REVISTA DE CIÊNCIASAGRÁRIAS
Amazonian Journal
of Agricultural and Environmental Sciences
www.ajaes.ufra.edu.br

http://dx.doi.org/10.4322/rca.2013.041

ORIGINAL ARTICLE

Phosphorus fertilization and base saturation in the formation of *Swietenia macrophyla* seedlings

Adubação fosfatada e saturação por bases na formação de mudas de mogno

Antonio Rodrigues Fernandes[1]
Anderson Martins de Souza Braz[2*]
Patrícia Ribeiro Maia[1]
Ismael de Jesus Matos Viégas[1]

[1]Universidade Federal Rural da Amazônia – UFRA, Av. Tancredo Neves, s/n, Terra Firme, 66077-530, Belém, PA, Brasil
[2]Universidade de São Paulo – USP, Escola Superior de Agricultura Luiz de Queiroz, Av. Pádua Dias, 11, CP 9, 13418-900, Piracicaba, SP, Brasil

Autor Correspondente:
*E-mail: andersonbraz@usp.br

KEYWORDS
Forest species
Growth
Fertilizer
Lime

PALAVRAS-CHAVE
Espécie florestal
Crescimento
Fertilizantes
Calcário

ABSTRACT: Production of quality seedlings with high survival rate in the environment for reforestation purposes still faces many obstacles, especially with respect to mineral nutrition. In this study, we aimed to evaluate the response of mahogany (*Swietenia macrophyla*) seedlings to the supply of P and base saturation in a Typic Hapludox (Oxisol) with sandy layer surface. We used a completely randomized experimental design with four phosphorus rates (0, 50, 100 and 150 mg dm^{-3} of P), with Arad phosphate rock source, with two base saturation levels (natural at 25% and corrected to 45%) and three replications. We assessed the following parameters: soil chemical attributes, stem diameter, plant height, root dry matter, aerial part dry matter, total dry matter, and aerial part dry matter/root dry matter ratio. The content of P in the soil increased with P supply levels, in the absence and presence of liming, respectively. Liming improved soil attributes and the growth of mahogany seedlings. The combination of liming with phosphorus fertilization positively influenced plant height and aerial part and total dry matter. In the absence of liming, P doses as from 100 mg kg^{-1} negatively influenced the growth of mahogany seedlings.

RESUMO: *A produção de mudas de qualidade, para fins de reflorestamento, que possibilite elevada taxa de sobrevivência no campo, ainda encontra muitos entraves, principalmente aqueles relacionados à nutrição mineral. O objetivo deste trabalho foi avaliar a resposta de mudas de mogno (Swietenia macrophyla) ao fornecimento de P e à saturação por bases, em Latossolo Amarelo de camada superficial arenosa. Utilizou-se o delineamento experimental inteiramente casualizado, sendo quatro doses de P (0, 50, 100 e 150 mg dm^{-3} de P), cuja fonte foi o fosfato natural Arad, com dois níveis de saturação por bases, a natural de 25% e o corrigido para 45%, com três repetições. Foram avaliados os atributos químicos do solo, o diâmetro do caule, a altura da planta e a massa seca das raízes, a parte aérea e total das plantas, e a relação raízes/parte aérea. O teor de P no solo aumentou com as doses de P, na ausência e na presença da calagem, respectivamente. A aplicação de calcário incrementou os atributos do solo e o crescimento das mudas de mogno. A combinação da calagem com a adubação fosfatada influenciou positivamente a altura de plantas e a massa seca da parte aérea e total. Na ausência da calagem, doses a partir de 100 mg kg^{-1} de P foram depreciativas ao crescimento das mudas de mogno.*

Recebido: 16/02/2013
Aceito: 03/04/2013

1 Introduction

In Brazil, several forest species are threatened with extinction, among which mahogany (*Swietenia macrophylla* King) stands out. It was once (1980-1992) the timber species of greatest economic value of the Amazon, the first in explored volume with approximately 900,000 t (BRASIL, 1992). Systematic, indiscriminate and selective timber exploitation may lead to a process of extinction, or at least to the disappearance of part of the genetic patrimony of one of the most sought tree species worldwide. Species scarcity associated with the difficulties created for the exploration of hardwoods has raised market prices, especially for mahogany, making it very attractive even for small farmers and indigenous communities, increasing the risk of predatory exploitation (GARRIDO FILHA, 2002).

Even after the ban on mahogany exploitation, the revegetation of areas has occurred very slowly because of the species low natural regeneration rate. Surveys conducted in logging areas found only 0.25 units per hectare of trees with DAP (diameter at breast height) greater than or equal to 30 cm. In these areas, seedlings are rare and quality production for reforestation purposes is a major problem to be overcome, mainly because this species is little studied regarding plantation management (CORDEIRO et al., 2009).

The study of forest species in the juvenile stage is the starting point for understanding the demand for nutrients, and proper fertilization can decisively contribute to plants to grow fast, strong, resistant, rustic and well nourished. Only in this way seedlings will present the necessary qualities to withstand the harsh after-planting environmental conditions (VALERI; CORRADINI, 2005). The use of good quality seedlings leads to a higher rate of seedling survival and to increased yield in young and adult phases in the field.

Seedling production in quantity and quality is one of the most important stages for the establishment of good forest populations of native species. The understanding of seedling nutrition and the use of substrate appropriate to cultivation are essential for defining an appropriate fertilization recommendation (GONÇALVES et al., 2000). Several scientific studies have been conducted and many technical advances have been achieved to improve the quality of seedlings of forest species, ensuring good adaptation and growth after planting (GONÇALVES et al., 2005; ARRUDA et al., 2007).

Researches on the supply of P for species used in afforestation and reforestation are scarce in the Amazon region; however, responses to phosphate fertilization have been observed, particularly because soils are deficient in this nutrient (SILVA et al., 2011; SANTOS et al., 2008a). Regarding the production of mahogany seedlings, there is very little technical information available for the region, mainly on mineral nutrition and in particular about phosphorus, which has limited the establishment of this species in the environment and/or resulted in high implantation costs. On the other hand, the use of phosphate fertilization, which is used very frequently in the mineral enhancement of substrates, with or without liming, has provided significant results in improving the quality of seedlings of various tree species (SANTOS et al., 2008a; RESENDE et al., 1999; NOVAIS; BARROS; NEVES, 1990). However, responses of plants to P application vary according to the level of this nutrient in the soil and/or substrate, as well as to species requirement with respect to source.

In highly weathered soils, low availability to plants has been identified as a cause for the inappropriate development of most crops in tropical soils. In these areas, where soils present high fixation capacity, nutrient deficiency is the most important nutritional factor restricting plant growth (SANCHEZ; SALINAS, 1981; MOREIRA; FAGERIA, 2009).

In acid soils poor in available phosphorus, there is a gradual increase in the availability of P with the application of natural phosphate fertilizers (NOVAIS; SMYTH, 1999), constituting a major factor considering that seedling formation takes long in forest species. Thus, the availability of P throughout the formation period of seedlings is an important aspect for the production of quality seedlings, which can range from eight months to a year, until they reach optimal conditions to be implemented in the field.

In this study, we aimed to evaluate the response of mahogany (*Swietenia macrophyla*) seedlings to the supply of P and base saturation in a Typic Hapludox (Oxisol).

2 Materials and Methods

Experiment was conducted at greenhouse conditions at the Federal Rural University of the Amazon – UFRA, Pará state, Brazil. The soil used as a substrate was collected in the layer of 0-0.2 m depth in Typic Hapludox (Oxisol) with medium texture (EMBRAPA, 2006) in the municipality of São Domingos do Capim, Pará state (1° 37' 30" S and 47° 52' 30" W). Mahogany seedlings were grown after *Braquiaria Brizantha* cultivation and treatments were then applied.

Experimental design was completely randomized in a factorial arrangement 4 x 2 with four replications. There were four levels of P (0, 50, 100 and 150 mg dm^{-3} of P_2O_5) of natural Arad phosphate (33% of P_2O_5) as a source and two levels of base saturation – V (dolomitic limestone with relative total neutralizing power – PRNT=65%, CaO=26% and MgO=13%), natural from the soil at 25% and corrected to V = 45%. Liming was estimated by the method of base saturation (CRAVO; BRASIL, 2007) using the equivalent of 1282 kg ha^{-1} to achieve the desired saturation, remaining incubated for three weeks.

Before experiment installation, soil samples were passed through a 20 mm sieve for determination of chemical and physical attributes (EMBRAPA, 1997). Results obtained were pH (H_2O) 5.2; 13.23 g kg^{-1} of organic matter; 0.64 mg dm^{-3} of P (Mehlich I); 0.2 mmol$_c$ dm^{-3} of K; 5.7 mmol$_c$ dm^{-3} of Ca; 4.8 mmol$_c$ dm^{-3} of Mg; 3.3 mmol$_c$ dm^{-3} of Al; 31.6 mmol$_c$ dm^{-3} of H+Al; and 25.3% base saturation. Soil particle size was as follows: 700 g kg^{-1} sand, 250 g kg^{-1} clay, and 50 g kg^{-1} silt.

In brachiaria cultivation all treatments were fertilized 10 days after germination: N, 200 mg dm^{-3}; K, 200 mg dm^{-3}; S, 50 mg dm^{-3}; B, 0.8 mg dm^{-3}; Zn, 3.6 mg dm^{-3}; Cu, 1.5 mg dm^{-3} and Mo, 0.15 mg dm^{-3}, as urea, K_2SO_4, KCl, H_3BO_3, $ZnCl_2$, $CuCl_2.2H_2O$, $(NH_4)6Mo_7O_{24}.4H_2O$. In the control treatment (zero P) fertilization was performed with 10 mg of P_2O_5 dm^{-3} utilizing triple superphosphate to ensure minimum brachiaria development until the end of the experimental period. In the cultivation of mahogany in succession, topdressing was performed with 50 mg dm^{-3} of N as urea (45% N) and 50 mg dm^{-3} of K with KCl (60% K_2O).

Mahogany seeds were placed to germinate in vermiculite substrate and humidity was kept with distilled water. When seedlings were approximately 8 cm high they were transplanted into 5 dm^{-3} capacity plastic pots. Irrigation of pots was performed daily to maintain 60% of total pore volume (TPV) monitored through daily weighing. Soil chemical analysis was performed according to Embrapa (1997) before transplantation of seedlings.

Evaluations were conducted eight months after transplanting when the seedlings were ready to be transplanted in the field. The following plant parameters were assessed: plant height, measured from the insertion of the cotyledons to the apical bud; stem diameter, obtained using a digital pachymeter, measuring close to substrate surface; aerial part, roots, and total dry matter, obtained after drying in a forced air oven at 70 °C until constant weight.

The data were subjected to analysis of variance, the level of significance determined by F test, and fit by regression equations with X for the levels of P and Y for the variables. Analysis of regression ($p \leq 0.05$) was performed to assess the relation between the levels of P applied and P contents in the soil.

3 Results and Discussion

The cultivation of pasture resulted in increased soil acidity, although there was an increase in the contents of Ca and Mg in the treatments without liming, while significant increases in the contents of Ca were observed in those where limestone was applied, and there was a reduction in the exchangeable Al in soil (Table 1). Such result corroborates Moreira, Carvalho and Evangelista (2005), who reported that the export of basic cations (Ca and Mg) also resulted in decreased soil pH, possibly because of the activity of the roots, increasing the CO_2 content in the soil. According to Siqueira et al. (1994), this may have been favored by the use of urea in the fertilizations with N that occurred after each pruning. The contents of P in the soil increased with the increase in the doses of P applied. These increases occurred linearly in the absence of liming ($\hat{y} = 3.298 + 0.242$ x; $R^2 = 0.98^{**}$) and exponentially in the presence of liming ($\hat{y} = 5.131\ e^{0{,}016x}$; $R^2 = 0.997^{**}$). Expressive and significant increases in the contents of P (Mehlich 1) in the soil, with the increase of the doses, fertilized with Araxá and Gafsa phosphates were observed by Holanda et al. (1995). Although it has been proven that Mehlich 1 overestimates the level of available P in soils fertilized with rock phosphate (RAIJ; FEITOSA; SILVA,1984), similar levels of P were found by Korndörfer, Lara-Cabezas and Horowitz (1999), Rossi et al. (1999) and Moreira, Malavolta and Moraes (2002) between resin and Mehlich 1 using Arad phosphate fertilization.

In the absence of liming, P provided positive effects on the diameter growth of mahogany seedlings, fitting a quadratic function (Figure 1). The maximum estimated diameter was 8.4 mm at the P level of 68.8 mg dm^{-3}. In the presence of liming, phosphate fertilization did not promote positive effects on diameter growth, while for height growth was linear, and in the absence of liming height growth was quadratic. The maximum height of 28.3 cm was achieved with a dose of 78.6 mg dm^{-3} of P applied to the soil. Positive responses from mahogany seedlings to corrective concerning diameter and height were observed by Tucci et al. (2007) in very clayey Oxisol with exchangeable Ca and Mg and available P contents

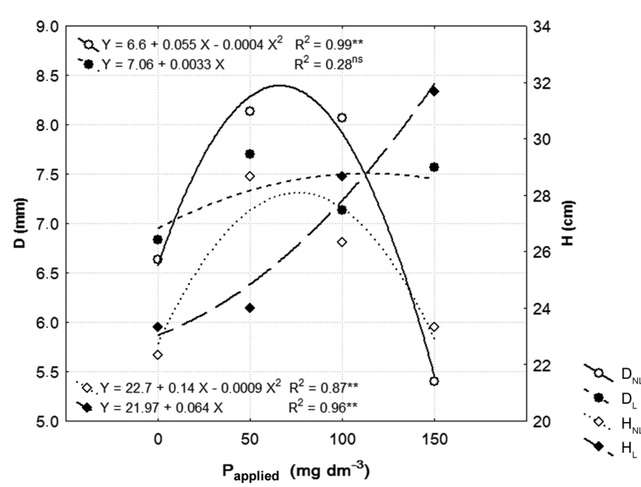

Figure 1. Diameter (D) and height (H) of mahogany seedlings according to Arad phosphate fertilization, in the absence (nl) and presence (l) of liming. *ns* and **, non-significant and significant ($p \leq 0.01$) by the *t* test, respectively.

Table 1. Soil chemical attributes after *Braquiaria brizantha* harvesting and before the planting of mahogany seedlings.

Treatments	pH	C	P	Ca	Mg	K	Al	Al+H
	H_2O	g kg^{-1}	mg dm^{-3}	---------------- mmol$_c$ dm^{-2} --------------------				
T_1NL*	4.37	12.99	4.94	10.6	10.0	1.3	9.2	62.5
T_2NL	4.31	12.93	12.17	11.8	9.9	0.4	9.4	62.3
T_3 NL	4.20	12.24	29.02	12.2	9.7	0.4	9.4	70.2
T_4 NL	4.07	11.44	39.65	13.3	10.9	0.3	10.6	68.9
T_1 L**	4.93	12.62	5.20	19.2	13.0	1.5	2.3	50.3
T_2 L	4.88	12.06	12.04	21.9	9.3	0.5	3.3	59.7
T_3 L	4.72	11.87	25.22	20.9	7.1	0.3	2.9	60.0
T_4 L	4.90	12.49	65.59	21.7	9.5	0.4	3.9	60.8

*NL = without liming; **L = liming.

lower than those observed in this study (Table 1). Linear growth in height and diameter in response to different levels of P up to 250 mg kg^{-1} in soils treated with liming was verified by Silva et al. (2007) in very clayey Oxisol. Within this line of research, positive responses to the application of corrective on mahogany plant height were obtained by Barros (2001) and Silva et al. (2007). Other forest species also responded positively to liming as found in the research work by Cruz et al. (2004) and Resende et al. (1999).

However, the lack of response in diameter to P application in the presence of liming may have occurred because of the content of this attribute available in the soil (5.2 mg dm^{-3}), which even low, may have been sufficient for the satisfactory growth of seedlings. In a study with mahogany seedlings, Silva et al. (2011) observed a lack of response in diameter growth to P sources and liming in plants grown in very clayey Oxisol with low P contents (2.0 mg kg^{-1}), which led these authors to suggest that this species is poorly sensitive to soil acidity and undemanding for P in the initial stage of growth.

The largest growth in diameter and height of mahogany seedlings was achieved with low levels of P. Other authors have suggested that the responses of forest species to P supply have been most effective with the use of moderate doses (FARIA; SIQUEIRA; CURI, 1996; RESENDE et al., 1999). Another result suggests that climax species, such as mahogany, do not respond to phosphorus fertilization up to eight months after seedling planting, and that positive effects can be observed only at 16 months (LIMA et al., 1997). In some cases, negative effects of the application of high P doses were observed in some species, indicating low external demand for the nutrient (ROCHA, 1995).

In a dystrophic Oxisol with clayey texture of the state of Amazonas, Souza et al. (2010) studied the nutritional requirement of mahogany for macronutrients and obtained the following descending order: P>S>K>N. In the same soil, Tucci et al. (2011) verified that fertilization with N (as urea) and P (as triple superphosphate) did not improve the quality of mahogany seedlings. However, greater efficiency both for nutrient absorption and mahogany species growth was observed for Arad phosphate fertilization, suggesting that P sources with lower solubility in water can be more efficient in highly weathered soils (SILVA et al., 2011), corroborating the results of this study. In field experiment and assay in pots in Sri Lanka, Jayasinghe and Ranasinghe (2012) obtained positive responses to the growth of mahogany seedlings subjected to phosphorus levels.

The relation of P contents in the soil with plant diameter was quadratic in the absence of liming, and non-significant ($p > 0.05$) in the presence of liming (Figure 2a). The content of P in the soil that provided the maximum diameter of 8.3 mm was 20.3 mg kg^{-1}; this is a fact of great importance because the diameter of stem is essential in the evaluation of seedling potential to survival and growth after planting (SOUZA et al., 2006). The contents of P in the soil influenced plant height regardless of the presence of liming (Figure 2b). The content of 21.7 mg kg^{-1} provided the greatest height (28.4 cm), while in the presence of liming this content was 59.6 mg kg^{-1} for a plant height of 32.0 cm.

Yields of aerial part dry matter (APDM) and root dry matter (RDM) in the absence of liming initially increased with the application of P doses and then decreased, while in the presence of liming, crescent APDM was observed with fit to quadratic functions (Figure 3a). Yield data of APDM and RDM showed no outliers, and mean RDM was higher in the presence of liming (Figure 3b). The level of P in the absence of liming that promoted the maximum estimated APDM agronomic yield was 52.5 mg dm^{-3} of P_2O_5 for 10.8 g/plant yield. Varied results have been obtained for mahogany seedlings response to liming and phosphate fertilization. Silva et al. (2007) also found that the APDM of mahogany seedlings was not affected by liming. The addition of P doses to the substrate for production of mahogany seedlings did not influence biometric variables such as APDM and RDM, even in Oxisol with low contents of

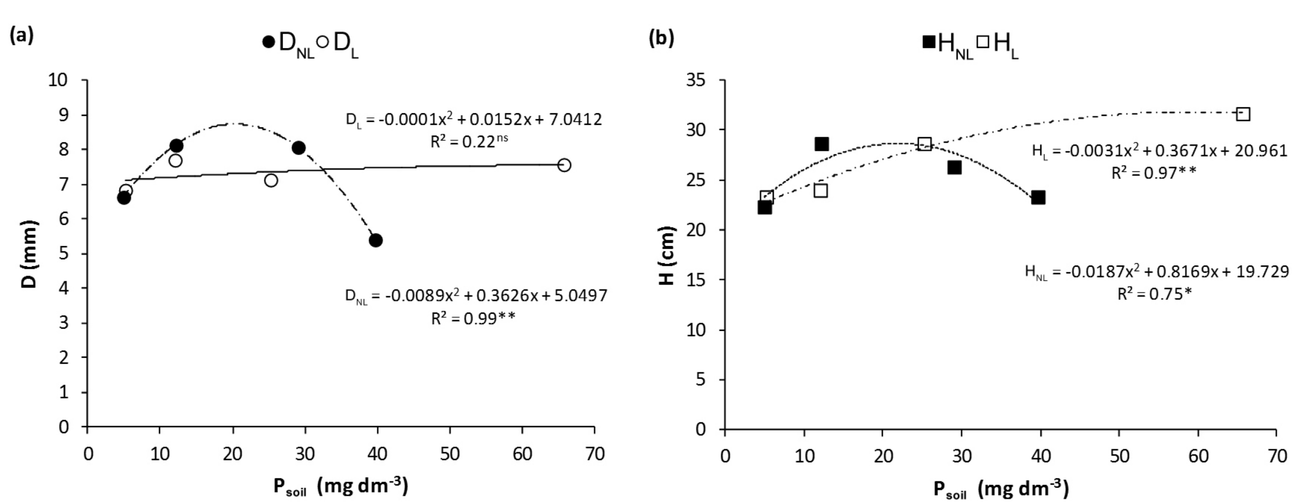

Figure 2. Diameter D (a) and height H (b) of mahogany seedlings in the absence (nl) and presence (l) of liming according to availability of P in the soil. *ns*, *, and **, non-significant and significant ($p \leq 0.01$ and $p \leq 0.05$) by the *t* test, respectively.

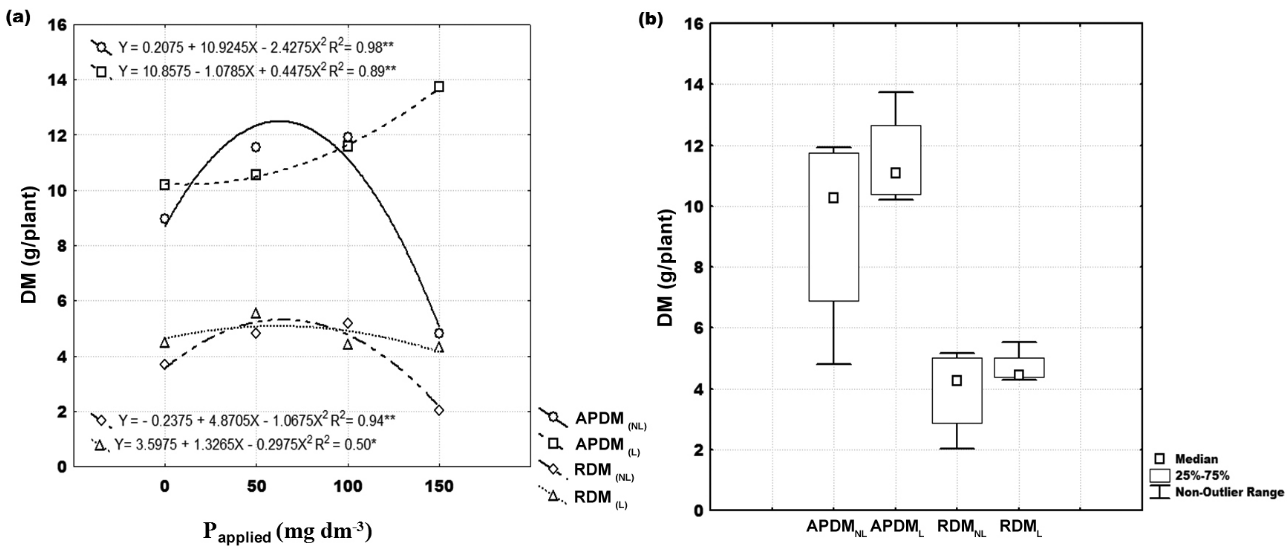

Figure 3. Aerial part dry matter (APDM) and root dry matter (RDM) of mahogany seedlings in the absence (nl) and presence (l) of liming as a function of Arad phosphate fertilization (a), and the empirical distribution of results in "boxplot" (b). * and **, significant ($p \leq 0.01$ and $p \leq 0.05$) by the *t* test, respectively.

available P (SILVA et al., 2011). Nevertheless, differently from the previous result and consistent with the APDM response in this study, Santos et al. (2008b) obtained a linear growth of mahogany seedlings grown in an Oxisol of very clayey texture subjected to doses of P in the presence of liming.

The maximum yield of estimated root dry matter, corresponding to 5.5 g/plant (Figure 3a), was achieved with the application of 70 mg dm^{-3} of P. Studying the behavior of several forest species, Fernandes et al. (2000) observed that the higher the level of P, the higher the APDM and RDM.

In the absence of liming, APDM and RDM reached the point of maximum estimated yield, based on the P content in the soil (Figure 4). On the other hand, in the presence of liming, APDM showed linear growth and RDM was not affected by P levels ($p > 0.05$). Phosphorus content in the soil without limestone application was 19.8 mg kg^{-1} for maximum APDM yield of 13.3 g/plant.

Total dry matter (TDM) yield as a function of phosphate fertilization in the absence of liming fitted a quadratic equation, where the estimated maximum level was 63 mg dm^{-3} of P to reach 17.8 g/plant yield (Figure 5). Moreover, for TDM with liming, the linear ascendant model was the most explanatory, showing that the P levels tested were below the necessity of the mahogany seedlings studied. Linear growth of the total dry matter of mahogany seedlings in clayey Oxisol was obtained by Santos et al. (2008b), using the maximal P level of 200 kg ha^{-1} (458 kg ha^{-1} of P_2O_5) in the presence of liming (2.0 t ha^{-1}), which corresponds to over three times the highest level for P and to one and a half times the liming amount tested in this research.

In the absence of liming, the RDM/APDM yield ratio was not influenced ($p < 0.05$) by the levels of P applied; while in the presence of liming, levels of P higher than 100 mg dm^{-3}

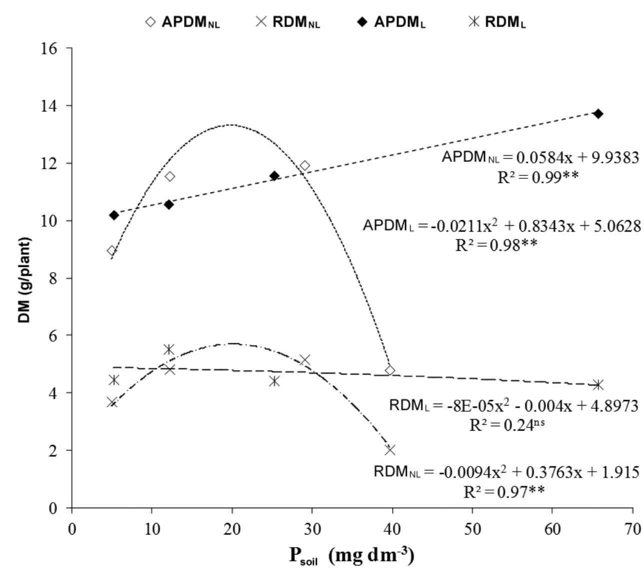

Figure 4. Aerial part dry matter (APDM) and root dry matter (RDM) of mahogany seedlings in the absence (nl) and presence (l) of liming according to the availability of P in the soil. ns and **, non-significant and significant ($p \leq 0.01$) by the *t* test, respectively.

caused negative effects (Figure 5). Reduction in the RDM/APDM ratio in climax species such as mahogany was observed by Resende et al. (2000), who suggested that the increased availability of P caused a decrease in root growth and the consequent accumulation of dry matter in aerial part. Greater growth of the aerial part of seedlings at the expense of their root systems may constitute an important factor in the success of the enterprise, because seedlings with less developed root systems will probably present better conditions to be implanted in the field (BERNARDI; CARMELLO; CARVALHO, 2000).

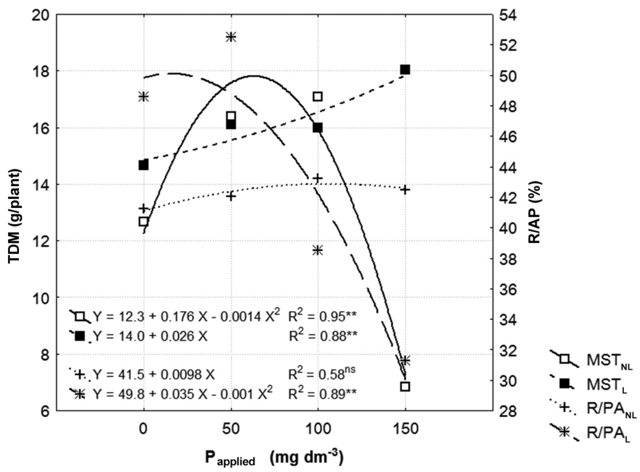

Figure 5. Total dry matter (TDM) and root dry matter/aerial part dry matter ratio (R/AP) as a function of Arad phosphate fertilization, in the absence (nl) and presence (l) of liming. *ns* and **, non-significant and significant ($p \leq 0.01$) by the *t* test, respectively.

4 Conclusions

Liming improved soil attributes as follows: increased pH values and calcium contents, decreased aluminum contents, and increased growth of mahogany seedlings. The combination of liming with Arad phosphate fertilization increased plant height, aerial part dry matter, and total dry matter. In the absence of liming, P levels as of 100 mg kg^{-1} negatively influenced the growth of mahogany seedlings.

References

ARRUDA, M. R.; PEREIRA, J. C. R.; MOREIRA, A.; TEIXEIRA, W. G. Enraizamento de estacas herbáceas de guaranazeiro em diferentes substratos. *Ciência e Agrotecnologia*, v. 31, n. 1, p. 236-241, 2007. http://dx.doi.org/10.1590/S1413-70542007000100035

BARROS, J. G. *Adubação e calagem para formação de mudas de mogno (Swietenia macrophylla King)*. 2001. 63 f. Dissertação (Mestrado)-Universidade Federal do Amazonas, Manaus, 2001.

BERNARDI, A. C. C.; CARMELLO, Q. A. C.; CARVALHO, S. A. Desenvolvimento de mudas de citros cultivadas em vaso em resposta à adubação NPK. *Scientia Agricola*, v. 57, n. 4, p. 733-738, 2000. http://dx.doi.org/10.1590/S0103-90162000000400022

BRASIL. Decreto-lei nº 7951, de 23 de janeiro de 1992. Relaciona oficialmente a flora brasileira ameaçada de extinção. *Diário oficial da República Federativa do Brasil,* Brasília, 24 jan. 1992. Seção 1, p. 870-872.

CORDEIRO, Y. E. M.; PINHEIRO, H. A.; SANTOS FILHO, B. G.; CORRÊA, S. S.; SILVA, J. R. R.; DIAS FILHO, M. B. Physiological and morphological responses of young mahogany (Swietenia macrophylla King) plants to drought. *Forest Ecology and Management*, v. 258, p. 1449-1455, 2009. http://dx.doi.org/10.1016/j.foreco.2009.06.054

CRAVO, M. S.; BRASIL, E. M. Recomendação de adubação e calagem para os solos. In: CRAVO, M. S.; VIÉGAS, I. J. M.; BRASIL, E. C. *Recomendações de adubação e calagem para o Estado do Pará*. Belém: Embrapa Amazônia Oriental, 2007. p. 262.

CRUZ, C. A. F.; PAIVA, H. N.; GOMES, K. C. O.; GUERRERO, C. R. A. Efeito de diferentes níveis de saturação por bases no desenvolvimento e qualidade de mudas de ipê roxo (*Tabebuia impetiginosa* (Mart.) Standley). *Scientia Florestalis,* v. 66, p. 100-107, 2004.

EMBRAPA. Centro Nacional de Pesquisa de Solos. *Manual de métodos de análises de solos*. Campinas: Embrapa, 1997. 212 p.

EMBRAPA. Centro Nacional de Pesquisa de Solos. *Sistema brasileiro de classificação de solos*. Brasília: Embrapa Produção de Informação; Rio de Janeiro: Embrapa Solos, 2006. 312 p.

FARIA, M. P.; SIQUEIRA, J. O.; CURI, N. Crescimento inicial da acácia em resposta a P, N, fungo micorrízico e rizóbio. *Revista Brasileira de Ciência do Solo,* v. 20, p. 209-206, 1996.

FERNANDES, L. A.; FURTINI NETO, A. E.; FONSECA, F. C.; VALE, F. R. Crescimento inicial, níveis críticos de fósforo e frações fosfatadas em espécies florestais. *Pesquisa Agropecuária Brasileira,* v. 35, n. 6, p. 1191-1198, 2000. http://dx.doi.org/10.1590/S0100-204X2000000600016

GARRIDO FILHA, I. Manejo florestal: questões econômico-financeiras e ambientais. *Estudos Avançados,* v. 16, n. 45, p. 91-106, 2002. http://dx.doi.org/10.1590/S0103-40142002000200007

GONÇALVES, J. L. M.; SANTARELLI, E. G.; MORAES NETO, S. P.; MANARA, M. P. Produção de mudas de espécies nativas: substrato, nutrição, sombreamento e fertilização. In: GONÇALVES, J. L. M.; BENEDETTI, V. (Org.). *Nutrição e Fertilização Florestal.* Piracicaba: IPEF, 2000. v. 1, p. 309-350.

GONÇALVES, J. L. M.; SANTARELLI, E. G.; NETO, S. P. M.; MANARA, M. P. Produção de mudas de espécies nativas. In: GONÇALVES, J. L. M.; BENEDETTI, V. (Org.). *Nutrição e Fertilização Florestal.* Piracicaba: IPEF, 2005. p. 309-350.

HOLANDA, J. S.; BRASIL, E. C.; SALVIANO, A. A. C.; CARVALHO, M. C. S.; RODRIGUES, M. R. L.; MALAVOLTA, E. Eficiência de extratores de fósforo para um solo adubado com fosfatos e cultivado com arroz. *Scientia Agricola*, v. 51, n. 3, p. 561-568, 1995. http://dx.doi.org/10.1590/S0103-90161995000300025

JAYASINGHE, S.; RANASINGHE, D. M. S. H. K. Investigation into the optimal fertilizer regime of Swietenia macrophylla (Mahogany). *International Forestry and Environment Symposium*, v. 14, 2012. PMid:22297093 PMCid:PMC3374531.

KORNDÖRFER, G. H.; LARA-CABEZAS, W. A.; HOROWITZ, N. Agronomic efficiency of reactive rock phosphates for corn production in Brazil. *Scientia Agricola,* v. 56, n. 2, p. 391-396,1999. http://dx.doi.org/10.1590/S0103-90161999000200019

LIMA, H. N.; VALE, F. R.; SIQUEIRA, J. O.; CURI, N. Crescimento inicial a campo de sete espécies arbóreas nativas em resposta à adubação mineral com NPK. *Ciência e Agrotecnologia,* v. 21, p. 189-195, 1997.

MOREIRA, A.; FAGERIA, N. K. Soil Chemical Attributes of Amazonas State, Brazil. *Communications in Soil Science and Plant Analysis*, v. 40, p. 2912-2925, 2009. http://dx.doi.org/10.1080/00103620903175371

MOREIRA, A.; CARVALHO, J. G.; EVANGELISTA, A. R. Relação cálcio e magnésio na fertilidade de um latossolo vermelho escuro distrófico cultivado com alfafa. *Ciência e Agrotecnologia*, v. 29, n. 4, p. 786-794, 2005. http://dx.doi.org/10.1590/S1413-70542005000400010

MOREIRA, A; MALAVOLTA, E; MORAES, L. A. Eficiência de fontes e doses de fósforo na alfafa e cestrosema cultivada em latossolo amarelo. *Pesquisa Agropecuária Brasileira,* v. 37, n. 10, p. 1459-1466, 2002. http://dx.doi.org/10.1590/S0100-204X2002001000014

NOVAIS, R. F.; SMYTH, T. J. *Fósforo em solo e planta em condições tropicais.* Viçosa: Universidade Federal de Viçosa, 1999. 399p.

NOVAIS, R. F.; BARROS, N. F.; NEVES,J. C. Nutrição mineral do eucalipto. In: BARROS, N. F.; NOVAIS, R. F. *Relação solo-eucalipto*. Viçosa: Folha de Viçosa, 1990. p. 25-98.

RAIJ, B. van.; FEITOSA, C. T.; SILVA, N.M. Comparação de quatro extratores de fósforo de solos. *Bragantia*, v.43, p.17-29, 1984. http://dx.doi.org/10.1590/S0006-87051984000100003

RESENDE, A. V.; FURTINI NETO, A. E.; MUNIZ, J. A.; CURI, N.; FAQUIN, V. Crescimento inicial de espécies florestais de diferentes grupos sucessionais em resposta a doses de fósforo. *Pesquisa Agropecuária Brasileira,* v. 34, n. 11, p. 2071-2081, 1999. http://dx.doi.org/10.1590/S0100-204X1999001100014

RESENDE, A. V.; FURTINI NETO, A. E.; CURI, N.; MUNIZ, J. A.; FARIA, M. R. Acúmulo e eficiencia nutricional de macronutrientes por espécies florestais de diferentes grupos sucessionais em resposta à fertilização fosfatada. *Ciência e Agrotecnologia*, v. 24, n. 1, p. 160-173, 2000.

ROCHA, R. C. *Desenvolvimento de espécies arbóreas com e sem micorrização, transplantadas para solo degradado contendo doses crescentes de fósforo*. 1995. 74 f. Dissertação (Mestrado)-Universidade Federal de Lavras, Lavras, 1995.

ROSSI, C.; DOS ANJOS, A. R. M.; DE CAMARGO, M. S.; WEBER, O. L. S.; IMHOFF, S.; MALAVOLTA, E. Efeito residual de fertilizantes fosfatados para o arroz: Avaliação do fósforo na planta e no solo por diferentes extratores. *Scientia Agricola*, v. 56, n. 1, p. 39-46, 1999. http://dx.doi.org/10.1590/S0103-90161999000100007

SANCHEZ, P. A.; SALINAS, J. G. Low input technology for managing Oxisols and Ultisols in tropical America. *Advances in Agronomy*, v. 34, p. 280-406, 1981.

SANTOS, J. Z. L.; RESENDE, A. V.; FURTINI NETO, A. E.; CORTE, E. F. Crescimento, acúmulo de fósforo e frações fosfatadas em mudas de sete espécies arbóreas nativas. *Árvore*, v. 32, n. 5, p. 799-807, 2008a.

SANTOS, R. A.; TUCCI, C. A. F.; HARA, F. A. S.; SILVA, W. G. Adubação fosfatada para a produção de mudas de mogno (*Swietenia macrophylla* King). *Acta Amazônica*, v. 38, n. 3, p. 453-458, 2008b. http://dx.doi.org/10.1590/S0044-59672008000300009

SILVA, A. R. M.; TUCCI, C. A. F.; LIMA, H. N.; FIGUEIREDO, A. F. Doses crescentes de corretivo na formação de mudas de mogno (*Swietenia macrophylla* King). *Acta Amazônica,* v. 37, n. 2, p. 195-200, 2007. http://dx.doi.org/10.1590/S0044-59672007000200004

SILVA, A. R. M.; TUCCI, C. A. F.; LIMA, H. N.; FIGUEIREDO, A. F.; SANTOS, J. Z. L.; BATISTA, I. M. P.; MIRANDA, J. F. M.; SOUZA, M. M. Calagem e adubação fosfatada para a produção de Mudas de *Swietenia macrophylla. Floresta,* v. 41, n. 3, p. 459-470, 2011.

SIQUEIRA, J. O.; MOREIRA, F. M. S.; GRISI, B.; HUNGRIA, M.; ARAÚJO, R. *Microrganismos e processos biológicos do solo*: perspectiva ambiental. Embrapa-BDF, 1994. 142 p.

SOUZA, C. A. M.; OLIVEIRA, R. B.; MARTINS FILHO, S.; LIMA. J. S. S. Crescimento em campo de espécies florestais em diferentes condições de adubação. *Ciências Florestais*, v. 16, n. 3, p. 243-249, 2006.

SOUZA, C. A. S.; TUCCI, C. A. F.; SILVA, J. F.; RIBEIRO, W. O. Exigências nutricionais e crescimento de plantas de mogno (*Swietenia macrophylla* King.). *Acta Amazoncia,* v. 40, n. 3, p. 515-522, 2010. http://dx.doi.org/10.1590/S0044-59672010000300010

TUCCI, C. A. F.; SOUZA, P. A.; VENTURIN, N.; BARROS, J. G. Calagem e adubação para produção de mudas de mogno (*Swietenia macrophylla* King). *Cerne*, v. 13, n. 3, p. 299-307, 2007.

TUCCI, C. A. F.; SANTOS, J. Z. L.; SILVA JUNIOR, C. H.; SOUZA, P. A.; BATISTA, I. M. P.; VENTURIN, N. Desenvolvimento de mudas de Swietenia macrophylla em resposta a nitrogênio, fósforo e potássio. *Floresta*, v. 41, n. 3, p. 471-490, 2011.

VALERI, S. V.; CORRADINI, L. Fertilização em viveiros para produção de mudas de Eucalyptus e Pinus. In: GONÇALVES, J. L. M; BENEDETTI, V. *Nutrição e fertilização florestal.* Piracicaba: IPEF. 2005. p. 168-190.