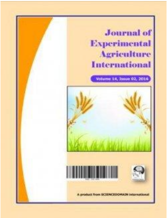

**_Journal of Experimental Agriculture International_**

**_32(4): 1-8, 2019; Article no.JEAI.47426_**
**_ISSN: 2457-0591_**
_(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)_

# Development of Pumpkin Young Plants Receiving Dosages of Phosphorus from Different Sources

**Tayssa Menezes Franco[1*], Marcos Vinicius Reis de Oliveira Junior[1],**
**José Darlon Nascimento Alves[2], Wendel Kaian Oliveira Moreira[3],**
**Juciley Lima de Souza[1], Marcus José Alves de Lima[1],**
**Emerson Carneiro Galvão[1] and Heráclito Eugênio Oliveira da Conceição[1]**

_[1]Department of Agronomy, Federal Rural University of Amazônia, Campus of Capitão Poço, Capitão Poço, Pará, Brazil._
_[2]Department of Agricultural Engineering, Federal University of Viçosa, Viçosa, Minas Gerais, Brazil._
_[3]Department of Agricultural Engineering, State University of Western Paraná, Cascavel, Paraná, Brazil._

### _Authors' contributions_

_This work was carried out in collaboration among all authors. Authors TMF, JDNA and WKOM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors HEOC and MJAL managed the analyses of the study. Authors MVROJ, JLS and ECG managed the literature searches. All authors read and approved the final manuscript._

### _Article Information_

DOI: 10.9734/JEAI/2019/v32i430110
Editor(s):
(1) Dr. Claude Bakoume, Institute of Agricultural, Research for Development, Cameroon.
Reviewers:
(1) Toungos, Mohammed Dahiru, Adamawa State University Mubi, Nigeria.
(2) Florin Sala, Banat University of Agricultural Sciences and Veterinary Medicine, Romania.
Complete Peer review History: http://www.sdiarticle3.com/review-history/47426

**_Original Research Article_**

**_Received 24 December 2018_**
**_Accepted 03 March 2019_**
**_Published 16 March 2019_**

## ABSTRACT

**Aims:** The research aimed to analyze the effect of five different dosages and three sources of phosphorus on the growth and development of young plants of pumpkins (_Cucurbita moschata_), cultivar _Jacarezinho_.
**Study Design:** The experimental design utilized was the completely randomized design with the factorial arrangement 5 x 3 with three repetitions.
**Place and Duration of Study:** The experiment was performed in a greenhouse of the Federal Rural University of Amazônia in the Capitão Poço City, Pará State. The research was carried out from March to April 2016.

---

_*Corresponding author: E-mail: tayssa.menezes2015@gmail.com;_

**Methodology:** The analyzed variables were plant height (PH), stem diameter (SD), number of leaves (NL), fresh root mass (FRM), fresh aerial mass (FAM), dry aerial mass, (DAM) and dry root mass (DRM) at 30 days after sowing. The averages of dosages x sources interactions were submitted to a regression analysis.

**Results:** There was a significant effect of the interaction dosage x source for the PH, FAM and DAM. However, the dose of fertilizer got an effect on the SD, with linear response. The plots that did not reserve any fertilizers showed the least response for all variables. ARAD was the source that had the least performance in the analyzed variables in comparison to others sources.

**Conclusion:** The superphosphate and triple superphosphate sources provided better development and accumulation of dry matter.

*Keywords: Agriculture; Cucurbita moschata; phosphate fertilization; vegetables.*

## 1. INTRODUCTION

Among the cultivated species of the Cucurbitaceae's family, the pumpkin (*Cucurbita moschata*) occupies a relevant position in agribusiness, being one of the most consumed vegetables in Brazil [1]. This vegetable presents a fruit of globular shape, with average weight of 2 kg to 3 kg, herbaceous stem, large dark green leaves. Its pulp is yellow, rich in nutrients as vitamins A and B complex, and in minerals including calcium, iron magnesium, potassium, and zinc [2]. Also, it presents good quality for consumption, conservation, and flavor [3].

According to the FAO [4] the world production of pumpkins has grown from 21.4 million tons in 2006 to 25.2 million tons in 2014 with an average yield of 13.4 $t.ha^{-1}$. In Brazil, there are few data about pumpkin's commercialization wherein the latest information available is of 2006 that showed that more than 127,000 farms harvested 84 thousand hectares of pumpkins (5.24% of the world harvested area). They produced 398 thousand tons (1.86% of world production), with an average of 4.5 $t.ha^{-1}$, below the world average (12.5 to 13.5 $t.ha^{-1}$) [5].

Vegetables require supply of nutrients in quantities satisfactory for their perfect growth and development that result in adequate yields. One of the factors that cause a decrease in productivity is unbalanced mineral nutrition that directly influences the production and the final quality of the harvest. Phosphorus (P) is one of the nutrients more demanded by plants due to its involvement in plant metabolism. This element plays a role in root growth [6-7], metabolic processes such as ATP's and nucleic acids' formations and photosynthesis [8-9] that result in high quality of the crops. However, the majority of Brazilian soils have low natural fertility and high phosphorus fixation capacity [10-11].

There are a few researches on the effect of phosphorus dosage and source of this nutrient on the development and yield of vegetables. When Nunes et al. [12] applied $P_2O_5$ dosage between 245 and 284.6 $mg.dm^{-3}$ of single superphosphate (SS) in radish crops cultivated at red latosol, they obtained higher plant height and dry aerial mass. Alves and Silva Filho [13] have realized a research with phosphorous omission in the nutritive solution in beet crop and they found high purplish on the leaves and roots, low plants growth and paralyzed roots growth. Avalhães et al. [14] have observed that dosage of 340 $mg.dm^{-3}$ from triple superphosphate (TSP) in dystrophic red latosol has caused increase of P in the leaves and fresh root mass in beet crop.

According to Grant et al. [15] phosphorus limitations at the beginning of vegetative cycle can result in limitations in roots and aerial part development that the plants may not recover even by increasing the P supply. Despite the high importance of phosphate fertilizer there is a lack of knowledge in relation to phosphorus necessities in young plants of pumpkins in Brazilian Amazon region. Therefore, the determination of ideal dosage for this crop is very important to seedling production system.

Another important aspect is the best choice of phosphate sources to be used because the inadequate choice can promote yield reduction. It has been known that there are many sources of phosphate used in agriculture, such as, single superphosphate and triple superphosphate. Resende et al. [16] mentioned that soluble phosphates such as single superphosphate and triple superphosphate show more performance in phosphorus supply to annual crops.

Besides soluble sources, there are natural phosphates that are insoluble in water, show slow liberation of P in soil solution and give more

P supply to the plants overtime. Faria et al. [17] reported that organic agriculture principles do not allow the use of soluble fertilizers made from industrial processes. The natural phosphates and thermophosphate are options that may be used in phosphate fertilizers in agriculture systems.

Thus, it is important news performance about this theme with objective to find new viable strategies for the farmers. The research aimed to analyze the effect of different dosage and sources of phosphorus in growth and development of young plants of pumpkins (*Cucurbita moschata*), cultivar *Jacarezinho*.

## 2. MATERIALS AND METHODS

The experiment was performed in a greenhouse of the Federal Rural University of Amazônia, Capitão Poço Campus, in the Capitão Poço City, Pará State (1°44'39" S; 47°3'26" W, altitude 73 m). The research was carried out from March, 24 to April, 24, 2016. The soil used was classified as dystrophic yellow latosol [18] and showed the following chemical characteristics: pH (water) = 4.9, M.O = 7.86 g.kg$^{-1}$, P = 3.0 mg.dm$^{-3}$, K = 15.0 mg.dm$^{-3}$, Na = 8.0 mg.dm$^{-3}$, Ca = 0.6 cmol.dm$^{-3}$, Ca + Mg = 0.8 cmol.dm$^{-3}$, Al = 0.8 cmol.dm$^{-3}$, H + Al = 3.96 cmol.dm$^{-3}$. According to the Köppen classification, the regional climate was classified as the Ami type (tropical altitude).

Pumpkins seeds of the cultivar *Jacarezinho* were used and to overcome their dormancy, they were soaked in distilled water for a period of 24 hours. After this step, five seeds were sown per 2 L-capacity pot.

The experimental design was the completely randomized design (CRD) with the factorial arrangement 5 x 3 constituted by five dosages of $P_2O_5$ and three phosphate sources with three repetitions. The dosages tested were 0; 22.5; 45; 67.5 and 90 kg.ha$^{-1}$ and the sources were single superphosphate (SS) with 18% of $P_2O_5$, triple superphosphate (TSP) with 44% of $P_2O_5$ and Natural Phosphate of ARAD (ARAD) with 33% of $P_2O_5$. The watering was done once a day to keep the soil moisture nearby the field capacity, by use of manual watering can. The choice of $P_2O_5$ dosages was realized according to Fertilization Manual of Pará State that indicates the dosage of 90 kg.ha$^{-1}$ de $P_2O_5$ for pumpkins [19].

Sowing was done on 24th March, after 10 days of sowing, the plants that showed less vigor were cut off, allowing the ones that are only uniform in aerial growth, leaving one plant per pot. The following variables were recorded 30 days after sowing (DAS):

- Plant height (PH) was measured from the surface of the soil to the top of the plant with a millimeter ruler.
- Stem diameter (SD) was measured with use of a pachymeter at 5 cm above the ground.
- Number of leaves (NL) was obtained by simple count.
- Fresh root mass (FRM) was obtained by weighing the roots in a precision balance and fresh aerial mass (FAM), obtained by weighing leaves + stem, in a precision balance (FA2204C, Yoke instrument, Shanghai, China).
- Dry aerial mass (stem + leaves) (DAM) and dry root mass (DRM) by using a forced air circulation oven at a temperature of 65°C until a constant mass and then the material was weighed on precision digital balance.

The data were evaluated using the Shapiro-Wilks and Levene tests to verify the normality and homoscedasticity assumption. Next, they were submitted to the analysis of variance and the means were compared by Tukey test. Finally, means of dosages and those of sources interactions were submitted to regression analysis using SISVAR software [20-21].

## 3. RESULTS AND DISCUSSION

The analysis of variance showed that there was significant effect of dosage x source interaction for the plant height (PH) ($P \leq 0.05$). For number of leaves (NL) and stem diameter (SD), there were significant effects just for each of the dosage of P and the source of P (Table 1).

There was no significant response of the interaction of the treatments to fresh root mass and dry root mass. However, there was statistic interaction for fresh and dry aerial mass (Table 1).

In relation to the plant height (PH) the quadratic model was verified to single superphosphate source with poorest performances recorded at 0 kg.ha$^{-1}$ of $P_2O_5$ that resulted in plants height between 2 and 2.5 cm. While the best dosage was at 57.25 kg.ha$^{-1}$ of $P_2O_5$ that led to plant height of up to 3.6 cm. Plants submitted to dosages more than 57.25 kg.ha$^{-1}$ showed a rapid decrease of this variable (Fig. 1).

This response can be due to chemical composition of fertilizers, because SS contains 18% soluble $P_2O_5$, 26% CaO and 12% S. So, this source give to soil, beyond P and Calcium, the Sulphur, that allow the formation of agricultural plaster that may realized soil correction that results in improving of root systems [22].

Similarly, Nunes et al. [12] observed significant response to plant height with an increase of the dosage of single superphosphate at dystrophic yellow latosol in radish. The authors found an increase of 61.7% (251.32 mg.dm$^{-3}$) in height plant in comparison to plants without phosphorus supply. We found linear adjustment in the applications of triple superphosphate that means an increase of PH with increasing dosages of $P_2O_5$. On the other hand, we did not observe statistical difference in the dosages of $P_2O_5$ from ARAD for this variable (Fig. 1).

The absence of a response from the ARAD source, may be related to its main characteristic is to have slow release of $P_2O_5$. Therefore, its use is more frequent in perennial species such as fruit trees [23]. However, Horowitz and Meurer [24] argued that in recent years, the use of alternative sources, such as phosphate rocks, has increased, although this product has low solubility in water when compared to soluble phosphates.

**Table 1. Summary of analysis of variance for plant height (PH), number of leaves (NL), stem diameter (SD), fresh root mass (FRM), fresh aerial mass (FAM), dry root mass (DRM) and dry aerial mass (DAM) of pumpkin young plants applied different dosages of P from different sources**

| Source of variation | DF | Mean squares | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | PH | NL | SD | FRM | FAM | DRM | DAM |
| Dosage | 4 | 29.02** | 17.41** | 0.01* | 57.31** | 50.23** | 0.35$^{ns}$ | 4.05** |
| Source | 2 | 17.25** | 12.35** | 0.00$^{ns}$ | 16.99$^{ns}$ | 49.46** | 0.08$^{ns}$ | 5.62** |
| Dosage x Source | 8 | 6.36* | 2.24$^{ns}$ | 0.01$^{ns}$ | 5.16$^{ns}$ | 6.92** | 0.28$^{ns}$ | 0.60** |
| Error | 30 | 2.60 | 1.24 | 0.00 | 6.81 | 1.88 | 0.28 | 0.19 |
| CV (%) | | 16.24 | 19.61 | 11.44 | 38.86 | 18.70 | 12.19 | 25.61 |

**significant at the 5% probability, ** significant at the 1% probability, ns: not significant, DF: degrees of freedom*

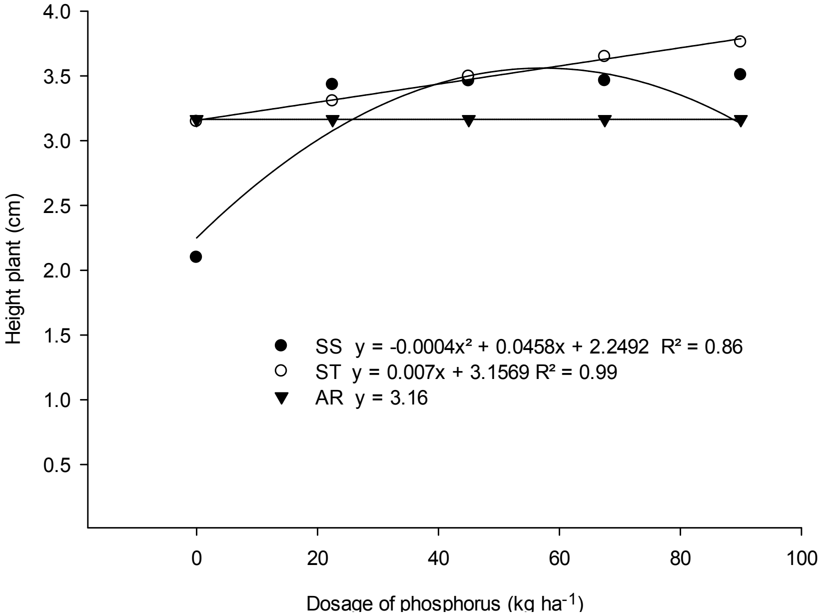

**Fig. 1. Height plant of pumpkin young plants in function of dosages and sources of phosphorus**

The response of number of leaves (NL) was adjusted to the quadratic model, where the ideal dosage was 62.5 kg.ha$^{-1}$, obtaining 6.78 leaves per plant. For the stem diameter (SD), the linear model was adjusted that showed that the increase of SD was directly proportional to the dosages of $P_2O_5$ (Figs. 2A and 2B).

The low performances observed at low doses of phosphorus might have resulted from phosphorus deficiency that affected the plant growth, because it caused less leaf emission, which reduced the leaf area, consequently, limits the capture of the solar radiation that resulted in lower production of photoassimilates [25].

According to Relative et al. [26], the low availability of P in the soil is a limiting factor for the development of the crop, because the nutrient, besides being a constituent of the nucleic acids, also has great importance in the storage and transfer of energy, being indispensable for good development of crops.

It was noticed that the production of fresh root mass (FRM) was influenced by the dosages of phosphorus ($P_2O_5$), and presented a quadratic adjustment. This result showed that the absence of the phosphate fertilization had severe consequences on the development of the root system. The best result was obtained with the 56.12 kg.ha$^{-1}$ of $P_2O_5$, which led to obtaining 8.88 g plant$^{-1}$ (Fig. 3A).

The high decrease of fresh root mass can be related phosphorus toxicity. According to Marschner [27], elevated concentrations of phosphorus can reduce photosynthesis due to the excessive exportation of triose-P from mitochondria to the cytosol, which is a prejudice the Rubisco regeneration and, therefore, the fixation of $CO_2$ in the photosynthetic process. Thus, phosphorus plays an important role in plant nutrition, as it performs metabolic functions such as the synthesis of proteins and nucleic acids [28]. Ideal dosage of phosphorus favors development of the root system, absorption of water and nutrients, increasing the quality and yield of harvested fruits.

On the other hand, the dry root mass (DRM) did not show statistical difference in function of $P_2O_5$ levels (Fig. 3B). Regarding fresh aerial mass (FAM), all sources showed quadratic adjustment in function of dosages, but the higher response was from TSP at 67.87 kg.ha$^{-1}$. The second source with better performance was the SS, at 86.68 kg.ha$^{-1}$, and the ARAD demonstrated the worst result.

As for the dry aerial mass (DAM), it was visible that all the sources fitted to the quadratic regression model, where again the best of them was the SS with 71.10 kg.ha$^{-1}$ of $P_2O_5$, followed by TSP with 56.33 kg.ha$^{-1}$ of $P_2O_5$ and finally the ARAD with 55 kg.ha$^{-1}$ of $P_2O_5$ (Fig. 3D).

However, for DAM the best performance was obtained by the SS source, this source had the advantage of containing sulfur in its composition which contributed directly to the plant growth. Sulfur (S) is absorbed by plants in the form of sulfate anionic, presents in organic matter, and a small proportion in the atmosphere, in the form of sulfuric gas. When there is deficiency of this secondary macronutrient, the protein synthesis is inhibited because the S is a participant of two essential amino acids (Cystine and Methionine), as a consequence the plants have a lower content of chlorophyll and less developed roots [29]. Many studies has showed the higher efficiency of TSP than natural phosphate, where the crops have more dry biomass production [30-32].

There was no significant difference between the sources of phosphorus for stem diameter (SD), fresh root mass (FRM) and dry root mass (DRM) (Table 2). Concerning NF, the most soluble sources (SS and ST) were better compared to ARAD.

**Table 2. Separation of mean values of number of leaves (NL), stem diameter (SD), fresh root mass (FRM) and dry root mass (DRM) of pumpkin young plants in function of phosphate sources**

| Sources of phosphorus | NL | SD | FRM | DRM |
|---|---|---|---|---|
| Single Superphosphate (SS) | 6.40a | 0.478a | 7.03a | 0.80a |
| Triple Superphosphate (TSP) | 6.00a | 0.468a | 7.57a | 0.91a |
| Natural Phosphate of Arad (ARAD) | 4.66b | 0.460a | 5.52a | 0.94a |

*Means in the column followed by same lowercase letter are not statistically different*

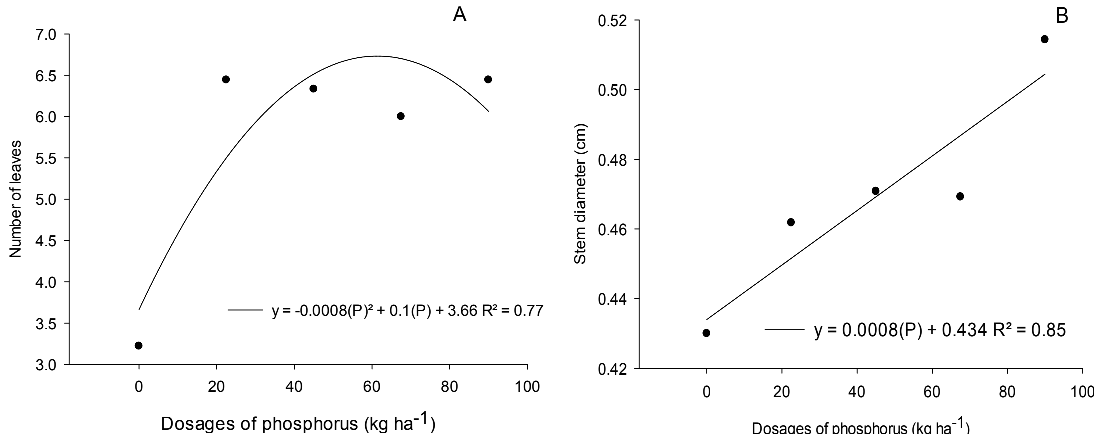

**Fig. 2. Number of leaves (A) and stem diameter (B) of pumpkin young plants in function of dosages and sources of phosphorus**

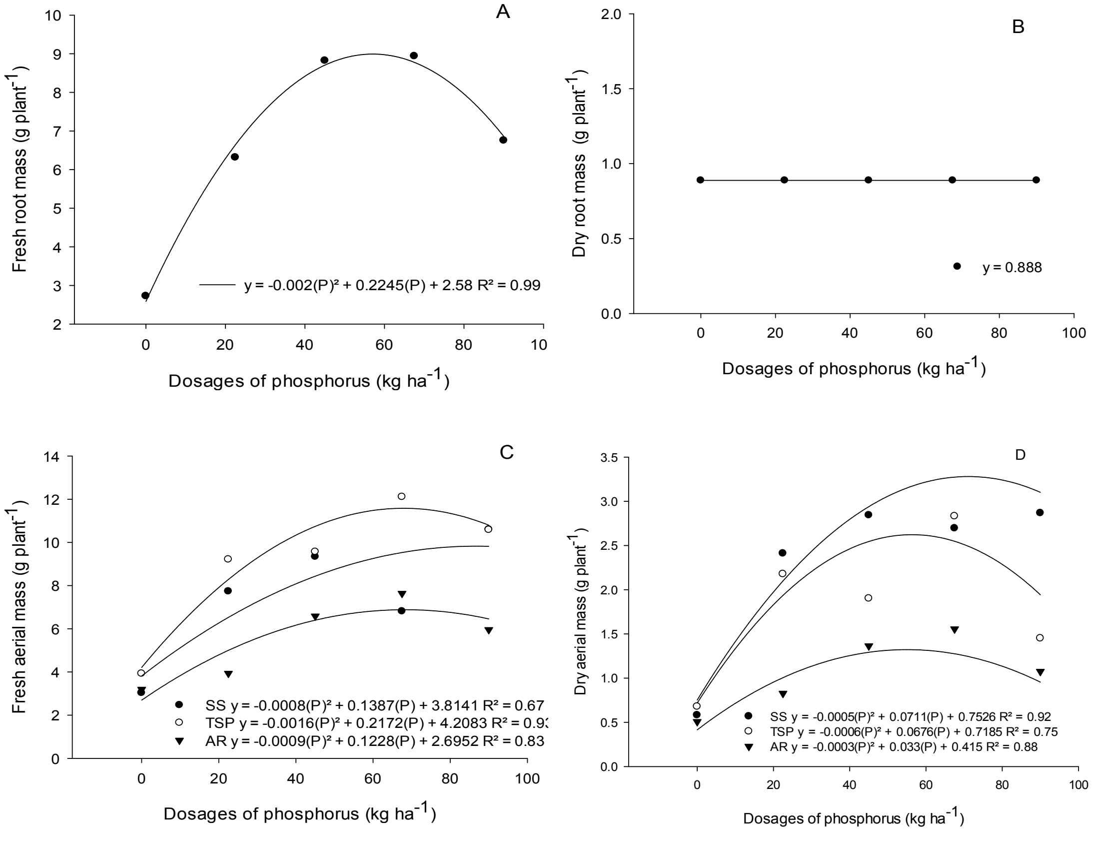

**Fig. 3. Fresh root mass (FRM) (A), dry root mass (DRM) (B), fresh aerial mass (FAM) (C) and dry aerial mass (DAM) (D) of pumpkin young plants in function of dosages and sources of phosphorus**

Relative et al. [26] found a similar result when testing the natural reactive phosphate doses of ARAD and triple superphosphate where there was no significant difference for the stem diameter in sugarcane. Kano et al. [33] observed a linear increase in the leaf area in lettuce in function of TSP dosages (0, 200, 400, 600 and 800 kg $ha^{-1}$ of $P_2O_5$).

## 4. CONCLUSION

Pumpkin young plants were significantly influenced by phosphate fertilization. As the superphosphate and triple superphosphate sources provided better development and accumulation of dry matter. The natural reactive phosphate of ARAD was the worst for all analyzed variables.

## ACKNOWLEDGEMENTS

The third and fourth authors appreciate the CNPq and Coordination for the Improvement of Higher Education Personnel (CAPES, financing code 001), respectively, for the scholarships.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Araújo HS, from Quadros BR, Cardoso I, Ismael A, Corrêa CV. Potassium doses covered in pumpkin culture. Tropical Agriculture Research. 2012;469-475.
2. Yavuz D, Yavuz, N, Seymen M, Türkmen Ö. Evapotranspiration, crop coefficient and seed yield of drip irrigated pumpkin under semi-arid conditions. Scientia Horticulturae. 2015;197:33-40. Available:http://dx.doi.org/10.1016/j.scienta.2015.11.010. (Accessed on: January, 16, 2019)
3. Branches SRR, Lima NRS, Anjos JL, Carvalho HWL, Oliveira IR, Sobral LF, Curado FF. Technical aspects of pumpkin cultivation in the Northeast region of Brazil. Aracaju: Embrapa Coastal Trails, 2010;36.
4. FAO. Agency of the United Nations for Food and Agriculture. FAOSTAT ; 2017. Available:<http://www.fao.org/faostat/en/#data/QC> (Accessed on: January 27, 2019)
5. IBGE. Brazilian Institute of Geography and Statistics. IBGE Automatic Recovery System (SIDRA). Agricultural Census; 2006. Available:<https://sidra.ibge.gov.br/pesquisa/censo-agropecuario/censo-agropecuario2006/ segundaapuracao> (Accessed on: January 27, 2019)
6. Filgueira FAR. New Olericultura Manual: Modern agro-technology in the production and commercialization of vegetables. 3. ed. Viçosa-MG: UFV. 2012;421.
7. Prates FBS, Lucas CDSG, Sampaio RA, Junior DDSB, Fernandes LA, June GRZ. Growth of Jatropha seedlings in response to single superphosphate and rock-flour fertilization. Revista Ciência Agronômica. 2012;43(2):207-213.
8. Taiz L, zeiger E. Plant physiology. 5. ed. Porto Alegre, Artmed. 2013; 918.
9. Oliveira RAD, Comin JJ, Tiecher T, Piccin R, Somavilla LM, Loss A, Brunetto G. Release of Phosphorus Forms from Cover Crop Residues in Agroecological No-Till Onion Production. Revista Brasileira de Ciência do Solo. 2017;41. Available:http://dx.doi.org/10.1590/18069657rbcs20160272 (Accessed on January, 04, 2019)
10. Novais RF, Smyth TH, Nunes FN. Phosphor. In: Novais et al. (Eds). Soil fertility. Brazilian Society of Soil Science. Viçosa-MG. 2007;471-552.
11. Mendes FF. Genetic control of phosphorus efficiency in tropical maize. Lavras: UFLA. 2012;134.
12. Nunes JAS, Bonfim-Silva EM, Moreira JCF. Production of radish subjected to phosphate fertilization. Journal of the University Center of Patos de Minas. 2014; 5:33-44.
13. Alves L, Silva Filho GN. Production of lettuce seedlings (*Lactuca sativa* L.) in presence of different phosphate sources and phosphate solubilizing microorganisms. Semina. 2009;30:557-562.
14. Avalhães CC, Mello Prado R, Gondim ARO, Alves AU, Correia MAR. Yield and growth of beet due to fertilization with phosphorus. Scientia Agraria. 2009;10(1): 075-080.
15. Grant CA, Flaten DN, Tomasiewicz DJ, Sheppard SC. The importance of phosphorus in the initial development of the plant. Agronomic Information, Piracicaba. 2001;95.
16. Resende AV, Furtini Neto AE, Alves VMC, Muniz JA, Curi N, Faquin V, et al. Sources and methods of phosphorus application to maize in cultivated soil of the Cerrado

region. Revista Brasileira de Ciência do Solo. 2006;30:453-466.
17. Faria CMB, Silva, DJ, Pinto JM, Gomes TCA. Effect of natural phosphates on melon plants cultivated in pots. Revista Brasileira de Ciência do Solo. 2006;30: 1083-1091.
18. Brazilian Agricultural Research Company - EMBRAPA. National Soil Research Center. Brazilian system of soil classification. 3.ed. Brasília. 2013;353.
19. Cravo MS, Viegas IJM, Brazil EC. Recommendations of Fertilization and Liming for the State of Pará 1st Edition. Belém: Embrapa Amazônia Oriental. 2010; 262.
20. Ferreira DF. Sisvar: A computer statistical analysis system. Science and Agro-Technology. 2011;35(6):1039-1042.
21. Banzatto DA, Kronka SN. Agricultural experimentation. 4 ed. Jaboticabal: Funep. 2006;237.
22. Vitti GC, Wit A, Fernandes BEP. Agronomic efficiency of natural reactive thermophosphates and phosphates. In: Symposium on Phosphorus in Brazilian Agriculture. Anais ... Piracicaba: POTAFOS. 2004;690-694.
23. Oliveira RLL, Alves JDN, Abade MTR, Saldanha ECM, Okumura RS. Response of soybean to phosphate fertilization on yellow latosol in northeastern Para. Enciclopédia biosfera, Goiânia. 2014; 10(18):2682-2689.
24. Horowitz N, Meurer EJ. Efficiency of two natural phosphates as a function of particle size. Ciência Rural. Santa Maria. 2003; 33(1):41-47.
25. Bonfim-Silva EM, Silva TJA, Cabral CEA, Gonçalves JM, Pereira MTJ. Production and morphology of the java legume submitted to phosphate fertilization. Enciclopédia Biosfera. 2011;7(12):1-10.
26. Relative TL, Caioni S, Lange A, Caioni C, Silva ACS, Yamashita OM, Neto AL. Residual of phosphorus in ratoon-cane for forage yield in the North of Mato Grosso. Revista de Ciências Agroambientais. 2016; 14(1):157-162.
27. Marschner H. Mineral Nutrition of higher plants. 2. Ed. London: A.P. 1995;889.
28. Niu F, Zhang D, Li Z, Van Iersel MW, Alem P. Morphological response of eucalypts seedlings to phosphorus supply through hydroponic system. Scientia Horticulturae. 2015;194:295-303. Available:<http://dx.doi.org/10.1016/j.scienta.2015.08.029.> (Accessed on: January, 19, 2019)
29. Raij BV. Soil fertility and fertilization. Piracicaba: Ceres / Potafos. 1991;343.
30. Frandoloso JF, Lana MC, Fontaniva S, Czycza RV. Efficiency of phosphate fertilizers associated with elemental sulfur in corn crop. Revista Ceres. 2010;57(5): 686-694. Available:<http://dx.doi.org/10.1590/S0034-737X2010000500019> (Accessed on: December, 18, 2018)
31. Fontoura SMV, Vieira RCB, Bayer C, Ernani PR, Moraes RPD. Technical efficiency of phosphate fertilizers in Oxisol under no-tillage. Revista Brasileira de Ciência do Solo. Campinas. 2010;34(6): 1907-1914.
32. Silva EFL, de Araújo ASF, dos Santos VB, Nunes LAPL, Carneiro RFV. Biological fixation of $N_2$ in cowpea under different doses and sources of soluble phosphorus. Bioscience Journal. 2010;26(3):394-402.
33. Kano C, Cardoso AII, Villas Boas RL. Nutrient accumulation and response of lettuce to phosphate fertilization. Revista Biotemas. 2012;25:39-47. Available:http://dx.doi.org/10.5007/2175-7925.2012v25n3p39 (Accessed on January, 19, 2019)

---

*Peer-review history:*
*The peer review history for this paper can be accessed here:*
*http://www.sdiarticle3.com/review-history/47426*