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# Nutritional study of *Schinus terebinthifolius* (Raddi) in response to potassium fertilization

## Estudo nutricional de *Schinus terebinthifolius* (Raddi) em resposta à adubação potássica

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## Abstract

The objective of this work was to evaluate the effect of K doses on the initial development and nutritional efficiency of Brazilian pepper tree. For this purpose it was developed under greenhouse conditions in pot experiment with five level of $K_2O$ (66.67, 133.33, 200, 266.67 and 333.33 mg $kg^{-1}$) a randomized complete block design with five replicates. At 180 days after transplant, all plants were harvested and evaluated for height, diameter, leaf area, root and shoot dry mass, root and shoot contents, and efficiency of uptake, use and translocation of nutrients. Potassium fertilization increased the development of Brazilian pepper tree, the highest plant height and stem diameter were obtained when the plants were grown with 210 mg $kg^{-1}$ K2O and the highest dry shoot mass, leaf area and nutrient content cultivating with the dose of 66,67 mg $kg^{-1}$ de $K_2O$.

**Keywords:** Brazilian pepper tree; Nutritional efficiency; Initial growth

## Resumo

O objetivo deste trabalho foi avaliar o efeito de doses de K no desenvolvimento inicial e eficiência nutricional de mudas da aroeirinha. Para isso foi desenvolvido em casa de vegetação um experimento em vasos com cinco doses de $K_2O$ (66,67, 133,33, 200, 266,67 e 333,33 mg $kg^{-1}$), dispostos em delineamento experimental de blocos casualizados, com cinco repetições. Aos 180 dias após transplante todas as plantas foram colhidas e avaliadas quanto à altura, diâmetro, área foliar, massa seca de raiz e da parte aérea, conteúdo em raiz e parte aérea e eficiência de absorção, de uso e de translocação dos nutrientes. A adubação potássica incrementou o desenvolvimento da aroeirinha, as maiores alturas das plantas e o diâmetro do caule foram obtidos quando as plantas foram cultivadas com 210 mg $kg^{-1}$ de $K_2O$ e as maiores massas secas da parte aérea, área foliar e conteúdo e eficiência de nutrientes quando as plantas foram cultivadas com a dose de 66,67 mg $kg^{-1}$ de $K_2O$.

**Palavras-chave:** Aroeirinha; Eficiência nutricional; Crescimento inicial

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## Introduction

*Schinus terebinthifolius* Raddi (Anacardiaceae), popularly known as Brazilian pepper tree, is a pioneer and native Brazilian species, occurring from the '*restinga*' to rain forests, on the banks of rivers and streams, growing in dry and poor soil. The plant is between 5 to 10 m high, the flowers are honey and the wood is durable (LORENZI, 2008).

The fruits and leaves of Brazilian pepper tree have medicinal properties as anti-diarrheal, astringent, diuretic, purgative, stomachic, tonic, anti-inflammatory, fungicidal and bactericidal (FENNER *et al*., 2006). In other studies, it was found that Brazilian pepper tree is effective in fighting gastritis and dyspeptic symptoms (SANTOS *et al*., 2010), to promote healing of surgical ulcer (LUCENA *et al*., 2006) and to combat bacterial vaginosis and improve autochthonous vaginal flora (AMORIM; SANTOS, 2003).

The species has great economic importance due to the high value of its fruits, however, these fruits are obtained in an extractive way. Thus, studies aimed at forestry studies about development and nutrition of Brazilian pepper tree, in view of the domestication and cultivation of this species for commercial production, are critical to reducing the extraction and acquisition of high quality raw material. The nutritional requirements of Brazilian pepper tree are not well understood, the few studies on the species are related to the manure fertilization associated with NPK (SOUZA *et al*., 2006), fertilization with N and/or P (FERNANDES *et al*., 2007; SANTOS *et al*., 2008) and association of gypsum and phosphorus (CARNEVALI, 2014). Silva *et al*. (2015) evaluated the effect of fertilization with N and K on the initial growth of Brazilian pepper tree and did not observe increase of the biomass production of plants using the doses of 0, 2 and 4 kg $m^3$ of N and K in commercial substrate.

K is an important nutrient in the plant physiological processes, both in biochemical functions as the necessary concentration. The requirement of K varies from species to species, however, the concentration between 20 to 50 g $kg^{-1}$ in dry matter is considered for optimal plant growth (EPSTEIN; BLOOM, 2006). This nutrient is present in plants as $K^+$ and is highly mobile, playing a fundamental role in photosynthesis, acting in the process of transforming light energy into chemical energy (MARSCHNER, 2011). In soil, the K availability as well as the ability of this nutrient supply depends on the presence of primary and secondary minerals, the application of fertilizers and soil cation exchange capacity (CEC), and the cycling of nutrient by plants (WERLE; GARCIA; ROSOLEM, 2008). In well-drained soils with low CEC, such as *Cerrado* Latosols, the energy retention of exchangeable cations $Ca^{2+}$, $Mg^{2+}$ and $K^+$ in the soil colloids following the Hofmeister series, resulting in more leaching of K (RAIJ, 2011).

Studies with K fertilizer at different forest species show that the nutrient increase or reduce plant growth. Reis *et al*. (2012) report that there was a reduction of *Dalbergia nigra* biomass production with increasing doses of K, and 30 mg $dm^{-3}$ of K was recommended for the production of seedlings. Other studies report that the addition of K increases biomass production, such as Cruz *et al*. (2011) studying the effect of macronutrients on the production of *Peltophorum dubium* seedlings. Duarte *et al*. (2015) verified that seedling production of *Platymenia foliolosa* is stimulated by the association of doses of K and S, obtaining the highest yields using 145 mg $dm^{-3}$ *of K and 45 mg* $dm^{-3}$ *of S. Cardoso et al. (2016) found that increased N, P and K doses promote the increase of Ceiba pentandra* biomass and recommend the use of the 80 kg $ha^{-1}$ $K_2O$ dose for seedling production.

Considering the importance of adequate supply of nutrients to plants, especially during the initial growth, this study aimed to evaluate the effect of five K levels in the initial development, macro and micronutrients content and nutritional efficiency of Brazilian pepper tree.

## Material and methods

The experiment was performed in a greenhouse in the Medicinal Plant Garden of the Federal University of *Grande Dourados*, in *Dourados*, from October 2010 to April in 2011. The

Medicinal Plants Garden is located at 22°14'16" S latitude and 54°49'2" W longitude. The climate is Cwa, by the Köppen classification system, with average annual rainfall of 1500 mm and average temperature of 22°C.

The soil type Dystrophic Red Latosol of B horizon was used with the following chemical characteristics: pH in water = 4.7, pH $CaCl_2$= 4.2, organic matter = 8.2 g $kg^{-1}$; P = 1.0 mg $dm^{-3}$; K = 0.5 $mmol_c$ $dm^{-3}$; Ca = 4.0 $mmol_c$ $dm^{-3}$; Mg = 2.0 $mmol_c$ $dm^{-3}$; Al = 14.1 $mmol_c$ $dm^{-3}$; H+Al = 76.0 $mmol_c$ $dm^{-3}$; sum of bases = 6.5 $mmol_c$ $dm^{-3}$; cation exchange capacity = 82.5 $mmol_c$ $dm^{-3}$ and base saturation = 7.9%, it was determined using the methodology described by Claessen (1997).

Due to the low fertility of the soil, the Brazilian pepper tree was studied with the following levels of K (66.67, 133.33, 200, 266.67 and 333.33 mg $kg^{-1}$ of $K_2O$, corresponding to 20, 40, 60, 80 and 100 kg $ha^{-1}$ of $K_2O$) using as a source KCl fertilizer. The treatments were arrangement in a randomized block design with five replicates. The complementary fertilization consisted of 62.46 mg $kg^{-1}$ of N urea as a source, 83.44 mg $kg^{-1}$ of $P_2O_5$ in form of triple superphosphate and 150 mg $kg^{-1}$ of the commercial formulated micronutrients FTE-BR12, incorporating into the soil five days before transplant, together with K. The nitrogen fertilization was split, with thirty-five days before the transplant and the remaining forty days after a first fertilization. The soil was sieving into mesh 6 mm and transferred to pots of 6 $dm^3$ (25x30x22 cm; height x upper Ø x lower Ø, respectively). To increase the base saturation to 60%, it was used dolomitic limestone with 100% total neutralizing power, incorporated manually 30 days before transplant. Each pot was internally coating with plastic bags to prevent loss of water and nutrients for leaching. Throughout the experimental period, the pots were kept moist at 70% of field capacity.

The fruits of Brazilian pepper tree were collected from one tree in Medicinal Plant Garden, which were scarified in a sieve 2 mm of mesh to remove the pericarp. The seeds were sown in polystyrene trays of 128 cells, filled with substrate Bioplant® (composed of: Pinus bark, coconut fiber, vermiculite, rice husk, nutrients and chemical characteristics: pH in water = 5, organic matter = 20 g $kg^{-1}$; P = 776 mg $dm^{-3}$; K = 1,410 $mmol_c$ $dm^{-3}$; Ca = 12.22 $mmol_c$ $dm^{-3}$; Mg = 4.72 $mmol_c$ $dm^{-3}$; Al = 0.17 $mmol_c$ $dm^{-3}$; H+Al = 8.1 $mmol_c$ $dm^{-3}$; sum of bases = 28,66 $mmol_c$ $dm^{-3}$; cation exchange capacity = 20.56 $mmol_c$ $dm^{-3}$ and base saturation = 72%). The experiment was carried out in a protected environment with 50% of luminosity. When the seedlings reached 5 cm in height, they were transplanted to the pots, the irrigations were daily maintaining the pots with 70% of the field capacity. The experimental unit consisted of 10 plants per pot.

From 30 to 180 days after transplant (DAT) were taken monthly, plant height and stem diameter of all plants. At 180 DAT, the plants were harvested whole and sectioned into root, stem and leaves, to obtain the leaf area ($cm^2$), measured in integrating LI-COR 3000 and fresh matter. The materials were put into an oven with forced air circulation at a temperature of 60°±5°C to obtain dry matter, they were subsequently ground to determine the macro and micronutrient concentrations (MALAVOLTA *et al*., 2006). Nutrient content was obtained based on the nutrient concentration and dry matter. From the dry matter and content of nutrients in the plant, the indices were calculated: absorption efficiency (SWIADER; CHYANA; FREIJIA, 1994), nutrient use efficiency (SIDDIQI; GLASS, 1981) and translocation efficiency (ABICHEQUER; BOHNEN, 1998).

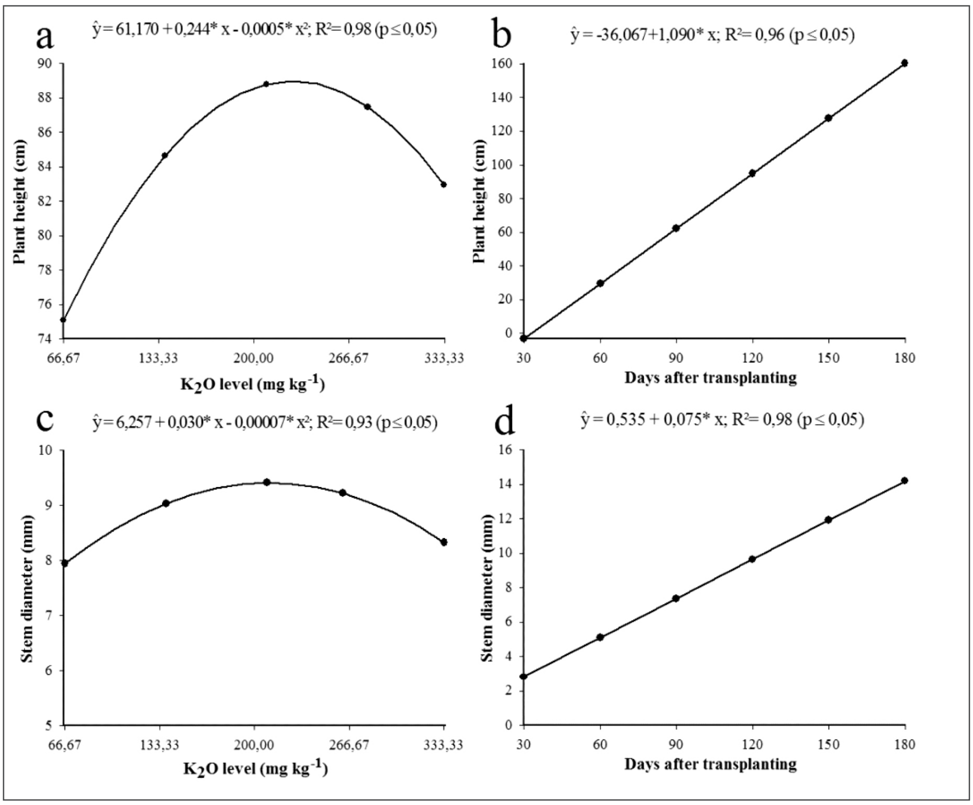
Plant height and stem diameter characteristics were subjected to analysis of variance in time subdivided plots, and when significant by the F test, regression equations were adjusted for $K_2O$ doses and days after transplantation, all up to 5% probability. All other evaluated characteristics were submitted to analysis of variance and when significant by the F test, regression equations were adjusted for $K_2O$ levels, all up to 5% probability.

## Results and discussion

The plant height and stem diameter were influenced by the factors $K_2O$ levels and evaluation times. The highest plant height (88.96 cm) was obtained using the adjusted K level of 227.16 mg kg$^{-1}$ (Figure 1a). The largest diameter of the stem (9.41 mm) was obtained using the adjusted K level of 210.21 mg kg$^{-1}$ (Figure 1c). The highest growth of the plant in height and diameter is associated with the synergistic effects of K with the hormone auxins, gibberellic acid and cytokinins, acting directly on the meristematic growth and promoting greater growth of the plant (OOSTERHUIS *et al*., 2014).

**Figure 1 – Plant height (a and b) and stem diameter (c and d) of Brazilian pepper tree plant grown with five levels of K. Dourados - 2012. *Significant at 5%.**

Figura 1 – Altura de planta (a e b) e diâmetro do caule (c e d) de aroeirinha cultivada com cinco doses de K. Dourados – 2012. *Significativo a 5%.




Source: Authors (2012)

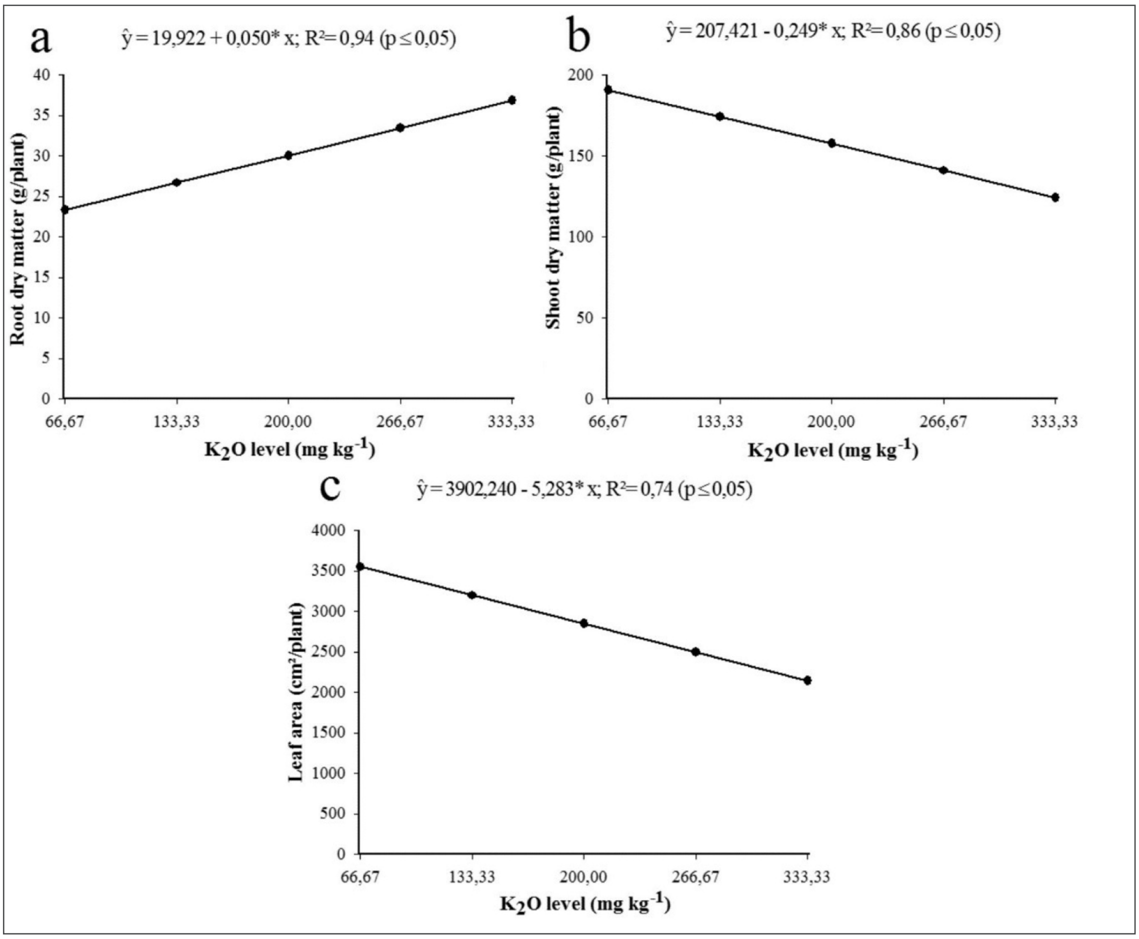
Another fact that must be observed is the cultivation of the species in a greenhouse with 50% of luminosity associated with the supply of chemical fertilizer of fast nutrient release. These associated factors contributed to the growth of the plant in search of a more adequate light condition to its development (TAIZ; ZEIGER, 2017).

The highest plant height (160.30 cm) and stem diameter (14.19 mm) were obtained at 180 DAT (Figure 1b and d, respectively). These results prove that the plants developed a greater growth in height than the diameter in a short period of time, proving the etiolation. Carnevali (2014), studying the use of gypsum and phosphorus in the initial growth and nutritional efficiency of Brazilian pepper tree, found that in full sun at 165 days after the plants had higher height (61.8 cm) and larger diameter (9.36 mm) at the highest $P_2O_5$ dose. Knapik et al. (2005) studying the initial growth of Brazilian pepper tree cultivated under NPK, verified a higher height of 12.65 cm and a larger stem diameter of 3.27 mm at 120 days after sowing.

Leaf area and dry matter of root and shoot were significantly influenced by K levels (Figure 2). The lowest K level provided higher leaf area (3549.96 $cm^2$/plant) and greater shoot dry matter (190.82 g/plant), while the largest root dry matter (36.41 g/plant) was obtained in the largest level of $K_2O$. The high concentration of $K^+$ in the cytosol increases the cellular turgor and leads to root lengthening, which consequently increases root production and root capacity to absorb nutrients (WANG; WU, 2015).

**Figure 2 – Root dry matter (a), shoot dry matter (b) and leaf area (c) of Brazilian pepper tree plant grown with five levels of K. Dourados - 2012. * Significant at 5%.**

Figura 2 – Massa seca de raiz (a), parte aérea (b) e área foliar (c) de aroeirinha cultivada com cinco doses de K. Dourados - 2012. *Significativo a 5%.




Source: Authors (2012)

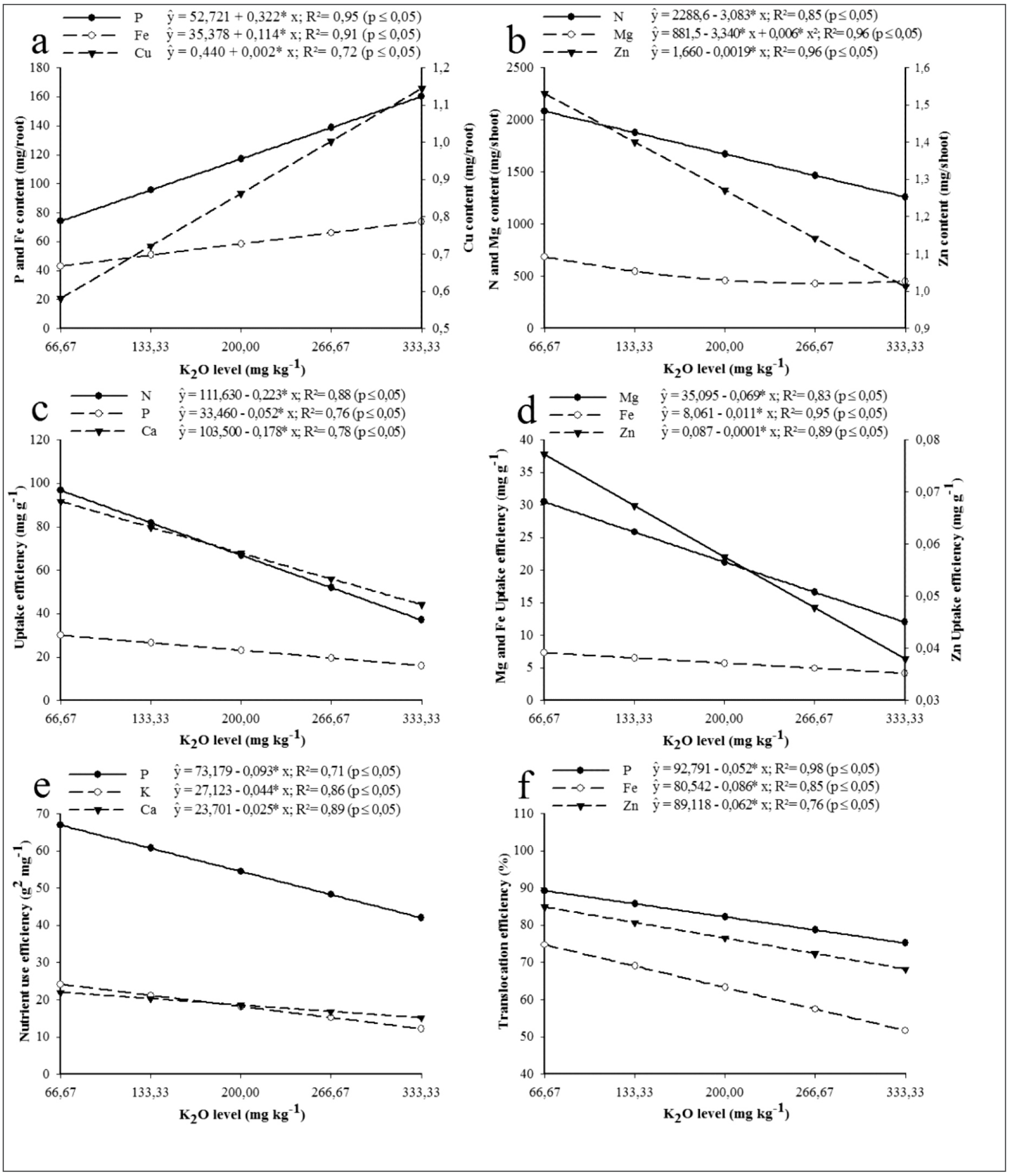
It is necessary to consider the occurrence of saline effect, caused by the addition of KCl to the soil. Oliveira *et al.* (2012), when submitted to *Ricinus communis* to salt stress with KCl also observed the increase in root production and low shoot production. At intermediate doses of KCl, there was a higher plant height, but with a low shoot dry mass production when compared to root dry mass production. Evidence of the saline effect of fertilizer and response to different species.

The levels of K significantly influenced the content of N, P, K, Cu, Fe and Zn of root and N, Mg, Fe and Zn in shoot. At root the maximum P content (160.22 mg/root), Cu (1.14 mg/root) and Fe (73.69 mg/root) was obtained at 333.33 mg $kg^{-1}$ of K (Figure 3a). For the content of N, K and

Zn was not adjusted regression in function of K levels, so obtained the average of 217.59 mg/root, 209.47 mg/root, 0.37 mg/root, respectively. The Ca content (average of 194.67 mg/root), Mg (average 87.66 mg/root) and Mn (average 1.51 mg/root) were not influenced by the levels of K.

**Figure 3 – Root (a) and the shoot (b) nutrient content, macronutrient (c) and micronutrient (d) uptake efficiency, nutrient use (e) and translocation (f) efficiency of Brazilian pepper tree plant grown with five levels of K. Dourados - 2012. * Significant at 5%.**

Figura 3 – Conteúdo de nutrientes na raiz (a) e na parte aérea (b); eficiência de absorção de macronutrientes (c) e micronutrientes (d), eficiência de uso (e) e de translocação (f) de aroeirinha cultivadas com cinco doses de K. Dourados – 2012. *Significativo a 5%.




Source: Authors (2012)

The higher N content (1260.72 mg/shoot), Mg (449.69 mg/shoot) and Zn (1.01 mg/shoot) was observed at a K level of 66.67 mg kg$^{-1}$ (Figure 3b). To the content of Fe was not possible to adjust regression, got average of 106.33 mg/shoot. The P content (average 545.87 mg/shoot), K (average 1796.91 mg/shoot), Ca (average 1736.50 mg/shoot), Cu (average 0.74 mg/shoots) and Mn (average 7.57 mg/shoot) was not influenced by the levels of K.

Despite the higher root dry mass production, the nutrient content in shoot was higher than in the root. Because it is a product of dry mass by nutrient concentration, the nutritional content can vary whatever the variation in mass or the concentration of an element. However, the leaves are a large drain of inorganic elements, since they constitute the most metabolically active organ due to the processes of photosynthesis and transpiration (TAIZ; ZEIGER, 2017).

Cultivating the Brazilian pepper tree in complete nutrient solution during 120 days, Andrade and Boareto (2012) verified that K is the element with the highest concentration in shoot (726 mg/plant), followed by N (572 mg/plant). When omission of K occurs, the N content does not change, however, the K drops to 115.5 mg/plant, with a reduction from 44 to 33 g of dry shoot mass. Resende *et al.* (2000) studying the content and nutritional efficiency of Brazilian pepper tree based on five levels of P, had higher P content (50.47 g/shoot), N (471.25 g/shoot), K (254.82 g/shoot), Ca (440.87 g/shoot), Mg (90.08 g/shoot) and S (42.05 g/shoot) at a dose of 800 mg kg$^{-1}$ of P at 90 DAT, similar to results found in this work, in the lowest level of K at 180 DAT.

The uptake efficiency of N, P, K, Ca, Mg, Mn, Fe and Zn has been influenced by levels of K, obtaining maximum 96.71 mg g$^{-1}$ of N, 29.97 mg g$^{-1}$ of P, 91.62 mg g$^{-1}$ of Ca, 30.47 mg g$^{-1}$ of Mg, 7.27 mg g$^{-1}$ of Fe and 0.07 mg g$^{-1}$ of Zn observed at the lowest level of K (Figure 3c and d). For the uptake efficiency of K and Mn was not adjusted regression, resulting in average 68.71 mg g$^{-1}$ and 0.31 mg g$^{-1}$, respectively. The uptake efficiency of Cu (average 0.05 mg g$^{-1}$) was not affected by the levels of K.

The increase of the potassium doses reduced the efficiency of nutrient absorption, a fact that reinforces the existence of the salt effect caused by KCl. The effect of salinity can affect nutrient uptake through the osmotic effect, reducing water absorption, and also through competition between ions (SILVA *et al.*, 2009). The fertilization with high levels of K tends to reduce the uptake of Ca and Mg, often causing deficiency of these two nutrients, because inter-ionic effects between the three nutrients occur in the form of competitive inhibition at the level of the cellular membrane (EPSTEIN; BLOOM, 2006). The process occurs when two elements combine with the same active site of the carrier (MALAVOLTA, 2006), but in this case, the absorption of $K^+$ is preferred because is monovalent and lower hydration degree compared to divalent, therefore, the K can traverse the plasma membrane with greater speed, depressing the uptake of slower cations such as Ca and Mg (MARSCHNER, 2011).

The nutrient use efficiency of P, K, Ca, Cu, Mn, Fe and Zn and translocation efficiency of N, P, Cu, Fe and Zn were influenced by levels of K. For use efficiency of Cu, Mn, Fe and Zn was not possible to adjust regression, resulting in average of 0.02 g$^2$ mg$^{-1}$, 0.004 g$^2$ mg$^{-1}$, 0.0002 g$^2$ mg$^{-1}$ and 0.02 g$^2$ mg$^{-1}$, respectively. The efficiency of use of N (average 19.06 g$^2$ mg$^{-1}$), Mg (average 59.34 g$^2$ mg$^{-1}$) was not affected by the levels of K. The greater use efficiency (in g$^2$ mg$^{-1}$) of P (66.95), K (24.13) and Ca (21.98) was observed at the lowest level of K (Figure 3e). The K efficiency use decreases with the increase of the applied doses, since the supply exceeds the needs of the culture. About Ca the reduction of efficiency is associated with lower absorption of the ion due to its competition with K supplied. The chloride ion present in the fertilizer may have caused competitive inhibition with phosphorus, which is absorbed as phosphate (LUCENA *et al.*, 2012).

According to Silva *et al.* (2006), the more nutrients use efficiency does not mean higher accumulation of these in plant tissues. In the Brazilian pepper tree seedlings, P and Mg were the nutrients with lower contents, however, they were most effective in producing dry matter. Unlike the P and Mg, the K showed high plants content but low use efficiency. Resende *et al.* (2000) also found that P and Mg were the nutrients with less content and more efficient in producing dry matter. These authors obtained in g$^2$ mg$^{-1}$, efficient use of nutrients in the decreasing order: S

(58.23), P (48.22), Mg (27.12), K (9.52), Ca (5.55) and N (5.17).

The lowest level of K provided greater translocation efficiency of P (89.27%), Fe (74.76%) and Zn (84.93%) (Figure 3f). For translocation efficiency of N (87.63%) and Cu (45.81%) was not adjusted regression. The translocation efficiencies of K (average 89.23%), Ca (average 89.05%), Mg (average 84.46%) and Mn (average 82.61%) were not influenced by levels of K. Although K does not perform any structural function in the plant, it performs various functions such as the neutralization of insoluble and soluble anions, pH stabilization, osmotic regulation of the plant and enzymatic activation, so at appropriate levels, K increases the translocation efficiency of the other nutrients.

Fertilization with potassium provided increases in height, diameter and dry matter of the root, however, this effect was due to soil salinization, which also reduced the dry matter of shoot and leaf area. The increase of the K doses reduced the nutrient content of the aerial part and efficiency of absorption, use and translocation of nutrients, fact that proves the salt effect provided by the use of KCl. Thus, the combinations of these data demonstrate that the plant is not demanding in K and that high levels of KCl may reduce the plant growth; however, further work should be performed to determine the best K level to provide higher yields and nutritional efficiency of the Brazilian pepper tree.

## Conclusion

The potassium fertilization increased the development of the Brazilian pepper tree, the higher plant heights and stem diameter were obtained when the plants were cultivated with 210 mg $kg^{-1}$ of $K_2O$ and the greater dry masses of the aerial part, leaf area and content and nutrient when plants were grown with the level of 66.67 mg $kg^{-1}$ $K_2O$.

High doses of K salinized the soil reducing the growth as well as the efficiency of uptake, use and translocation of nutrients.

The Brazilian pepper tree presents high efficiency of absorption of N and K and high efficiency use of P and Mg.

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## References

ABICHEQUER, A. D.; BOHNEN, H. Eficiência de absorção, translocação e utilização de fósforo por variedades de trigo. **Revista Brasileira de Ciência do Solo**, Viçosa, MG, v. 22, n. 1, p. 21-26, 1998.

AMORIM, M. M. R.; SANTOS, L. C. Tratamento da vaginose bacteriana com gel vaginal de aroeira (*Schinus terebinthifolius* Raddi): ensaio clínico randomizado. **Revista Brasileira de Ginecologia e Obstetrícia**, Rio de Janeiro, v. 25, n. 2, 2003.

ANDRADE, M. L. F.; BOARETTO, A. E. Deficiência nutricional em plantas jovens de aroeira-pimenteira (*Schinus terebinthifolius* Raddi). **Scientia Forestalis**, Piracicaba, v. 40, n. 95, p. 383-392, 2012.

CARDOSO, A. A. S. *et al*. Respostas nutricionais de mudas de sumaúma à adubação nitrogenada, fosfatada e potássica. **Científica**, Jaboticabal, v. 44, n. 3, p. 421-430, 2016.

CARNEVALI, N. H. S. **Efeito de gesso agrícola e fósforo no crescimento inicial e eficiência nutricional de Schimts terebmthifolim Raddi (Anacardiaceae)**. 2013. Tese (Doutorado em Agronomia) - Universidade Federal da Grande Dourados, Dourados, 2014.

CLAESSEN, M. E. C. (ed.). **Manual de métodos de análises de solo**. 2. ed. Rio de Janeiro: EMBRAPA; CNPS, 1997. 212 p.

CRUZ, C. A. F. *et al*. Macronutrientes na produção de mudas de canafístula em Argissolo Vermelho amarelo da região da Zona da Mata, MG. **Ciência Florestal**, Santa Maria, v. 21, n. 3, p. 445-457, 2011.

DUARTE, M. L *et al*. Crescimento e qualidade de mudas de vinhático (*Platymenia foliolosa* Benth.) em resposta à adubação com potássio e enxofre. **Ciência Florestal**, Santa Maria, v. 25, n. 1, p. 221-229, 2015.

EPSTEIN, E.; BLOOM, A. J. (ed.). **Nutrição mineral de plantas**: princípios e perspectivas. 2. ed. Londrina: Planta, 2006. 403 p.

FENNER, R. *et al*. Plantas utilizadas na medicina popular brasileira com potencial atividade antifúngica. **Revista Brasileira de Ciências Farmacêuticas**, São Paulo, v. 42, n. 3, p. 369-394, 2006.

FERNANDES, A. R. *et al*. Crescimento e absorção de nutrientes por mudas de freijó (*Cordia goeldiana* Huber) em função de doses de fósforo e de zinco. **Revista Árvore**, Viçosa, MG, v. 31, n. 4, p. 599-608, 2007.

KNAPIK, J. G. *et al*. Crescimento inicial de *Mimosa scabrella* Benth., *Schinus terebinthifolius* Raddi e *Allophylus edulis* (St. Hil.) Radl. sob diferentes regimes de adubação. **Boletim de Pesquisa Florestal,** Colombo, n. 51, p. 33-44, 2005.

LORENZI, H. (ed.). Árvores Brasileiras: manual de identificação e cultivo de plantas arbóreas nativas do Brasil. 5. ed. Nova Odessa: Instituto Plantarum. 2008. v. 1, 384 p.

LUCENA, P. L. H. *et al*. Avaliação da ação da aroeira (*Schinus terebinthifolius* Raddi) na cicatrização de feridas cirúrgicas em bexiga de ratos. **Acta Cirúrgica Brasileira**, São Paulo, v. 21, p. 46-51, 2006.

LUCENA, C. C. *et al*. Efeito do estresse salino na absorção de nutrientes em mangueira. **Revista Brasileira de Fruticultura**, Jaboticabal, v. 34, n. 1, p. 297-308, 2012.

MALAVOLTA, E. (ed.). **Manual de nutrição mineral de plantas**. São Paulo: Ceres, 2006. 638 p.

MARSCHNER, H. (ed.). **Mineral nutrition of higher plants**. 3. ed. San Diego: Academic Press, 2011. 672 p.

OOSTERHUIS, D. M. *et al*. The physiology of potassium in crop production. **Advances in agronomy**, Newark, v. 126, p. 203-233, 2014.

OLIVEIRA, M. A. *et al*. Morfoanatomia de *Ricinus communis* L. (Euphorbiaceae) expostas a estresse salino. **Perspectiva Online**: Ciências Biológicas e da Saúde, Campos dos Goytacazes, v. 7, n. 2, p. 76-88, 2012.

RAIJ, B. V. (ed.). **Fertilidade do solo e manejo de nutrientes**. Piracicaba: IPNI, 2011. 420 p.

REIS, B. E. *et al*. Crescimento e qualidade de mudas de jacarandá-da-bahia (*Dalbergia nigra* (Vell.) Allemão ex Benth.) Em resposta à adubação com potássio e enxofre. **Ciência Florestal**, Santa Maria, v. 22, n. 2, 2012.

RESENDE, A. V. *et al*. Acúmulo e eficiência nutricional de macronutrientes por espécies florestais de diferentes grupos sucessionais em resposta à fertilização fosfatada. **Ciência e agrotecnologia**, Lavras, v. 24, n. 1, p. 160-173, 2000.

SANTOS, J. Z. L. *et al*. Crescimento, acúmulo de fósforo e frações fosfatadas em mudas de sete espécies arbóreas nativas. **Revista Árvore**, Viçosa, MG, v. 32, n. 5, p. 799-807, 2008.

SANTOS, S. B. *et al*. Comparação da eficácia da aroeira oral (*Schinus terebinthifolius* Raddi) com omeprazol em pacientes com gastrite e sintomas dispépticos: estudo randomizado e duplo-cego. **Gastroenterologia Endoscopia Digestiva**, São Paulo, v. 4, n. 29, p. 118-125, 2010.

SIDDIQI, M.; GLASS, A. D. M. Utilization index: a modified approach to the estimation and comparison of nutrient utilization efficiency in plants. **Journal of Plant Nutrition**, New Jersey, v. 4, p. 289-302, 1981.

SILVA, C. E. M. *et al*. Eficiência no uso dos nutrientes por espécies pioneiras crescidas em pastagens degradadas na Amazônia central. **Acta Amazônica**, Manaus, v. 36, n. 4, p. 503-512, 2006.

SILVA, E. N. *et al*. Acúmulo de íons e crescimento de pinhão-manso sob diferentes níveis de salinidade. **Revista Ciência Agronômica**, Fortaleza, v. 40, n. 2, p. 240-246, 2009.

SILVA R. J. N. *et al*. Efeito da adubação de cobertura no desenvolvimento de aroeira pimenteira. **South American Journal of Basic Education, Technical and Technological**, Rio Branco, v. 2, n. 2, p. 33-42, 2015.

SOUZA, C. A. M. *et al*. Crescimento em campo de espécies florestais em diferentes condições de adubações. **Ciência Florestal**, Santa Maria, v. 16, n. 3, p. 243-249, 2006.

SWIADER, J. M.; CHYANA, Y.; FREIJIA, F. G. Genotypic differences in nitrate uptake and utilization efficiency in pumpkin hybrids. **Journal of Plant Nutrition**, New Jersey, v. 17, p. 1687-1699, 1994.

TAIZ, L.; ZEIGER, E. **Fisiologia e Desenvolvimento Vegetal**. 6. ed. Porto Alegre: Artmed, 2017. 888 p.

WANG, Y.; WU, W. H. Genetic approaches for improvement of the crop potassium acquisition and utilization efficiency. **Current Opinion in Plant Biology**, London, v. 25, p.46-52, 2015.

WERLE, R.; GARCIA, R. A.; ROSOLEM, C. A. Lixiviação de potássio em função da textura e da disponibilidade do nutriente no solo. **Revista Brasileira de Ciência do Solo**, Viçosa, MG, v. 32, p. 2297-2305, 2008.