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Phosphorus application effects on seeding chia

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Abstract: Chia (*Salvia Hispanica* L.) is an annual herbaceous plant belonging to the family Lamiaceae, with large proportions of omega-3, omega-6, antioxidants, fibers and proteins in its composition. Information and recommendations on its cultivation are still limited, as interest in the plant is recent. Thus, the objective of this work is to verify the effects of the application of phosphorus doses in the sowing of chia. The experiment was conducted under field conditions, at Fazenda da Universidade Estadual de Maringá, at the Umuarama Regional Campus. The soil of the place where the typical Dystrophic Red Latosol, with sandy texture experiment was implanted. The experimental design was a randomized block with five treatments and five replicates. The treatments were composed of five doses of phosphorus at sowing (0, 30, 60, 90, 120 kg ha^{-1}). The dry mass of the aerial part, final population of plants, mass of 1,000 grains, productivity and oil content were evaluated. Phosphorus rates application at sowing provided positive increases in the vegetative and reproductive chia development.

Key words: Salvia hispanica, fertilization fosfatada, oleaginosa.

Efeitos da aplicação de fósforo na semeadura de chia

Resumo: A Chia *(Salvia Hispanica* L.*)* é uma planta anual herbácea pertencente a família Lamiaceae, com grandes proporções de ácidos graxos ômega-3, ômega-6, antioxidantes, fibras e proteínas em sua composição. As informações e recomendações técnicas sobre o seu cultivo ainda são limitadas, pois o interesse pela planta é recente. Deste modo, o objetivo desse trabalho é verificar os efeitos da aplicação de doses de fósforo na semeadura da chia. Foi conduzido o experimento em condições de campo, na Fazenda da Universidade Estadual de Maringá no Campus Regional de Umuarama. O solo do local onde foi implantado o experimento é um Latossolo Vermelho Distrófico típico, com textura arenosa. O delineamento experimental utilizado foi o de blocos casualizados com cinco tratamentos e cinco repetições. Os tratamentos foram compostos por cinco doses de fósforo na semeadura (0, 30, 60, 90, 120 kg ha^{-1}). Foram avaliados a massa seca da parte aérea, população final de plantas, massa de 1.000 grãos, produtividade e teor de óleo. A aplicação de doses de fósforo na semeadura proporcionou incrementos positivos no desenvolvimento vegetativo e reprodutivo da chia.

Palavras-chave: *Salvia hispânica*, fertilização fosfatada, oleaginosa.

Introduction

Chia (*Salvia hispanica* L.) is an annual herbaceous plant belonging to the Lamiaceae family, native to Mexico and Guatemala (Orozco and Romero, 2003), approximately one meter high (Aguillera, 2013), but Irala (2013) affirmed that in Paraguay the plants can reach up to 1,7 m in height.

It has a stem covered with hairs. Opposite leaves, oval or elliptical in shape from four to 8 cm in length and three to five in width (Pozo, 2010). The flowers are hermaphrodite, purple and white and appear in terminal inflorescences. Fruits are indehiscent, whose seed is rich in oil (Aguillera, 2013). Recent research shows that the seed has a high nutritional value with high content of linolenic acid (omega-3) and linoleic (omega-6), antioxidants, dietary fiber and protein (Rabbit and Sallas-Melado, 2014).

The plant is best adapted to medium to sandy soils, well drained, not very humid, tolerant to acidity and not able to withstand frost (Jiménez, 2010), however Miranda (2012) states that measures should be recommended for regulate the pH of soil. It is a species of wide geographic distribution (Hernandez-Gomez et al., 2008), in Brazil it can be cultivated in different places, temperature, altitude and rainfall meet the requirements of the culture (Migliavacca et al., 2014).

Planting can be done in the months of October to November, when conditions are more favorable to development, but can also be done in the months of March and April (Migliavacca et al., 2008). It is recommended that 3 kg ha^{-1} be used in spacing of 0.5 m between rows using 20-25 seeds per meter well distributed (Miranda 2012; Irala, 2013), this recommendation can vary from 5 kg ha^{-1} (Irala, 2013) or even 6 kg ha^{-1} (Busilacchi et al., 2013). The interest in the plant is recent and there are no in-depth studies on fertilization.

When growing a portion of the soil years after years, soil nutrients will occasionally be insufficient for the correct development of the plant. One way to make the plants available again is through a well-made fertilizer, giving the plant the elements, it needs (Malavolta, 1997).

Phosphorus is the nutrient that most reduces yield in soils that are never or poorly managed (van Raij et al, 1997). In general, phosphorus stimulates root growth, accelerates maturation, stimulates flowering, assists seed formation, and increases the winter cold resistance (Malavolta 1997). Phosphate fertilization is of great importance for obtaining better quality oil (Ramos et al., 2005).

The objective of this work was to evaluate the effect of phosphorus rates applied to sowing of chia.

Material and Methods

Experiment was conducted under field conditions, on Farm of Universidade Estadual de Maringá, located at 23 ° 47 'south latitude and 53 ° 14' west longitude. Climate is subhumid with average annual temperature of 24 ° C and average rainfall of 1,600 mm. The soil is a typical Dystrophic Latosol with sandy texture (EMBRAPA, 2018).

Climate of the region is classified as Cfa, being subtropical, with average temperature in the coldest month below 18 °C and average temperature of the month warmer above 22 °C, with hot summers, frosts infrequent and trends of concentration of rains in the summer months, but without a defined dry season (IAPAR, 2014).

Sowing was done in December. Since there is no recommendation for fertilization of chia, the recommendations for peppermint were used as the basis, since it belongs to the same botanical family, which consisted of 20 and 60 kg ha^{-1} of nitrogen and K_2O at sowing respectively (Pauletti and Motta, 2017). P_2O_5 rates were applied according to treatments.

Each experimental plot was composed of five lines with five meters in length, spaced by 0.45 m, with approximately 25 seeds per meter and 3 kg ha^{-1} of seeds. The three central lines were considered as useful area, with 0.5 being seen at both ends.

Experimental design was a randomized block with five treatments and five replicates. The treatments were composed of five doses of P2O5 applied at sowing (0, 30, 60, 90, 120 kg ha^{-1}). The source used was simple superphosphate.

In the conduction of the experiment, manual weeding was performed whenever necessary to control weeds.

Manual harvest was carried out, at the end of the crop cycle, by cutting the aerial part of the plants, in the useful area of each experimental plot.

After the harvest, the grains were threshed and the sieves were cleaned, removing the impurities from the harvest for analysis.

The shoots were harvested at 65 °C, then weighed and the data were converted into kg ha^{-1}, thus obtaining the shoot dry matter.

Before harvesting, the plants of the useful area were counted and the values converted to plants per hectare, thus obtaining the final population of plants.

It was evaluated the mass of 1,000 grains, for which they will be counted and weighed by the average of two replicates per plot, in a precision scale.

Yield was obtained by weighing the grains harvested in the useful area and later conversion to kg ha-^{1}. Both the 1,000 grain mass and the yield will have their values standardized at 13% moisture. (Brazil, 1992).

Oil content in the seeds was quantified in the laboratory, by the methodology of extraction with petroleum ether in Soxhlet type apparatus (IAL, 2008).

Statistical analysis was performed following the variance analysis model, using the Sisvar program, using the 5% level of significance. The means were compared by linear or quadratic regression, with the same level of significance.

Results and Discussion

According to the information generated from the analysis of variance, there was no significant effect on the final population of plants and on the number of inflorescences per plant (Table 1). Ferreira et al. (2006) reported that the plant population did not vary according to the applied phosphorus doses. This demonstrates that the use of phosphorus did not cause toxicity.

Shoot dry matter the chia plants were adjusted in increasing linear regression (Figure 1). This means that according to the increase of phosphorus rates there was an increase in dry matter, the same was observed in the work of Ramos et al. (2005), which applied increasing doses of phosphorus in mint (*Mentha* x villosa), and verified an increase in shoot dry matter production. Low supply of phosphorus to the plants may lead to a decrease in leaf area, due to the reduction of leaf numbers and also the limitation to leaf expansion (Rodríguez et al., 1998). According to Bonfim-Silva et al. (2011), phosphorus in adequate levels, besides showing positive effects to the expansion of the leaf area, also shows results on the height, emission and growth of leaves, allowing greater capture of solar radiation and increased photoassimilates production.

Table 1. Inflorescences per plant and final plant population of chia, under function of phosphorus rates applied in sowing. Umuarama, PR, 2016 / 17

P_2O_5 rates kg ha^{-1}	**Inflorescences per plant number**	**Plants population One thousand plants ha^{-1}**
0	21,5	261
30	12.7	227
60	18,2	194
90	26,7	183
120	22,2	222
V.C.(%)	15,1	21,2
L.R.	n.s.	n.s.
Q.R.	n.s.	n.s.

V.C. = variation coeficient; L.Q. and Q.R. = linear and quadratic regression, respectively; n.s. = not significance.

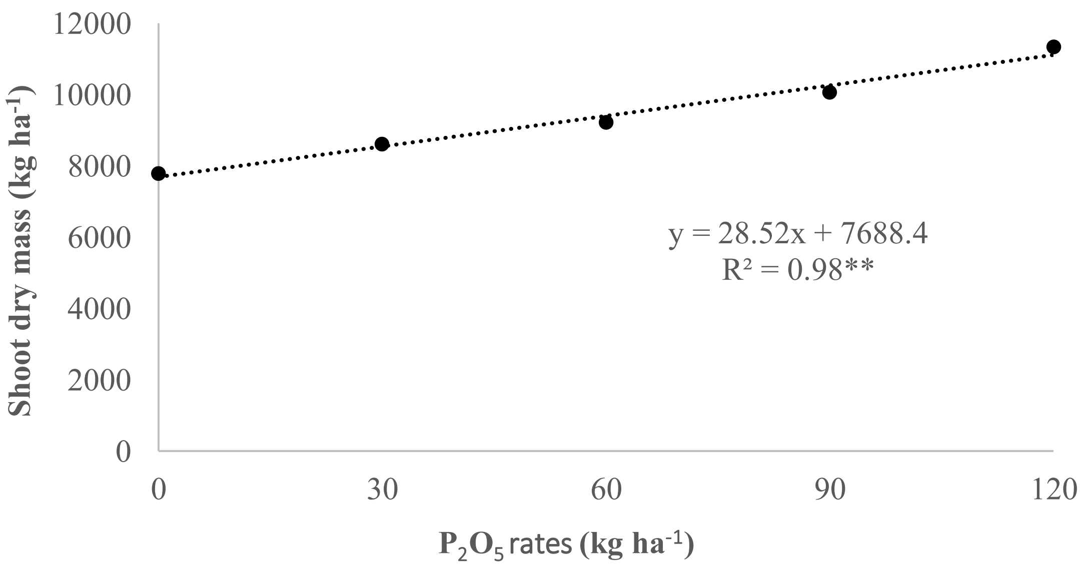

Figure 1. Shoot dry matter of chia (kg ha^{-1}), under function of phosphorus rates applied in sowing. Umuarama, PR, 2016 / 17. ** = 1% significative. Variation coeficient = 16,1%.

The increase in shoot dry matter production was expected, since phosphorus is an essential element to the growth and reproduction of plants, which can not demonstrate their maximum yield potential without a correct nutritional supply (Marschner, 1995). It is known that in its inorganic form, phosphorus is a substrate or final product in various enzymatic reactions, including those of photosynthesis and carbohydrate metabolism, is essential element in regulation of metabolic pathways in the cytoplasm and in the chloroplast, synthesis of starch and sucrose , triphosphate transport and translocation of sugars (Mitra et al., 1993).

Phosphorus rates application also had a significant effect on the mass of 1,000 grains (Figure 2), a result similar to that found by Dourado et al. (2001), which observed an effect of the increase of the doses of phosphorus applied at sowing, in the mass of 1,000 grains of crotalaria (*Crotalaria juncea* L.).

Chia yield adjusted linearly as a function of the increase of phosphorus rates applied in soil (Figure 3). The yield response at application doses are also reported in the work of Zucarelli et al. (2006), which obtained significant results with the increase of phosphorus rates applied in bean sowing (*Phaseolus vulgaris* L.) cultivated in the water period. The yields achieved are plausible, because phosphorus plays a fundamental role in the energy transfer of the cell, in respiration and photosynthesis, besides acting as a structural component in plants. (Taiz and Zeiger, 2013). In this way the absence of this element can act as a limiting factor in the development and in factors of crop yield (Santos and Kliemann, 2005).

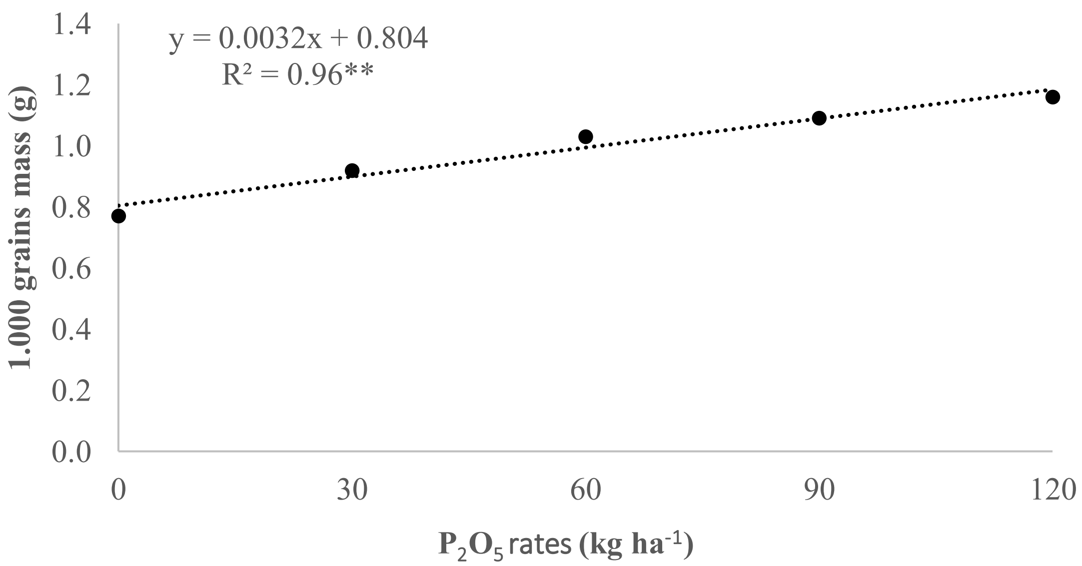

Figure 2. 1.000 grains mass of chia (grams), under function of phosphorus rates applied in sowing. Umuarama, PR, 2016 / 17. ** = 1% significative. Variation coeficient = 14,1%.

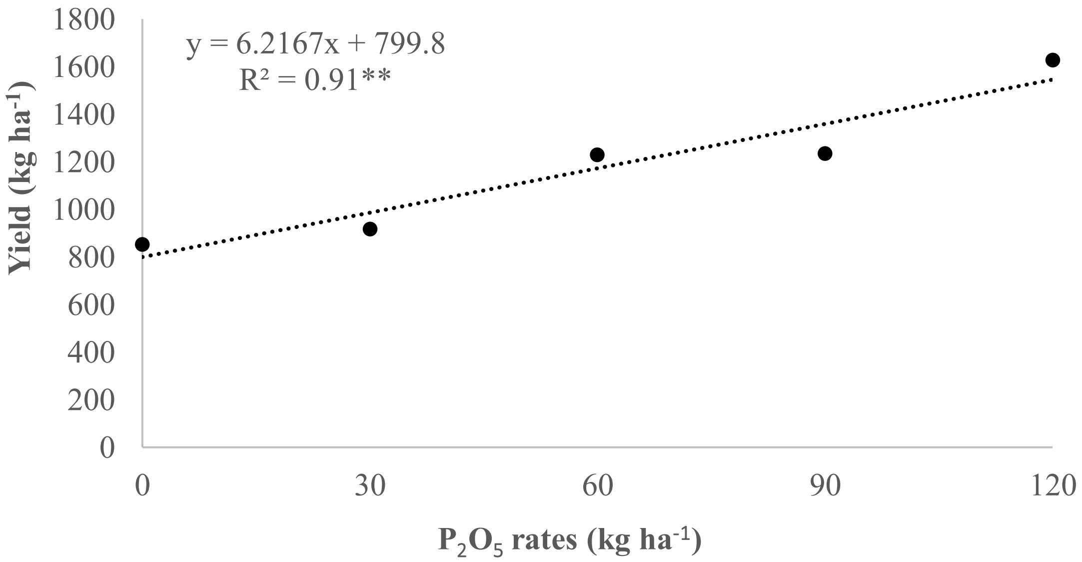

Figure 3. Chia yield (kg ha^{-1}), under function of phosphorus rates applied in sowing. Umuarama, PR, 2016 / 17. ** = 1% significative. Variation coeficient = 14,7%.

Oil content (Figure 4) showed a significant increase as a function of increase rates phosphorus, according to David et al. (2006) this is probably due to the action of essential elements in metabolic processes, allowing to state in this study that maximum rate provided the highest oil content. According to Malavolta et al. (1997), phosphorus is a constituent of molecules such as DNA and RNA and participates in protein and lipid synthesis, which makes it indispensable in oil plants. According to David et al. (2007), phosphorus participates in several stages of biosynthetic route for the formation of oil from mono- and sesquiterpenes, as part of enzyme molecules or reaction products catalyzed by these enzymes.

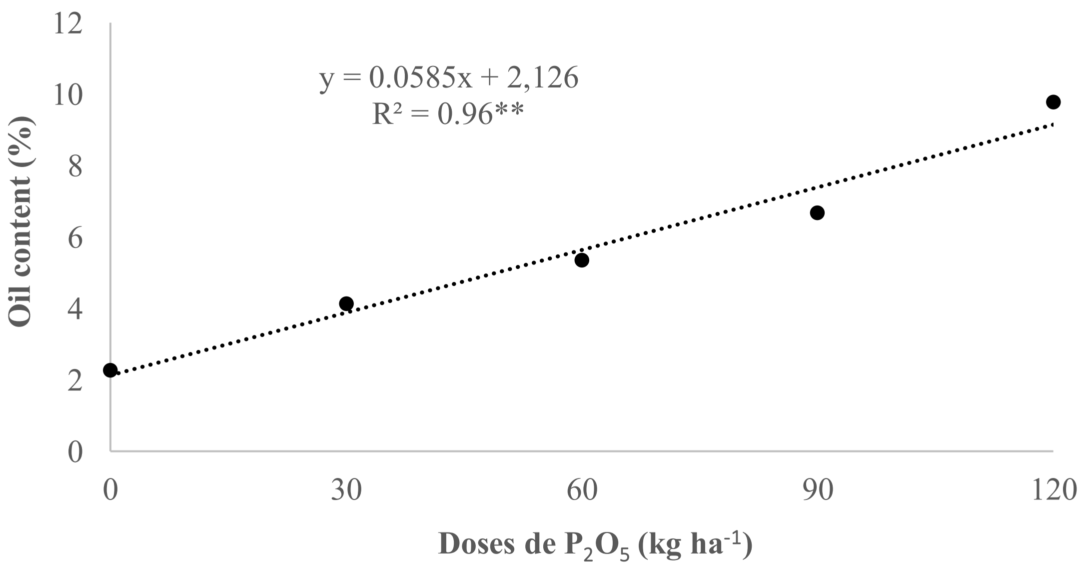

Figure 4. Oil content (%), under function of phosphorus rates applied in sowing. Umuarama, PR, 2016 / 17. ** = 1% significative. Variation coeficient = 8,6%.

O teor de óleo (Figure 4) apresenta percentual de aumento de x% da testemunha para x% do tratamento na maior dose, de acordo com David et al. (2006) isso provavelmente se deve à ação de elementos essenciais nos processos metabólicos, permitindo afirmar neste estudo que a taxa máxima proporcionou o maior teor de óleo. Segundo Malavolta et al. (1997), o fósforo é um constituinte de moléculas como DNA e RNA e participa da síntese de proteínas e lipídios, o que o torna indispensável em plantas oleaginosas. De acordo com David et al. (2007), o fósforo participa de várias etapas da rota biossintética para a formação de óleo a partir de mono- e sesquiterpenos, como parte de moléculas enzimáticas ou produtos de reação catalisados por essas enzimas. Os teores de óleo são diferentes na literatura, entretanto, não se tem dados da produção de óleo na região. Como o cultivo da chia é recente no Brasil, os valores encontrados nos teores de óleo podem ser divergentes devido ao alto grau de heterogenia entre as plantas, haja vista que não existem cultivares registrados para a chia.

Conclusion

Phosphorus rates application at sowing provided positive increases in the vegetative and reproductive development of chia.

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