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Growth of *Khaya senegalensis* plant under water deficit

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The objective of the present study was to evaluate the initial growth of *Khaya senegalensis* plants under water deficit. The work was carried out at Ipameri, Goiás on a bench in full sun following the completely randomized experimental design with six treatments and six replications. 120-day-old mahogany plants (*Khaya senegalensis*) grown in eight-liter pots were subjected to six treatments for 12 days (plants irrigated daily with 100, 80, 60, 40, 20 and 0% of evapotranspiration) with six replications. At 132 days after emergence, the plants were assessed for: plant height, stem diameter, number of leaves, foliar area, daily transpiration, relative water content, total chlorophylls and carotenoids, leaf, stem and root mass ratios, and total biomass. The data were submitted to F-test and, when significant, to regression test at 5% probability. High stomatal control, reduced transpiration, low leaf concentration of total chlorophylls and increased root system growth to the detriment of the shoot growth indicate that *Khaya senegalensis* is tolerant to moderate water deficit.

Key words: Silviculture, wood noble, forest physiology.

INTRODUCTION

Planted trees have high potential for generating wealth in Brazil. The competitiveness of the Brazilian forestry sector, resulting from technological development and fast growth and adaptation of forest species, places the country in a prominent position in the world market (Ferreira et al., 2012). The Brazilian forestry sector accounts for 3.5% of the gross domestic product (Abraf, 2013). Extensive forestry-suitable land associated with applied technology has increased the exploration of planted forests. Around 90% of the lumber produced in Brazil comes from planted forests and only 10% from plant extraction (Ibge, 2014). Despite the high potential for growth of the Brazilian forestry sector, the exploration of new areas depends on the tolerance of species to common abiotic stresses occurring in northeastern and mid-western Brazil.

Changes in climate have prolonged the frequency and intensity of dry periods and reduced rainfall in different

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regions of the world. Abiotic stress is the leading cause of low crop productivity worldwide, reducing the average yield of most crops by over 50%. In forests, drought is the major limitation to growth, establishment and survival of plants (Zang et al., 2014).

Dry periods are a challenge to plant growth and development as it causes significant metabolic changes. Low water availability decreases photosynthesis, stomatal conductance, transpiration rate and productivity of woody species. Under such circumstances, growth is typically restricted to the root system, as a strategy for water absorption from deeper soil layers (Kozlowski and Pallardy, 1997). Tolerance to water deficit is a result of several features that are expressed distinctly by the different species. Dehydration severity depends on plant age and nutrition conditions, soil type and depth, and atmospheric evaporation demand. Thus, the adoption of more than just one drought tolerance strategy is certainly suitable for any type of environment (Sambatti and Caylor, 2007; Taiz, 2013; Matos et al., 2014.).

Eucalyptus represents about 70% of planted forests in Brazil (Gonçalves et al., 2009). There is a need, therefore, to diversify the production of raw material by introducing promising drought hardy species for wood production such as *Khaya senegalensis*. The exploration of various species makes the sector less vulnerable to biotic and abiotic weather.

The African mahogany (*K. senegalensis*), an exotic species of the Meliaceae family, stands out for its excellent wood quality, high prices in domestic and international markets, wood appreciated for carpentry, woodwork, shipbuilding and production of decorative veneers (Nikiema and Pasternak, 2008). Its wood is considered to be hardwood with excellent commercial value and physical and mechanical properties similar to Brazilian mahogany (*Swietenia macrophylla*). Slow growth and high number of branches are undesirable characteristics of *K. senegalensis*. However, the timber commercial value and water deficit tolerance make the species promising to increase the agricultural frontier of forest species, particularly in areas unfit due to scarce rainfall (Pinheiro et al., 2011).

The *K. senegalensis* species evolved in a tropical wet and dry climate in West Africa (rainfall ranging between 600 to 800 annual mm) and most likely adapts well to semi-arid regions of Brazil. The *Khaya ivorensis* saplings tolerate short periods of moderate water deficit; however, this type of study is still limited to *K. senegalensis* (Albuquerque et al., 2013).

Information about *K. senegalensis* growth under abiotic stress condition is scarce and insufficient for the development of forestry programs. Elucidating physiological performance of *K. senegalensis* under water deficit condition is necessary for commercial exploration in arid and semiarid regions. Considering the need to seek information of this nature to enable the production of *K. senegalensis* in regions with low rainfall, as well as better understanding of the attributes of this species to tolerate drought, enabling its wide commercial exploration, this study aimed at evaluating the initial growth of *K. senegalensis* plants under water deficit.

MATERIALS AND METHODS

The work was carried out on a bench in full sun at the Goiás State University experimental unit in Ipameri Campus (17°43'19"S, 48°09'35"W, Alt. 773 m), Ipameri, Goiás. According to Köppen classification the region has tropical climate (Aw) with dry winter and rainy summer. Mahogany seeds (*K. senegalensis*) were sown in eight-liter pots containing a mixture of soil, sand and manure at 3:1:0.5 proportion, respectively for offering adequate water storage, aeration, mineral nutrients. After analysis of the mixture composition, the substrate pH correction and fertilization were made accordingly. At 120 days after germination the plants were submitted to six treatments for 12 days (plants irrigated daily with 100, 80, 60, 40, 20 and 0% of evapotranspiration) with six replications. The water volume supplied was estimated following recommendations of Allen et al. (2006). At 132 days after germination, the following variables were analyzed: plant height, stem diameter, number of leaves, leaf area, daily transpiration, relative water content, total chlorophylls and carotenoids, root, stem and leaf mass ratios, and total biomass.

Growth variables

The number of leaves, leaf area, plant height and stem diameter were measured using a graduated ruler and a digital pachymeter. Destructive analyses were then performed when leaves, roots and stems were oven-dried at 72°C until constant dry weight was reached, and then they were weighed separately. Using the dry matter data, the leaf, root and stem mass ratios and total biomass were calculated.

Transpiration

The daily transpiration was estimated by gravimetry, comparing the difference in weight of the pots at one-hour intervals from 07:00 and 18:00 according to Cavatte et al. (2012).

Leaf relative water content (RWC)

The relative water content was determined by extracting five 12-mm diameter foliar discs, which were weighed and saturated for 18 h in Petri dishes with distilled water. Subsequently, the discs were weighed again and dried at 70°C for 72 h, in order to obtain the dry matter weight. The specific leaf area (SLA) was obtained from the equation proposed by Pedó et al. (2013).

Photosynthetic pigments

In order to determine the total concentrations of chlorophylls and carotenoids (Chl *a*+*b*), foliar discs were extracted (third pair of fully expanded leaves) and placed in dishes containing dimethyl sulfoxide (DMSO). Subsequently, extraction was carried out in water bath at 65°C for three hours. Aliquots were extracted for spectrophotometric analysis at 490, 646 and 663 nm. Chlorophyll *a*

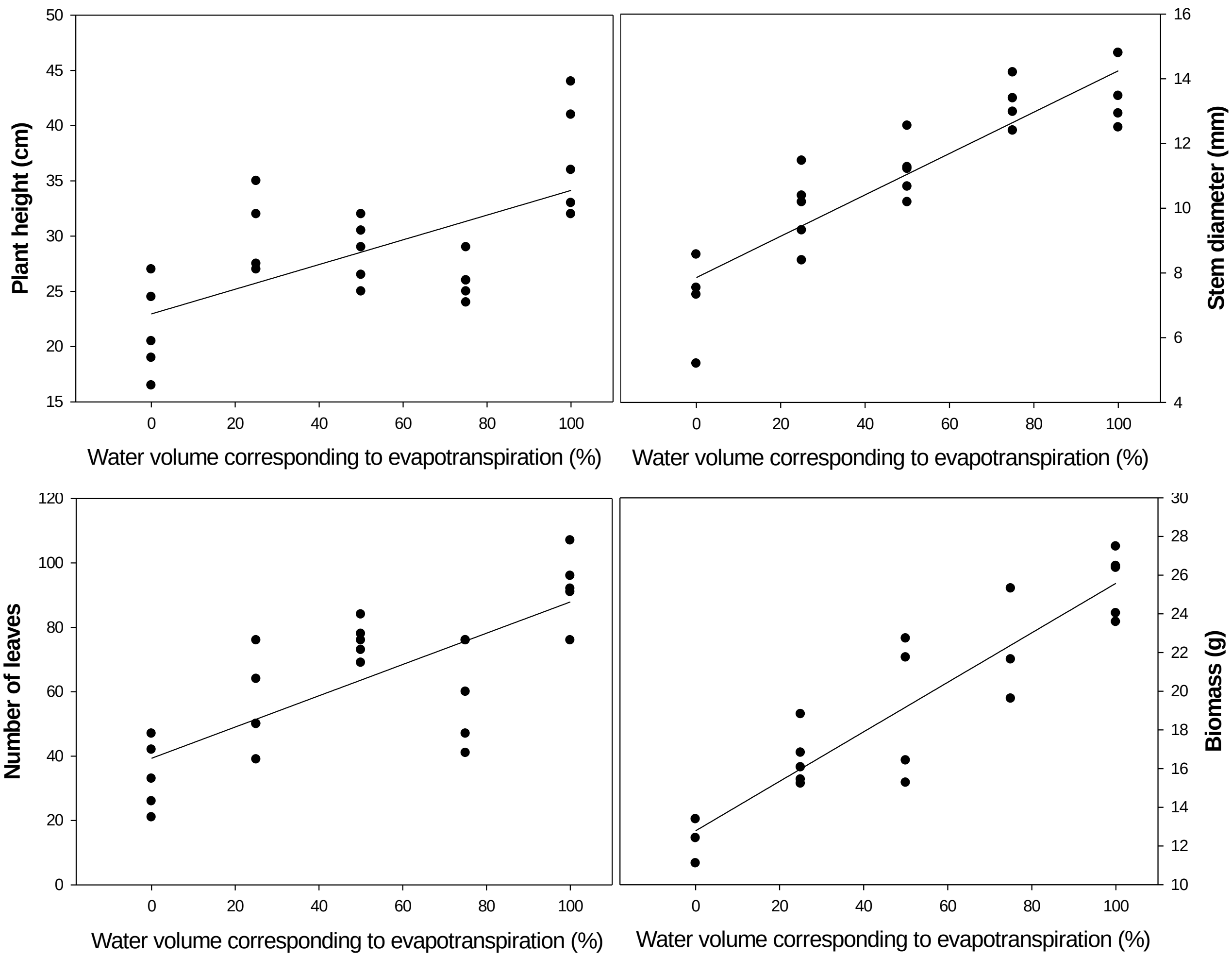

Figure 1. Regression equations for plant height Y=22.9604+0.1118x R2=0.97**, stem diameter Y=7.8564+0.0639x R2=0.99**, number of leaves Y=39.3200+0.4856x, R2=0.95** and biomass Y=12.7847+0.1279x R2=0.98** of Mahogany seedlings irrigated with different water volumes. ** Significant at 1% probability level by F test.

(Chl *a*) and chlorophyll *b* (Chl *b*) contents were determined through the equation proposed by Wellburn (1994).

Statistical procedures

Each water regime corresponded to one treatment. The variables were subjected to variance analysis following the completely randomized experimental design, with six treatments and six replications. The data were submitted to F-test and, when significant, to regression test at 5% probability. All statistical analyses were performed using SISVAR 5.3 software (Ferreira, 2011).

RESULTS

The regression curves for the growth variables: plant height, stem diameter, number of leaves and biomass are shown in Figure 1. All variables listed showed significant regression curve at 1% probability level for the F-test. The plants irrigated with water volume corresponding to 100% of daily evapotranspiration were 74% taller than the plants treated with 0% water. The same response pattern was observed for stem diameter, number of leaves and total biomass, so that the plants irrigated with 100% of evapotranspiration showed values higher than those of plants irrigated with smaller volumes of water (20, 40, 60, 80%).

The regression curves for relative water content, transpiration, leaf concentration of total chlorophylls and root mass ratio are shown in Figure 2. All the variables mentioned showed significant regression curve at 1% probability by F-test. The plants irrigated with 100% of the daily evapotranspiration water volume were 78% taller than the plants treated with 0% of water. The same response pattern was observed for the relative water content, so that the plants irrigated with 100% of

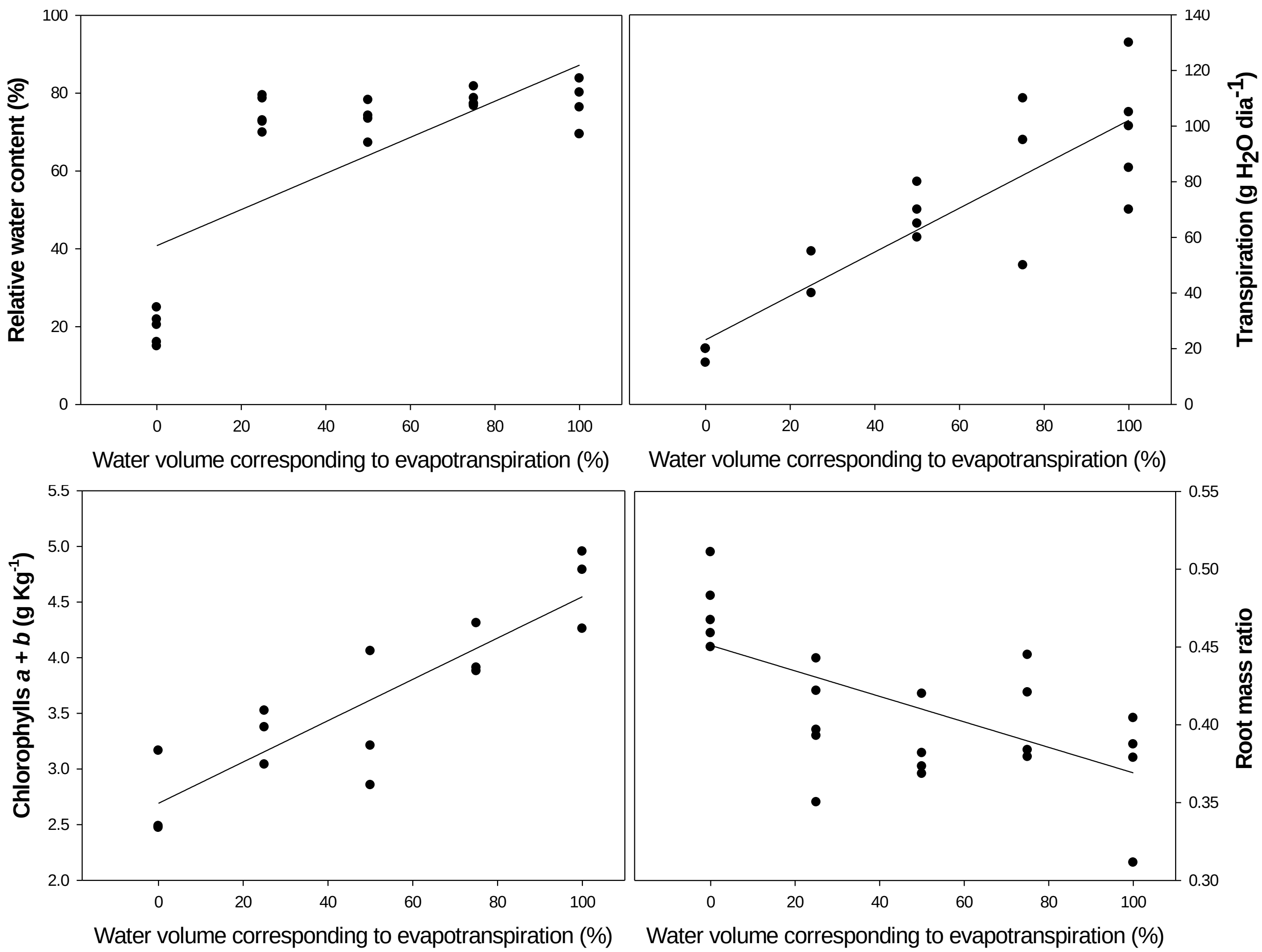

Figure 2. Regression equations for relative water content Y=40.8162+0.4639x, R^2=0.94**; transpiration Y=23.2084+0.7888x, R^2=0.78**; Y=2.6919+0.0186x, R^2=0.99**; chlorophylls (*a*+*b*) Y=2.6919+0.0186x, R^2=0.99** and root mass ratio Y=0.4510 – 0.0008x R^2=0.99** of Mahogany seedlings irrigated with different water volumes. ** Significant at 1% probability by F test.

evapotranspiration showed higher values than those of the plants irrigated with smaller water volumes (20, 40, 60, 80%). The leaf chlorophyll concentration was 59% higher in plants irrigated with 100% of evapotranspiration water volume. The plants irrigated with smaller volumes of water showed higher root mass ratio values. The plants treated with 0% of water content showed root mass ratio values 82% higher than those of plants irrigated with 100% of evapotranspiration.

DISCUSSION

The identification of forest species tolerant to drought is indispensable for the expansion of the agricultural frontier in the Brazilian semiarid region. Tolerance to abiotic stresses is a key factor for the survival and establishment of forest species in tropical ecosystems (Worbes et al., 2013). In forests, drought is a major obstacle to the establishment, growth and productivity of plants, as it is for most terrestrial plant communities (Allen et al., 2010; Luyssaert et al., 2010). Low water availability in the soil resulted in lower relative water content in the plant and considerably affected the growth of *K. senegalensis*. The reduced values of plant height, stem diameter and number of leaves in plants under water stress indicate that the species growth is highly sensitive to the plant water status. In addition, it is noted that plants irrigated with water volume equivalent to 80% of evapotranspiration already presented reduced variables. Studies have associated greater drought tolerance in trees with low growth rates (Rose et al., 2009; Taeger et al., 2013.).

The reduced transpiration rate in plants under water stress is associated with high stomatal sensitivity and efficient mechanism for water loss reduction through stomatal closing. The high stomatal control, typical of isohydric plants, has probably affected the carbon assimilation rate and, consequently, the accumulation of biomass and plant growth under low water availability, as stomatal closing also limits CO_2 inflow, while limiting the loss of water in vapor form. The results corroborate those found by Lima et al. (2007) when evaluating transpiration and stomatal conductance in *Swietenia macrophylla* plants under water deficit. According to Hommel et al. (2014), stomatal closing in response to water deficit alters the water use efficiency and decreases the photosynthetic rate.

The reduction in leaf chlorophyll concentration can be associated with the species photoprotection mechanism, because under water deficit condition, the formation of free radicals that damage membranes and proteins is common (Matos et al., 2009). In these circumstances the reduced absorption of light energy due to low chlorophyll concentration is an important morphophysiological adjustment to minimize the deleterious effects of excess photochemical energy. The high root mass ratio in plants under water stress indicates that even in a position of diffusive limitation and photosynthesis reduction, the plants partitioned assimilates to the root system growth. According to Albuquerque et al. (2013), *K. senegalensis* plants under water deficit invest part of the phosphate trioses in maintaining the starch content. Later on, glucose is broken, which through respiration produces ATP to support the growth of the root system. The results of this study corroborate those found by Ky-Dembele et al. (2010), who found greater root system growth when assessing growth responses of *K. senegalensis* under water deficit and Okali and Dodoo (1973) reported the reduction of perspiration and increase in the partitioning of assimilates to the root system of plants *K. senegalensis*.

The high stomatal control, low transpiration, reduced total leaf chlorophyll concentration and increased growth of the root system at the expense of the shoot growth show that *K. senegalensis* is tolerant to moderate water deficit.

Conclusions

1. *K. senegalensis* plants show efficient morpho-physiological adjustment to reduce water loss through transpiration and increase the root system growth under water deficit condition.
2. *K. senegalensis* plants are tolerant to moderate water deficit.

Conflict of Interests

The authors have not declared any conflict of interests.

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