

Phytometric and Productive Characteristics of Safflower Submitted to Phosphate Fertilization in the Oxisol of the Brazilian Cerrado

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Abstract

The safflower (*Carthamus tinctorius* L.), in particular, has been soaring in significance as an alternative for oil and biodiesel production. In this context, the goal of this study was to assess the influence exerted by phosphate fertilization on the phytometric and productive characteristics of the safflower raised on the Oxisol of the Cerrado. The experiment was performed in a greenhouse, using pots of 3 dm⁻³ in volume. Adopting the completely randomized design, five doses of phosphorus (P₂O₅: 0, 90, 180, 360 and 540 mg·dm⁻³) and six replicates were included. The following variables were estimated, viz., number of leaves, plant height, and stem diameter, besides chlorophyll index (SPAD index), number of chapters and shoot dry matter. Barring the shoot dry matter and number of chapters, all the other variables were evaluated on days 30 and 45 after the plants were transplanted. Data were submitted to analysis of variance at 1%, 5% and 10% probabilities, and regression analysis, at 1% and 5% probabilities, respectively. All the variables revealed significant differences and adjustments to the linear regression model (P < 0.1), excepting the SPAD index on day 30 after the plant emergence which was adjusted to the quadratic regression model. The highest findings of 24.47 for leaf number, 34.97 cm for plant height, 3.76 mm for stem diameter, 64.76 for chlorophyll index, 5 units for the number of chapters and 3.45 g for dry shoot mass were recorded in response to the highest phosphorus dose in the experimental range (P₂O₅: 540 mg·dm⁻³). Phosphate fertilization was observed to affect the phytometric characteristics and boost the development of the safflower plants cultivated in the Cerrado Oxisol, substantiating that safflower could be a viable cash crop that can be established in the Brazilian Cerrado.

Keywords

Carthamus tinctorius L., Alternative Culture for Biodiesel, Oleaginous

1. Introduction

Safflower (*Carthamus tinctorius* L.) holds great promise as a potential alternative to oil and biodiesel production [1]. This annual crop from the Asteraceae family, to which the sunflower (*Helianthus annuus* L.) belongs, originated somewhere between Asia and Africa [2] [3].

With seeds high in oil content (27% to 37%) [4], besides minerals (Zn, Cu, Mn, and Fe), vitamins (thiamine and β -carotene) and tocopherols (α , β , and γ) [5], it produces high-quality oil which is tasteless and colorless. As the oil is similar in composition to that of sunflower (*Helianthus annuus* L.), it can also find extensive use in human consumption and for industrial purposes [6] [7].

In Brazil, studies on safflower culture are still in the inceptive stage and, as the economic potential and environmental significance of this crop are increasingly becoming known, further researchers focused on the productive process from the perspective of soil fertility and plant nutrition are required [8] [9] [10] [11].

The roughly 14.55 million hectares [12] demarcated in the state of Mato Grosso in 2017, for raising cereals, legumes and oilseeds can be utilized to include safflower cultivation as a profitable option in this production process. However, in the tropical regions, where soils like Oxisol cover a large area of the Cerrado, the phosphorus content is low. This is because of the phenomenon of phosphorus fixation in the soil components which act as a considerable sink for phosphorus, requiring the application of phosphorus as fertilizer in doses several times greater than those required by the crops [13]. However, in Brazil, phosphorus is provided in the form of soluble phosphates, which intensely react in the soil, and support their absorption by the plant roots.

In light of these facts, this study aimed at assessing the effect of phosphate fertilization on the phytometric and productive characteristics of the safflower, cultivated in the Oxisol of the Cerrado.

2. Material and Methods

The experiment was conducted between September and December of 2016 in a greenhouse at the Federal University of Mato Grosso, University Campus of Rondonópolis, with the coordinates of 16°27'49"S latitude, 50°34'47"W longitude, at 284 m altitude. The region, according to the Köppen classification, experienced Aw type of climate, which is hot and humid, characterized by the rainy season in the summer and drought in the winter [14]. The temperature during the period varied between 24.1°C and 30.6°C, and the relative humidity between 56% and 69%. The day length was 12.2 hours.

The completely randomized experimental design was selected, including five

doses of phosphorus (P_2O_5 : 0, 90, 180, 360 and 540 $mg \cdot dm^{-3}$) with six replicates, using the BAG-IMA MT 187 safflower cultivar, obtained from the germplasm bank of Mato Grosso Cotton Institute (IMAmt), Brazil.

The soil, from a region supporting Cerrado vegetation, was collected from 0 to 0.2 m depth and sieved through a mesh with 4 mm sized openings to fill the container; it was also passed through a 2 mm mesh for chemical and granulometric characterization [15].

The soil collected from the prescribed depth revealed the chemical characteristics listed: pH (H_2O) = 4.7; O.M = 20.6 $g \cdot Kg^{-1}$; P = 1.7 $mg \cdot dm^{-3}$ (Mehlich-1); K = 24 $mg \cdot dm^{-3}$; Ca = 0.2 $cmol \cdot dm^{-3}$; Mg = 0.2 $cmol \cdot dm^{-3}$; Al = 0.8 $cmol \cdot dm^{-3}$; H + Al = 5.20 $cmol \cdot dm^{-3}$; CTC = 5.66 $cmol \cdot dm^{-3}$; Zn = 0.7 $mg \cdot dm^{-3}$; Cu = 0.5 $mg \cdot dm^{-3}$; Fe = 194 $mg \cdot dm^{-3}$; Mn = 13.4 $mg \cdot dm^{-3}$; B = 0.26 $mg \cdot dm^{-3}$ and S = 6.8 $mg \cdot dm^{-3}$. Based on the soil granulometry the following distinctions could be made: 507 $g \cdot Kg^{-1}$ of sand, 116 $g \cdot Kg^{-1}$ of silt and 377 $g \cdot Kg^{-1}$ of clay.

The soil pH was raised through liming, by implementing the base saturation method [16]. The dolomitic limestone (PRNT of 80.3%) was incorporated to increase the base saturation to 60%. Post liming, the soil was moistened up to 60% of its water retention capacity [9], and subjected to a 28-day incubation period in a sealed plastic bag.

Once the soil was incubated, it was filled with pots 3 dm^3 in volume. The safflower seedlings were then transplanted into the pots on day 5 post plant emergence. Phosphate fertilization (P_2O_5) in 90, 180, 360 and 540 $mg \cdot dm^{-3}$ doses was performed on the same day that the seedlings were transplanted, employing simple superphosphate, along with potassium fertilization (200 $mg \cdot dm^{-3}$) using as a source potassium chloride (PA), pure for the analysis. Nitrogen fertilization was done following the recommended dosage of 200 $mg \cdot dm^{-3}$ [17], with urea as the source, given in divided doses in solution form, in three equal applications applied at intervals of 10 days from the date of transplanting.

Micronutrient fertilization was accomplished by adding a solution of 1 $mg \cdot dm^{-3}$ of B and Cu, 3 $mg \cdot dm^{-3}$ of Mn and Zn and 0.2 $mg \cdot dm^{-3}$ of Mo [9]. The gravimetric irrigation method was employed, maintaining the moisture at 60% of the maximum soil water retention capacity [18].

The variables assessed included, number of leaves, plant height, stem diameter, chlorophyll index (SPAD index), and number of chapters and shoot dry matter. On day 62 after transplanting, the plants were cut. Except for the variables shoot dry matter and number of chapters evaluation was done on days 30 and 45 after transplanting.

The variable plant height was determined using a graduated ruler from the ground level to the plant apex. The stem diameter was recorded using a digital caliper, at about 2 cm from the soil surface. The number of chapters was counted in each experimental plot. The chlorophyll index was obtained from the average of the random readings of five leaves using the Chlorophyll Meter SPAD-502[®] equipment.

The shoot dry matter was calculated using the plant material cut on day 62 after transplanting. This material was packed in paper bags and then oven dried with forced air circulation at 65°C until constant mass was achieved. The dried samples were then weighed using a semi-analytical balance.

Data were submitted to the Shapiro-Wilk ($P > 0.01$) and Levene ($P > 0.01$) tests to check the residual normality and homoscedasticity, respectively. Thereafter, the analysis of variance was performed at 1%, 5% and 10% probabilities and the findings were submitted to regression analysis at 1% and 5% probabilities. The SISVAR statistical software was used [19].

3. Results and Discussion

For the variables, number of leaves on days 30 and 45, plant height on day 45, SPAD index on days 30 and 45, number of chapters and shoot dry matter, the results of the analysis of variance showed significance at 1%. For plant height on day 30 and stem diameter on day 45 the significance was noted at 5% and for stem diameter on day 30, the significance was seen at 10%. All the variables were adjusted to the linear regression model (at 1% probability), barring the SPAD chlorophyll index on day 30, which was adjusted to the quadratic model at 5% probability.

The most number of leaves in the assessment on day 30 after transplanting was 8.93, while on day 45 after transplanting it was 24.47 when the highest phosphorus dose (540 mg·dm⁻³) was added; this shows a 29.68% increase in the first instance and 49.86% in the second when compared to the treatment lacking the phosphorus fertilization (Figure 1).

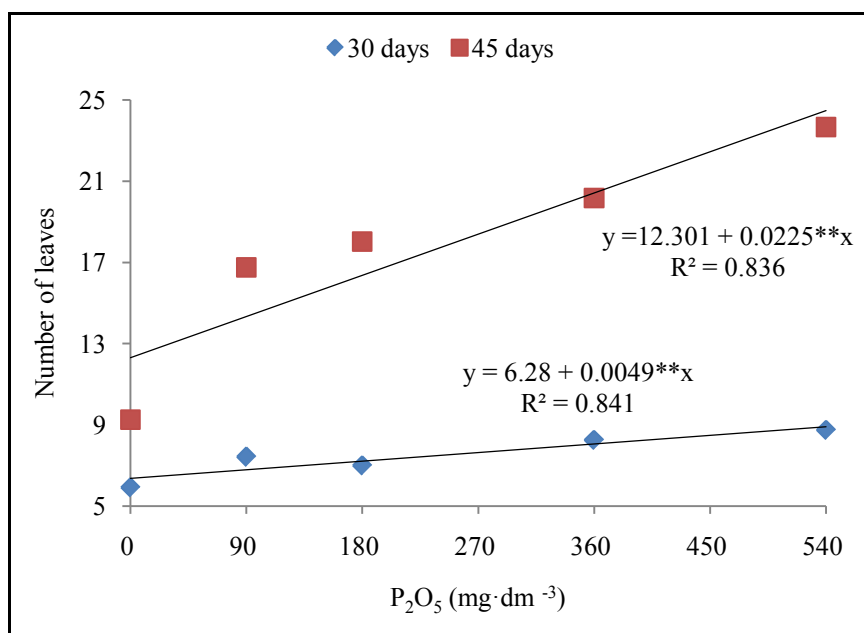


Figure 1. Number of leaves of safflower (*Carthamus tinctorius* L.) on days 30 and 45 post-transplanting in response to the phosphorus doses (0, 90, 180, 360 and 540 mg·dm⁻³ of P₂O₅). **Significance at 1%.

The number of leaves in plants belonging to the same family, like sunflower, rises proportionally to the phosphorus doses, showing between 31% and 35% increase in comparison to the treatment lacking the phosphate fertilization [20]. Likewise, the safflower culture responded significantly to the raised phosphorus doses (0.04 to 0.72 g·pot⁻¹) and produced plants having the most number of chapters [8]. These results may reiterate the crucial role played by phosphorus in the energy metabolism, and the addition of this nutrient induces a higher emission and leaf growth, besides increasing the leaf area [21], which promotes the absorption of solar radiation and, therefore, enhances photoassimilate production [22].

The greatest heights were noted in response to the phosphorus (P₂O₅) dose of 540 mg·dm⁻³, registering 20.92 cm on day 30 and 34.97 cm on day 45 (Figure 2). On comparison of the plant heights in response to the highest phosphorus dose in the experimental range (540 mg·dm⁻³) with the treatment that lacked phosphate fertilization, the increments were 30.98% and 34.97% on days 30 and 45, respectively.

Phosphorus is vital to the cell energy transfer, respiration, and photosynthetic processes, and its lack or low availability during the early developmental stages produces a limitation from which the plant does not subsequently recover [23]. Studies were done on the sunflower cultivation established that supplementation with phosphorus doses increased plant growth when compared with the treatment that was denied phosphorus fertilization [20] [24].

The variable stem diameter in response to phosphorus doses was adjusted to the linear regression model (Figure 3), for which the highest findings were 2.72

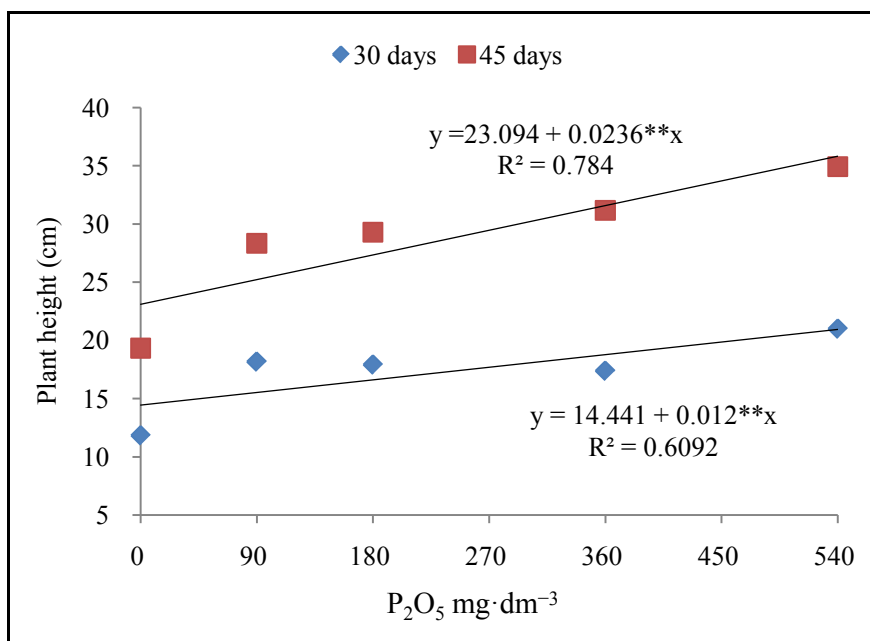


Figure 2. Plant height of the safflower (*Carthamus tinctorius* L.) on days 30 and 45 post-transplanting, in response to the phosphorus doses (0, 90, 180, 360 and 540 mg·dm⁻³ of P₂O₅). **Significance at 1%.

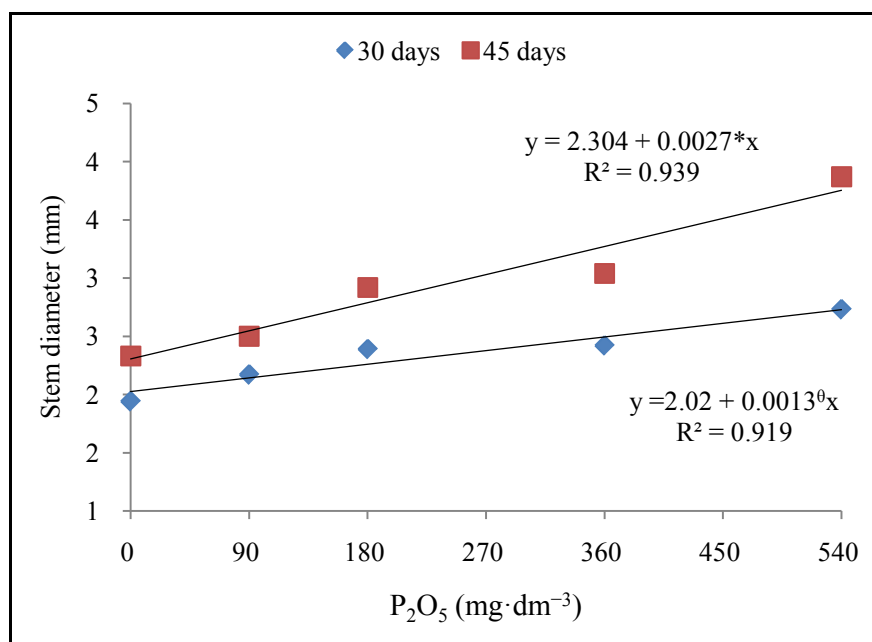


Figure 3. Stem diameter in safflower (*Carthamus tinctorius* L.) on days 30 and 45 post-transplanting in response to the phosphorus doses (0, 90, 180, 360 and 540 mg·dm⁻³ of P₂O₅), with significance at 10% (θ) on day 30 and at 5% (*) on day 45.

mm and 3.76 mm, on days 30 and 45 after transplanting, respectively. In comparison with the treatment, lacking such fertilization the increase was 25.74% on day 30 and 38.83% on day 45 after transplanting.

Phosphorus is vital for the plant processes of cell division, reproduction, metabolism, photosynthesis, respiration, and synthesis of organic substances [25] [26]. Hence, the stem diameter increase is also linked to the rise in the phosphorus supply, which in turn, boosts the production of the photoassimilates stored in the leaves and stem, encouraging the production of the plant structures [27].

On day 30, the maximum chlorophyll index recorded was 47.53 in response to the 376.23 mg·dm⁻³ dose, whereas on day 45, the highest index was 64.76 in response to the 540 mg·dm⁻³ dose (Figure 4). An increase of 18.16% was noted on day 30 post-transplanting, and of 23.42% on day 45. The chlorophyll index showed a tendency to rise in response to the phosphorus supplementation, making it clear that the higher phosphorus concentrations contribute towards higher nutrient utilization and the enhanced chlorophyll content in safflower [9] [28].

The most number of safflower chapters visible on day 62 post-transplanting, was a result of the highest phosphorus dose, which induced the greatest production of this variable (Figure 5). The highest phosphorus dose caused a 54.80% rise in the number of chapters when compared to the treatment lacking phosphate fertilization (Figure 6). In crops like safflower, as the number of chapters is directly linked to the production, their measurement is of immense significance of [17]. As the genetic variability in the species *Carthamus tinctorius* L. is

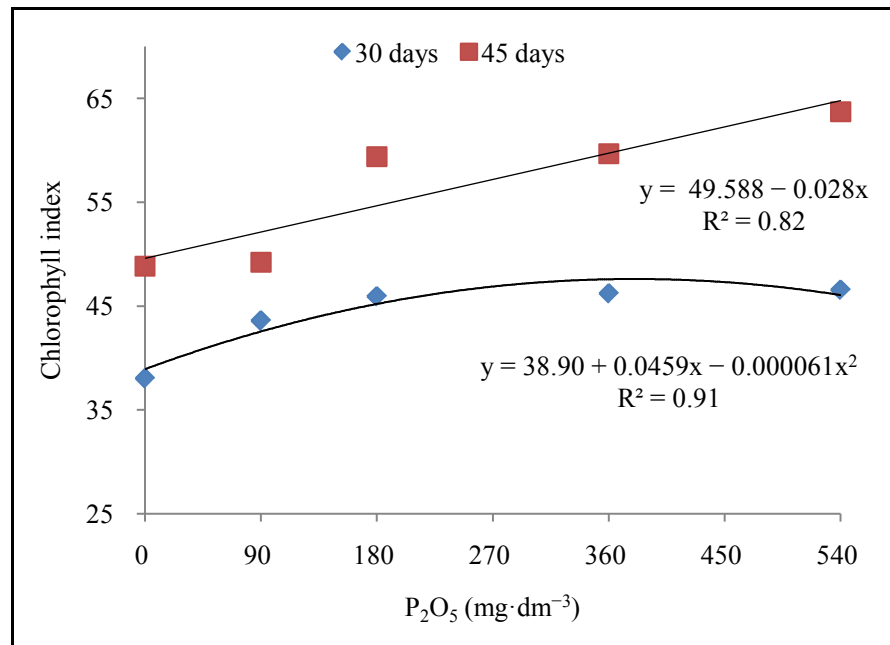


Figure 4. Chlorophyll content (SPAD index) of the safflower (*Carthamus tinctorius* L.) on days 30 and 45 post-transplanting in response to the phosphorus doses (0, 90, 180, 360 and 540 mg·dm⁻³ of P₂O₅), ** and * significant at 1% e 5%, respectively.

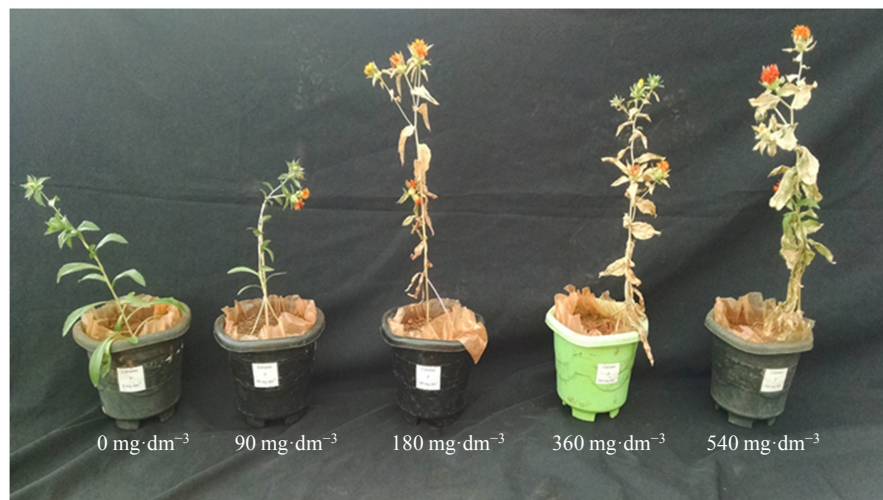


Figure 5. Safflower plants on day 62 post-transplanting submitted to different phosphorus doses (0, 90, 180, 360 and 540 mg·dm⁻³ of P₂O₅).

very high, the number of chapters may vary in accordance to each genotype - for instance, the PI401475 produces 5, whereas the PI613409 produces 9 [29].

The shoot dry matter production in safflower was adjusted to the linear regression model with the maximum production of 3.45 g·pot⁻¹ in response to the highest phosphorus dose in the experimental range, indicating a 57.10% increase (Figure 7).

At the culmination of the experiment, the shoot dry matter of the four plants was 33.22 g·pot⁻¹, in response to the phosphate fertilization (150 mg·dm⁻³ of

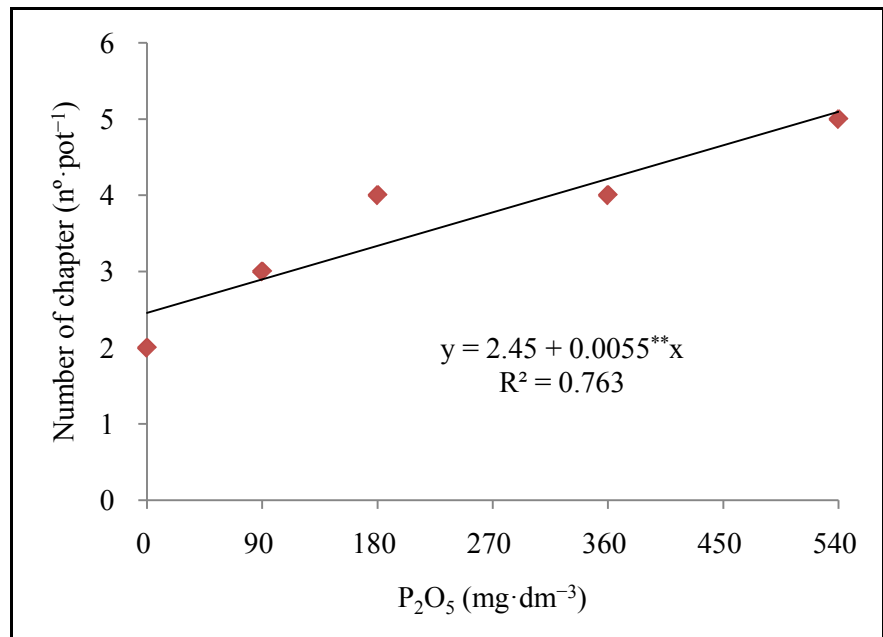


Figure 6. Number of chapter of the safflower (*Carthamus tinctorius* L.) on 62 days post-transplanting in response to the phosphorus doses (0, 90, 180, 360 and 540 mg·dm⁻³ of P₂O₅). **Significant at 1%.

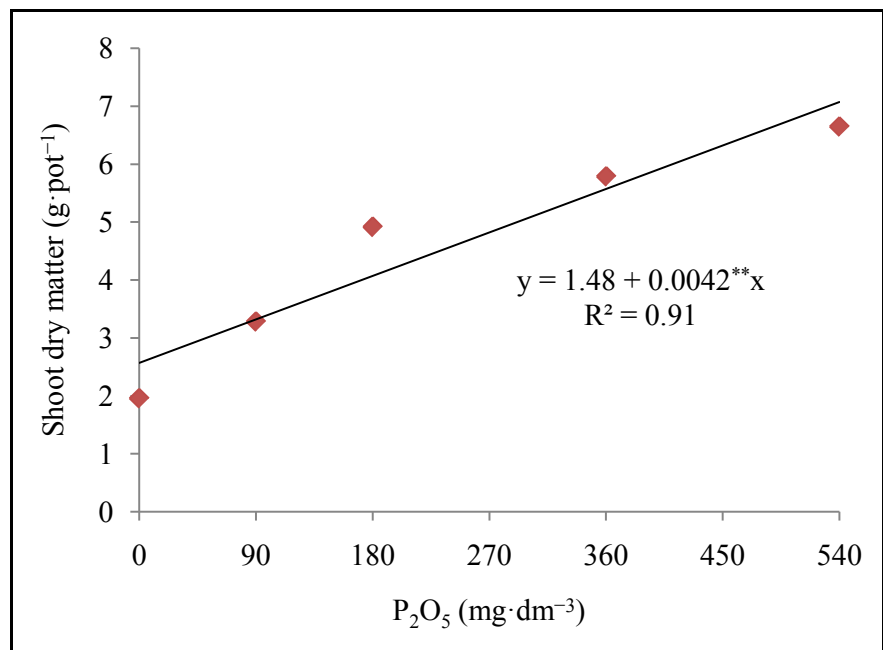


Figure 7. Shoot dry matter of the safflower (*Carthamus tinctorius* L.) on 62 days post-transplanting in response to the phosphorus doses (0, 90, 180, 360 and 540 mg·dm⁻³ of P₂O₅). ** Significant at 1%.

P₂O₅) [9]. The safflower showed a rise in production with the increased availability of the phosphorus [8]. Safflower cultivation normally responds positively to mineral fertilization, and when phosphorus and nitrogen were applied they induced a significant boost in the yield and characteristics of the components of

production of safflower [29] [30].

Growth rate and plant productivity are contingent upon the phosphorus nutrient efficiency [30]. Phosphorus strongly influences the dry matter yield, as it directly takes part in the metabolic processes of the plants, by supplying the required energy, as well as significant constituents of several protein complexes [21] [31] [32] [33].

4. Conclusion

Phosphate fertilization was observed to positively affect the phytometric and productive characteristics of the safflower crop cultivated in the Oxisol of the Cerrado, demonstrating that safflower can be a viable crop that can be introduced in the Brazilian Cerrado.

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