

MORPHOPHYSIOLOGICAL AND NUTRITIONAL BEHAVIOR OF *Hymenaea stigonocarpa* Mart. ex Hayne (FABACEAE) SEEDLINGS SUBMITTED TO LIMING

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ABSTRACT – Liming is beneficial for plants as it promotes pH elevation, neutralization of toxic aluminum, increase in calcium (Ca^{2+}) and magnesium (Mg^{2+}) supply, and provides greater root systems. However, it is known that different species, mainly those native to the Cerrado, respond in different ways to this technique. Given the above, the objective of this study was to determine how *Hymenaea stigonocarpa* (“Jatobá-do-Cerrado”) seedlings respond to liming in Dystrophic Red Latosol. The plants were cultivated in four-liter pots, submitted to different base saturation (natural soil, 30, 45, 60 and 75% V) and maintained in a greenhouse. Biometrics, biomass, nutritional content and physiological parameters were evaluated. A difference in Ca^{2+} and Mg^{2+} contents between leaves and stems was observed, leading to significant reductions in stomatal conductance, transpiration, internal CO_2 concentration and internal and external CO_2 concentration ratios, resulting in a reduction of the investment in growth and biomass. Given these results, there is no need for liming in the production of *H. stigonocarpa* seedlings in a Dystrophic Red Latosol.

Keywords: Growth; Jatobá-do-Cerrado; Base Saturations.

COMPORTAMENTO MORFOFISIOLÓGICO E NUTRICIONAL DE MUDAS DE *Hymenaea stigonocarpa* Mart. ex Hayne (FABACEAE) SUBMETIDAS A CALAGEM

RESUMO – A calagem é benéfica para as plantas por promover a elevação do pH, neutralização do alumínio tóxico, aumentar o fornecimento de cálcio (Ca^{2+}) e magnésio (Mg^{2+}) e propiciar maior sistema radicular. No entanto, sabe-se que as espécies, principalmente nativas do Cerrado, respondem de formas distintas a essa técnica. Diante do exposto, o objetivo deste estudo foi determinar de que forma mudas de *Hymenaea stigonocarpa* (“Jatobá-do-Cerrado”) respondem a calagem em Latossolo Vermelho Distrófico. As plantas foram cultivadas em vasos de quatro litros, submetidas a diferentes saturações de bases (solo natural, 30, 45, 60 e 75% de V) e mantidas em casa de vegetação. Foram avaliadas a biometria, biomassa, teor nutricional e parâmetros fisiológicos. Houve diferença para o teor de Ca^{2+} e Mg^{2+} nas folhas e caule e isso culminou na redução significativa da condutância estomática, transpiração, concentração interna de CO_2 e a relação concentração interna e externa de CO_2 , o que levou a redução do investimento em crescimento e biomassa. Diante dos resultados obtidos, para a produção de mudas de *H. stigonocarpa* em Latossolo Vermelho Distrófico não há necessidade de realizar calagem.

Palavras-Chave: Crescimento; Jatobá do cerrado; Saturações de bases.



1. INTRODUCTION

Low fertility and nutrient availability, problems such as soil acidity and aluminum toxicity limit plant productivity, preventing plants from reaching their full potential (Rao et al., 2016). To correct these factors, liming is practiced. This technique aims to improve production potential by correcting soil acidity to obtain optimum yields. The soil acid/alkaline balance (as measured by pH) is very important in maintaining optimal soil nutrient availability and minimizing potential toxicities (Agegnehu et al., 2019). Liming increases base saturation and calcium and magnesium availability, while phosphorus and molybdenum fixation which are reduced by the inactivation of reactive constituents and toxicity due to excess soluble aluminum, iron and manganese, is corrected, also promoting root growth and improving nutrient absorption (Agegnehu et al., 2019).

Several studies have applied this technique in the production of forest species seedlings. These studies indicate that species from different ecological groups present positive to liming responses, and that this result is only obtained for plants classified as pioneers and secondary species (Furtini Neto et al., 1999). However, some studies report no difference between pioneer and climax species (Macedo, 2008), and others demonstrate that liming did not promote differences even in pioneers, as in the case of *Schizolobium parahyba* (Vell.) S. F. Blake and *Leucochloron incuriale* (Vellozo) Barneby and Grimes (Coneglian et al., 2016; Santos et al., 2019). Liming promoted negative responses to seedling growth in *Plathymenia foliolosa* Benth and *Dimorphandra mollis* Benth (Freitas et al., 2017b; Cota et al., 2019), while positive response was noted in *Dalbergia nigra* (Vell.) Allemão ex Benth (Carlos et al., 2018). These results indicate that forest species may respond in different ways.

Studies of this nature are scarce for some Cerrado species, and no information in the literature to help seedling producers is available. This is the case for *Hymenaea stigonocarpa* Mart ex Hayne from the Fabaceae botanical family, a medicinal species found in the Brazilian savannah, popularly known as "*Jatobá-do-Cerrado*" and widely used against general and respiratory pain (Fiebig and Pasa, 2018). *H. stigonocarpa* also produces high quality hard and sturdy wood (Moraes et al., 2018) and is also used in the recovery of degraded areas (Silva et al., 2014).

In nutritional terms, studies indicate that *H. stigonocarpa* responds to phosphate fertilization (Alves et al., 2015) as well as agro-industrial waste (Mizobata et al., 2016). However, no research demonstrating liming effects on *H. stigonocarpa* seedling production is available. Given the above, the aim of this study was to determine how *H. stigonocarpa* seedlings respond to elevation base saturation (liming) in a Dystrophic Red Latosol.

2. MATERIAL AND METHODS

2.1 Cultivation conditions and experimental design

This study was conducted in a greenhouse at the Federal Institute Goiano-campus Rio Verde (17°47' S e 50°54'W), Goiás, Brazil. The soil classified as a Dystrophic Red Latosol (Embrapa, 2013), was collected from the 0.0-0.20 m deep soil layer. Samples from 0.0-0.20 m in depth were collected at five different points for chemical analyses, according to the Embrapa (2009) methodology and granulometry assessments according to the pipette method (Embrapa, 1997). Thus, the soil in its natural condition displays the following characteristics: pH of 4.3; 0.30 cmolc dm⁻³ of aluminum (Al³⁺); 0.4 cmolc dm⁻³ of calcium (Ca²⁺); 0.1 cmolc dm⁻³ of magnesium (Mg²⁺); 1 mg dm⁻³ of phosphorous (P); 100 mg dm⁻³ of potassium (K); 2.7 g kg⁻¹ of organic matter, 12% base saturation (V) and 500, 320 and 180 g kg⁻¹ clay, sand and silt, respectively.

Plants were grown in four-liter pots and the experimental design was completely randomized, consisting of five treatments (natural soil, 30, 45, 60 and 75% de V) and four repetitions each, totaling 20 experimental units. The Raij (1981) methodology was used to raise the soil base saturation to the levels of interest. The corrective agents calcium carbonate (CaCO₃) and magnesium carbonate (MgCO₃) were used at a 4: 1 ratio (Freitas et al., 2017a) and incorporated individually into the pots.

Basic fertilization was calculated by meeting the basic fertilization requirements (mg dm⁻³), according to Carlos et al. (2015): 180 of N, 300 of P, 150 of K, 40 of S, 1.33 of Cu, 0.81 of B and 4 of Zn. Monoammonium phosphate, urea, ammonium sulfate, potassium chloride, copper sulfate, boric acid and zinc sulfate were used as sources, all applied as a nutrient solution.

H. stigonocarpa seeds were manually scarified according to Santos (2011) and two were placed in each pot. After germination, thinning was performed leaving only one plant per pot. Planting occurred after 20 days of incubation in potted soil. The soil was maintained at 60% of field capacity according to the International Association of Engineering Geology (IAEG, 1979).

2.2 Biometric and biomass assessments

Biometric evaluations consisted of plant height (H) obtained with a millimeter ruler, taking as default the apical meristem (Delarmelina et al., 2014) and stem diameter (SD) measured with a digital caliper. The total number of expanded leaves (NL) was also counted.

Using photographic records of the leaves of each experimental unit, the leaf area (LA) was calculated using The Image J Software (Research Services Branch, National Institute of Mental Health, Bethesda, Maryland, USA). With the leaf area and leaf dry mass (LDM) data, the specific leaf area (SFA) was calculated using the formula proposed by Barbieri Junior et al. (2007): $SFA = LA/LDM$.

The plants were cut into leaves, stems and root and washed in distilled water. After separation of the vegetative organs, they were maintained in a forced air circulation oven at 65 °C until constant weight. Subsequently, the leaf dry mass (LDM), stem dry mass (SDM) and root dry mass (RDM) were obtained (Delarmelina et al., 2014).

2.3 Gas exchanges

The physiological analyses comprised photosynthetic rate [A , $\mu\text{mol}(\text{CO}_2) \text{m}^{-2} \text{s}^{-1}$] and transpiratory rate [E , $\text{mmol}(\text{H}_2\text{O}) \text{m}^{-2} \text{s}^{-1}$], stomatal conductance [g_s , $\text{mol}(\text{H}_2\text{O}) \text{m}^{-2} \text{s}^{-1}$], internal CO_2 concentration (C_i), relationship between internal and external CO_2 concentrations (C_i/C_a) and electron transport rate (ETR, $\mu\text{mol} \text{m}^{-2} \text{s}^{-1}$), all performed using portable infrared gas analyzer (Infra Red Gas Analyser – IRGA, model Li-6400XT, Li-Cor, Nebraska, EUA) on a fully expanded leaf, between 8 and 11 am.

2.4 Nutritional Content

Leaf, stem and root Ca^{2+} and Mg^{2+} determinations were performed by atomic absorption spectrophotometry (Embrapa, 2009).

2.5 Data analysis

The data were subjected to analysis of variance by the F test for all variables at a significance level of 5% ($p \leq 0.05$). When differences were found between treatments, the regression analysis was used as function of base saturation levels for each significant variable, through the SISVAR 5.3 statistical program (Ferreira, 2011).

3.RESULTS

3.1 Biometric and biomass results

Biometric and biomass variables were not significantly affected by increased base saturation. However, both decreased with increasing base saturation (Figure 1A, C, D, E, F, G and H), except for stem diameter. The treatment resulting in the highest growth and biomass was the no liming (12%). The highest increase in stem diameter was observed at the highest base saturation (75%) (Figure 1B).

3.2 Nutritional Content

A difference between treatments was noted for nutritional content. Increased base saturation led to increased Ca^{2+} and Mg^{2+} content in both *H. stigonocarpa* seedling leaves (Figure 2A and C) and stems (Figure 2B and D). The data fit an increasing linear model, where the higher base saturation (75%) allowed for greater Ca^{2+} and Mg^{2+} translocation to leaves and stems.

3.3 Gas exchanges

All physiological *H. stigonocarpa* seedling parameters were reduced with increasing base saturation. Differences were found between treatments for transpiration, stomatal conductance, internal CO_2 concentration internal and external CO_2 ratios (Figure 3). The obtained data for these variables fit a decreasing linear model (Figure 3). The highest values found for physiological variables were 11.3 for A ; 0.15 for g_s ; 2.6 for E ; 274.8 for C_i ; 0.68 for C_i/C_a and 104.5 for ETR, all promoted in the non-liming treatment (12%).

4.DISCUSSION

The increases base saturation did not influence *H. stigonocarpa* seedling growth and biomass

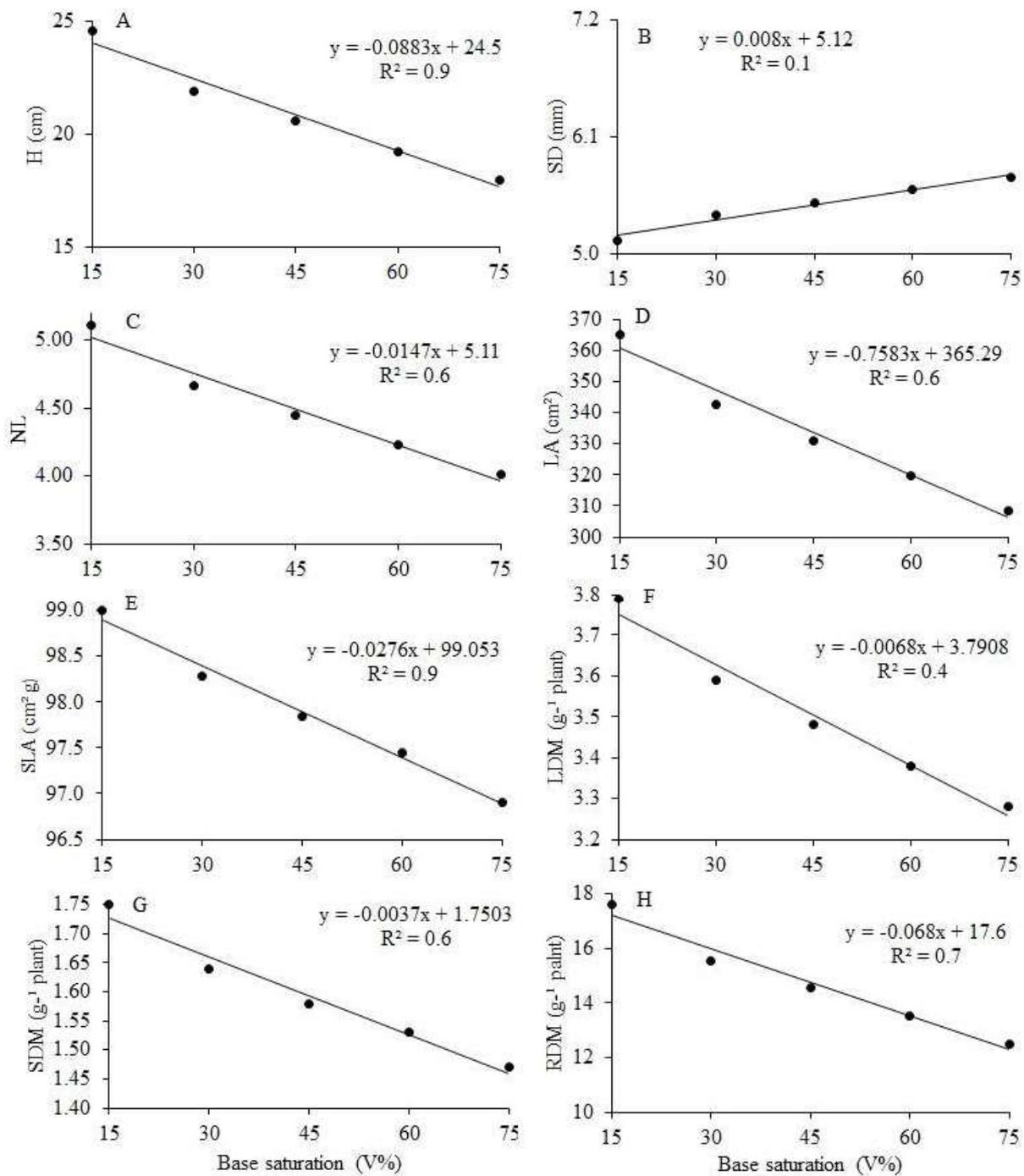


Figure 1 – Biometry and biomass for *Hymenaea stigonocarpa* (Fabaceae) seedlings submitted to base saturation elevation in Dystrophic Red Latosol. H-height, SD-stem diameter, NF-leaf number, LA-leaf area, SLA-specific leaf area, LDM-leaf dry mass, SDM-stem dry mass and RDM-root dry mass.

Figura 1 – Biometria e biomassa de mudas de *Hymenaea stigonocarpa* (Fabaceae) submetidas a elevação da saturação de bases em Latossolo Vermelho Distrófico. H-altura, D-diâmetro, NF-número de folhas, AF- área foliar, AFE-área foliar específica, MSF-massa seca foliar, MSC-massa seca do caule e MSR-massa seca radicular.

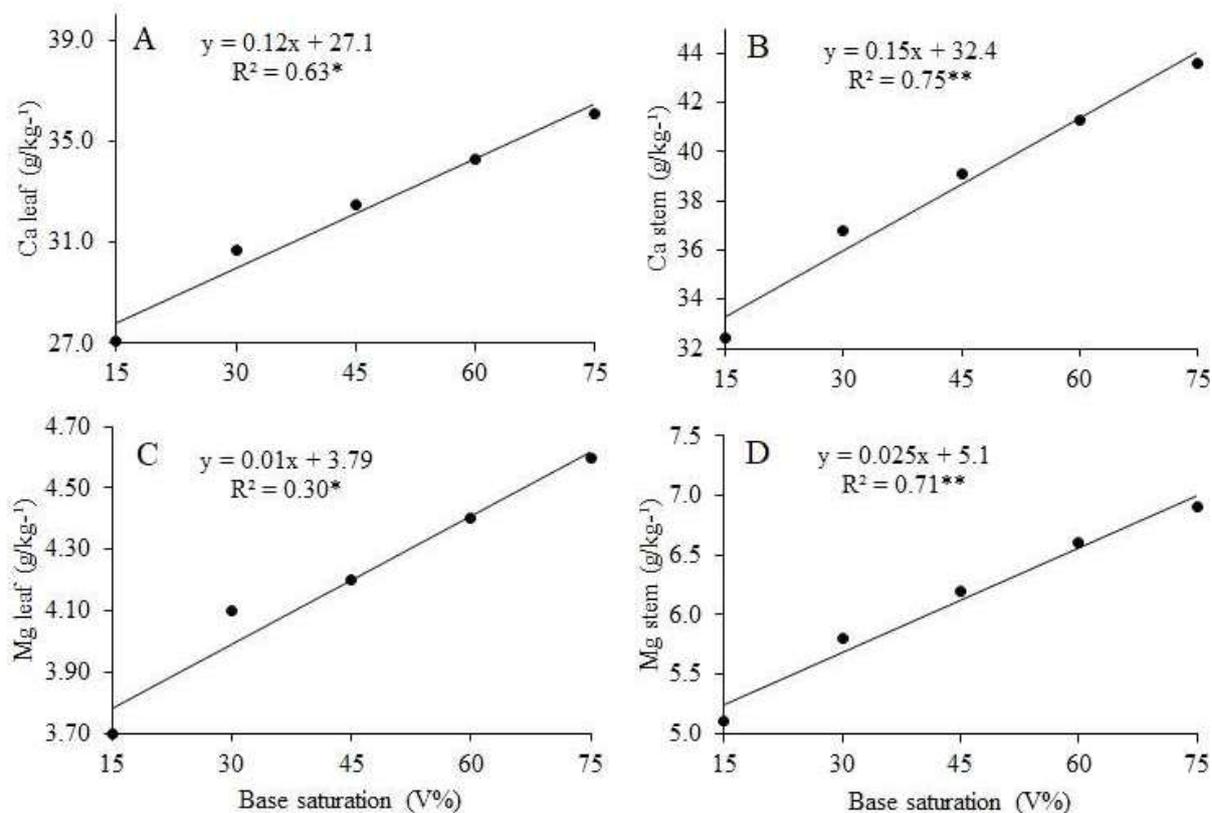


Figure 2 – Nutritional content of Calcium (Ca²⁺) and Magnesium (Mg²⁺) in *Hymenaea stigonocarpa* (Fabaceae) seedling leaves and stems submitted to different base saturations in Dystrophic Red Latosol.

Figura 2 – Teor nutricional de Cálcio (Ca²⁺) e Magnésio (Mg²⁺) em folhas e caule de mudas de *Hymenaea stigonocarpa* (Fabaceae) submetidas a diferentes saturações de bases em Latossolo Vermelho Distrófico.

parameters, although the highest values were obtained in the non-liming treatment, except for stem diameter. This indicates that Ca²⁺ and Mg²⁺ content found in the studied soil associated to high seed nutritional reserves are sufficient for initial demands (Carlos et al., 2014), and is one of the reasons why liming is not necessary for the seedling production of other Cerrado species, such as *Hymenaea courbaril* L (Furtini Neto et al., 1999), *Mimosa caesalpiniiifolia* Benth (Costa Filho et al., 2013), *S. parahyba* (Coneglian et al., 2016), *P. foliolosa* (Freitas et al., 2017b) and *D. mollis* (Cota et al., 2019).

Although no difference in growth and biomass was noted, a difference in Ca²⁺ and Mg²⁺ content in both *H. stigonocarpa* seedling leaves and stems was observed. This is due to the fact that liming increases the availability of these nutrients in soil. However, this technique seems to be advantageous only for fast-

growing species, as slow-growing species may absorb and translocate these nutrients, but do not use them as efficiently. Thus, liming under the conditions of this study for *H. stigonocarpa* seedlings is characterized as a waste, since no responses in terms of growth due to increased base saturation in Dystrophic Red Latosol were observed. This is not uncommon, as several Cerrado species, such as *Astronium fraxinifolium* Schott, *Guazuma ulmifolia* Lam, *Anadenanthera macrocarpa* (Benth.) Brenan, *Inga edulis* Mart (Silva et al., 2011) and *L. incuriale* (Santos et al., 2019) have displayed the same behavior in relation to liming.

Even considering that liming is unnecessary under the studied conditions, the nutritional requirement of seedlings in other soil types may be different. For example, Bernardino et al. (2005), Souza et al. (2008) and Souza et al. (2010) observed no significant effect under increased base saturation

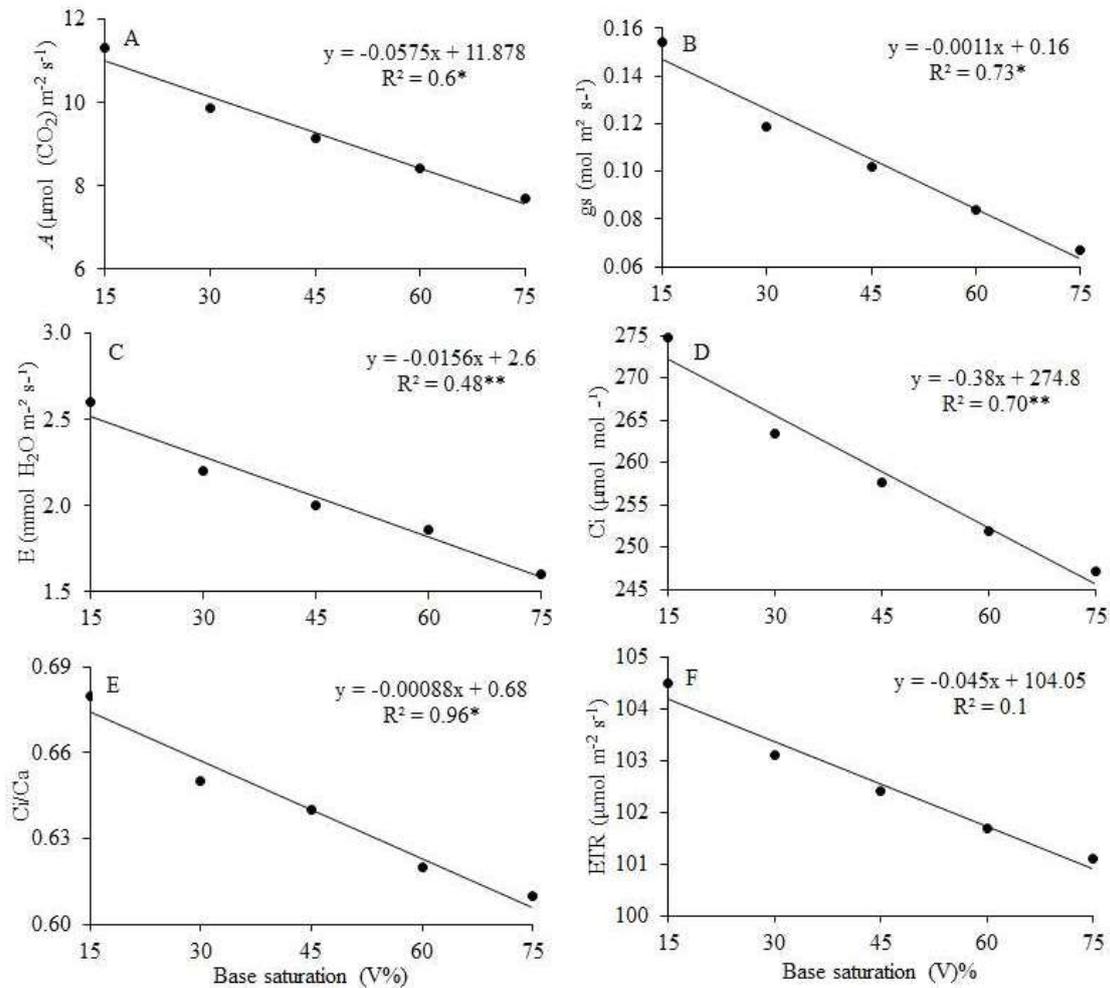


Figure 3 – Physiological parameters of *Hymenaea stigonocarpa* (Fabaceae) seedlings submitted to base saturation elevation in Dystrophic Red Latosol. A -photosynthesis, g^s -stomatal conductance, E-transpiration, C_i-internal CO₂ concentration, C_i/C_a-relationship between internal and external CO₂ concentrations and ETR-electron transport rate.

Figura 3 – Parâmetros fisiológicos de mudas de *Hymenaea stigonocarpa* (Fabaceae) submetidas a saturações de bases em Latossolo Vermelho Distrófico. A-fotosíntese, g^s-condutância estomática, E-transpiração, C_i-concentração interno de CO₂, C_i/C_a-relação entre concentração interna e externa de CO₂ e ETR-taxa de transporte de elétrons.

elevation on the morphological characteristics of *A. macrocarpa*, *Machaerium nictitans* (Vell.) Benth and *Senna macranthera* (DC. Ex Collad.) HS Irwin and Barneby seedlings when grown in Argisol, while a significant response was noted when these same species were cultivated in dystrophic Alatosol.

The increased Ca²⁺ and Mg²⁺ content in leaves and stems inversely affected stomatal conductance, transpiration, internal CO₂ concentrations and the relationship between internal and external CO₂ concentration in *H. stigonocarpa* seedlings. With reduced stomatal conductance, both transpiration

and internal CO₂ concentration become limited. This affects other physiological parameters such as internal and external CO₂ concentration ratios and, mainly, photosynthesis. In addition, decreased gas exchanges lead to growth, development and seedling quality compromises, as these factors are related (Taiz and Zeiger, 2013).

The behavior noted in the seedlings as a function of liming indicates the possibility of toxicity. According to White and Broadley (2003), excess Ca²⁺ in soil can lead to toxicity and reduced plant growth. Rothwell and Dodd (2014) observed leaf area

reduction, g_s , A and shoot biomass of two Fabaceae family species as a function of liming. The authors state that an alternative signal transmitted by the xylem decreases the stomatal conductance and gas exchange of the assessed species.

Liming effects on three Fabaceae family species studied by Rothwell et al. (2015) were similar to those observed in the present study, with no differences in nutritional contents, except for Ca^{2+} . In addition, the authors also observed decreased g_s , C_i , A and biomass accumulation. The authors attributed this behavior to increased Abscisic Acid (ABA) as a result of liming. Liming decreases water potential, resulting in increased ABA, which in turn decreases plant transpiration through stomatal closure, limiting CO_2 absorption and leading to low internal CO_2 concentrations, interfering with photosynthesis and, thus, resulting in decreased biometric parameters and biomass (Rothwell et al., 2015), as in observed herein.

Given this information, it is noted that some plants grow well at low soil Ca^{2+} concentrations and respond very little when the availability of this nutrient increases, in some cases leading to growth inhibition, as observed in *P. foliolosa* and *D. mollis* (Freitas et al., 2017b; Cota et al., 2019). This is due to the fact that excessive Ca^{2+} absorption in plants leads to ionic balance disturbances, decreased absorption of other nutrients or changes in cytosol pH (Balakrishnan et al., 2000).

5. CONCLUSIONS

Hymenaea stigonocarpa seedlings respond negatively to base saturation increases in Dystrophic Red Latosol, indicating no need for liming for seedling production.

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