12.7 at a dosage of 80kg.ha $^{-1}$. Rosal [17] obtained a maximum of 10 to 11 pods per plant at the maximum applied dose, which was 160kg.ha $^{-1}$. This difference can be explained by the difference between the cultivars used, which may present different conditions and behaviors.

Regarding the weight of one hundred grains (PCG) (Fig. 4), it is noted that the treatments with the use of gypsum in the soil, except at the rate of 40kg ha $^{-1}$, presented statistically higher results than those without application of gypsum.

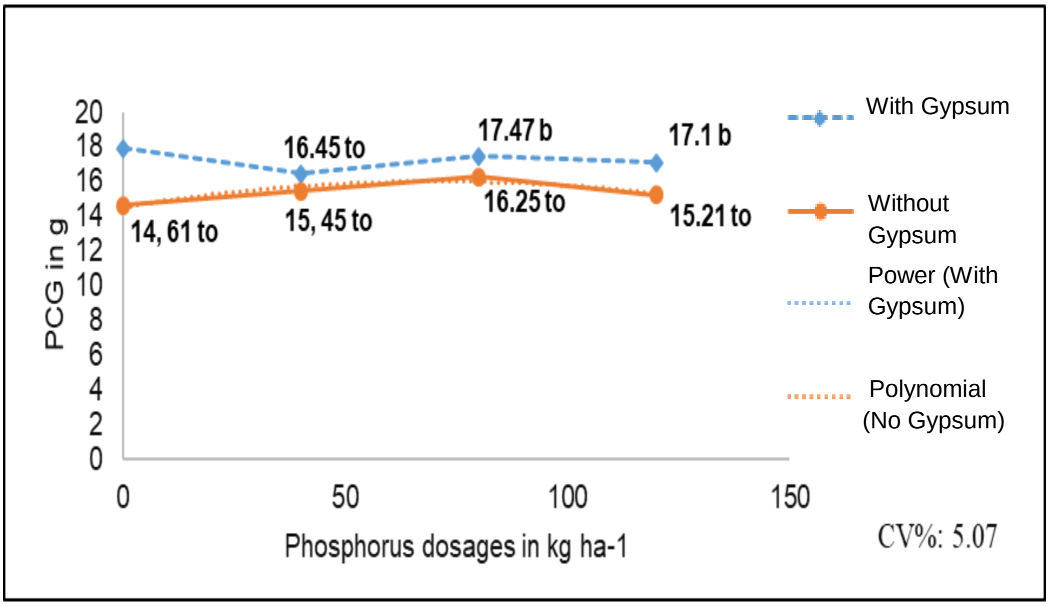

Fig. 4. Averages obtained for the weight of one hundred grains (PCG) in cowpea cultivar BR17 GURGUEIA, submitted or not to the application of gypsum and different doses of phosphorus. Araguatins - TO, 2018

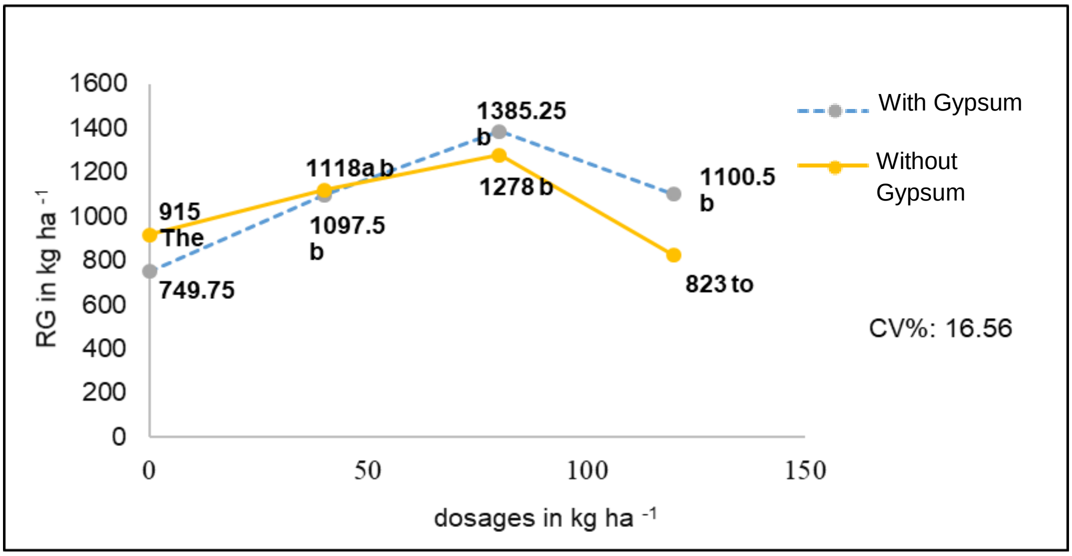

Fig. 5. Averages of grain yield (GR) of cowpea, cultivar BR 17 GURGUEIA, submitted or not to the application of gypsum and different doses of phosphorus. Aragua tins - TO, 2018

The result observed in the graph can be justified by the action that gypsum exerts indirectly on the development of roots in depth, as it facilitates the availability of nutrients and water for the plant, favoring the filling of grains.

Saldanha et al. [18] claim that this fact can be justified by the ability of gypsum to condition the root environment in a way that facilitates root development in depth. This response has been observed in most annual crops and is attributed to the fact that there is a greater distribution of the roots of the crops in the deeper layers, due to the reduction of chemical barriers and greater use of the nutrients available to the plant.

As for the component of grain yield (GR), the results were significantly favorable for the phosphorus doses (Fig. 5).

The crop response to phosphate fertilization depends on soil fertility, being favorable in soils with the absence or low presence of this nutrient.

The maximum productivity obtained was 1385 kg. ha $^{-1}$ with a dose of 80 kg. ha $^{-1}$, with a decrease with excess dose. This result is an indication that, under the conditions studied, phosphate fertilization cannot exceed the optimal amount of production.

Saldanha et al. [18] obtained, applying 80kg.ha $^{-1}$, a productivity of 1450 kg. ha $^{-1}$ in a dystrophic Haplic Plintosol in the edaphoclimatic conditions of the state of Piauí. Rosal [17] obtained an average productivity of 943 kg. ha $^{-1}$ at the rate of 90 kg. ha $^{-1}$ in a dystrocohesive yellow latosol. The difference in the results can be explained by the varied edaphoclimatic conditions and fertility levels of the mentioned soils.

Brazil [19] claim that, in general, the action of phosphorus in the soil will be influenced by the clay content present. In their studies carried out under the conditions of the state of Amazonas in a very clayey yellow oxisol, 60kg.ha $^{-1}$ of P_2O_5 was sufficient to raise the content of this nutrient in the soil to a level considered ideal for the development of the crop.

4. CONCLUSION

From the research, it is possible to notice that for the cowpea crop, the phosphorus dosage that stood out was 80kg ha $^{-1}$. This dosage showed better results in practically all parameters evaluated, including yield parameters. As for the use of gypsum, the results were better in treatments with the application of this soil conditioner. However, the results were not so expressive. This fact clarifies the use of gypsum as a long-term benefit in the culture, and can remain acting for years.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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