ENFLO
Ecologia e Nutrição Florestal/*Ecology and Forest Nutrition*
www.enflo.com.br

ISSN: 2316-980X http://dx.doi.org/10.5902/2316980X40086 Scientific Article/Artigo Científico

Initial growth of *Swietenia macrophylla* seedlings in acidity correction and phosphate nitrogen fertilization[1]

Julio Conceição dos Santos Neto[2]; Dráuzio Correia Gama[3]; Everaldo Pereira Oliveira[4]; Liniker Fernandes da Silva[5]; Róbson Borges de Lima[6]

Abstract: For a commercial reforestation success, it is necessary to know the species specific nutritional requirements used to overcome fertility limitations in a given site, allowing to fertility costs optimize in seedlings production. The objective of this study was to responses evaluate of *Swietenia macrophylla* King seedlings subject to nitrogen and phosphorus different dosages in corrected soil. The experiment was conducted between January and April 2015 in a greenhouse at the Universidade Federal do Recôncavo da Bahia, in Cruz das Almas (BA). The experimental design was a 5 x 2 factorial scheme (five different doses of phosphorus (Pn) in nitrogen absence and presence [N_0 and N_1]), making ten treatments, completely randomized. After 90 days of sowing, aerial part height (h) and stem based diameter of seedlings were measured. The data were submitted to variance analysis (ANOVA) at 5% error probability level. Treatments did not statically differ from each other, showing the same effect of P dosages with and without N on soil acidity correction with limestone ($CaCO_3$) condition on initial growth of *Swietenia macrophylla* seedlings.

Keywords: Mahogany; Nutritional efficiency; Seedling production

Crescimento inicial de mudas de *Swietenia macrophylla* sob correção de acidez e adubação nitrogenada fosfatada

Resumo: Para o sucesso de um reflorestamento comercial, faz-se necessário conhecer às exigências nutricionais específicas de determinada espécie a superar as limitações da fertilidade em determinado sítio, permitindo otimizar os custos de fertilidade na produção de mudas. Objetivou-se avaliar as respostas de mudas de *Swietenia macrophylla* King. submetidas às diferentes dosagens de nitrogênio e fósforo em solo corrigido. A condução do experimento ocorreu entre janeiro a abril de 2015 em casa de vegetação da Universidade Federal do Recôncavo da Bahia, em Cruz das Almas (BA). O delineamento experimental foi esquema fatorial 5 x 2 (cinco doses diferentes de fósforo (P_n) em ausência e presença de nitrogênio [N_0 e N_1]), perfazendo dez tratamentos, em delineamento inteiramente casualizado. Após 90 dias de semeadura, foram medidas a altura da parte aérea (h) e o diâmetro à altura do coleto das mudas. Os dados foram submetidos à análise de variância (ANOVA) ao nível de 5% de probabilidade de erro. Os tratamentos não diferiram estaticamente entre si, evidenciando o mesmo efeito das dosagens de P, com e sem N, na condição de correção de acidez do solo com calcário ($CaCO_3$), no crescimento inicial das mudas de *Swietenia macrophylla*.

Palavras – chave: Mogno; Eficiência nutricional; Produção de mudas

[1] Received on 19 September 2019 and accepted for **scientific article** publication on 15 January 2020.
[2] Forest Engineer. Master student in Forest Science, Universidade Estadual do Sudoeste da Bahia - UESB. E-mail: <julionetoguitar94@gmail.com>
[3] Forest Engineer. Master student in Forest Science, Universidade Estadual do Sudoeste da Bahia - UESB. E-mail: <drauziogama@hotmail.com>
[4] Forest Engineer. Universidade Federal do Recôncavo da Bahia – UFRB. E-mail: <velgmfiel@hotmail.com>
[5] Dr. in Forest Sciences. Assistant Professor, Universidade Federal do Recôncavo da Bahia – UFRB. E-mail: <linikerfs@gmail.com>
[6] Dr. in Forest Sciences. Assistant Professor, Universidade do Estado do Amapá - UEAP. E-mail: <robson.lima.ef@gmail.com>

Introduction

Swietenia macrophylla King. (Meliaceae family: Swietenioideae sub-family), known as Brazilian mahogany, is a climax tree species endemic to Amazon region and, as an adult it can reach up to 70 m in height and 3.50 m in DBH (diameter at breast height). It is considered one of the most valuable species in world, due to produces a beauty wood and, due to its highly technological characteristics appreciated such as texture, medium density and easy workability, for example, which makes the specie commonly used in furniture industry (SOUZA et al., 2010; ALMEIDA et al., 2010; COSTA et al., 2013; VIEIRA and WEBER, 2015).

The Brazilian mahogany sawnwood price varies from R$ 1,100.00 to 1,800.00 m³ in intern market to R $ 3,600.00 in external market (BRASIL, 2016; NATIVIDADE, 2016). Until 2007, approximately 279 thousand tonnes of Brazilian mahogany sawnwood, considered as well as *Cedrela* spp. and *Tabebuia* spp., a valuable wood with high international value. The high wood price in international market has stimulated a large scale, causing a drastic reduction of natural stocks of this species in Brazil, causing risk of extinction as there is no renewal in same proportions as exploitation (ALMEIDA et al., 2010; VIEIRA and WEBER, 2015). However, in some Brazil regions, extensive species cultivation has been carried out, whether in form of pure monocultures or intercropped such, e.g., agroforestry systems (SAF's) and crop-livestock-forest integration systems (ILPF's) (GUIMARÃES NETO et al., 2004; COSTA et al., 2013; CONDÉ et al., 2013; SANCHES et al., 2016).

In a seedlings production system of forest species, in addition to need substrate and adequate recipient, nutritional recommendation must also be carried out in an appropriate manner, ensuring seedling morphophysiological quality to its optimal development (SOUZA et al., 2010; ROWEDER et al., 2015; VIEIRA and WEBER, 2015). Therefore, research on nutritional requirements becomes essential, with greater emphasis on nutrients content associated with liming and nitrogen fertilization with phosphorus and potassium, since a determined nutrient absence, e.g. phosphorus, can cause initial growth reduction of mahogany seedlings (SANTOS et al., 2008; TUCCI et al., 2009; VIÉGAS et al., 2012).

For a commercial reforestation success, it is necessary to specific nutritional requirements know of each forest species to be cultivated, given of fertility limitations that a given site may present (SOUZA et al., 2010; ROWEDER et al., 2015). This contributes to optimized fertilization planning, which can result in reduced costs for seedling production. The objective of this study is analyzing the initial growth of *Swietenia macrophylla* seedlings under soil acidity correction and phosphate nitrogen fertilization.

Material and methods

Study area

The experiment was carried out at Universidade Federal do Recôncavo da Bahia (UFRB) in Cruz das Almas municipality, Bahia state (Lat. 12º 40'12 ”S, Long. 39º 06 '07” W), located in phytogeographic domain region of Atlantic Forest biome, with predominantly Yellow Ferralsol (USDA, 2014), that correspond to “Latossolo Amarelo” (RODRIGUES et al., 2009) in Brazilian System of Soil Classification (BRASIL, 2006)

The study region is located at an elevation of 220 m from the mean sea level, with means air temperature and annual rainfall of 23.0 ºC and 1,136 mm, respectively (CLIMATE-DATA, 2012). The region climate is humid tropical of Af type, characterized as relatively hot and humid, according to Köppen classification (ALVARES et al., 2013).

Experiment design

In UFRB experimental field, seeds were collected from *Swietenia macrophylla* matrix trees to seedlings produce in substrate (soil), formed by fine sand collected of 10-40 cm depth, previously sieved in a 4 mm mesh, with chemical characteristics determined according to Embrapa (BRASIL, 2009), as shown in Table 1.

Table 1 - Chemical analysis of substrate used for *Swietenia macrophylla* seedlings production after acidity correction and phosphate nitrogen fertilization.
Tabela 1 - Análises químicas do substrato utilizado para produção de mudas de *Swietenia macrophylla* após correção de acidez e adubação nitrogenada fosfatada.

pH (H_2O)	K	Ca^{2+}	Mg^{2+}	Al^{3+}	Na^{2+}	H+Al	SB	CEC	P	V
					$cmol_c.dm^{-3}$				mg^3	(%)
5.6	0.2	2.0	0.6	0.2	0.3	5.1	3.1	8.2	2.7	37.8

Where: pH = Hydrogen potential; K = potassium; Ca = calcium; Mag = magnesium; Al = aluminum; Na = sodium; H + Al = potential acidity; SB = sum-of-bases; CEC = cation exchange capacity; P = phosphor; V = base saturation.

Limestone ($CaCO_3$) was added to substrate in 1.7 g proportion to correct acidity and 0.31 g of potassium chloride (KCl). The limestone required dose was obtained using a one hectare (100 m x 100 m) ratio, considering a depth of 0.20 m from soil collected (2,000,000 dm^{-3} kg L), with 2,300 g for 2,000,000 dm^{-3} , obtaining 1.7 g each 1.5 dm^{-3} of soil (soil volume in recipient). The value of potassium (K_2O) was obtained by proportional ratio of molecular mass by potassium chloride (KCl), in relation to soil volume in recipient (1.5 dm^{-3}), adapted based on Sorreano et al. (2012).

For limestone ($CaCO_3$) reaction to occur and pH correct, 130 ml of water were used, where it was incubated for a week. A plastic bag with 1.5 dm^3 volume was used as a recipient for seedlings production. From the emergency, two nitrogen fertilizers (urea) were used to seedlings cover fertilization (30 mg dm^{-3}) in February and March, with an 15 days of interval and 1.7 g of granulated nitrogen application.

Statistical design used was completely randomized with four repetitions in a factorial scheme (5 x 2) with five levels of phosphorus doses (P_2O_5) in nitrogen absence and presence, respectively, N_0 and N_1, totaling 10 treatments (Table 2).

Table 2 - Treatments composition for *Swietenia macrophylla* seedlings production after acidity correction and phosphate nitrogen fertilization.
Tabela 2 - Composição dos tratamentos utilizados para a produção de mudas de *Swietenia macrophylla* após correção de acidez e adubação nitrogenada fosfatada.

Treatments	Composition (doses)
$P_1 N_0$	0 mg dm^{-3} of P x 0 mg dm^{-3} of N
$P_2 N_0$	150 mg dm^{-3} of P x 0 mg dm^{-3} of N
$P_3 N_0$	300 mg dm^{-3} of P x 0 mg dm^{-3} of N
$P_4 N_0$	450 mg dm^{-3} of P x 0 mg dm^{-3} of N
$P_5 N_0$	700 mg dm^{-3} of P x 0 mg dm^{-3} of N
$P_1 N_1$	0 mg dm^{-3} of P x 30 mg dm^{-3} of N
$P_2 N_1$	150 mg dm^{-3} of P x 30 mg dm^{-3} of N
$P_3 N_1$	300 mg dm^{-3} of P x 30 mg dm^{-3} of N
$P_4 N_1$	450 mg dm^{-3} of P x 30 mg dm^{-3} of N
$P_5 N_1$	700 mg dm^{-3} of P x 30 mg dm^{-3} of N

Where: P = phosphor; N = nitrogen

Data collection and analysis

The experiment was carried out between January to April 2015, in a greenhouse with relative humidity and ambient temperature controlled conditions. After 90 days of sowing, seedlings were evaluated by aerial part height measuring, measuring from plants stem based to apex, with graduated ruler. And, diameter and height of stem based measurement was performed using a digital caliper.

The data obtained were submitted to variance analysis (ANOVA) and adjusted in regression equations for analyzed variables, dependent on P doses at 5% error level probability. The SISVAR® software was used to statistical analyzes (FERREIRA, 2011).

Results

Descriptive summary of t growth variables in height (cm) and stem based diameter (mm) mahogany seedlings, evaluated after 90 days of germination, and are shown in Table 3.

Table 3 - Height and stem based diameter growth of *Swietenia macrophylla* seedlings after 90 days of germination in response to P_n (phosphorus) doses applied in nitrogen absence (N_0) and presence (N_1) with acidity correction.
Tabela 3 - Crescimento em altura e diâmetro a altura do coleto de mudas de *Swietenia macrophylla* após 90 dias da germinação em resposta às doses de P_n (fósforo) aplicadas em ausência (N_0) e presença (N_1) de nitrogênio com correção de acidez.

Treatments	Minimum	Mean	Maximum	MSD (±)	CV (%)
			Height (cm)		
P_0 N_0	16.00	22.35	26.90	2.46	22.04
P_0 N_1	17.50	19.63	22.70	1.29	13.11
P_1 N_0	21.10	23.58	28.40	1.66	14.04
P_1 N_1	18.20	23.10	29.00	2.22	19.26
P_2 N_0	23.90	25.83	29.00	1.15	8.90
P_3 N_1	15.20	20.53	23.00	1.83	17.79
P_3 N_0	18.00	22.47	26.60	2.49	19.18
P_3 N_1	18.10	22.08	28.00	2.41	21.82
P_4 N_0	23.40	25.73	28.20	1.39	9.34
P_4 N_1	17.10	19.50	22.40	1.55	13.77
			Stem based diameter (mm)		
P_0 N_0	0.35	0.39	0.45	0.02	10.68
P_0 N_1	0.19	0.35	0.49	0.06	35.35
P_1 N_0	0.31	0.38	0.46	0.03	18.28
P_1 N_1	0.34	0.37	0.41	0.09	10.33
P_2 N_0	0.27	0.37	0.41	0.03	18.10
P_3 N_1	0.33	0.34	0.35	0.01	2.99
P_3 N_0	0.28	0.32	0.35	0.02	11.27
P_3 N_1	0.25	0.29	0.31	0.01	9.99
P_4 N_0	0.23	0.37	0.49	0.08	35.44
P_4 N_1	0.17	0.22	0.25	0.03	19.81

Where: MSD = mean standard deviation; CV = coefficient of variation; $P_1 N_0$ = 0 mg dm^{-3} de P x 0 mg dm^{-3} de N; $P_2 N_0$ = 150 mg dm^{-3} of P x 0 mg dm^{-3} of N; $P_3 N_0$ = 300 mg dm^{-3} of P x 0 mg dm^{-3} of N; $P_4 N_0$ = 450 mg dm^{-3} of P x 0 mg dm^{-3} of N; $P_5 N_0$ = 700 mg dm^{-3} of P x 0 mg dm^{-3} of N; $P_1 N_1$ = 0 mg dm^{-3} of P x 30 mg dm^{-3} of N; $P_2 N_1$ = 150 mg dm^{-3} of P x 30 mg dm^{-3} of N; $P_3 N_1$ = 300 mg dm^{-3} of P x 30 mg dm^{-3} of N; $P_4 N_1$ = 450 mg dm^{-3} of P x 30 mg dm^{-3} of N; $P_5 N_1$ = 700 mg dm^{-3} of P x 30 mg dm^{-3} of N.

According to variance analysis (Table 4), after data transformation (y + 1.0 square root), the test was not significant ($p > 0.05$) for the N factors (nitrogen absence and presence) and P_n (phosphorus dosages), evaluated after to 90 days. This resulted in similar effects on mean growth in height and stem based diameter of *Swietenia macrophylla* seedlings. The interaction test was also not significant ($p > 0.05$), where the effect of phosphorus measurements in height and diameter growth is independent of nitrogen (and vice versa).

Table 4 - Variance analysis (ANOVA) for growth of height and stem based diameter variables in response to P_n (phosphorus) doses applied in nitrogen absence (N_0) and (N_1) presence in *Swietenia macrophylla* seedlings production with soil/substrate acidity correction.
Tabela 4 - Análise de variância (ANOVA) para as variáveis do crescimento em altura e do diâmetro à altura do coleto em resposta às doses de P_n (fósforo) aplicadas em ausência (N_0) e presença (N_1) de nitrogênio para produção de mudas de *Swietenia macrophylla* após correção de acidez do solo/substrato.

FV	DF	Height	Stem based diameter
N	1	(*) 0.5108^{ns}	(*) 0.2408^{ns}
P_n	4	(*) 0.5852^{ns}	(*) 0.1110^{ns}
P_n*N	4	(*) 0.6624^{ns}	(*) 0.6941^{ns}
Error	30		
Transformed mean		4.45 cm	1.14 mm
CV (%)		28.75	4.82
Original data mean		22.48 cm	0.34 mm
CV (%)		15.93	17.22

Where: FV = factor of variation; DF = degrees of freedom; N = nitrogen; P_n = phosphor doses; (*) = P value; ns = not significant ($p < 0.05$); CV (%) = coefficient of variation.

Discussion

The non-existence of statistical differences between treatments, in growth of *Swietenia macrophylla* seedlings, can probably be attributed to 90-day period as insufficient time to detect contrasts. This can also be observed in other studies that considered practically the same time evaluation interval, e.g., in Tucci et al. (2011) who, in the 100 days, also concluded that nitrogen (N) and phosphorus (P) fertilization did not improve mahogany seedlings quality; and in Silva et al. (2011) that after 90 days was little growth influenced by phosphate fertilization.

However, in Fontes et al. (2013) study, in seedlings evaluating after 150 days, also in Farralsols in Rio de Janeiro state, there was a high plant response to phosphate fertilization, in liming presence. In Cardoso et al. (2015) study, after 90 days of observation, the pH increase provided by liming, caused greater P availability to plants, probably favoring this nutrient accumulation in seedlings.

In Souza et al. (2010) study, evaluating the mahogany seedlings after 120 days of germination, the authors concluded that without phosphorus addition, in liming presence or absence, there was of *S. macrophylla* seedlings development limitation, when produced in Amazon region, with Ferralsols as a substrate, indicating P as one of the most limiting nutrients to the species growth. To Silva Júnior et al. (2018), the consequent soil pH increase tends to availability rise of P and other nutrients to plant. However, the decrease in plant growth can occur with increasing calcium doses (Ca).

The greater phosphorus availability for the plant, when in liming presence, is due to liming promoting the precipitation reduction of phosphorus (P) with aluminum (Al) exchangeable with hydroxyl groups (OH^-) released, Al^{3+} complexing (TROEH and THOMPSON, 2007). What can be seen, in view of studies observed, is that calcium conditions better results to promote initial plant growth, when applied with a corrective effect, thus avoiding , the calcium addition application as a nutrient in addition to liming, although, according to Viégas et al. (2012), calcium is third most demanded element for mahogany development.

The limestone effects on seedling growth up to 90 days are independent of N or P presence. In Cardoso et al. (2015) study, limestone did not influence the N availability to mahogany. This was also verified by Tucci et al. (2011), where the initial mahogany seedlings development in dystrophic Ferralsols suffered little influence from the supply of nutrients nitrogen and phosphorus increasing doses. Tucci et al. (2007) also concluded that liming, associated with phosphate correction and fertilization with N, P and K, caused higher nutrient content and higher growth rates in plants.

Conclusions

The initial growth analysis of *Swietenia macrophylla* seedlings showed that this species is not demanding in phosphorus doses, both in nitrogen presence or absence, demonstrating that there is only need to apply limestone ($CaCO_3$) to soil (substrate) acidity correct.

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