

Response curve of *salvia hispânica* L. to different dosages of phosphorus in soils of the cerrado

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Abstract—This study aimed to evaluate the response curve of phosphorus fertilization to the development and productivity of *Salvia hispânica*

L. in Cerrado soils in the South of Tocantins. The Chia seeds used in the experiments came from producers in the region of Katueté — Paraguay. The experiments were carried out in the experimental area at the Federal University of Tocantins, University Campus of Gurupi-TO, in the agricultural years 2014/2015 and 2015/2016, through a randomized block design with four repetitions. The treatments consisted of five levels of phosphorus fertilizer (0, 30, 60, 90 e 120 kg ha⁻¹). At 120 days after emergence, the following characteristics were evaluated plant height, upper stem height, stem diameter, bunches number, length of bunches, and grain Productivity. The data were submitted to analysis of variance and regression at the 5% probability level by the F test. The analysis of the results showed that the doses of 30 and 60 kg ha⁻¹ of phosphorus influenced positively in the most development and productivity in the culture of Chia in the harvest 2014/2015. The results also showed that increasing doses of phosphorus had not positive effects in the agronomic characteristics at the culture of Chia in the harvest 2015/2016. The maximum grains Productivity found in the isolated doses of P was superior to 157 kg ha⁻¹.

Keywords—fertilization, Chia, management, tropical soils.

I. INTRODUCTION

The Chia (*salvia hispânica* L.) is a herbaceous plant in the family Lamiaceae, native to southern Mexico [1]. The cultivation is gaining importance by their grain they produce excellent nutritional value, could be used in food as a health supplement and food formulation, resulting in this way, an increase of production, consumption, and demand-led primarily by

consumers worldwide as the United States, Canada, Japan and Australia [2, 3]. Currently, the commercial seed Productivity vary between 500 and 600 kg ha⁻¹, more some producers of Salta (Argentina) and Acatic (Mexico) have obtained 1,000 and 1,260 kg ha⁻¹, respectively [4, 5]. In Brazil, the Chia finds favorable conditions to good development, reaching between 200 and 800 income kg ha⁻¹ [6], although not as farming

fertilizer recommendations and coverage, cultural practices, harvest season among others, one of the main limitations for raising the productivity of soil conditions.

The requirement of nitrogen and phosphorus are low, however, the fertilization recommendations change according to region and type of soil so if it makes necessary more research on agronomic techniques for culture [7, 8]. Brazilian tropical soil nutritional requirement is highly variable especially in the Cerrado biome that exhibits poor in nutrients, especially phosphorus, which is often the most limiting nutrition of plants not only by low concentration but also for your link to soil colloids, affecting your availability [9]. Thus, the phosphate fertilization is essential for proper growth and better productivity of crops, because this nutrient is involved in the participation of cell membranes, nucleic acids and ATP, essential functions for the plants [10].

Fornasiere Filho (2007) [11] states that the available phosphorus in soil is an element essential to the nutrition of plants, playing a key role in the transfer and use of energy. In addition to being part of the establishment of a series of important compounds of plant cell respiration, photosynthesis, and intermediaries several vital functions in the plant

metabolism. The match is considered as an essential element for plants, by your active participation of compounds and reactions, and may not be replaced by other nutrients [10].

Considering the increasing international demand for Chia, the scarce information on your agronomic management, and the importance of phosphate fertilization of crops in soils of cerrado in Brazil. Objective to evaluate the response to phosphate fertilization for the development and productivity of *Salvia hispânica* L. in cerrado soils in the southern region of Tocantins.

II. MATERIALS AND METHODS

The tests were carried out on 2014/2015 and 2015/2016 crop, in the experimental area of the University Campus of Gurupi, located 11° 43' 45 " South latitude and 49° 04' 07" w, with an average height of 285m. The experiments were installed on land classified as red yellow Latosols dystrophic, profound, acid e de texture sandy (EMBRAPA, 2013) [12]. The data on precipitation, temperature and relative humidity in the period of conducting the experiments were collected at the weather station on Campus of Gurupi, and are presented in Figure 1.

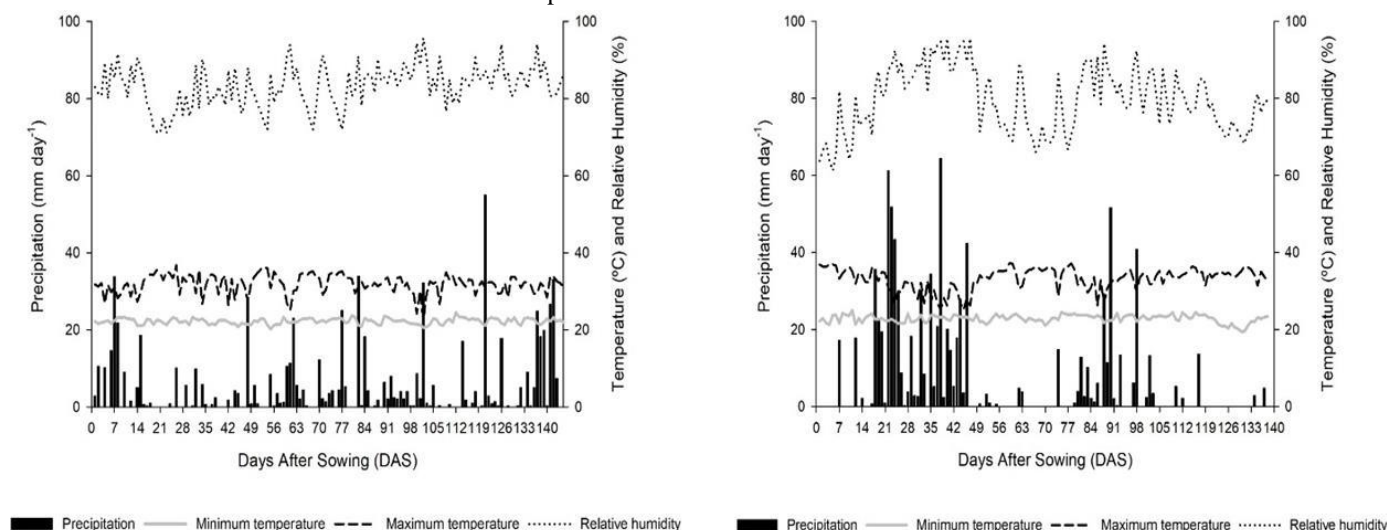


Fig. 1: Daily average values of temperatures(°C), daily total pluvial precipitation (mm) and daily average values of relative humidity (%), that occurred during the period 9 December 2014 the 3 of May 2015 (A) and 14 December 2015 the 2 May 2016 (B), Gurupi, TO.

The areas presented history with common bean and soybean farming in the off-season and cultivation of rice in the year. The physical and chemical characterization of the soil of the experimental area, at a depth of 0.00-0.20 m in 2014/2015 presented the following characteristics: pH em CaCl₂ = 5,2; M.O =

1,6% P (MeI) = 1,3 mg dm⁻³; K =37 mg dm⁻³; Ca+Mg = 2,5 cmolcdm⁻³; H+Al = 2,20 cmolcdm⁻³; Al = 0,00cmolcdm⁻³; SB = 2,19 cmolcdm⁻³; V = 50%; 69 dag kg⁻¹ of sand; 5 dag kg⁻¹ of silt and 26 dag kg⁻¹ of clay. To harvest 2015/2016 presented the following characteristics: pH in CaCl₂ = 5,0; M.O =

2,2 % P (Mel) = 39,3 mg dm⁻³; K =91 mg dm⁻³; Ca+Mg = 3,2 cmolcdm⁻³; H+Al = 2,0 cmolcdm⁻³; Al = 0,00 cmolcdm⁻³; SB = 2,19 cmolcdm⁻³; V = 58%; 75 dag kg⁻¹ of sand; 5 dag kg⁻¹ of silt and 20 dag kg⁻¹ of clay.

In both cases, the tillage was performed conventionally with plowing and two harrows. The experiments were conducted in experimental design, in random blocks with five, doses of phosphorus (0, 30, 60, 90, 120 kg ha⁻¹). The parcels consisted of 6,4 m², each composed of four rows of 4 m and 0.40 m spaced. Was considered the area the two central rows, disregarding 0, 5 m from each end.

For both assays, the phosphate fertilization was performed in the furrow applying the doses at the time of sowing, in the form of triple superphosphate. Potassium and nitrogenous fertilization were performed according to soil analysis.

Chia seeds were from producers in the region of Katueté-Paraguay. Using 3 g in 4 linear meters, aiming to achieve population end of 750,000 plants per hectare. In both cases, the thinning to 25 days after the emergency, leaving only 30 plants per linear meter.

Weed control was performed with manual weeding to 20:45 days after emergence, what stage the plants are sensitive to herbicide applications. Furthermore, herbicides were applied with active ingredient Clethodim (0.30 L p.c. ha⁻¹) at 60 and 75 days after emergence.

The culture has shown itself sensitive to common pests of other species, being made three applications of insecticide to 60, 80 and 120 days after emergence for caterpillar control falsa-medideira (*Chrysodeixis includens* and *Spodoptera* sp), vaquinha (*Macrodactylus pumilio*) and whitefly (*Benisia tabaci*) being used Alfacipermetrina (0,5 g i.a. ha⁻¹) e Diflubenzuron - Fenil-uréia (3,6 g i.a. ha⁻¹), for the control of caterpillar and vaquinha, and for the control of whitefly Acetamiprid (75 g i.a. ha⁻¹).

Due to the Veranico present in the last years in both cases a fixed conventional sprinkler irrigation system was installed. Both operating at a pressure of 20 MCA every two days, providing a water depth of 5.2 mm/hour. The water supply was carried out so that the culture did not suffer from water stress in critical phases such as emergence, flowering, and grain filling.

In the 2014/2015 crop due to the disuniformity of the natural maturation of the crop, the harvests were performed manually between 135 and 145 days after

sowing, harvesting the useful area when the plants reached 90% of yellow and dry leaves. In the 2015/2016 crop, the harvest was carried out manually at 138 days after emergence, standardizing the harvest point with desiccant with active ingredient Parachate (1,0 L P.C. ha⁻¹) when most bunches of plots reached 90% of dark coloration.

For evaluation of the characteristics phytotechnics, sampled ten plants representative of the area of each parcel. The characteristics evaluated were: number of curls obtained per plant, determined by direct counting in the plants sampled and transformed in m²(This characteristic was not considered in the 2015/2016 crop by the disuniformity that the crop presented in the emission of bunches); plant height measured in cm from the base of the plant's lap to the insertion of the bunches main; height of the upper stem measured in cm from the lap of the plant to the center point of the insertion of the last upper stem; diameter of the stem expressed in mm, using a digital caliper; length of the bunches expressed in cm, measured with ruler. Subsequently, of the bunches were threshing, cleaned identified by treatment and stored in plastic bags for evaluation of grain Productivity (kg ha⁻¹), The seed Productivity was obtained from the seed mass of the bunches harvested in the useful area of the plot, and the weight was measured on a digital scale. The values found in each plot were transformed into kilograms per hectare.

Data were subjected to analysis of variance and regression to the 5% level of probability for the F-test. To check the significance of the effects of the chosen regression model of higher degree. Analyses were performed with the use of computational SISVAR application version 5.3 [13].

III. RESULTS AND DISCUSSION

For the characteristic plant height in the 2014/2015 crop, the Chia culture responded significantly to the phosphate fertilization, presenting a quadratic adjustment in response to the application of P. The highest plant height was observed in the dose of applied phosphorus, 60 kg ha⁻¹ with 184.94 cm, and the lowest mean at the dose 0 kg ha⁻¹, with 159.84 cm (Figure 2A). In the 2015/2016 harvest crop for the same characteristic, a quadratic response was observed, varying from 158.87 cm to 170.91 cm, although there was no significant difference between the doses (Figure 2B).

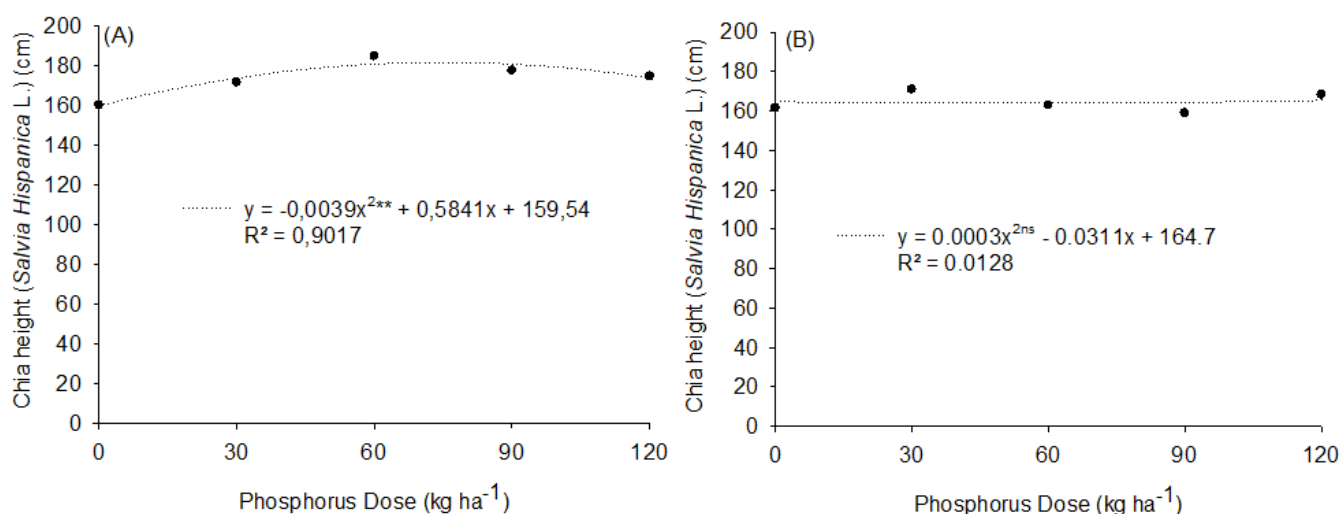


Fig. 2: Height of Chia plants as a function of five doses of phosphorus, 2014/2015 crop (A) and harvest 2015/2016 (B).

In the 2014/2015 crop for the characteristic height of the upper stem, the phosphate fertilization was significantly answered, presenting a quadratic response, in which the lowest height was observed at the dose of 0 kg ha⁻¹ (129,84 cm), showing a decreasing behavior After the dose of 60 kg ha⁻¹ (146,02 cm) (Figure 3A). In the 2015/2016 harvest for the same characteristic, there was no significance between the P doses, however, a quadratic response was observed, being the maximum at the dose 120 kg ha⁻¹ (127,81 cm) and the minimum at the dose 0 kg ha⁻¹ (117,52 cm) (Figure 3B).

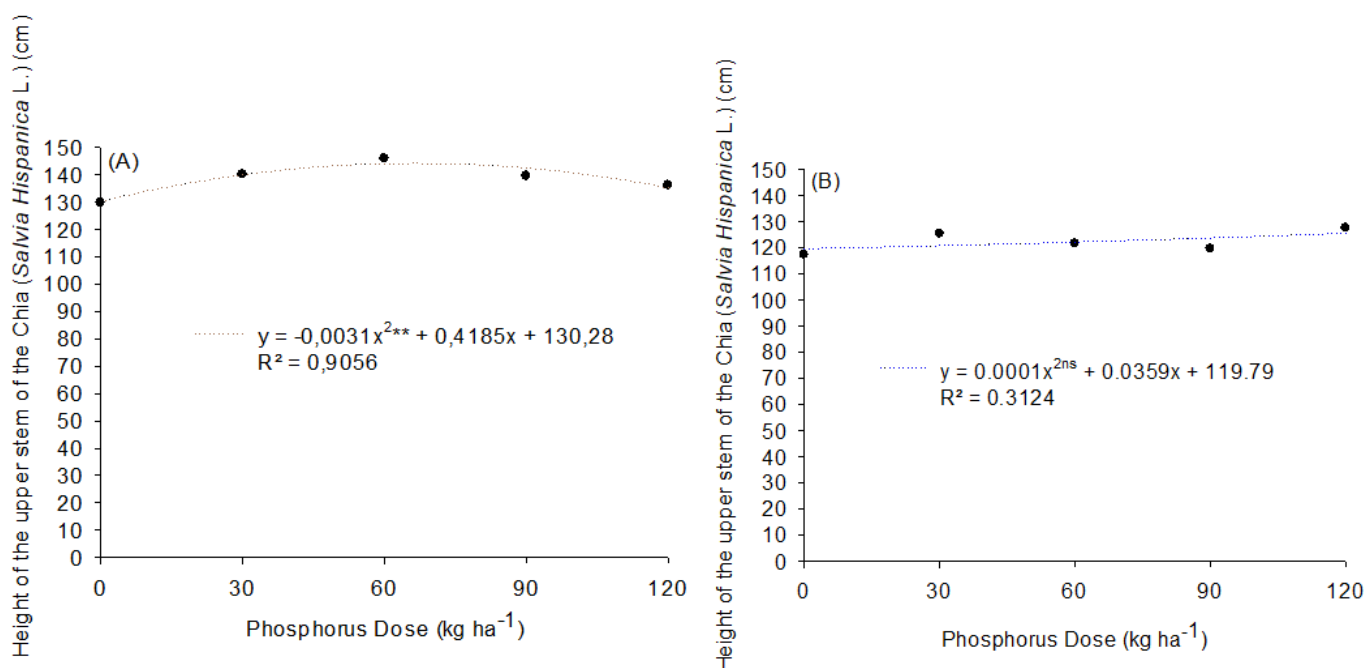


Fig. 3: Height of the upper stem of Chia plants in the function of five doses of phosphorus, 2014/2015 crop (A) and harvest 2015/2016 (B).

In the 2014/2015 crop for the characteristic, stem diameter there were significances between the doses, P (Figures 4A). The quadratic equation was the one that best adjusts to the highest mean in the dose of 60 kg ha⁻¹, with a value of 9, 15 cm, with an increment equivalent to 23, 93% when compared to the dose that results in a lower mean (6, 96 cm at the dose of 0 kg ha⁻¹). In the 2015/2016 crop for the characteristic, stem diameter was observed quadratic response varying

from 6, 58 cm to 7, 17 mm, although there was no significant difference between the doses (Figure 4B).

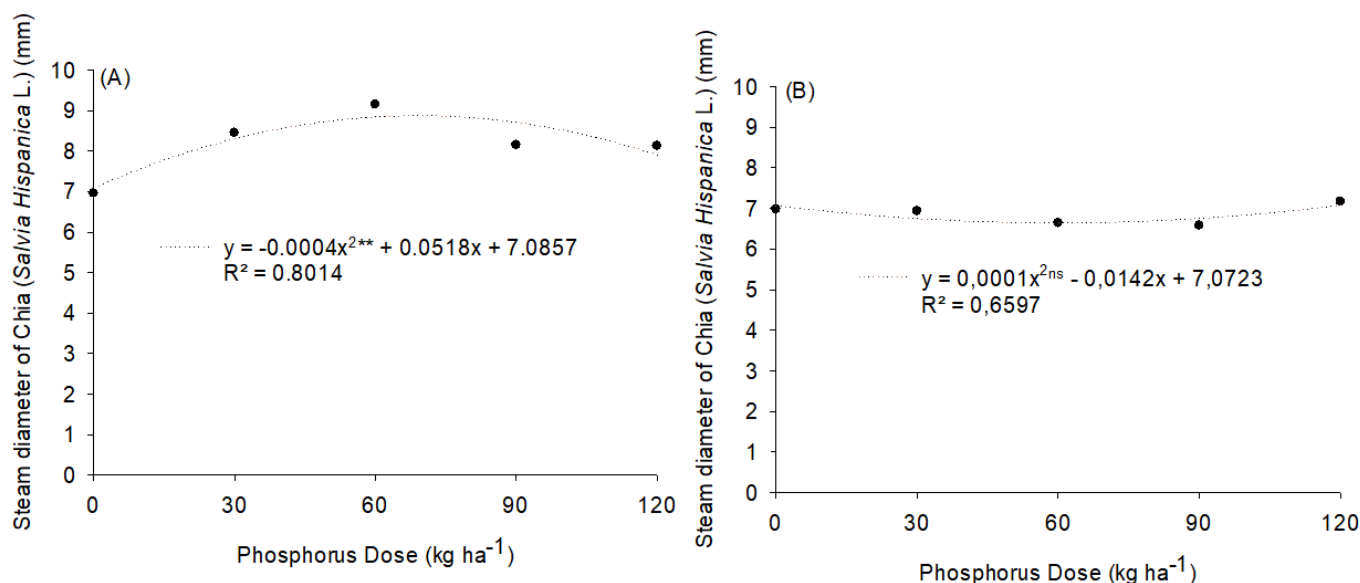


Fig. 4: Stalk diameter of Chia plants in the function of five doses of phosphorus, 2014/2015 crop (A) and harvest 2015/2016 (B).

For the characteristic number of bunches, there was a difference between the doses of phosphorus, being the quadratic equation that best adjusted, with maximum point in the application of 90 kg ha⁻¹ (227,03 bunches per m²) and lower mean at the dose of 0 kg ha⁻¹ with 141,17 bunches per m² (Figure 5).

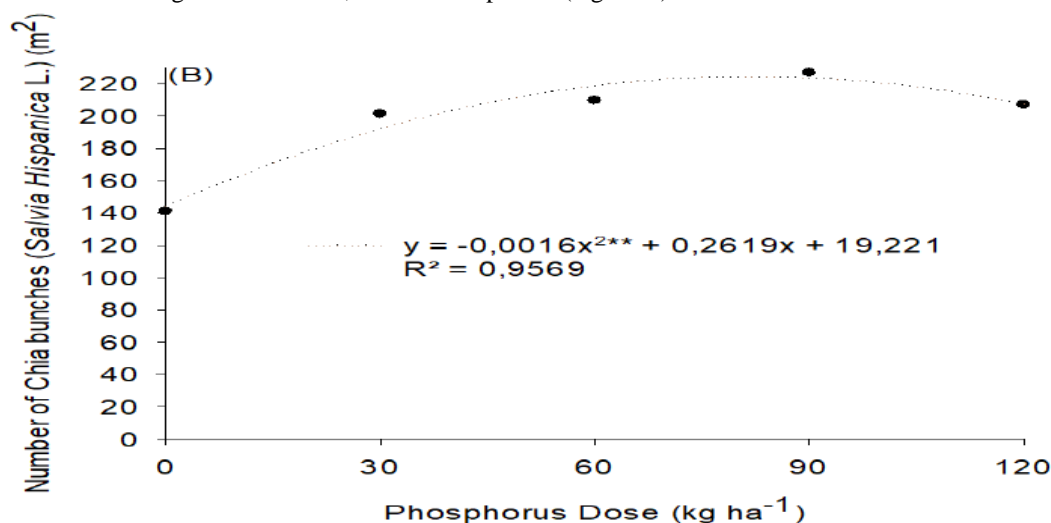


Fig. 5: A number of bunches of Chia plants as a function of five doses of phosphorus, 2014/2015 crop.

In the 2014/2015 crop for the characteristic length of the bunches, there was no difference between the doses of phosphorus, however, presented a quadratic response, in which the lowest height was observed at the dose of 0 kg ha⁻¹ (12,84 cm), showing decreasing behavior after the dose of 60 kg ha⁻¹ (13,47 cm) (Figure 6A). In the 2015/2016 crop for the same characteristic, a quadratic response with a variation of 10, 47 cm to 11, 77 cm was observed, although there was no significant difference between the doses (Figure 6B).

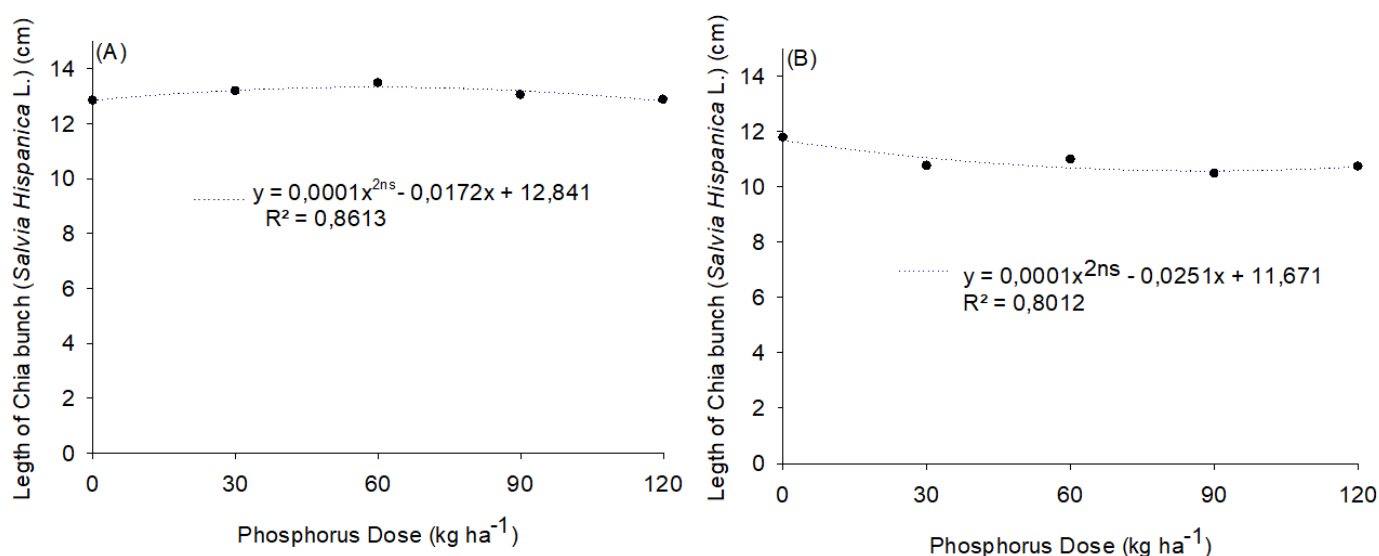


Fig. 6: Length of the bunches of Chia plants in the function of five doses of phosphorus, 2014/2015 crop (A) and harvest 2015/2016 (B).

In the 2014/2015 crop for grain Productivity, there was no difference between the P rates and the quadratic equation was the one that best adjusted, with a maximum point of 157, 87 kg ha⁻¹ estimated at the dose of 60 kg ha⁻¹ and of minimum productivity at the dose of 0 kg ha⁻¹ (122, 63 kg ha⁻¹) (Figure 7A). The same behavior was observed for the plant height, upper stem height, stem diameter, and bunches length characteristics. In the 2015/2016 crop for the grain Productivity characteristic, there was no difference between the P doses, however, a quadratic response with a variation of 159, 17 to 203, 72 kg ha⁻¹ was observed, although there was no significant difference between the doses (Figure 7B).

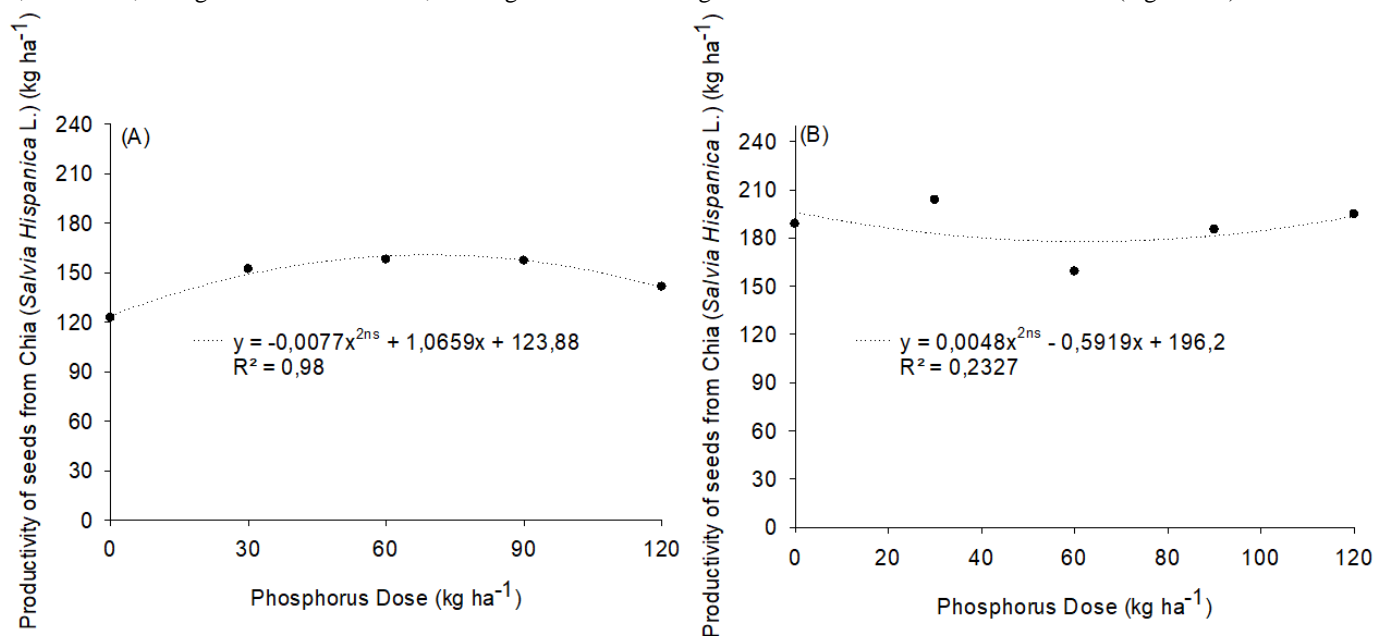


Fig. 7: The productivity of Chia grain as a function of five doses of phosphorus, 2014/2015 crop (A) and harvest 2015/2016 (B).

For the phosphate fertilization in the 2014/2015 crop, the results obtained for plant height, the height of the upper stem, stem diameter, number of bunches were expected, because it is an element that

participates directly in plant growth, and both the Absence as excess may interfere in their development. According to Machado et al. (2011) [14], the level of availability of P existing in tropical soils is very low to

the point of compromising the development of plants. High concentrations decrease its absorption, reducing its availability in the plant, affecting the application and consequently, in its development [15]. However, at adequate levels, it promotes higher height, emission, and growth of leaves, besides resulting in larger leaf area, allowing greater uptake of solar radiation and increase in the production of Photoassimilates [16].

Naomi et al. (2014) [17] studied the growth and productivity of *Salvia officinalis* L. and observed that phosphorus shows significant effects on plant height and the highest results were obtained in plots where

60 kg ha⁻¹ of P was applied and the lower results where there was no application of P.

It was observed that unfertilized plants had the smallest height of the upper stem (Figure 2B), showing that this element is indispensable for development. The absence of phosphorus can reduce several important biochemical functions in plant physiology [10], which may have negatively contributed to the height of the stems. Maia et al. (2008) [18] studying *Hyptis suaveolens* (Lamiaceae) reported that nutrient limitations caused alterations in plant morphology.

According to Bonfim-Silva et al. (2011) [16] phosphorus deficiency includes the reduction of stem length, which directly influences the size of the plant. Adequate phosphorus concentrations allow the production of carbohydrates and sugars indispensable for the composition of their vegetal tissues [19]. According to Coelho et al. (2007) [20], the stem diameter is a characteristic of little relevance, however, it has an important function in the support of the architecture of the plants decreasing the lodging indexes and favoring the mechanized harvesting.

A low number of bunches in unfertilized plants is observed. These results are plausible because this nutrient has a fundamental role in the transfer of cell energy, respiration, and photosynthesis, besides acting as a structural component in plants [10]. Thus, the absence of the nutrient may also limit crop production factors, mainly in soils, where the natural availability of this element is found at low levels [21, 22].

Phosphorus presents low mobility in the soil and a large capacity to be adsorbed by clay, minerals, and oxides. Faced with this problem, many plant species have shown that the supply of phosphorus is indispensable in the initial phase of the plant life for a satisfactory growth of the crop [9], since under conditions of low concentration and availability, can result in restrictions of which the plant does not recover, even if the supply of phosphorus at

appropriate levels is subsequently increased. Although there was no significant difference between the different doses of phosphorus, it was observed higher productivity in the treatments with phosphate fertilization. Low phosphorus doses may have been similar to the highest doses due to residues present in the soil of previous crops.

For phosphorus in the 2015/2016 crop, no significant response was observed at plant height, upper stem height, length of bunches, stem diameter and grains productivity with an increment of doses. Souza et al. (2013) [23] verified that the phosphorus doses did not significantly influence the physiological aspects of growth and biomass production of *Mentha piperita* L. Belonging to the family Lamiaceae. However, David et al. (2007) [24] studied the same species, observed variation in behavior for many of the variables evaluated, when subjected to different levels of phosphorus.

The lack of response from Chia to high P doses for all evaluated traits could probably be explained by the fact that the crop is a rustic species, that is, little improved and not responsive to high concentrations of P. According to Gómez et al. (2008) [25] the *Salvia hispânica* L. requires a rescue program of the native species in order to better plan its management through a future breeding program and avoid loss of genetic material. Moreover, the lack of response may be associated with a slight loss of genetic variability in the process of domestication of Chia culture, the plant selection is being carried out from domesticated plants [26].

Another factor that may have contributed to the absence of response to phosphate fertilization is the content of the nutrient present in the soil (0.0393 g dm⁻³), with low phosphorus doses, has become satisfactory for the good development of certain characteristic of culture of Chia throughout the cycle, supplying the plant's need and consequently not responding to the high doses of applied fertilization. This is evidenced by analyzing the characteristic of the length of the bunches, which presented the best means at the dose of 0 kg ha⁻¹. (11, 77 cm).

The response of Chia to phosphate fertilization, in this study, was mainly affected by the availability of P in the soil, due to the historic of the use of the area, which showed an addition of P corresponding to previous crops, allowing amortization in the doses of fertilization phosphate. According to Wright (2009) [27], the presence of phosphorus is dependent both on soil management and historic use of the area.

However, to confirm the obtained results, it is necessary to perform other tests of phosphate fertilization, since the species is adapting to the edaphoclimatic conditions of the country and the region under study where the nutritional requirements are still unknown.

IV. CONCLUSION

The doses of 30 and 60 kg ha⁻¹ of phosphorus influenced positively in the higher development and productivity in Chia culture in the 2014/2015 crop. The increasing doses of phosphorus did not positively influence the agronomic traits of Chia culture in the 2015/2016 crop. The maximum grain productivity found in P doses was higher than 157 kg ha⁻¹.

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