Seedlings of *Cedrela fissilis* Vell. respond to single superphosphate application, but not to liming[1]

Tayssa Menezes Franco[2*], *Juciley Lima de Souza*[3†], *José Darlon Nascimento Alves*[4], *Fabio Costa Esteves Junior*[4], *Jairo Neves de Oliveira*[4], *Eric Victor de Oliveira Ferreira*[4]

10.1590/0034-737X202370050006

ABSTRACT

Cedro-rosa (*Cedrela fissilis*) is native to Brazil with great potential for seedling production. However, soil correction is necessary to improve its performance, due to the edaphoclimatic conditions in Brazil, where soils have a high weathering degree and large amounts of Fe and Al oxides. Here, we evaluated the combined effect of soil acidity correction by liming and phosphate fertilization using single superphosphate on the growth and development of cedro-rosa seedlings cultivated in Amazonian soil. The study was carried out in a greenhouse at the Universidade Federal Rural da Amazônia (UFRA) – Campus Capitão Poço, between July and December 2019. Different levels of base saturation (V%) showed no influence on the variables analyzed. On the other hand, phosphorus (P), calcium (Ca), and sulfur (S) supplied by single superphosphate significantly influenced growth and development of cedro-rosa seedlings. The optimum P levels for stem diameter (SD), leaves number (LN), root dry matter (RDM), stem dry matter (StDM), leaf dry matter (LDM), total dry matter (TDM) were 405, 286, 385, 421.87, 393.75, 445 mg dm^{-3} of P, respectively. Seedling quality (DQI) showed a positive linear response to levels of P, Ca, and S in single superphosphate. Thus, fertilization with P was necessary at the nursery stage for the cultivation of the species in soil of low chemical fertility. For better quality of cedro-rosa seedlings grown in pots, the application of 400 mg dm^{-3} of P is recommended.

Keywords: *Cedrela fissilis* Vell.; native species; mineral nutrition; base saturation; Amazonian soils.

INTRODUCTION

Seedling production is one of the most important stages for a productive and efficient forest stand; thus, providing the nutritional needs of seedlings optimizes seedling growth and initial establishment (Bognola & Maeda, 2012). In this sense, knowledge of the soil chemical and physical characteristics is crucial at the nursery stage.

Moreover, in Brazil, production of forest seedlings is intense due to the expansion of agricultural areas and the high demand for wood products, leading to the exploitation of native remnants, intensive deforestation, and degradation of areas (Freitas *et al.*, 2017). Therefore, revegetation of these areas is essential to improve the soil physical and chemical characteristics, providing the necessary protection through plant cover to reduce soil losses by erosion (Silva *et al.*, 2011a).

Furthermore, the choice of the correct species to be cultivated is essential, given the soil and climate characteristics of the region. Research should focus on the use of native species at the nursery stage; nevertheless, few studies have investigated the production of native

Sumbitted on August 11th, 2022 and accepted on March 20th, 2023.
[1] This work is part of a research project carried out by Universidade Federal Rural da Amazônia, Capitão Poço, PA, Brazil.
[2] Universidade Federal de Viçosa, Departamento de Engenharia Agrícola, Viçosa, MG, Brazil. Tayssa.menezes2015@gmail.com
[3] Universidade do Oeste do Paraná, Departamento de Engenharia Agrícola, Cascavel, PR, Brazil. juciley.ufra@gmail.com
[4] Universidade Federal Rural da Amazônia, Capitão Poço, PA, Brazil. jose.darllon@hotmail.com; fabioesteves1408@gmail.com; jairoufracap22@gmail.com; ericsolos@yahoo.com.br
*Corresponding author: tayssa.menezes2015@gmail.com
† *In Memoriam*

forest seedlings for timber production or recovery of degraded areas (Gonçalves *et al.*, 2012). Most native forest species are poorly studied and scientific knowledge is needed to scale up seedling production with quality, such as cedro-rosa (*Cedrela fissilis* Vell.), facilitating crop management and reducing production costs (Oliveira *et al.*, 2014).

Cedro-rosa is a forest species of the Meliaceae family and is classified as a late secondary successional species (Freiberger *et al.*, 2013), widely distributed throughout the Brazilian territory (Pias *et al.*, 2015). Cedro-rosa has good development in regions with deep, well-drained soils with a clayey to sandy-clay texture, as well as in temperate and humid climates at subtropical and tropical altitude (Angeli, 2005).

Cedro-rosa also has a high commercial value, with potential use in landscaping and in the production of high-quality wood (Martins & Lago, 2008). This species is also used in civil construction, frames, wainscoting, panels, linings, trimmings, packaging, musical instruments, and fine furniture (IPT, 2019). Thus, due to the environmental and economic importance of native tree species, mainly in seedling production, adequate nutrition is needed for the full development of cedro-rosa.

Most Brazilian soils are highly acidic under natural conditions with low nutrient availability, mainly phosphorus (P), due to high adsorption of phosphate ions to iron and aluminum oxides (Freitas *et al.*, 2017). Therefore, practices to correct chemical constraints of the soil are necessary for the satisfactory development of cultivated species. Liming is an essential practice to correct soil acidity, as it neutralizes Al^{+3} and increases the pH, supplies Ca and Mg, improves the soil cation exchange capacity, increasing nutrient availability to plants (Ronquim, 2012) and favoring both root development and crop yield.

Brazilian forest species have shown a response to P application in nutrition and growth of Brazilian mahogany (*Swietenia macrophylla* King) seedlings (Silva *et al.*, 2011b). The supply of 600 mg dm^{-3} of P_2O_5 at 25% base saturation increased the growth of *Cassia grandis* Linnaeus seedlings (Freitas *et al.*, 2017). To maximize the production of Australian cedar seedlings, the base saturation needs to be raised to 50% (Braga *et al.*, 2015).

Organic and mineral fertilization in cedro-rosa showed that the combination of 10% of poultry litter with NPK fertilization provided better conditions for seedling development (Rego *et al.*, 2021). However, few studies have investigated the effect of base saturation and P fertilization on the production of cedro-rosa seedlings.

Furthermore, it appears that native forest species have different responses to P fertilization and to soil acidity correction, which requires evaluations of these factors for the development of cedro-rosa seedlings. Thus, this study evaluated the combined effect of liming and P, Ca, and S fertilization by single superphosphate on the initial development of cedro-rosa seedlings grown in Amazonian soil.

MATERIAL AND METHODS

The experiment was carried out in a greenhouse at the Universidade Federal Rural da Amazônia (UFRA) – Campus Capitão Poço – Pará State – Brazil (01º44’47” S and 47º03’34” W), between July and December 2019. In the region, air temperature ranges from 25.6 - 26.9 °C with an annual average of air temperature of 26.2 °C (Pacheco & Bastos, 2001). The climate of the region is Am type (altitude tropical) (Köppen classification) with annual precipitation around 2,500 mm and a short dry season between September and November and relative humidity between 75 and 89% in the months with the lowest and highest precipitation volumes, respectively (Schwartz, 2007). The precipitation volumes and mean air temperatures were recorded during the experimental period (Figure 1). The main soil type of the region is the Oxisol (Soil Survey Staff, 2014), classified as Latossolo by the Brazilian soil classification system (Santos *et al.*, 2018).

The soil used in the experiment was collected (0.20 – 0.40 m) near the area of secondary vegetation on the premises of UFRA-CCP. Afterward, the soil samples were dried, sieved through a 2-mm mesh, and chemically analyzed (Table 1) at the laboratory of EMBRAPA - Amazônia Oriental (Belém – PA).

The results of the soil chemical analysis (Table 1) were used to calculate the need for liming, using the base saturation method (Raij, 1983) according to each treatment. The dolomitic limestone (Relative Power of Total Neutralization- “PRNT” = 98%) was mixed with the soil volume in each pot and placed to incubate for 30 days.

Cedro-rosa (*Cedrela fissilis* Vell.) seeds were obtained from the company Sementes Caiçara LTDA. The seeds were submitted to the dormancy breaking process by the imbibition method in distilled water for 24 h. Five seeds were sown in polyethylene bags (1 kg) filled with local soil. The bags were placed in a screened nursery with 30% shading until the seedlings had four pairs of developed leaves. Subsequently, thinning was performed and only the most vigorous plants were transplanted into plastic pots filled with 8 L of soil (Table 1). In these pots, the plants were grown in full sun (greenhouse without cover).

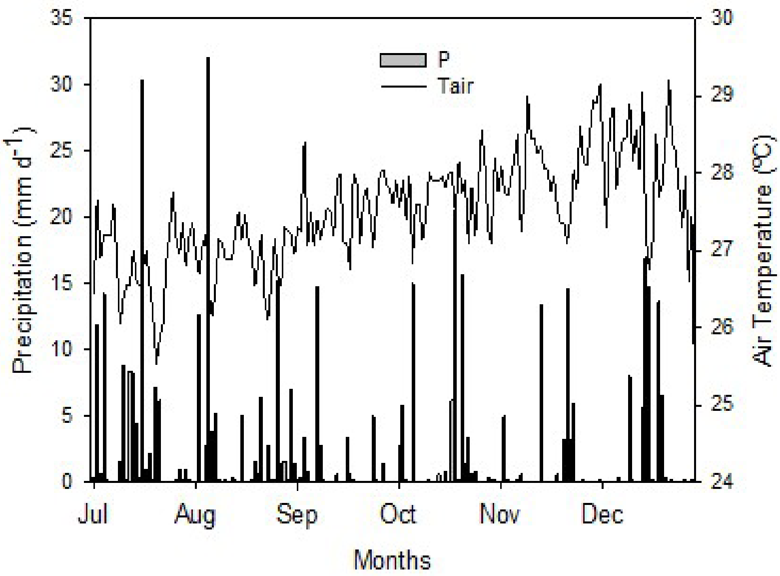

Figure 1: Air temperature (Tair) and daily total precipitation (P) during the experimental period.

Table 1: Soil chemical characterization (0.20 – 0.40 m) used in the experiment

pH	P	K	Na	Al^{+3}	Ca^{+2}	Mg^{+2}	H+Al	CEC		Saturation	
								Total	Effective	Bases	Aluminum
Water	mg dm^{-3}			cmolc dm^{-3}						%	
4.74	15	12	5	0.7	0.1		3	3.24	0.96	7.5	74.74

pH – hydrogen ionic potential; P, K, and Na: extraction with Mehlich-1 and determination by colorimetry (P) and by flame photometry (K and Na); Ca, Mg and Al: extraction with 1 mol/L KCl and determination by atomic absorption spectrophotometer (Ca and Mg) and titration (Al); H+Al: extraction with Ca acetate pH 7.0 and determination by titration; CEC – cation exchange capacity.

After transplanting, fertilization was carried out with N (500 mg dm^{-3}) and K (500 mg dm^{-3}), using the commercial sources urea (45% N) and potassium chloride (60% K_2O) of installment form at transplanting (100 mg dm^{-3}), 15 days after transplanting (DAT) (200 mg dm^{-3}), and 30 DAT (200 mg dm^{-3}). Fertilization with micronutrients was performed with pure reagents for analysis (p.a.), using nutrient solution applied five DAT on the soil surface of each pot: B – 0.5; Cu - 1.5; Fe - 5; Mn - 10.0; Mo – 0.2 and Zn – 5.0 mg dm^{-3} (Malavolta, 1980). During the experiment, irrigation was performed manually to keep the soil at field capacity in the absence of rain.

The experimental design was in randomized blocks with four replications in a 4 x 4 factorial scheme: four levels of base saturation- V (7.5, 20, 40, and 60%), equivalent respectively to 0, 1.65, 4.30, and 6.94 g of limestone pot^{-1}), and four levels of P (0, 100, 200, and 400 mg dm^{-3} of P), using the single superphosphate source (18% P_2O_5, 16% Ca, and 8% S), which was applied to the soil surface in each pot (8 L).

During the experimental period, growth variables were measured monthly, such as plant height (PH), leaf number (LN), and stem diameter (SD). PH was measured with a graduated ruler, considering height from the ground level to the last apical bud. SD was obtained with a digital caliper and measurements were taken at 1 cm from the soil surface. For LN, a simple count of all fully expanded leaves of each plant was performed.

At 120 DAT, the plants were harvested and their parts were separated, dried in an oven with forced air circulation (70 ºC) until reaching constant mass, and weighed on an analytical balance to determination dry matter (DM). Root dry matter (RDM), stem dry matter (StDM), leaf dry matter (LDM), shoot dry matter – SDM (LDM+ StDM), as well as RDM/SDM ratio- and total dry matter – TDM (SDM+RDM) were determined. To collect the roots, the entire root system was washed under tap water in a sieve (2-mm mesh) to separate the soil. The Dickson quality index – DQI (Dickson *et al.*, 1960) was estimated with the growth and DM variables (equation 1):

$$\frac{TDM}{\frac{PH(cm)}{SD(mm)}+\frac{SDM(g)}{RDM(g)}} \quad \text{(equation 1)}$$

where:

TDM = total dry matter (SDM+RDM), in g;
PH = plant height, in cm;
SD = stem diameter, in mm;
SDM = shoot dry matter, in g;
RDM = root dry matter, in g.

Verification of normality assumptions (Kogomorov – Smirnov test) and homogeneity of variances (Bartlet and Levene tests) were carried out. Then, analysis of variance (ANOVA, $p < 0.05$) was performed to verify the effect of the factors and the interaction between the factors on the response variables. When significant, the results were adjusted to the regression models (linear and quadratic) and those with the highest determination coefficient (R^2) were chosen. The Tukey test was applied for base saturation (V) levels. In addition, Pearson's correlation coefficient (r) was estimated between the variables PH, SD, LN, RDM, StDM, LDM and DQI. All statistical analyses were performed using the Sisvar software (Ferreira, 2011) and the graphs were generated using Sigma Plot version 12.

RESULTS AND DISCUSSION

Analysis of variance showed a significant effect ($p < 0.05$) only for P levels (and Ca and S) by single superphosphate in all variables analyzed. The seedlings showed no response to base saturation levels through liming (Figures 1, 2, 3, and 4). However, it should be noted that each species responds differently to liming (Vieira *et al.*, 2020). In general, native tree species show satisfactory growth in acidic soils with low Ca availability (Furtini Neto *et al.*, 2000), as observed in the conditions of the current study (Table 1). Furtini Neto *et al.* (1999) observed satisfactory growth of cedro-rosa seedlings in the treatment with only the Ca addition (12 $mmol_c\ dm^{-3}$) in the soil with an acidic pH, indicating that the species seedlings responded to the supply of Ca and not to the correction of acidity by liming.

Fontes *et al.* (2013) found a similar result and reported that, in general, cedro-rosa did not show a significant response to liming in the production of total seedling biomass. The growth of Australian cedar, for example, was not affected by base saturation (60, 70, 75, and 80%) up to 150 days after planting the seedlings (Oliveira *et al.*, 2015). In addition, liming did not show a significant effect on dry biomass production of *Theobroma grandiflorum* seedlings, when cultivated in a substrate with base saturation (BS) of 60% (Souza *et al.,* 2021) and for the root biomass of *Anadenanthera colubrina* in BS of 24 and 60% (Gomes *et al.,* 2004).

This pattern may indicate a protection mechanism for the species in which Al^{+3} bioaccumulates in the roots and is not translocated to the shoots; thus, keeping the photosynthetic apparatus functioning (Presotto *et al.,* 2018) through the release of organic acids by the root system, which inhibits the effect of Al, giving plants the ability to raise the pH in the rhizosphere, reducing Al solubility and absorbing Al ions with subsequent immobilization in specific locations (Vale *et al.*, 1996; Beutler *et al.*, 2001; Hartwig *et al.*, 2007; Presotto *et al.*, 2018).

P fertilization and liming on *Cassia grandis* Linnaeus f. showed no significant responses for growth and biomass variables (Freitas *et al.*, 2017). On the other hand, a significant effect of base saturation was observed in teak seedlings grown in a Red Oxisol (Favare *et al.*, 2012).

Plant height (PH) responded linearly to single superphosphate fertilization (P, Ca, and S levels), while stem diameter (SD) showed a quadratic behavior to these nutrients supply, expressing the maximum value with the estimated level of 405 mg dm^{-3} of P (Figures 2A and 2B). The largest leaf number (LN) (7.19 leaves/plant) was obtained at the estimated level of 286 mg dm^{-3} of P, more than the double value without P application (Figure 2C). Increases in these biometric variables are essential for the survival rate of seedlings of forest species, especially due to adverse environmental conditions, such as dry spells and wind action. In addition, SD is essential for the financial return of the forester, due to wood production (Coneglian *et al.*, 2016).

NPK doses in rainbow eucalyptus (*Eucalyptus deglupta*) showed a positive effect of P on the PH and SD of the seedlings (Pereira *et al.*, 2021). The variables PH and SD showed a positive response to P addition in Açoita-cavalo (*Luehea divaricata* Mart.) seedlings for (Ceconi *et al.*, 2006). P fertilization and mycorrhizal inoculation on mulungu (*Erythrina velutina* Willd.) and ipê-roxo [*Handroanthus impetiginosus* (Mart. ex DC) Mattos] seedlings showed a significant increase in PH, SD, and LN with increasing doses of P (Leite *et al.*, 2014; Lopes, 2022).

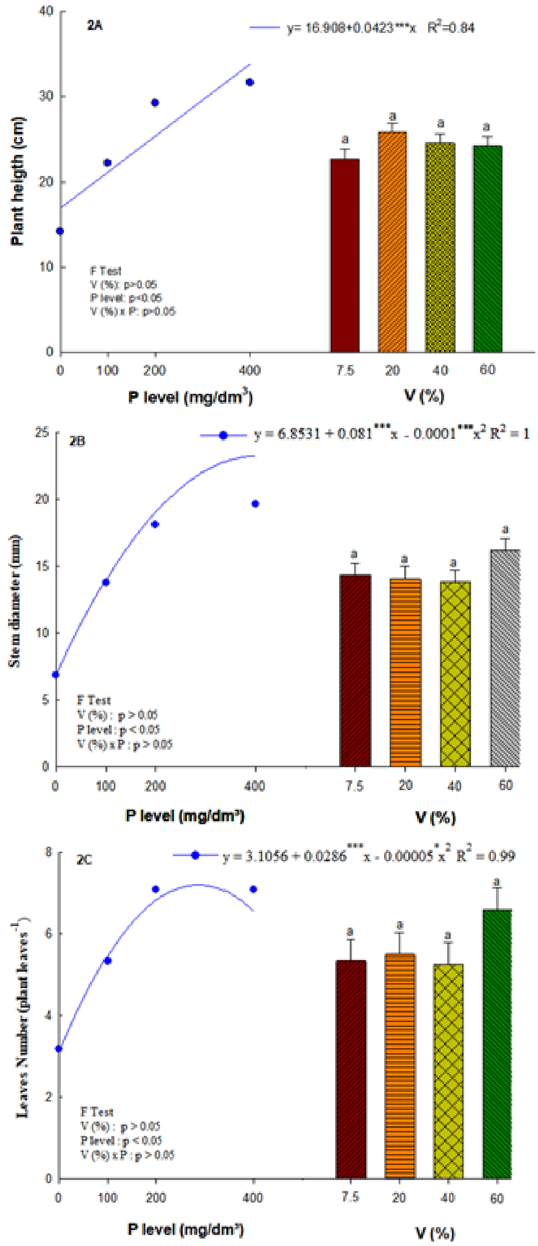

Figure 2: Plant height - PH (A), stem diameter - SD (B), and number of leaves - LN (C) of cedro-rosa seedlings as a function of P doses and base saturation levels (V%). Means followed by the same letters in the columns are considered statistically equal by the Tukey test ($p > 0.05$).

The response of plant growth (PH, SD, and LN) to P fertilization is consistent with low chemical fertility of the soil, mainly with low P availability (Table 1). In weathered tropical soils, the largest fraction of inorganic P is adsorbed by Fe and Al oxides, making P scarcity a limiting factor for plant growth in these environments (Novais *et al.*, 2007). P supply is essential for respiration and photosynthesis, as P is a component of ATP molecules. In addition, P participates in the formation of nucleic acids, coenzymes, and phospholipids. Thus, P is essential for the full development of plants (Bucher *et al.*, 2018; Prado, 2020). P fertilization by single a superphosphate source provides Ca and S and theses nutrients may also improve plant growth. Ca is crucial for the middle lamella formation of the cell wall and S is a constituent of some amino acids and vitamins (Taiz *et al.*, 2017; Kerbauy, 2019).

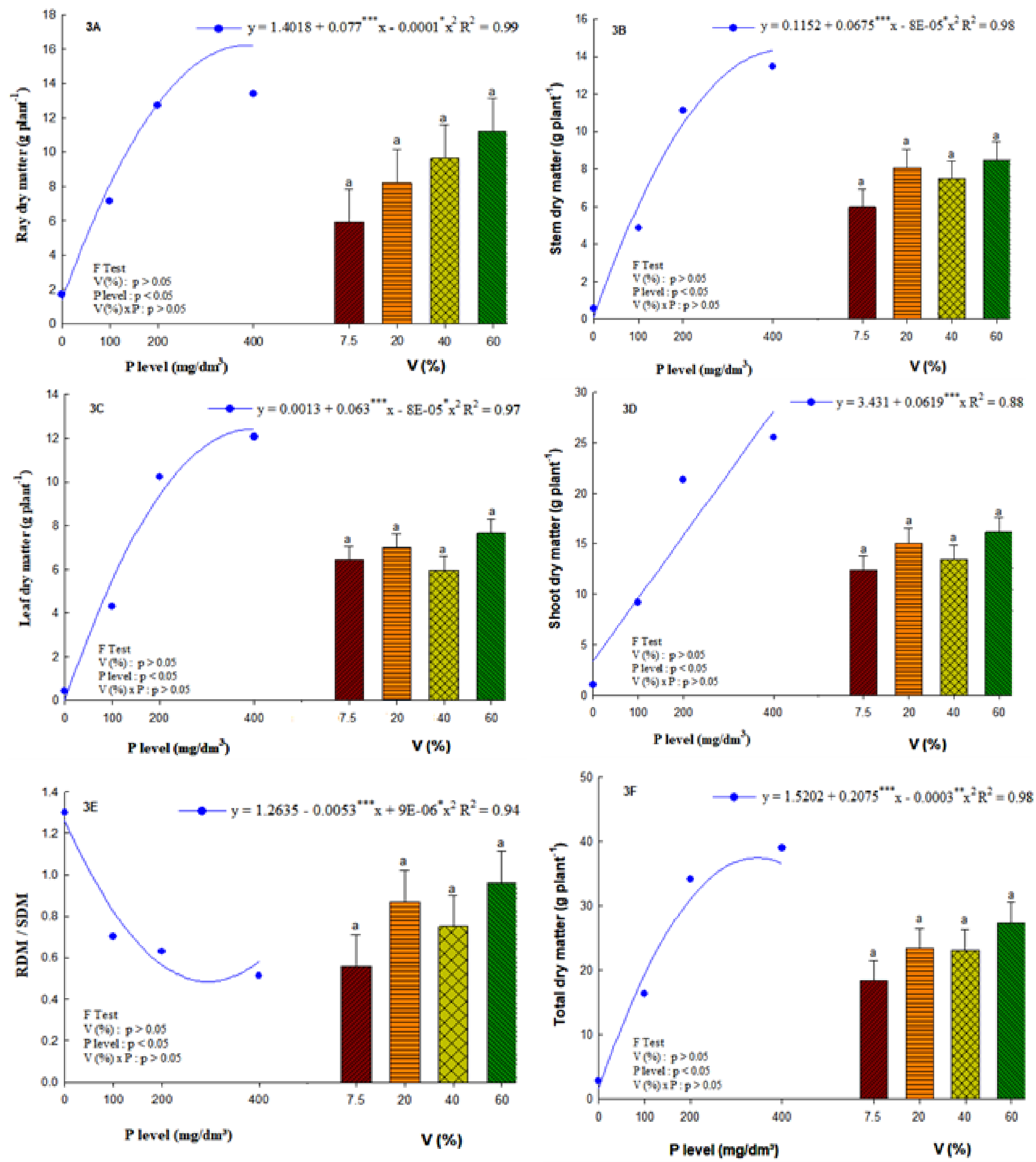

Figure 3: Dry matter production root- RDM (A), stem - StDM (B), leaf- LDM (C), shoot- SDM (D) RDM/SDM ratio (E), and tota l- TDM (F) of cedro-rosa seedlings as a function of P doses and base saturation levels (V%). Means followed by the same letters in the columns are considered statistically equal by the Tukey test ($p > 0.05$).

For dry matter (DM) production of different plant organs, there was a response to single superphosphate supply, but not to liming (Figure 3). P fertilization promoted a quadratic response in RDM, StDM, and LDM and a positive linear response for SDM. For RDM, the maximum production (16.22 g plant^{-1}) was obtained with the estimated level of 385 mg dm^{-3} of P (Figure 3A).

The adequate number of roots is essential for water and nutrient absorption by the plant, boosting plant growth (Kerbauy, 2019). Thus, biomass evaluation by the destructive method is also of great importance in the evaluation of seedling quality (Cruz *et al.*, 2011). The increase in biomass production observed on current study is related to the P, Ca, and S effect on plants by single superphosphate supply, which promote aerial and root growth and play a key role in metabolites related to energy acquisition, and use and cell development (Prado *et al.*, 2010; Taiz *et al.*, 2017). Alves *et al.* (2015) observed an increase in shoot DM of *Hymenaea stigonocarpa* submitted to a single superphosphate rather than a triple superphosphate.

The estimated level of 421.87 mg dm^{-3} of P provided the maximum production (14.35 g plant^{-1}) of StDM (Figure 3B). On the other hand, the maximum LDM (12.40 g plant^{-1}) was observed with the addition of 393.75 mg dm^{-3} of P (Figure 3C). Increasing P levels provided a linear increase in SDM production (Figure 3D). For the RDM/SDM ratio, a quadratic response was observed, decreasing with increasing P levels (Figure 3E). TDM showed a quadratic response to P levels (Figure 3F) in which the estimated level of 345.8 mg dm^{-3} of P provided the maximum TDM production (37.4 g plant^{-1}) of cedro-rosa seedlings.

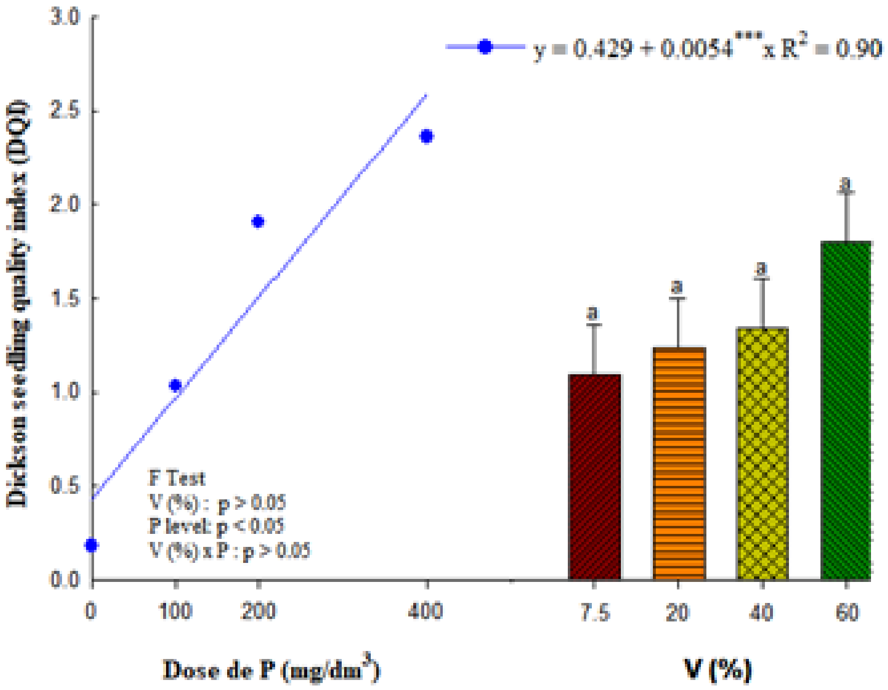

Figure 4: Dickson quality index (DQI) of cedro-rosa seedlings as a function of P doses and base saturation levels (V%). Means followed by the same letters in the columns are considered statistically equal by the Tukey test ($p > 0.05$).

Table 2: Pearson's correlation coefficient (r) for plant height (PH), stem diameter (SD), number of leaves (LN), root dry matter (RDM), shoot (SDM), leaf (LDM) and total dry matter (TDM), in addition to the Dickson quality index (DQI) of cedro-rosa seedlings submitted to P doses at base saturation (V%)

Variable	PH	SD	LDM	SDM	RDM	TDM	DQI
LN	0.57*	0.73*	0.73*	0.69*	0.69*	0.73*	0.68*
PH		0.79*	0.77*	0.84*	0.66*	0.78*	0.59*
SD			0.88*	0.91*	0.86*	0.92*	0.90*
LDM				0.95*	0.88*	0.97*	0.91*
SDM					0.86*	0.97*	0.89*
RDM						0.95*	0.94*
TDM							0.89*

*5% of probability.

Effects of P levels and liming have been assessed in Red-Yellow Oxisol on seedling production of forest species (mahogany, cedro-rosa, sage, and Australian cedar) (Fontes *et al.*, 2013). The authors reported a positive P effect on DM production, such as TDM. For cedro-rosa, the maximum TDM was obtained with the application of 200 to 300 mg dm^{-3} of P without a significant response to liming for this variable. P application had a positive linear effect on DM production of mahogany (*Swietenia macrophylla* King) seedlings cultivated in Yellow Oxisol (Santos *et al.*, 2008). P fertilization showed a quadratic effect on SDM of two *Eucalyptus* genotypes with maximum production between 110 and 125 mg dm^{-3} of P (Novais & Ferreira, 2016).

The increase in soil base saturation (V%) did not influence the Dickson quality index (DQI) of cedro-rosa seedlings. On the other hand, a linear increase in DQI was observed with increasing P, Ca, and S levels by single superphosphate supply (Figure 4). Thus, P fertilization plays an important role for a higher survival rate of plants in the field, contributing to the success of forest stands and to the economic return of producers, as higher DQI confers higher seedling quality (Gomes & Paiva, 2012; Freitas *et al.*, 2017).

Other studies on forest species also reported a positive response of DQI to P fertilization, such as guapuruvu (*Schizolobium parahyba*) (Garcia & Souza, 2015), timbaúba (*Enterolobium contortisiliquum*) (Leite *et al.*, 2017), African mahogany (Santos *et al.*, 2020) and ipê-roxo (Lopes, 2022). P application increased the survival percentage of eucalyptus seedlings (*E. urophylla and E. grandis*) in the field (Rocha *et al.*, 2013).

There was a significant positive correlation ($p < 0.05$) between growth and biomass variables of cedro-rosa seedlings submitted to single superphosphate supply and limestone application (Table 2).

The high correlation observed between DQI and RDM was significant as well as the high correlation between DQI and SD and dry biomass variables, as they are important variables for seedling survival. Furthermore, LN is significantly correlated with DM production, as biomass is the final product of photosynthesis (Taiz *et al.*, 2017). A positive correlation has been reported between the variables PH, SD, RDM, SDM, TDM, and DQI of *Cassia grandis* seedlings subjected to P levels and liming (Freitas *et al.*, 2017).

CONCLUSIONS

Supply of P, Ca, and S is essential for the initial development of cedro-rosa seedlings grown in soil with low chemical fertility in the Brazilian Amazon. The application of 400 mg dm^{-3} of P in pots is recommended for better seedling quality. However, plants adapted to acidic soil do not need lime application in the initial growth phase.

REFERENCES

Alves JDN, Souza FCA, Oliveira ML, Oliveira MCMA & Okumura RS (2015) Fontes de fósforo no crescimento inicial de mudas de jatobá-do-cerrado. Nucleus, 12:299-308.

Angeli A (2005) Identificação de espécies florestais: *Cedrela fissilis* (cedro). Available at: <https://www2.ipef.br/identificacao/cedrella.fissilis.asp>. Accessed on: July 19th, 2021.

Beutler AN, Fernandes LA & Faquin V (2001) Efeito do alumínio sobre o crescimento de duas espécies florestais. Revista Brasileira de Ciência do Solo, 25:923-928.

Bognola AI & Maeda S (2012) Influência de calagem e adubação fosfatada no crescimento inicial de eucalipto e nos níveis críticos de P. Pesquisa e Floresta Brasileira, 32:401-407.

Braga MM, Neto AEF & Oliveira AH (2015) Influence of base saturation in quality and growth of australian cedar seedlings (*Toona ciliata* M. Roem var. australis). Ciência Florestal, 25:49-58.

Bucher CA, Bucher CPC, Araujo AP & Sperandio MVL (2018) Fósforo. In: Fernandes MS, Souza SR & Santos LA (Eds.) Nutrição Mineral de Plantas. 2ª ed. Viçosa, Sociedade Brasileira de Ciência do Solo. p. 401-428.

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.

Coneglian A, Ribeiro PHP, Melo BS, Pereira RF & Júnior JD (2016) Initial growth of *Schizolobium parahyba* in Brazilian cerrado soil under liming and mineral fertilization. Revista Brasileira de Engenharia Agrícola e Ambiental, 20:908-912.

Cruz CAF, Paiva HN, Cunha ACMCM & Neves JCL (2011) Crescimento e qualidade de mudas de fedegoso cultivadas em Latossolo Vermelho-Amarelo em resposta a macronutrientes. Scientia Forestalis, 39:21-33.

Dickson A, Leaf A & Hosner JF (1960) Quality appraisal of white spruce and white pine seedling stock in nurseries. The Forest Chronicle, 36:10-13.

Favare LG, Guerrini IA & Backes C (2012) Níveis crescentes de saturação por bases e desenvolvimento inicial de teca em um Latossolo de textura média. Ciência Florestal, 22:693-702.

Ferreira DF (2011) Sisvar: a computer statistical analysis system. Ciência e Agrotecnologia, 35:1039-1042.

Fontes AG, Gama-Rodrigues AC & Gama-Rodrigues EF (2013) Eficiência nutricional de espécies arbóreas em função da fertilização fosfatada. Pesquisa Florestal Brasileira, 33:09-17.

Freiberger MB, Guerrini IA, Galetti G, Fernandes DM & Corrêa JC (2013) Crescimento inicial e nutrição de cedro (*Cedrela fissilis Vell.*) em função de doses de nitrogênio. Revista Árvore, 37:385-392.

Freitas ECS, Paiva HN, Leite HG & Oliveira NSN (2017) Crescimento e qualidade de mudas de *Cassia grandis* Linnaeus f. em resposta à adubação fosfatada e calagem. Ciência Florestal, 27:509-519.

Furtini Neto AE, Resende AV, Vale FR, Faquin V & Fernandes LA (1999) Acidez do solo, crescimento e nutrição mineral de algumas espécies arbóreas, na fase de muda. Cerne, 5:01-12.

Furtini Neto AE, Siqueira JO, Curi N & Moreira FMS (2000) Fertilização em reflorestamento com espécies nativas. In: Gonçalves LM & Benedetti V (Eds.) Nutrição e fertilização florestal. Piracicaba, IPEF. p.351-383.

Garcia ÉA & Souza JP (2015) Avaliação da qualidade de mudas de *Schizolobium parahyba* em função de diferentes aplicações de adubo fosfatado. Tekhne e Logos, 6:51-59.

Gomes JM & Paiva HN (2012) Viveiros florestais: propagação sexuada. Viçosa, Editora UFV. 116p.

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

Gonçalves EO, Paiva HN, Neves JCL & Gomes JM (2012) Nutrição de mudas de angico-vermelho (*Anadenanthera macrocarpa* (Benth.) Brenan) submetidas a doses de N, P, K, Ca E Mg. Revista Árvore, 36:219-228.

Hartwig I, Oliveira AC, Carvalho FIF, Bertan I, Silva JAG, Schmidt DAM, Valério IP, Maia LC, Fonseca DAR & Reis CES (2007) Mecanismos associados à tolerância ao alumínio em plantas. Semina: Ciências Agrárias, 28:219-228.

IPT - Instituto de Pesquisas Tecnológicas (2019) Informações sobre madeiras: Cedro. Available at: <http://www.ipt.br/informacoes_madeiras/29.htm>. Accessed on: July 19th, 2021.

Kerbauy GB (2019) Fisiologia vegetal. 3ª ed. Rio de Janeiro, Guanabara Koogan. 420p.

Leite TS, Dombroski JLD, Freitas RMO, Leite MS & Rodrigues MRO (2017) Produção de mudas de *Enterolobium contortisiliquum* e partição de assimilados em resposta à adubação fosfatada e inoculação com fungos micorrízicos. Ciência Florestal, 27:1157-1166.

Leite TS, Freitas RMO, Dombroski JLD, Leite MS & Rodrigues MRO (2014) Crescimento e partição da biomassa de mudas de mulungu sob adubação fosfatada e inoculação micorrízica. Pesquisa Florestal Brasileira, 34:407-415.

Lopes RKS (2022) Crescimento inicial de mudas de ipê-roxo (*Handroanthus impetiginosus*) inoculadas com *Rhizophagus intraradices* e suprimento de fósforo. Undergraduate thesis. Universidade Federal Rural da Amazônia, Capitão-Poço. 40p.

Malavolta E (1980) Elementos de nutrição mineral de plantas. São Paulo, Ceres. 251p.

Martins L & Lago AA (2008) Conservação de semente de *Cedrela fissilis*: teor de água da semente e temperatura do ambiente. Revista Brasileira de Sementes, 30:131-167.

Novais D & Ferreira J (2016) Comportamento de dois genótipos de eucalipto submetidos a diferentes doses de fósforo. Enciclopédia Biosfera, 13:281-289.

Novais RF, Alvarez VH, Barros NF, Fontes RL, Cantarutti RN & Neves JCL (2007) Fertilidade do solo. Viçosa, SBCS. 1017p.

Oliveira JR, Souza FVP, Silva UTG, Duarte N & Pinto SIC (2015) Saturação por bases para o cultivo do Cedro australiano. Global Science and Technology, 8:96-102.

Oliveira LR, Lima SF & Lima APL (2014) Crescimento de mudas de cedro-rosa em diferentes substratos. Pesquisa Florestal Brasileira, 34:187-195.

Pacheco NA & Bastos TX (2001) Caracterização climática do município de Capitão Poço-PA. Belém, Embrapa Amazônia Oriental. 17p.

Pereira IM, Silva DHP, Coneglian A, Santos TEB & Interamnense MT (2021) Desenvolvimento inicial de eucalipto arco íris (*Eucalyptus deglupta* Blume) sob diferentes adubações com macronutrientes. Revista de Biotecnologia & Ciência, 10:20-28.

Pias OHC, Berghrtti J, Somavilla L & Catarelli EB (2015) Qualidade de mudas de cedro em função da utilização de fertilizantes e recipientes de diferentes tamanhos. Revista Agro@mbienteOn-line, 9:208-213.

Prado RM (2020) Nutrição de Plantas. 2ª ed. São Paulo, Editora Unesp. 416p.

Prado RM, Franco CF & Puga AP (2010) Deficiências de macronutrientes em plantas de soja cv. BRSMG 68 (Vencedora) cultivada em solução nutritiva. Comunicata Scientiae, 1:114-119.

Presotto RA, Pereira MG, Zonta E & Mattiello EM (2018) Influência do Al^{3+} em solução nutritiva no crescimento de três espécies florestais utilizadas na recuperação de áreas degradadas. Ciência Florestal, 28:384-392.

Raij VB, Camargo APD, Cantarella H & Silva NMD (1983) Alumínio trocável e saturação em bases como critérios para recomendação de calagem. Bragantia, 42:149-156.

Rego FC, Damasceno JL, Silva RTL, Junior FCE, Demartelaere ACF, Leão FAN, Santos PS, Coutinho PWR, Mata TC, Costa AP, Silva TPP, Paiva LL, Ruppenthal V, de Araújo WL, Lorenzetti E, Silva LHP, Abreu LCPC, Oliveira JM, Abraão PC, Bernardi D & Souza JB (2021) Adubação orgânica e mineral no crescimento inicial de mudas de *Cedrela Fissilis* Vellozo. Brazilian Journal of Development, 7:103918-103940.

Rocha JHT, Borelli K, Pietro MR, Backes C & Neves MB (2013) Production and development of *Eucalyptus* seedlings in function of doses of phosphorus. Revista Cerne, 19:535-543.

Ronquim CC (2012) Potencial alelopático de duas espécies arbóreas. In: 19ª Reunião Anual do Instituto de Botânica. Proceedings, Embrapa/RAIBT. s/p.

Santos HCA, Souza GF, Saldanha ECM, Santa-Brígida MRS, Romão ALS & Costa RR (2020) Correção do solo e adubação fosfatada no crescimento e produção de biomassa em mudas de mogno africano. Agrarian, 13:393-404.

Santos HG, Jacomine PKT, Anjos LHC, Oliveira VA, Lumbreras JF, Coelho MR, Almeida JA, Araújo Filho JC, Oliveira JB & Cunha TJF (2018) Sistema Brasileiro de Classificação de Solos. 5ª ed. Brasília, Embrapa. 356p.

Santos RA, Tucci CAF, Hara FAZ & Silva WG (2008) Adubação fosfatada para a produção de mudas de mogno (*Swietenia macrophylla* King). Acta Amazônica, 38:453-458.

Schwartz G (2007) Manejo sustentável de florestas secundárias: espécies potenciais no Nordeste do Pará, Brasil. Amazônia: Ciência & Desenvolvimento, 3:125-147.

Silva AH, Pereira JS & Rodrigues SC (2011a) Desenvolvimento inicial de espécies exóticas e nativas e necessidade de calagem em área degradada do Cerrado no triângulo mineiro (Minas Gerais, Brasil). Agronomía Colombiana, 29:287-292.

Silva TAF, Tucci CAF, Santos JZL, Batista IMP, Miranda JF & Souza MM (2011b) Calagem e adubação fosfatada para a produção de Mudas de *Swietenia macrophylla*. Floresta, 41:459-470.

Soil Survey Staff (2014) Keys to Soil Taxonomy. 12º ed. Washington, USDA-Natural Resources Conservation Service. 372p.

Souza FJL, Galvão JR, Viana TC, Pacheco MJB, de Almeida OL, de Almeida GV, de Jesus AMBS & Lima LM (2021) Fontes fosfatadas e acidez do solo na produção de mudas de *Theobroma grandiflorum*. Nature and Conservation, 14:141-148.

Taiz L, Zeiger E, Moller IM & Murphy A (2017) Fisiologia e desenvolvimento vegetal. 6ª ed. Porto Alegre, Artmed. 888p.

Vale FR, Furtini Neto AE, Reno NF & Resende A (1996) Crescimento radicular de espécies florestais em solo ácido. Pesquisa Agropecuária Brasileira, 31:609-616.

Vieira CR, Weber OLS & Scaramuzza JF (2020) Saturação por bases no crescimento e na qualidade de mudas de paricá. Scientia Forestalis, 48:e2934.