UFSM

# Ciência Florestal

ISSN 1980-5098
Open access

Ci. Fl., Santa Maria, v. 32, n. 2, p. 1047-1060, Apr./June 2022 • https://doi.org/10.5902/1980509847949
Submitted: 2nd/07/2020 • Approved: 26th/08/2021 • Published: 24th/06/2022

**Nota Técnica**

# Volume, biomass, carbon stock and efficiency of water use in irrigated eucalyptus

## Volume, biomassa, estoque de carbono e eficiência do uso da água em eucalipto irrigado

**Adriano da Silva Lopes[I], Marcos Vinicius Folegatti[II], Eder Duarte Fanaya Júnior[III], Gabriel Queiroz de Oliveira[IV], Jean Carlos Lopes de Oliveira[V], Kelvin Melgar Rosalvo Brito[I], Norton Hayd Rego[I]**

[I]Universidade Estadual de Mato Grosso do Sul, Aquidauana, MS, Brazil
[II]Universidade de São Paulo, Piracicaba, SP, Brazil
[III]Instituto Federal de Educação, Ciência e Tecnologia Catarinense, Camboriú, SC, Brazil
[IV]Freelance Researcher, Dourados, MS, Brazil
[V]Universidade Federal do Espírito Santo, Jerônimo Monteiro, ES, Brazil

## ABSTRACT

Since eucalyptus is a fast-growing plant, it offers advantages in comparison to other forest species, and the use of localized irrigation systems can increase yield and reduce time to cutting. The aim of this study was to evaluate two eucalyptus hybrids, growth in crop condition: irrigated and dry land, during the first year of development of the crop. The experiment was set up in April 2011 in the irrigation experimental area of the State University of Mato Grosso do Sul, in the municipality of Aquidauana, Mato Grosso do Sul, Brazil. A randomized block experimental design was use in split-plots, with four blocks and two replications within each block. Plots were composed of the irrigation treatments (drip, micro sprinkler and no irrigation), and the subplots were composed of two eucalyptus hybrids (Grancam and Urograndis). Evaluations occurred at 60, 120, 180, 240, 300 and 360 days after transplant (DAT), measuring the height of plants and trunk diameter; and, thus, the volume, biomass, carbon stock and efficiency in water use in all the periods evaluated was estimated. Data were subject to analysis of variance and compared by the Tukey test at the level of 5% probability. It is concluded that at 360 DAT, the drip and micro sprinkler irrigations led to gains in biomass and carbon stock of around 190% as compared to eucalyptus without irrigation.

**Keywords:** Drip irrigation; Micro sprinkler; Grancam; Urograndis

## RESUMO

Como o eucalipto é uma planta de crescimento rápido, oferece vantagens em comparação com outras espécies florestais, e o uso de sistemas de irrigação localizados pode aumentar o rendimento e reduzir o tempo de corte. O objetivo deste estudo foi avaliar o crescimento de dois híbridos de eucalipto, em condição de cultura: terra irrigada e seca, durante o primeiro ano de desenvolvimento da cultura. O experimento foi realizado em abril de 2011 na área experimental de irrigação da Universidade Estadual de Mato Grosso do Sul, no município de Aquidauana, MS, Brasil. O delineamento experimental foi em blocos casualizados, com quatro blocos e duas repetições em cada bloco. As parcelas foram compostas pelos tratamentos de irrigação (gotejamento, microaspersão e sem irrigação), e as subparcelas foram compostas por dois híbridos de eucalipto (Grancam e Urograndis). As avaliações ocorreram aos 60, 120, 180, 240, 300 e 360 dias após o transplante (DAT), medindo a altura das plantas e o diâmetro do tronco; e, assim, foram estimados o volume, a biomassa, o estoque de carbono e a eficiência no uso da água em todos os períodos avaliados. Os dados foram submetidos à análise de variância e comparados pelo teste de Tukey ao nível de 5% de probabilidade. Conclui-se que, a 360 DAT, as irrigações por gotejamento e microaspersão levaram a ganhos de biomassa e estoque de carbono de cerca de 190% em comparação com o eucalipto sem irrigação.


**Palavras-chave:** Irrigação por gotejamento; Micro aspersor; Grancam; Urograndis

## 1 INTRODUCTION

Brazil has grown eucalyptus as a crop since 1908 and currently 6.97 million hectares of Brazilian land is covered by commercially grown eucalyptus forests (INDÚSTRIA BRASILEIRA DE ÁRVORES, 2020). Just as for other exotic crops, such as coffee, sugarcane and soybeans, some species of eucalyptus have found ideal conditions for large scale production in Brazilian soil and climatic conditions. Conditions are so ideal that practically all the large cellulose and wood industries from around the world are present in Brazil. Allied with preservation of native forests, eucalyptus absorbs 196 million tons of atmospheric carbon per year, contributing to reduction of the greenhouse effect (QUEIROZ; BARRICHELO, 2007).

According to Alves *et al*. (2013), there is little information on the water needs of the eucalyptus crop for various reasons, such as the hardiness of eucalyptus, the high cost involved in setting up irrigation systems due to the dimensions of the planted area and, moreover, because eucalyptus is traditionally a dryland crop.

Carneiro *et al*. (2008) say that, reforestation with eucalyptus is still a controversial matter in regard to water consumption and its relationship to water availability in watersheds. The search for knowledge of the interactions that occur between the environmental conditions and the gas exchanges in the tree canopy are essential for determination of the amount of water transpired by these forests.

Martins *et al*. (2008), in a study performed for the purpose of detecting the effect of soil water deficit on eucalyptus species, found that the values of the water fraction that may be transpired in relation to the eucalyptus species (*Eucaliptus grandis* and *Eucaliptus saligna*) were greater than those of most annual and perennial crops studied, indicating good adaptation of these species to soil water deficit.

Smith, Heath and Woodbury (2004) mentioned that studies on carbon capture are important in the evaluation of a forest as a natural resource, as well as in the relationship between climate changes and the accumulation of greenhouses gases in the atmosphere since forests remove carbon dioxide from the atmosphere and store it in organic form.

Therefore, considering the forest productivity, corresponds to the biomass developed proportion in a given period, would with or without irrigation, provide a different biomass accumulation and carbon stock for both situations? Irrigated treatments are expected to be more efficient than the control, and there's a hierarchy in performance between hybrids and irrigation systems. Therefore, the work's aim was to evaluate the two eucalyptus hybrids productivity behavior, under two localized irrigation systems in different periods after plantation.

## 2 MATERIAL AND METHODS

The study was conducted in the irrigated agriculture experimental area at the Aquidauana University Unit of the State University of Mato Grosso do Sul (UUA/UEMS), located in the municipality of Aquidauana, Mato Grosso do Sul State, Brazil, with the geographic coordinates 20°20' South, 55°48' West and mean altitude of 174 meters.

Climate in the region, according to the Köppen classification, was describe as Aw, i.e., hot tropical wet and dry climate, with a rainy season in the summer and dry season in the winter, and mean annual rainfall of 1200 mm. According to Schiavo *et al*. (2010) the soil of the experimental field features as characteristics the textural B horizon presence, such as low CTC (<27 $cmol_c$ $kg^{-1}$ clay) and low base saturation, which makes it fall under the subgroup level as a typical Ultisol.

Nitrogen, Potassium and Phosphate fertilization upon planting the seedlings was carried out based on soil chemical analysis (Table 1) and according to the recommendations of Andrade (2004), corresponding to 30 and 40 kg $ha^{-1}$ of $P_2O_5$ and $K_2O$, respectively.

Table 1 – Chemical characterization of soil

| **Depth (m)** | ***pH** | **P** | **O.M.** | **K** | **Ca** | **Mg** | **Al** | **H+Al** | **BS** | **CEC** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **mg $dm^{-3}$** | **g $dm^{-3}$** | **$cmol_c$ $dm^{-3}$** | | | | | | |
| 0.0 – 0.2 | 6.5 | 16.6 | 22.0 | 0.66 | 3.7 | 0.9 | 0.0 | 2.2 | 5.26 | 7.46 |
| 0.2 – 0.4 | 6.3 | 12.6 | 13.0 | 0.28 | 3.4 | 0.7 | 0.0 | 2.2 | 4.38 | 6.58 |
| 0.4 – 0.6 | 6.2 | 7.3 | 9.0 | 0.16 | 2.6 | 0.6 | 0.0 | 2.0 | 3.36 | 5.36 |

Source: Authors (2020)

In where: *pH in water 1:2.5. O.M. – Organic Matter; BS – Base Saturation; CEC – Capacity Exchange Cations.

On April 19th, 2011, planting holes were dug, within which the NPK fertilizer 04-20-20 was mixed with soil in the amount of 115 g per plant (127.78 kg $ha^{-1}$).

Before setting up the experiment, the area was disked and weed control was carried out by desiccating weeds with the application of glyphosate herbicide at the rate of 4.0 L $ha^{-1}$ of the commercial product containing 360 g a.i. $L^{-1}$.

The experimental design was randomized blocks with split-plots, using four blocks and two replications within each block. The treatments used in the plots consisted of two irrigation systems (micro sprinkler and drip) and a dryland area. In the split-plots, the treatments were the eucalyptus hybrids, namely, Urograndis, clone I224 (*Eucalyptus urophilla x E. grandis)* and Grancam, clone 1277 (*E. grandis* x *E. camaldulensis)*.

The experimental area was three hectares (3.0 ha), 1.0 ha with a drip irrigation system, 1.0 ha with a micro sprinkler irrigation system and 1.0 ha without irrigation. The eucalyptus seedlings/plantlets were transplanted in the field on April 20th, 2011; the seedlings had an average height of 30 cm and were space at 2.25 x 4.00 m.

The area irrigated by drip irrigation was composed of pressure compensating drip emitters with a flow rate of 2.4 L $h^{-1}$, a spacing of 0.5 m between emitters and working pressure of 100 kPa. In the case of micro sprinkler irrigation, micro sprinkler nozzles were use with an individual flow rate of 48 L $h^{-1}$, 1.5 m sprinkler radius and working pressure of 400 kPa, set up at 30 cm from each plant.

Each split-plot contained two experimental units (useful area) with ten plants; the areas of the experimental units were composed of two rows of plants, each row with a length of 11.25 m, corresponding to 90 $m^2$.

Irrigation management was based on the estimate of reference evapotranspiration (ETo) from equation of Penman-Monteith (ALLEN *et al*., 1998). Crop evapotranspiration (ETc) was estimate according to Eq. (1), followed by adaptations for localized irrigation calculated according to Eq. (2) (BERNARDO; SOARES; MANTOVANI, 2008):

$$ETc = EToKc \quad (1)$$

In which: Kc – crop coefficient (0.70 – 0.82) estimated daily for Eucalyptus (ALVES *et al*., 2013).

$$ETc_{Loc} = ETc\ K_L \quad (2)$$

In which: $ETc_{Loc}$ – crop evapotranspiration according to the localized irrigation method, mm $d^{-1}$; and $K_L$ – correction factor according to the localized irrigation method, estimated according to Eq. (3) (BERNARDO; SOARES; MANTOVANI, 2008).

$$K_L = 0.1\sqrt{PWA} \quad (3)$$

In which: PWA – Percentage of wetted area calculated according to Bernardo, Soares and Mantovani (2008).

The drip and micro sprinkler irrigation systems obtained PWA values of 25% and 79%, respectively. For calculation of the irrigation water depth, readily available water for localized irrigation ($RAW_{Loc}$) was use as a criterion, which was calculate according to Eq. (4).

$$RAW_{Loc} = \left(\theta_{fc} - \theta_{pwp}\right) Z \, p \, \frac{PWA}{100} \quad (4)$$

In which: $\theta_{fc}$ – soil moisture at field capacity (matric potential of -10 kPa, $m^3\ m^{-3}$); $\theta_{pwp}$ – soil moisture at the permanent wilting point (matric potential of -1500 kPa, $m^3\ m^{-3}$); Z – depth of the root system, 970 mm (REIS *et al*., 2006); and "p" – soil water depletion factor for conifers (0.7), recommended by Allen *et al*. (1998).

The $RAW_{Loc}$ was 38.9 and 58.8 mm for drip irrigation and micro-sprinkler irrigation. Nevertheless, irrigation was always carry out when the sum of the $ETc_{Loc}$ was greater than or equal to 9.0 mm.

Data collection began at 60 DAT (days after planting) (June 19th 2011) and was undertaken every 60 days up to 360 DAT, at which time plant height (HEI) and stem diameter (SD) were measured. HEI was measure with the aid of a tape measure, and the unit of measure used was centimeters (cm). SD was measure with a caliper rule in millimeters (mm), which was converted to "cm". With these parameters, it was possible to quantify stem volume (SV) per plant, which was estimate according to Eq. (5).

$$SV = SBA\ HEI\ 0.5 \quad (5)$$

In which: SV – stem volume, $cm^3$; SBA – stem basal area, $cm^2$; HEI – plant height, cm; and 0.5 – eucalyptus form factor (VILAS BÔAS; MAX; MELO, 2009).

In the individual plant biomass estimate (Y) and, consequently, fixed carbon stock, besides the model proposed by Brown (1997) was use, corresponding to Eq. 6:

$$Y = \exp\left[-3.1141 + 0.9719 \ln\left(SD^2\ HEI\right)\right] \quad (6)$$

For the estimate of carbon stock, equation 7 was multiply by 0.47, the coefficient suggested by Eggelston *et al*. (2006).

Water use efficiency (WUE) was determined between the biomass ratio/reading (kg) and total amount of water precipitated (mm) in each period, for all the treatments.

With this data in hand, analysis of variance was make for each parameter. For those that showed a significant effect of the treatments by the F test, the Tukey mean comparison test was carry out at 5% probability using the software Statistical Analysis Systems, version 9.0.

## 3 RESULTS AND DISCUSSION

The total water depths (irrigation + rainfall) applied during the experiment were 1277.89; 1,455.60 and 914.63 mm, respectively, for the drip irrigation, micro sprinkler and dryland management systems; the water depth from rainfall corresponded to 914.63 mm. It may thus be observed that in this period the total water depth for eucalyptus irrigated by micro sprinkler irrigation was 12% greater than eucalyptus irrigated by drip irrigation and 37.17% greater than that of dryland management.

There was an effect of the irrigation systems on the eucalyptus parameters evaluated in all the periods evaluated in Aquidauana (Table 2). At 60 DAT, the SV obtained mean values of 0.0031 and 0.0035 $cm^3$, respectively, with the drip and micro sprinkler irrigation systems. They differed from each other; however, both differed from dryland management (0.0028 $cm^3$). As of 120 DAT, it was observed that the micro sprinkler treatment did not differ from the drip irrigation for SV, while at 360 DAT, the difference in volume of the irrigated treatments as compared to dryland management was already approximately 200%.

Table 2 – Average values to stem volume (SV), biomass, fixed carbon and water use efficiency (WUE) of irrigated and dryland eucalyptus, according to days after transplantation (DAT), in Aquidauana, Mato Grosso do Sul State, Brazil. 2011/2012

| Irrigation | SV ($dm^3$) | Biomass (kg) | Carbon (kg) | WUE ($kg\ mm^{-1}\ ha^{-1}$) |
|---|---|---|---|---|
| | | 60 DAT | | |
| Drip | 0.0031b | 0.0038b | 0.0018b | 0.0361b |
| Micro-sprinkler | 0.0035a | 0.0043a | 0.0020a | 0.0333c |
| Dryland | 0.0028c | 0.0034c | 0.0016c | 0.0634a |
| DMS | 0.0002 | 0.0002 | 0.0001 | 0.0023 |
| | | 120 DAT | | |
| Drip | 0.0128a | 0.0149ab | 0.0070ab | 0.1023a |
| Micro-sprinkler | 0.0177a | 0.0203a | 0.0095a | 0.1017a |
| Dryland | 0.0081b | 0.0095b | 0.0044b | 0.1174a |
| DMS | 0.00750 | 0.00826 | 0.00388 | 0.04478 |
| | | 180 DAT | | |
| Drip | 0.0569ab | 0.0633ab | 0.0298ab | 0.2464a |
| Micro-sprinkler | 0.0849a | 0.0930a | 0.0437a | 0.2961a |
| Dryland | 0.0402b | 0.0450b | 0.0212b | 0.3549a |
| DMS | 0.0396 | 0.0421 | 0.0198 | 0.1692 |
| | | 240 DAT | | |
| Drip | 0.3432a | 0.3626a | 0.1704a | 0.6481a |
| Micro-sprinkler | 0.3691a | 0.3898a | 0.1832a | 0.5958a |
| Dryland | 0.2088b | 0.2232b | 0.1049b | 0.5781a |
| DMS | 0.12257 | 0.12677 | 0.05958 | 0.20511 |
| | | 300 DAT | | |
| Drip | 1.5324a | 1.5554a | 0.7310a | 2.0397a |
| Micro-sprinkler | 1.9961a | 2.0111a | 0.9452a | 2.2703a |
| Dryland | 0.4599b | 0.4818b | 0.2265b | 0.9601b |
| DMS | 0.5618 | 0.5546 | 0.2607 | 0.6899 |
| | | 360 DAT | | |
| Drip | 4.4045a | 4.3413a | 2.0404a | 3.7744a |
| Micro-sprinkler | 4.9317a | 4.8450a | 2.2772a | 3.6980a |
| Dryland | 1.5669b | 1.5879b | 0.7463b | 1.9289b |
| DMS | 1.96262 | 1.87564 | 0.88155 | 1.47037 |

Source: Authors (2020)

In where: Mean values followed by different letters, in the same DAT period, differ among themselves at the level of 5% probability by the Tukey test.

It was also observed that the biomass and the carbon fixed at 60 DAT exhibited the same behavior as occurred for SV, in the irrigation treatments at 60 DAT (Table 2), i.e., micro sprinkler irrigation led to better results than drip irrigation and dryland management. Over the 360 DAT, the increase in biomass and in fixed carbon for the irrigation treatment in relation to dryland management was around 190%.

WUE showed quite different behavior in eucalyptus development about the effect of irrigation. Eucalyptus hybrids irrigated by drip and micro sprinkler irrigation, on the one hand, and dryland management, on the other, were statistically different at 60 DAT, such that the dryland management obtained the highest average (Table 2).

From the period of 120 to 240 DAT, WUE did not obtain a difference at the 5% level of probability for the irrigation treatments. As of the period of 300 DAT, it was found that there was inversion in the behavior of WUE in relation to the beginning of the period (60 DAT), showing that irrigation led to a greater quantity of biomass per water content applied.

According to Carneiro *et al*. (2008), the effect of irrigation provided moisture at the depth of 60 to 90 cm due to water application by the drip irrigation system, in Entisols. There may be a greater concentration of fine roots in this layer, which are more efficient in extraction from the soil solution, contributing to an increase in development of the eucalyptus.

Only at 60 DAT was observed that the SV, biomass, fixed carbon and WUE of the Grancam hybrid were not significantly greater than the Urograndis hybrid (Table 3). For the period evaluated, these results indicate that the parameters evaluated are strongly connect to the trait of a genetic nature of the Grancam hybrid.

For Reis *et al*. (2006), the Grancam hybrid showed a tendency toward greater height, diameter and volume in the non-irrigated treatment, a behavior different from the Urograndis hybrid, whose growth tended to be greater in the irrigated treatment. Nevertheless, these same authors explained its greater growth under water stress through the fact that the Grancam hybrid has deep roots (0.97 m) and a greater proportion of biomass allocated to the root system (26%).

Table 3 – Stem volume (SV), biomass, fixed carbon and water use efficiency (WUE) for the eucalyptus hybrids, according to days after transplantation (DAT), in Aquidauana, MS, Brazil. 2011/2012

| Clone | SV ($dm^3$) | Biomass (kg) | Carbon (kg) | WUE ($kg\ mm^{-1}\ ha^{-1}$) |
|---|---|---|---|---|
| | | 60 DAT | | |
| Grancam | 0.0030b | 0.0036b | 0.0017b | 0.0433b |
| Ugrandis | 0.0033a | 0.0041a | 0.0019a | 0.0453a |
| | | 120 DAT | | |
| Grancam | 0.0191a | 0.0219a | 0.0103a | 0.1580a |
| Ugrandis | 0.0066b | 0.0079b | 0.0037b | 0.0563b |
| | | 180 DAT | | |
| Grancam | 0.0935a | 0.1027a | 0.0483a | 0.4646a |
| Ugrandis | 0.0278b | 0.0315b | 0.0148b | 0.1336b |
| | | 240 DAT | | |
| Grancam | 0.4395a | 0.4629a | 0.2176a | 0.8774a |
| Ugrandis | 0.1745b | 0.1875b | 0.0881b | 0.3373b |
| | | 300 DAT | | |
| Grancam | 1.7286a | 1.7484a | 0.8217a | 2.3101a |
| Ugrandis | 0.9303b | 0.9505b | 0.4468b | 1.2033b |
| | | 360 DAT | | |
| Grancam | 4.5957a | 4.5280a | 2.1282a | 4.0091a |
| Ugrandis | 2.6730b | 2.6548b | 1.2478b | 2.2584b |

Source: Authors (2020)

In where: Mean values followed by different letters, in the same DAT period, differ among themselves at the level of 5% probability by the F test.

According to Stape *et al*. (2010), although irrigation causes a significant increase in volume and SV in most studies, there are still controversies in the manner of quantifying efficiency in water use. Almeida *et al*. (2007) showed that water use efficiency in this species varies dramatically according to leaf area index and the age of the populations.

Comparing the SV in this study, it is clear that, initially, the development of eucalyptus hybrids under the effect of irrigation is greater than dryland eucalyptus. Since the present study was carried out over 360 DAT, we suggest subsequent evaluations quantifying the soil water availability in regard to water use efficiency in growing eucalyptus.

Among the climatic characteristics, water deficit has been reported as limiting environmental factor the achievement of high productivity for Eucalyptus (STAPE; BINKLEY; RYAN, 2004). According to Gatto *et al*. (2010), eucalyptus plantations are effective option for carbon capture and can immobilize at least 50,000 kg $ha^{-1}$ $year^{-1}$ of $CO_2$ from the atmosphere.

## 4 CONCLUSIONS

Throughout the development of the Grancam and Urograndis eucalyptus hybrids in Aquidauana, Mato Grosso do Sul State, Brazil, the drip and micro sprinkler irrigation systems provide greater stem volume, biomass and fixed carbon in comparison to non-irrigated hybrids.

At 360 DAT, the drip and micro sprinkler irrigations led to gains in biomass and carbon stock of around 190% as compared to eucalyptus without irrigation.

As of 300 days after transplanting, the irrigated treatments lead to greater water use efficiency by the eucalyptus trees.

In the period from 120 to 360 days after transplanting, the Grancam hybrid shows better parameters than Urograndis in stem volume, biomass, fixed carbon and water use efficiency.

## REFERENCES

ALLEN, R. G. *et al*. **Crop Evapotranspiration**: guidelines for computing crop requirements. Roma: FAO, 1998.

ALMEIDA, A. C. *et al*. Growth and water balance of *Eucalyptus grandis* hybrid plantations in Brazil during a rotation for pulp production. **Forest Ecology and Management**, Amsterdam, v. 251, n. 1/2, p. 10-21, 2007.

ALVES, M. E. B. *et al*. Estimate of the crop coefficient for Eucalyptus cultivated under irrigation during initial growth. **Cerne**, Lavras, v. 19, n. 2, p. 247-253, 2013.

ANDRADE, L. R. M. Corretivos e fertilizantes para culturas perenes e semiperenes. *In*: SOUSA, D. M. G.; LOBATO, E. (ed.). **Cerrado, correção do solo e adubação**. Brasília: Embrapa, 2004. p. 317-366.

BERNARDO, S.; SOARES, A. A.; MANTOVANI, E. C. **Manual de irrigação**. Viçosa: Editora UFV, 2008.

BROWN, S. **Estimating biomass and biomass change of tropical forests**: a primer. Roma: FAO, 1997.

CARNEIRO, R. L. C. *et al*. Consumo de água em plantio de eucalipto: parte 2 – Modelagem da resistência estomática e estimativa da transpiração em tratamentos irrigados e não-irrigados. **Revista Árvore**, Viçosa, MG, v. 32, n. 1, p. 11-18, 2008.

EGGELSTON, S. *et al*. **IPCC Guidelines for National Greenhouse Gas Inventories**. Kanagawa: IGES, 2006.

GATTO, A. *et al*. Estoques de carbono no solo e na biomassa em plantações de eucalipto. **Revista Brasileira de Ciência do Solo**, Viçosa, MG, v. 34, n. 4, p. 1069-1079, 2010.

INDÚSTRIA BRASILEIRA DE ÁRVORES. **Relatório Anual 2020**. Brasília, DF, 2020. Disponível em: https://iba.org/datafiles/publicacoes/relatorios/relatorio-iba-2020.pdf. Acesso em: 05 abr. 2021.

MARTINS, F. B. *et al*. Deficiência hídrica no solo e seu efeito sobre transpiração, crescimento e desenvolvimento de mudas de duas espécies de eucalipto. **Revista Brasileira de Ciência do Solo**, Viçosa, MG, v. 32, n. 3, p. 1297-1306, 2008.

QUEIROZ, L. R. S.; BARRICHELO, L. E. G. **O eucalipto - Um século no Brasil**. São Paulo: Neoband Soluções Gráficas, 2007.

REIS, G. G. *et al*. Crescimento de raízes e da parte aérea de clones de híbridos de Eucalyptus grandis x Eucalyptus urophylla e de Eucalyptus camaldulensis x Eucalyptus spp submetidos a dois regimens de irrigação no campo. **Revista Árvore**, Viçosa, MG, v. 30, n. 6, p. 921-931, 2006.

SCHIAVO, J. A. *et al*. Caracterização e classificação de solos desenvolvidos de arenitos da formação Aquidauana-MS. **Revista Brasileira de Ciência do Solo**, Viçosa, MG, v. 34, n. 3, p. 881-889, 2010.

SMITH, J. E.; HEATH, L. H.; WOODBURY, P. B. How to estimate forest carbon for large areas from inventory data. **Journal of Forestry**, Washington, v. 102, p. 25-31, 2004.

STAPE, J. L.; BINKLEY, D.; RYAN, M. G. Eucalyptus production and the supply, use and efficienty of the use of water, light and nitrogen across a geographic gradient in Brazil. **Forest Ecology and Management**, Amsterdam, v. 193, n. 1/2, p. 17-31, 2004.

STAPE, J. L. *et al*. Influence of water, nutrients and stand structure on wood production in the eight sites of the Brazil *Eucalyptus* Potential Productivity Project. **Forest Ecology and Management**, Amsterdam, v. 259, n. 9, p. 1684-1694, 2010.

VILAS BÔAS, O.; MAX, J. C. M.; MELO, A. C. G. Crescimento comparativo de espécies de Eucalyptus e Corymbia no município de Marília, SP. **Revista do Instituto Florestal**, São Paulo, v. 21, n. 1, p. 63-72, 2009.

## Authorship Contribution


### 1 – Adriano da Silva Lopes

Agronomist, Dr., Professor

https://orcid.org/0000-0003-2211-6576 • lopes@uems.br


Contribution: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Software, Validation, Visualization (Tables), Writing – original draft, Writing – review & editing


### 2 – Marcos Vinicius Folegatti

Agronomist, Dr., Professor

https://orcid.org/0000-0002-9510-5176 • mvfolega@usp.br


Contribution: Resources, Supervision


### 3 – Eder Duarte Fanaya Júnior

Agronomist, Dr., Professor

https://orcid.org/0000-0002-2292-6504 • eder.fanaya@ifc.edu.br


Contribution: Visualization (Tables), Writing - review & editing


### 4 – Gabriel Queiroz de Oliveira

Agronomist, Dr., Freelance Researcher

https://orcid.org/0000-0001-8801-6864 • gabrielqo@hotmail.com


Contribution: Writing – review & editing


### 5 – Jean Carlos Lopes de Oliveira

Forestry Engineer, MSc., Doctoral Student

https://orcid.org/0000-0003-3547-5439 • oliveirajcl34@gmail.com


Contribution: Writing – review & editing


### 6 – Kelvin Melgar Rosalvo Brito

Forestry Engineer, MSc., Doctoral Student

https://orcid.org/0000-0002-0687-6017 • kelvin_rosalvo@hotmail.com


Contribution: Writing – review & editing

**7 – Norton Hayd Rego**

Agronomist, Dr., Professor

https://orcid.org/0000-0002-2364-1674 • norton@uems.br

Contribution: Conceptualization, Methodology

## How to quote this article

Lopes, A. S.; Folegatti, M. V.; Fanaya Júnior, E. D.; Oliveira, G. Q.; Oliveira, J. C. L.; Brito, K. M. R.; Rego, N. H. Volume, biomass, carbon stock and efficiency of water use in irrigated eucalyptus. Ciência Florestal, Santa Maria, v. 32, n. 2, p. 1047-1060, 2022. DOI 10.5902/1980509847949. Available from: https://doi.org/10.5902/1980509847949.