Nitrogen Fertilization in the Initial Growth of *Khaya senegalensis* A. Juss Plants Under Greenhouse Conditions

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Abstract

African mahogany is an exotic specie and its cultivation has increased in Brazil due to the high value of its timber on the international market. Nutrition with nitrogen is an important factor for species with high biomass production and specific studies on this species are essential. The present study aimed to assess the initial growth of African mahogany plants submitted to nitrogen fertilization. The experiment was set up and carried out in a greenhouse, with 7 dm^3 plastic pots using a oxisoil sampled from the surface layer. A completely randomized experimental design was used with five treatments and six replications. The treatments consisted of five N levels: 0, 40, 80, 120 and 160 mg dm^{-3}, using urea as the source. The following were assessed at 180 days: height, stem diameter, leaf, stem, root and total dry matter, N content in the leaves in the African mahogany leaves. The African mahogany seedlings had high N demand and responded positively to the N used and the growth variables was positive with increase in N level. However, as it presented increasing linear effect, the N level can not be estimated, that would provide the maximum initial development for this plant species.

Keywords: African mahogany, forest fertilization, silviculture

1. Introduction

The demand for hardwood has increased greatly and commercial plantations of these species are not being managed to keep up with the rhythm in the market growth (Petrauski et al., 2012). Thus, in order to meet the hardwood demand, it has become necessary to increase commercial plantations of native and exotic species and adopt management practices that ensure efficiency and high yield in the forests plantations (Ciriello et al., 2014).

Among the species exotic to Brazil that are used for commercial ends on the international market there is the African mahogany (*Khaya senegalensis* A. Juss), which belongs to the family Meliaceae. This specie is naturally from Mauritania and Eastern Senegal to the north of Uganda. It has high commercial value on the international market and is commercialized in several countries in Europe. Also, the African mahogany wood used mainly in for veneers, luxury furniture, interior constructions and shipbuilding (Pinheiro et al., 2011).

The importance of this specie has grown in Brazil because the plant resistance to attack and damage caused by *Hypsipyla grandella* (Zeller), a pest that severely attacks thenative mahogany plantations (*Swietenia macrophylla* King). Furthermore, African mahogany adapted well to Brazilian soils also has exceptional silviculture characteristics, as good architecture, with a straight trunk that does not fork, and has few problems with others pests and diseases in all its growth phases (Verzignassi et al., 2009).

The knowledge in nutritional requirements of species is an important tool for obtaining plants with high growth and biomass increase. Nitrogen (N) is outstanding among the nutrients, once it is required in larger quantities by most crops (Marques et al., 2006). In forest species, Goulart et al. (2017) studied *Tabebuia serrafolia* (Vahl) G. Nichols seedlings 125 days after transplant and verified positive responses in seedling growth in height, stem diameter, canopy dry matter and root dry matter up to the level of 100 mg dm^{-3}. Ciriello et al. (2014) reported bigger growth in *Calophyllum brasiliense* Cambèss plants with the level of 40 mg dm^{-3} N at 10 months of age. However, for exotic hardwood species, such as African mahogany, there are few studies on nitrogen fertilization. Therefore, the authors in this present study aimed to assess the initial growth of African mahogany plants (*K. senegalensis* A. Juss) given nitrogen fertilization.

2. Methods

The experiment was set up in a greenhouse in the experimental area at the State University of Goiás, Ipameri Campus (geographic coordinates: 17°43′19″ latitude S and 48°09′35″ longitude W; 764 m altitude). The temperature inside the greenhouse ranged from 11 °C (minimum) to 43 °C (maximum) and the mean was 27 °C.

The soil used was classified as oxisoil (Embrapa, 2018) collected from the surface layer (0.20 to 0.40 m). The soil presented the following attributes: 620, 80 and 300 g kg^{-1} sand, silt and clay, respectively, organic matter = 9.0 g kg^{-1}, CTC (pH 7.0) = 3.36 $cmol_c$ dm^{-3}, V% = 34.6; pH ($CaCl_2$) = 5.1, H + Al = 2.2 $cmol_c$ dm^{-3}, P (Mehlich-1) = 1.2 mg dm^{-3}, B = 0.19 mg dm^{-3}, Fe = 43.9 mg dm^{-3}, K = 0.04 $cmol_c$ dm^{-3}, Ca = 0.8 $cmol_c$ dm^{-3}, Mg = 0.3 $cmol_c$ dm^{-3}, Cu = 1.9 mg dm^{-3}, Zn = 0.2 mg dm^{-3} and Mn = 3.4 mg dm^{-3}.

A completely randomized experimental design was used with five treatments and six replications, totalizing 30 experimental units with one plant each (African mahogany). The treatments were five N levels: 0, 40, 80, 120 and 160 mg dm^{-3} and urea (45%) used as fertilizer source. The levels used were equivalent to 0, 80, 160, 240 and 320 kg ha^{-1}. At the day of seedling transplant, the soil contained in the pots was fertilized with micronutrients [Mo (0.1 mg dm^{-3}), Cu (0.5 mg dm^{-3}), B (0.5 mg dm^{-3}), Zn (5 mg dm^{-3}), Mn (1.5 mg dm^{-3})] and macronutrients [K (80 mg dm^{-3}) and P (150 mg dm^{-3})]. The sources used were: Na_2MoO_4, $CuSO_4$, H_3BO_3, $ZnSO_4$, $MnSO_4$, KCl and P_2O_5, respectively. The nutrients were applied to the soil in each pot and incorporated. Each pot had 7 dm^3 capacity, with five drainage holes in the base.

After 180 days, the growth variables were assessed by measuring the stem diameter (SD), number of folioles (NF) and plant height (H). The plants were then separated into leaves, stem and roots to determine the dry matter. Finally, the parts of the plants were washed with distilled water and placed in a forced air chamber for 72 hours at 70°C until constant matter was obtained. After drying, the parts of the plant were weighed on 0.01 g precision analytic scales to determine the dry matter of the leaves (LDM), stem (SDM) and root (RDM).

To analyze the N leaf content (NCL), the leaves were ground in a Willey-type stainless steel grinder, with a 20 mesh sieve. The Kjeldahl method (Silva, 2009) was then used to determine the N. The N amount in the leaves (NAL) was obtained by multiplying the macronutrient content (g kg^{-1}) by the weight of the leaf dry matter (g).

After verifying the assumptions of normality and homogeneity of residual variances of the data, they were submitted to canonic analysis of variables and simple regression analysis to assess the influence of the N levels on each variable. The statistical analyses were carried out using the R software (R Core Team, 2018) and the candisc package (Friendly & Fox, 2017).

3. Results

There were variation among the treatments for all the variables assessed. A gradual increment of plant height, stem diameter, number of folioles, root dry matter, stem dry matter, leaf dry matter with increasing doses of N (from 0 to 160 mg dm^{-3}; Figure 1) was observed. However, the N content in the leaves had the opposite result, and the biggest values were obtained with the lowest N level (0 mg dm^{-3}).

Considering the lack of overlap between the confidence intervals, it is possible to show three distinct treatment groups: the first group contained the samples referent to the 0 mg dm^{-3} N level, where the plants had the lowest values for the growth variables; the second group was formed by the samples that received the 40 and 80 mg dm^{-3} N levels, where the plants presented intermediate development and the third group was formed by the samples fertilized with 120 and 160 mg dm^{-3} N levels where the plants presented the highest values for the growth variables (Figure 1).

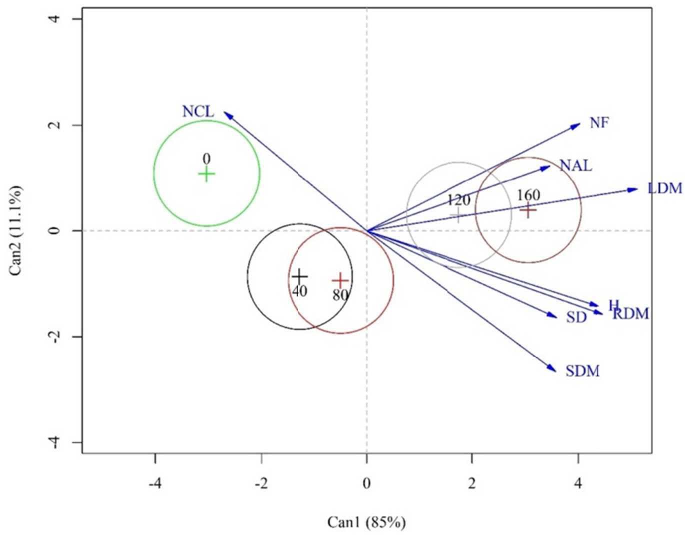

Figure 1. Biplot showing the mean values (+) and the 95% confidence intervals of the two cannonic variables obtained from plant height (H), stem diameter (SD), number of folioles (NF), root dry matter (RDM), stem dry matter (SDM), leaf dry matter (LDM), N content in the leaves (NCL) and N amount in the leaves (NAL) of *Khaya senegalensis* A. Juss plants fertilized with N levels: 0, 40, 80, 120 and 160 mg dm^{-3}

The regression functions for height, stem diameter, number of folioles, root dry matter, stem dry matter, leaf dry matter, total dry matter and N content in the leaves fitted the growing linear model. It was observed that there was an increase in all these variables starting with the application of the N 40 mg dm^{-3} level that increased with the higher applied dose (Figures 2A to 2H). However, the N content in the leaves, decreased with the increasing of dose levels, varying from 19.3 to 13.1 g kg^{-1} (Figure 2H).

The mean height of the African mahogany plants measured that received the maximum N level (160 mg dm^{-3}) was 53.8 cm, 73.7% higher than the height observed (31 cm) in the individuals that did not receive nitrogen fertilization (0 mg dm^{-3}) (Figure 2A). For others variables, the observed increases obtained with the highest N level (160 mg N dm^{-3}) in relation to the control treatment (0 mg N dm^{-3}) were: 30.6% for SD (Figure 2B); 95.5% for NF (Figure 2C); 125.1% in RDM (Figure 2D); 144.2% in SDM (Figure 2E); 168.6% in LDM (Figure 2F); and 75.6% in NAL (Figure 2G).

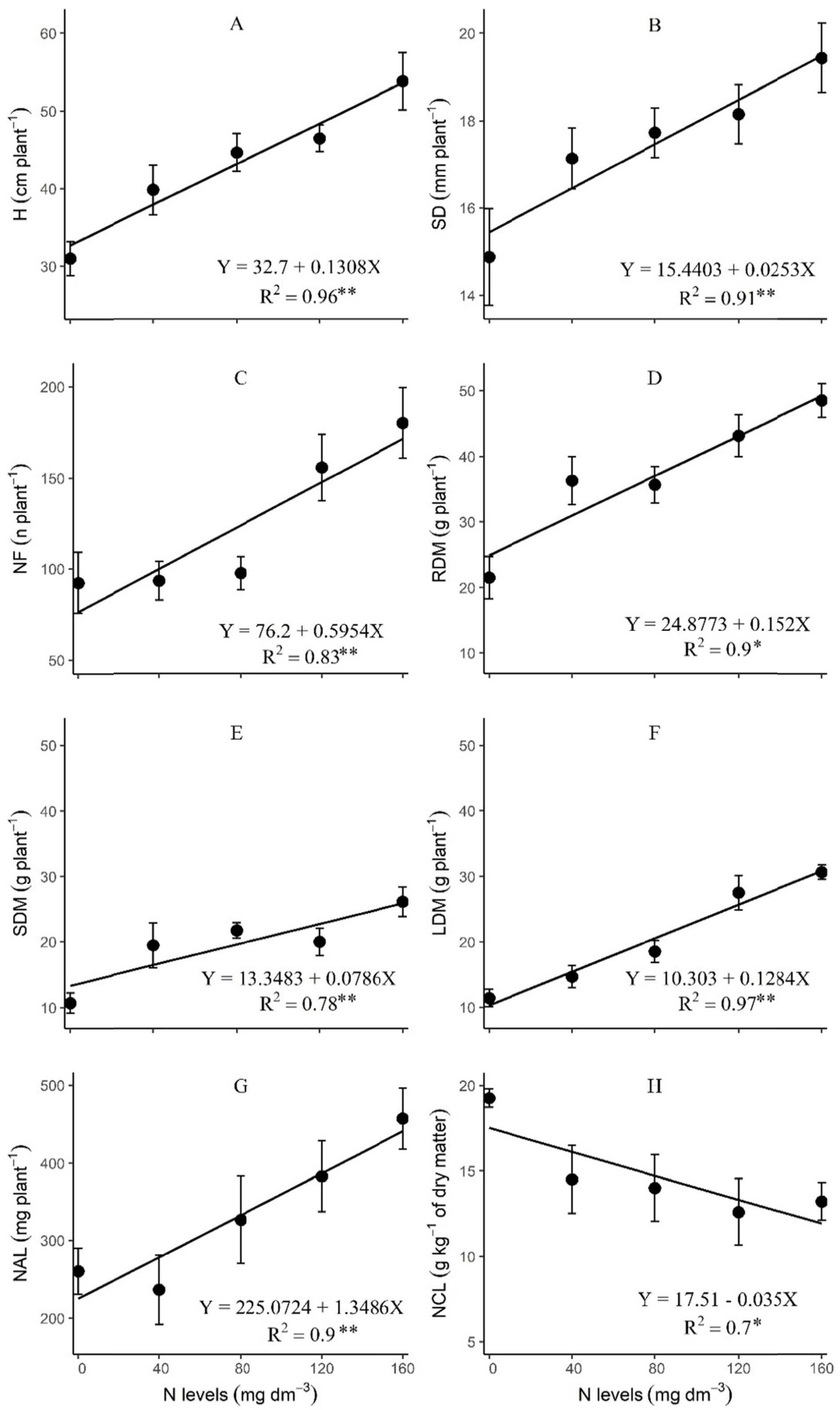

Figure 2. Result of the regression analysis for plant height (H) (A), stem diameter (SD) (B), number of folioles (NF) (C), root dry matter (RDM) (D), stem dry matter (SDM) (E), leaf dry matter (LDM) (F), N content in the leaves (NAL) (G) and N amount in the leaves (NCL) (H) of *Khaya senegalensis* A. Juss fertilized with different N levels. ** Significant at 1% probability; * significant at 5% probability. The dots indicate the means and the bars represent the standard error

4. Discussion

The increment of height, diameter, number of folioles, dry matter and N content in the leaves of African mahogany plants due to higher applied dose of N, that ranged from 30.6% to 168.6% in relation to the control, showed the importance of nitrogen fertilization in the initial plant growth of the species. Similar results were obtained by Moro et al. (2014) in *Pinus taeda* L., but they differed from those obtained by Tucci et al. (2011) in plants of *Swietenia macrophylla*. It is known that N is one of the nutrients required in a higher quantity that performs structural actions in aminoacids, proteins, and photosynthetic pigments and especially takes part in the processes of photosynthesis, respiration, cell multiplication and differentiation (Marques et al., 2006).

The biggest increasing in height, 73.7% observed with the 160 mg dm^{-3} N level application compared to the control, may be justified by the low organic matter content in the soil, 9 g kg^{-1} soil, resulting in low N supply to the plants. Seedling canopy height correlates well with initial growth in the field, and is technically accepted as a good measure of seedling performance potential (Cruz et al., 2006).

The linear regression, with increment of 30.6% in the stem diameter compared to the control, also showed a good response to nitrogen by *K. senegalensis* A. Juss in the initial development phase. Stem diameter is one of the most important parameters to estimate survival, after planting of seedlings of different forest species (Afonso et al., 2017). However, as reported in several studies, gains from N supply are much more modest or in some cases are absent in initial seedling growth. The absence of response to nitrogen fertilization in plants of *Swietenia macrophylla* King was observed by Tucci et al. (2009), and in *Peltophorum dubium* (Spreng.) Taub. by Cruz et al., (2011). Cruz et al. (2006) found an increase of up to 8% in the stem diameter due to nitrogen fertilization in *Samanea inopinata* (Harms) Ducke.

The number of leaves increased 95.5% compared to the control, while for the MSF the increasing was 168.6%. This reflected in the gains on SDM and RDM of 144.2% and 125.1%, respectively. Similar results were reported by Freiberger et al., (2013), but in *Cedrela fissilis* Vell., Cruz et al. (2006) found highest plant dry matter indicating in this way better seedling quality.

The nitrogen content found in the *K. senegalensis* A. Juss leaves decreased 31.4% with the N dose increased. This result is directly related to the effect of dilution, since there was increase of dry matter production and N accumulation (Fernandes et al., 2008). The plants that receveid increasing levels (40, 80, 120 and 160 mg dm^{-3}) showed best results in all the variables analyzed when compared to the plants given the level 0 mg dm^{-3} N level. Because that, they had lower contents of N in the leaves. The values found are considered adequate for plant growth and development, in which according to Epstein and Bloom (2006), are approximately 15 g kg^{-1}.

The linear increment obtained in the present study was due to the fact that large quantities of N are required by the plants, especially in the initial development phase (Malavolta et al., 1997). However, as the plant develops nitrogen management continues to require attention, since plants usually respond well to nitrogen fertilization, excess N is harmful and the quantities supplied to the plant should be well adjusted in relation to the quantity of the other nutrients. In this sense, Ciriello et al. (2014), worked with guanandi (*Calophyllum brasiliense* Cambèss) seedlings, in which observed positive responses to increasing N levels, but at the maximum level (160 mg dm^{-3}) there was a negative effect on diameter and root dry matter mass. Corcioli et al. (2016) studied another African mahogany species (*K. ivorensis* A. Chev.), and also showed the importance of N in the initial seedling growth, since the development of plants submitted to N omission via fertilization was negatively affected.

The responses to the nitrogen levels used in the present study showed the importance of this macronutrient on the initial biomass production in African mahogany plants however, once it is presented an increasing linear effect, the N level can not be estimated which would provide the maximum initial development to plants of this species. However, our results showed that African mahogany (*K. senegalensis* A. Juss) has high nitrogen requirement in the initial development phase.

5. Conclusions

The better performance of African mahogany seedlings was obtained with the dose of 160 mg dm^{-3} N.

This level of application can be used as fertilization for the production of species in soils with chemical and physical characteristics similar to those used in the present study.

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