Australian Journal of Crop Science
AJCS

AJCS 12(07):1108-1113 (2018) ISSN:1835-2707
doi: 10.21475/ajcs.18.12.07.PNE1035

Initial growth of Brazilian Firetree (*Schizolobium parahyba* (Vell.) S.F.Blake) fertilized with phosphorus in Red-Yellow Latosol

Matheus da Silva Araújo[1]*, Ademilson Coneglian[2], Bárbara Elias Reis Hodecker[3], Adilson Pelá[2], Rogério Nunes Gonçalves[2], Ednaldo Candido Rocha[2]

[1]Universidade de Brasília, Campus Darcy Ribeiro, highway CP 4357, 70910-900, Brasília, Distrito Federal, Brazil
[2]State University of Goiás, Campus Ipameri, highway GO-330, km 241, 75780- 000 Zip, Ipameri, Goiás, Brazil
[3]União Pioneira de Integração Social (UPIS), Campus Lagoa Bonita, highway BR 020, km 12, DF 335, km 4,8, 70390-125, Brasília, Distrito Federal, Brazil

Abstract

Due to the scarcity of information on the use of fertilizers on the Brazilian Firetree (locally known as guapuruvu), this study aimed to evaluate the initial stages of guapuruvu (*Schizolobium parahyba* (Vell.) S.F.Blake.) plant growth using different doses of phosphorus (P). The experiment was conducted within a greenhouse environment in dystrophic Red-Yellow Latosol soil samples from the Brazilian Cerrado as the substrate in plastic containers with a capacity of 10 dm^3. The experimental design was completely randomized, with six treatments and four replicates each, totaling 24 experimental units. The treatments consisted of six different treatments of P: 0; 50; 100; 150; 200 and 250 mg dm^{-3}, using triple superphosphate as the P-source. At 150 days, the plant height, root crown diameter, number of leaves, dry matter (leaves, stems and roots) and P content in leaves, stems, roots and soil were evaluated. In addition, the Dickson Quality Index was estimated. The results showed that plants treated with doses of 100 to 250 mg dm^{-3} of P had higher growth rates among the analyzed variables. Guapuruvu revealed a requirement for phosphorus in the early stages of development at the studied edaphoclimatic condition, demonstrating the necessity for the application of phosphorus doses above 100 mg dm^{-3} via fertilizers in soils with low P availability.

Keywords: Guapuruvu, Forest Nutrition, Phosphate Fertilization.
Abbreviations: P_ phosphorus; DQI_the dickson quality index; TDMW_was determined as a function of total dry matter weight; H_plant height; CD_root crown diameter; DLSMW_ dry leaf and stem matter weight; DRMW_ and dry root matter weight; PCA_ principal component analysis.

Introduction

Commercial forest production in Brazil primarily refers to plantations of pine, eucalypts, rubber and teak, with most production occurring in the Southeast region, followed by the South, Northeast, Midwest and Northern regions (Ibá, 2016). However, current high prices and scarcity of hardwoods on the market have increased the need for alternative logging sources, for example native species such as guapuruvu.

The guapuruvu or Brazilian Firetree, *Schizolobium parahyba* (Vell.) S.F.Blake, is a tree species native to the Atlantic Forest (Sousa et al., 2005), which stretches from the state of Bahia to Santa Catarina (Carvalho et al., 2008). It has great potential for cultivation in the South and Southeast regions of Brazil due to its rapid growth (Brienza Júnior et al., 1991), recovery capacity of riparian forests and several other purposes, for which the wood and bark can be used, as well as being considered a promising source of cellulose pulp (Ferreira et al., 2007).

In the case of forest species, particularly native ones, there is still little information regarding their nutritional requirements at the time of initial growth (Ceconi et al., 2006). Due to the diverse range of species with different nutritional demands, it becomes difficult to define a fertilization regime that satisfies all species, as the optimal nutrient dose for one species may not be the best fertilization for others (Reis et al., 2012).

In this context, phosphorus has been highlighted among the macronutrients for plant development as one of the elements used in greater quantities in the fertilization of forest species in Brazil. Phosphorus is a vital compound in the processes and structures that promote plant development such as photosynthesis, respiration, energy storage and transfer, cell division, cell growth and several other plant processes. Therefore, its absence can lead to delay in plant development, as it is a fundamental ingredient in the production of metabolic energy (Taiz; Zeiger, 2013). The symptoms of P deficiency are not as conspicuous as for other macronutrients, revealing developmental delay with dark green to purplish coloration in older leaves (Araújo; Machado, 2006). Marques et al. (2004) concluded that *Schizolobium amazonicum* (Hub.) plants subjected to omission of P showed reduced size, with fewer leaves and a longer tap root with few lateral roots.

As an exhaustible resource widely used in Brazilian agriculture, and because it is a macronutrient, the adequate management of phosphorus is vital to the maintenance of chemical reserves and economic viability of projects (Cabral et al., 2016). Over 90% of soil analyses in Brazil show low levels of available phosphorus (P). In addition to the general lack of P in Brazilian soils, the element presents strong interaction with the soil (fixation), which reduces the efficiency of phosphate fertilization (Faquin, 2005).

There are few reports in the literature on the cultivation of *S. parahyba* (Vell.) S.F.Blake subjected to fertilization, which is an essential practice to obtain better cultivation conditions (Chaves et al., 2011; Leal et al., 2013). Hebling (2005) found a positive influence of phosphorus sources on the dry matter parts of *S. parahybae* (Vell.) S.F.Blake. Coneglian et al. (2016) observed that the species develops well in acidic soils; however, it requires mineral fertilization during the initial stages of growth.

There are still few studies related to the nutritional demand of P and its importance in the cultivation of *S. parahybae* (Vell.) S.F.Blake in Cerrado soils. For the commercial use of this native species, it will be necessary to develop economically viable production techniques, particularly for the initial stages of the crop cycle. Considering the specie's potential and the scarce existence of research on the subject, our objective was to evaluate the initial growth of guapuruvu plants (*S. parahybae* (Vell.) S.F.Blake in Brazilian Cerrado soil fertilized with phosphorus.

Results

Growth variables and phosphorus levels

There was significant variation (Pseudo F = 12.2; p = 0.001; R^2 = 0.77) between treatments for the variables height, root crown diameter, dry leaf, stem and root matter, P content in leaves and stem, Dickson quality index and soil P content (Figure 1).

When analyzing axis 1 of the PCA, which explained 57% of the variation in the data, a gradual increase was observed in the values of the variables height, root crown diameter, dry leaf and stem matter, dry root matter, P content in the leaves, stems, roots and soil, and Dickson quality index as the doses of P were increased. However, samples from the plots fertilized with P doses of 100, 150 and 200 mg dm^{-3} were shown to be relatively similar. Furthermore, axis 2 of the PCA, which explained 18% of the variation in the data, indicated that samples which received doses of 50, 100 and 150 mg dm^{-3} of P presented high levels of dry root matter and Dickson quality index (Figure 1).

The variables height and P content in the leaves and roots presented a significant fit to the linear regression model, which showed the highest values through application of the maximum dose of phosphorus (250 mg dm^{-3}). The average height of plants treated with the 250 mg dm^{-3} dose of P was 80.25 cm, 26.37% higher than that found (63.5 cm) for the lowest dose of P (0 mg dm^{-3}) (Figure 2A). The highest P (250 mg dm^{-3}) dose tested showed a 1450% increase in P content in the leaves and a 136.36% increase in P content in the roots of the plants when compared to the lowest dose (Figure 2E and G).

The root crown diameter, dry leaf and stem matter, dry root matter, Dickson quality index and P content in the stem and the soil presented significant fit (p <0.05) to the quadratic regression model, showing an increase in response to the initial doses and decrease the higher doses.

It was estimated that the 172 mg dm^{-3} P dose provided the largest root crown diameter (17.6 mm) (Figure 2B). For dry leaf and stem matter, it was noted that there was greater production with the estimated dose of 233 mg dm^{-3}, corresponding to 60.49 g $plant^{-1}$ (Figure 2C). As the phosphorus doses increased, there were increases in the production of dry root matter until the estimated dose of 146 mg dm^{-3}, resulting in an estimated weight of 26.2 g $plant^{-1}$ (Figure 2D). The P dose that provided the best Dickson Quality Index score was estimated at 188 mg dm^{-3} (Figure 2H). The highest P content in the stem of the guapuruvu plants was at the estimated dose of 218 mg dm^{-3}, obtaining 1.02 mg g^{-1} (Figure 2F). For phosphorus content available within the soil, an increase in the concentration was also observed as the P doses increased. Up to the 100 mg dm^{-3} dose, the available P content within the soil remained low and stable. However, with doses from 150 mg dm^{-3} and higher there was a marked accumulation of available P within the soil (Figure 2I).

Discussion

The guapuruvu plants cultivated in the absence of phosphate fertilization presented inferior development in all evaluated characteristics when compared to those that received fertilization (Figure 1). The phosphorus participates in energetic structures that foster cellular and photosynthetic activities, promoting plant development. Therefore, lack of P results in less plant growth (Taiz and Zeiger, 2013; Marschner, 1997).

With the increase of P doses there was linear growth in height and quadratic growth in the root crown diameter. Thus, the effects of phosphorus application on the analyzed variables represent the need of this nutrient for cultivation at the initial growth stages (Figure 2A and B). Cardoso et al. (2015) also observed that the supply of increasing levels of P positively affected plant growth in the height and root crown diameter of Brazilian mahogany (*Swietenia macrophylla* King). Studying the same species, Santos et al. (2008) verified that the effect of phosphate fertilization promoted a linear effect to increase the plant's stem base, where the dose that promoted the greatest growth was 200 kg ha^{-1} of P. It is important to note that the survival of seedlings planted in fields may be related to seedling diameter, which can provide greater growth and root formation (Gomes et al., 2002).

In relation to the increase of dry leaf and stem matter, the guapuruvu plants presented maximum increases of dry matter at the estimated P dose of 233 mg dm^{-3}, where a quadratic effect was verified. From this dose a decrease was observed, which may be related to the specie's characteristics, as some species cannot avoid high P consumption, causing toxicity from the element (Rocha et al., 2013 and Furtini Neto et al., 1996). Analyzing the requirements of eucalyptus at different phosphorus doses, Rocha et al. (2013) verified the quadratic effect of P doses on the increase of dry leaf and stem matter.

The supply of P to the plants also favored the growth of the root system resulting in the increase of dry root matter as a function of the increase of P content within the soil (Figure 2D), which potentially allowed the plants to exploit a higher volume of soil, and may result in increased water and nutrient uptake (Schwambach et al., 2005).

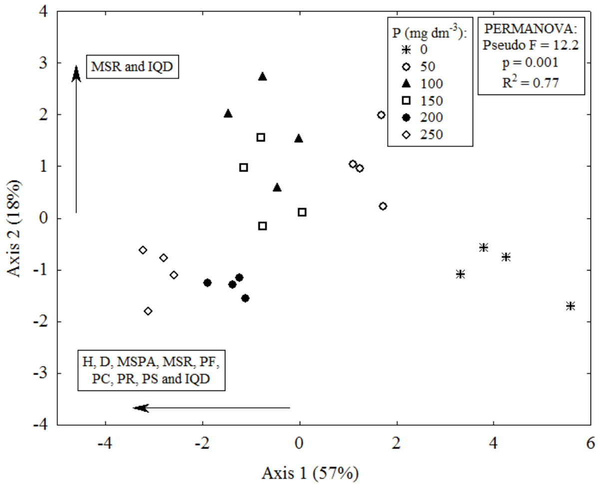

Fig 1. Results of the principal component analysis (PCA) and permutational multivariate analysis of variance (PERMANOVA) for height (H), root crown diameter (D), dry leaf and stem matter (MSPA), dry root matter (MSR) content of P in the stem (PC), leaves (PF), roots (PR) and soil (PS) and Dickson quality index (IQD).

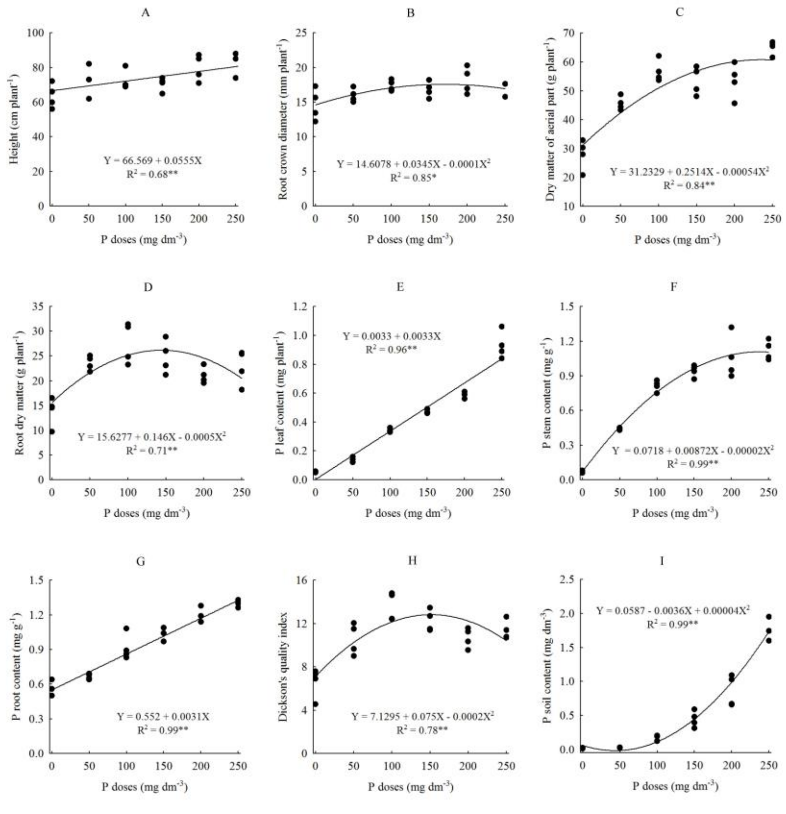

Fig 2. Adjusted regressions for plant height (A), root crown diameter (B), dry leaf and stem matter (C) dry root matter (D), P content of leaves (E), stems (F) and roots (G), Dickson Quality Index (H) and P content within the soil (I) of *guapuruvu* plants as a function of phosphorus doses. * Significant at 5% probability and ** significant at 1% probability.

In evaluating the initial development of guavira (*Campomanesia adamantium*), Vieira et al. (2011) verified the specie's P requirements, obtaining a higher root yield when cultivated at high doses (380 kg ha^{-1}) of the nutrient. Dechassa et al. (2003) and Marschner (1997) described that the rate of root growth depends on the supply of phosphorus, which is important in transferring energy from the cell, respiration, photosynthesis. This has negative responses when is unavailable and reduces the accumulation of biomass and root growth.

In general, the dry leaf, stem and root matter of guapuruvu plants was influenced by increasing doses of phosphorus. The plants subjected to the 0 mg dm^{-3} dose and the maximum dose (250 mg dm^{-3}) presented the smallest increases in biomass, which verifies the lack of phosphorus or excess of the macronutrient retards and harms the production of plant biomass. At high concentrations, phosphorus may decrease the availability of zinc to the plant (Corrêa et al., 2002). Under these conditions, the plants showed low development in diameter, Dickson quality index, dry leaf, stem and root matter, as verified in guapuruvu plants treated with the maximum dose (250 mg dm^{-3}). Therefore, in order to reach the maximum productive potential of a plant, the correct supply of nutrients is necessary.

In evaluating the increase of total dry matter in *Jatropha curcas* L., Silva et al. (2009) found a reduction of 68% in total dry matter yield when the plants were subjected to the omission of phosphorus. Also in this study, the dose that promoted improvement of the analyzed aspects was in the range of 57 mg dm^{-3}. Increased quadratic effects in dry leaf, stem and root matter were found by Stahl (2013) in *Eucalyptus dunnii* Maiden, where the dose provided the highest yield of 256 mg dm^{-3}, a fact that may be related to the high initial growth rate of the species. Stahl (2013) described that the responses observed from high P doses can be explained by the use of plant pots in the experiment, allowing a better relation between roots and soil, with better exploitation of the soil by the root system. However, in a nutrient solution study on African mahogany using the nutrient omission technique, Corcioli et al. (2016) did not find any differences in the production of dry matter, when P was omitted, when compared to the treatment with the nutrient.

The higher the value of the Dickson Quality Index, the higher is the quality of seedlings. The largest guapuruvu seedlings with higher biomass and better development indexes (DQI) were obtained by applying 150 to 200 mg dm^{-3}, with maximum values at the estimated P dose of 188 mg dm^{-3}. These results reveal the specie's need for this nutrient (Figure 2H).

The P rates recommended for better growth in the analyzed variables of guapuruvu plants ranged from 150 to 250 mg dm^{-3} (Figure 2). Gomes (2004) found values of 127 mg dm^{-3} for angico-white, and 191 mg dm^{-3} for garapa, while Balieiro et al. (2001) obtained values varying from 98 to 209 mg dm^{-3} for *Acacia holocericea* A. Cunn. Ex G. Don.

In general, there were increases in nutrient content of the leaves, stems and roots, when P supply increased (Figure 2E, F and G). The increase of P accumulation within the plants in this study, through the provision of increasing levels of this nutrient, is possibly related to its low natural availability in the studied soil (0.8 mg dm^{-3} of P), and also to the need of the species (Viégas et al., 2012; Coneglian et al., 2016). Santos et al. (2008) also observed an increase in the accumulation of P in mahogany seedlings cultivated in dystrophic Yellow Latosol under greenhouse conditions as a function of the supply of increasing doses of P in the soil presenting a linear response in the accumulation of P up to an 800 mg dm^{-3} dose.

The available P content inside the soil, low and stable up to the 100 mg dm^{-3} dose, indicates that at these concentrations the plants were able to absorb all available P with the rest fixed in the soil (Figure 1). Considering the accumulation of P in the whole plant (Figures E, F and G), the values were approximately 60 to 80 mg $plant^{-1}$. As the plant pot had 10 liters, and 2500 mg of P was applied per plant pot, approximately 5% was utilized, with the remainder fixed.

Finally, it is evident that the plants in this study presented higher initial growth in most of the analyzed variables (Figures 1 and 2) when subjected to treatments of 100 to 150 mg dm^{-3}. Therefore, it is not necessary to apply high doses as the species is sensitive to the presence of elevated P, and the excess nutrient becomes fixed within the soil. Thus, it is important to ensure an adequate supply of nutrients that guarantees maximum productivity and avoids wasting of fertilizers, guaranteeing the best economic return to guapuruvu growers and producers.

Materials and Methods

Location and installation of the experiments

The experiment was installed and conducted in a greenhouse environment at the State University of Goiás, experimental area, Ipameri Campus (geographical coordinates 17º 43' 19" S latitude and 48º 09' 35" W longitude, 764 m above sea level). The dimensions of the greenhouse used were: 30.0 m long, 7.0 m wide and 3.5 m in height, with the sides covered by 50% black sombrite and under 150 micron transparent plastic.

The substrate used was a Brazilian Cerrado soil classified as dystrophic Red-Yellow Latosol (Embrapa, 2013), collected from the subsurface layer (0.20 – 0.40 m). In the physicochemical analysis, the substrate showed the following initial values: pH ($CaCl_2$) = 4.11; P (Mehlich) = 0.8 mg dm^{-3}; K = 28 mg dm^{-3}; Ca^{2+} = 0.3 $cmol_c dm^{-3}$; Mg = 0.2 mg dm^{-3}; Al^{3+} = 0.1 $cmol_c$ dm^{-3}; Zn = 1.0 mg dm^{-3}; Fe = 38.4 mg dm^{-3}; Mn = 1.1 mg dm^{-3}; Cu = 0.6 mg dm^{-3}; B = 0.4 mg dm^{-3}; H + Al = 5.61 $cmol_c$ dm^{-3}; SB = 0.25 $cmol_c$ dm^{-3}; CTC (T) = 5.86 $cmol_c$ dm^{-3}; MO = 1.53 g dm^{-3}, 300, 80.0 and 620.0 mg dm^{-3} of clay, silt and sand, respectively.

Statistical design and plant materials

The species evaluated was *S. parahyba* (Vell.) S.F.Blake. The seedlings were produced from seeds obtained from Pederneiras in the state of São Paulo, sown in 53 cm^3 tubes filled with commercial substrate, where they remained until the planting date of the proposed treatments. The plants received no fertilization during this period. Thirty days after sowing the plants were transplanted to black polyethylene pots with perforated bases, each filled with 10 dm^{-3} of soil.

The experimental design was completely randomized, with six treatments and four replicates each, totally 24 experimental units. The treatments consisted of six doses of phosphorus (P): 0; 50; 100; 150; 200 and 250 mg dm^{-3}, using triple superphosphate fertilizer as the source.

In response to the physiochemical analysis of the soil, all soil treatments were limed before fertilization to raise soil base saturation to 60%. Fertilization with nitrogen (50 mg dm^{-3}) and potassium (100 mg dm^{-3}) was then carried out within the plantation. Subsequently, a nitrogen fertilizer (200 mg dm^{-3}) was applied at 30 days. The sources used for liming and fertilization were: dolomitic limestone PRNT 92, urea and potassium chloride, respectively. The doses of the established nutrients were applied individually in each pot. The doses referring to the proportions of fertilizers used were adapted according to Santos et al. (2008).

Soil moisture was maintained throughout the experimental period at approximately 60% of the soil's maximum water retention capacity. The volume of evapo-transpirated water was replenished daily by weighing the pots and irrigating with distilled water. Manual weed control was also performed to ensure that substrate is not disinfested. In order to homogenize and randomize uncontrolled factors, the positions of the pot plants were randomly changed every 7 days in all treatments.

Evaluated characteristics

One hundred and fifty days after transplantation, growth variables were evaluated by measuring plant height, from the base of the stem to the apex of the plant using a graduated ruler, and collecting diameter using a digital caliper. The plants were then separated into leaves, stems and roots for the determination of dry matter. Plant parts were washed with distilled water and then placed into a forced air circulation oven for 72 hours at a temperature of 70 °C until constant matter was obtained. After drying, the plant material was weighed in an analytical balance with 0.01 g precision to determine the dry matter of leaves, stems, and roots.

The Dickson Quality Index (DQI) was determined as a function of total dry matter weight (TDMW), plant height (H), root crown diameter (CD), dry leaf and stem matter weight (DLSMW) and dry root matter weight (DRMW), using the following formula (Dickson et al., 1960):

$$\mathrm{DQI} = \frac{\mathrm{TDMW(g)}}{\frac{\mathrm{H(cm)}}{\mathrm{CD(mm)}} + \mathrm{DLSMW(g)/DRMW(g)}}$$

After determining dry matter, grinding of the material was carried out with a Willey type stainless steel mill with a 20 mesh sieve, followed by analysis of the phosphorus content in the leaves, stems and roots.

To determine the phosphorus content within the soil, a sample from each experimental unit was analyzed using the Mehlich extractive solution. In order to determine the phosphorus content in the leaves, the spectrophotometric method with molybdenum blue was used, according to methodology described by Silva (2009).

Statistical analysis

A principal component analysis (PCA) and permutational multivariate analysis of variance – PERMANOVA (Anderson, 2001) were used to test differences between treatments. The data was standardized before carrying out these analyses, and the Euclidean Distances were adopted as measures of spacing between the samples. Variables that presented a correlation coefficient with the axes greater than 0.6 were inserted into the PCA graph in absolute values. In addition, to evaluate the influence of the P doses on each variable, simple regression analysis was used. Statistical analyses were conducted using SISVAR 5.4 (Ferreira, 2011) and R version 3.2 (R Development Core Team, 2015) software with the vegan package (Oksanen et al., 2016).

Conclusion

Guapuruvu plants (*S. parahyba* (Vell.) S.F.Blake) require phosphorus in the initial stages of development, where it is necessary to apply phosphorus via fertilizers in soil with low availability. The P treatments between 100 and 200 mg dm^{-3} provided higher initial development of guapuruvu plants (*S. parahyba* (Vell.) S.F.Blake), taking into account the diameter, seed quality index and dry root matter.

Acknowledgements

We thank the State University of Goiás, for the scholarship to the researcher (PROBIP/PrP 009/2016) granted to AP and ECR.

References

Araújo AP, Machado CTT. Nutrição mineral de plantas. In: Fernandes MS. (Ed.) (2006) Viçosa. 432.

Adami C, Hebling S (2005) Efeitos de diferentes fontes de fósforo no crescimento inicial de *Schizolobium parahyba* (Vell.) S. F. Blake. Nat Online. 3: 13-18.

Anderson MJ (2001) A new method for non-parametric multivariate analysis of variance. Aust Ecol. 26: 32-46.

Balieiro FC, Oliveira IG, Dias LE (2001) Formação de mudas de *Acacia holosericea* e *Acacia auriculiformis*: resposta a calagem, fósforo, potássio e enxofre. Rev Arv. 25: 183-191.

Brienza Junior S, Yared JAG, Jarvis PG (1991) Agroforestry systems as an ecological approach in the brazilian amazon development. Agro Systems. 45: 319-323.

Cabral CEA, Cabral LS, Silva EMB, Carvalho KSC, Kroth BE, Cabral CHA (2016) Resposta da *Brachiaria brizantha* cv. marandu a fertilizantes nitrogenados associados ao fosfato natural reativo. Comu Scient. 7: 66-72.

Cardoso AAS, Santos JZL, Tucci CAF, Farias EP, Moura RPM (2015) Influência da acidez e do teor de fósforo do solo no crescimento inicial do mogno. Pesq Flores Brasil. 35: 1-10.

Carvalho MG, Nascimento IA, Carvalho AG (2008) 5-desoxiflavonóides e lignana isolados da madeira de *Schizolobium parahyba* (Vell.) S.F. Blake (guapuruvu). Quím Nova. 31: 1349-1352.

Ceconi DE, Poletto I, Brun EJ, Lovato T (2006) Crescimento de mudas de açoita cavalo (*Luehea divaricata* Mart.) sob influência da adubação fosfatada. Cerne. 12: 292-299.

Chaves LHG, Gheyi HR, Ribeiro S (2011) Consumo de água e eficiência do uso para cultivar de mamona paraguaçu submetida à fertilização nitrogenada. Eng Ambient. 8: 126-133.

Coneglian A, Ribeiro PHP, Melo BS, Pereira RF, Dorneles Junior J (2016) Initial growth of *Schizolobium parahybae* in brazilian cerrado soil under limingand mineral fertilization. Rev Bras de Eng Agríc e Amb. 20: 908-912.

Corcioli G, Borges JD, Jesus RP (2016) Deficiência de macro e micronutrientes em mudas maduras de *Khaya ivorensis* estudadas em viveiro. Cerne. 22: 121-128.

Corrêa FLO, Souza CAS, Carvalho JG, Mendonça V (2002) Fósforo e zinco no desenvolvimento de mudas de aceroleira. Rev Bras de Frutic. 24: 793-796.

Dechassa NMK, Claassen N, Steingrobe B (2003) Phosphorus efficiency of cabbage (*Brassicao leraceae* L. Var. Capitata), carrot (*Daucus carota* L.), and potato (*Solanum Tuberosum* L.). Plant and Soil. 250: 215-224. Dickson A, Leaf AL, Hosner JF (1960) Quality appraisal of white spruce and white pine seedling stock in nurseries. For Chron. 36: 10-13.

Embrapa (2013) Sistema brasileiro de classificação de solos. 3.ed. Embrapa Solos, Brasília. 201.

Faquin V (2005) Nutrição mineral de plantas. Lavras. 183.

Ferreira DF (2011) Sisvar: a computer statistical analysis system. Ciên e Agrotec. 35: 1039-1042.

Ferreira RA, Oliveira LM, Tonetti OAO, Davide A. C (2007) Comparação da viabilidade de sementes de *Schizolobium parahyba* (Vell.) Blake – leguminosae caesalpinioideae, pelos testes de germinação e tetrazólio. Rev Bras de Sement. 29: 83-89.

Furtini Neto AE, Barros NF, Godoy MF, Novais RF (1996) Eficiência nutricional de mudas de *Eucalyptus* em relação a fósforo. Rev Arv. 20: 17-28.

Gomes KCO, Paiva HN, Neves JCL, Barros NF, Silva SR (2004) Influência da saturação por bases e do fósforo no crescimento de mudas de angico-branco. Rev Arv. 28: 785-792.

Gomes JM, Couto L, Leite HG, Xavier A, Garcia SLR (2002) Parâmetros morfológicos na avaliação da qualidade de mudas de *Eucalyptus grandis*. Rev Arv. 26: 655-664.

Ibá, Industria brasileira de árvores. Relatório Anual (2016). Disponível em: <http://http://iba.org/images/shared/Biblioteca/IBA_RelatorioAnual2016_.pdf>. Acesso em: 15 de fevereiro de 2017.

Leal AJF, Lazarini E, Rodrigues LR, Marcandalli LH (2013) Plantas de cobertura e modos de aplicação de calcário. Rev Bras de Ciênc do Sol. 37: 491-501.

Marques TCLLSM, Carvalho JG, Lacerda MPC, Mota PEF (2004) Crescimento inicial do paricá (*Schizolobium amazonicum*) sob omissão de nutrientes e de sódio em solução nutritiva. Cerne, 10: 184-195.

Marschner H (1997) Mineral nutrition of higher plants. 2. ed. San Diego: Academic. 889.

Oksanen JF, Blanchet G, Friendly M, Kindt R, Legendre P, Mcglinn D, Peter RM, O'hara RB, Gavin LS, Peter SM, Stevens HH, Szoecs E, Wagner H (2016) Vegan: community ecology package. R package version 2.4-0. Available at.

R development core team. R version 3.2.0: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing. 2015. Acessado em 15 mar. 2017. Online. Disponível em: http://www.R-project.org.

Reis BE, Paiva HN, Barros TC, Ferreira AL, Cardoso WC (2012) Crescimento e qualidade de mudas de jacarandá-da-bahia (*Dalbergia nigra* (vell.) Allemão ex benth.) em resposta à adubação com potássio e enxofre. Ciênc Florest. 22: 389-396.

Rocha JHT, Pietro MR, Borelli K, Backes C, Neves MB (2013) Produção e desenvolvimento de mudas de eucalipto em função de doses de fósforo. Cerne. 19: 535-543.

Santos JZL, Resende AV, Furtini Neto AE, Corte EF (2008) Crescimento, acúmulo de fósforo e frações fosfatadas em mudas de sete espécies arbóreas nativas. Rev Arv. 32: 799-807.

Schwambach J, Fadanelli C, Fett Neto A (2005) Mineral nutrition and adventitious rooting in microcuttings of *Eucalyptus globules*. Tree Physiol. 25: 487-494.

Silva EB, Tanure LPT, Santos SR, Resende Júnior PS (2009) Sintomas visuais de deficiências nutricionais em pinhão-manso. Pesq Agropec Bras. 44: 392-397.

Silva FC (2009) Análise química de tecido vegetal. In: Manual de análises químicas de solo, plantas e fertilizantes. 2 ed. Brasília: Embrapa informação tecnológico. 193-204.

Sousa DB, Carvalho GS, Ramos EJA (2005) Paricá - *Schizolobiumam azonicum* Huber ex Ducke. Informativo Técnico, n. 13. Manaus: Rede de sementes da amazônia.

Stahl J, Ernani PR, Gatiboni LC, Chaves DM, Neves CU (2013) Produção de massa seca e eficiência nutricional de clones de *Eucalyptus dunni* e *Eucalyptus benthamii* em função da adição de doses de fósforo ao solo. Ciênc Florest. 23: 287-295.

Taiz L, Zeiger E (2013) Fisiologia vegetal. 5. ed. Porto Alegre: Artmed. 954.

Vieira MC, Perez VB, Heredia NAZ, Santos MC, Pelloso IAO, Pessoa SM (2011) Nitrogênio e fósforo no desenvolvimento inicial da guavira *Campomanesia adamantium* (Cambess.) O. Berg cultivada em vasos. Rev Bras de Plant Medic. 13: 542-549.

Viégas IJM, Lobato AKS, Rodrigues MFS, Cunha RLM, Frazão DAC, Oliveira Neto CF, Conceição HEO, Guedes EMS, Alves GAR, Silva SP (2012) Visual symptoms and growth parameters linked to deficiency of macronutrients in young *Swietenia macrophylla* plants. Int J Food, Agric Environ. 10: 937-940.