








## Articles

# Hydrogel associated with soil moisture levels in the cultivation of *Eucalyptus urograndis*

Hidrogel associado a níveis de umidade do solo no cultivo de *Eucalyptus urograndis*

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## ABSTRACT

Although technological advances have occurred in the Brazilian forestry sector, there is still no standardization for the cultivation of *Eucalyptus urograndis* regarding the amount of water which needs to be applied at different stages of plant development and the doses of soil moisture conditioners to reduce the water deficit in the soil. The objective of this study was to evaluate the use of hydrogels for their association with soil moisture levels in regard to *Eucalyptus urograndis*. This study was conducted in a greenhouse at the Federal University of Reconcavo, Bahia. The treatments consisted of four levels of soil moisture (50, 75, 100%, and 125%) and four doses of the available hydrogel (0, 1.5, 3.0 and 4.5 g L<sup>-1</sup>) in a randomized design in a 4 × 4 factorial scheme with 16 treatments and four replicates. The evaluated parameters were height (H), stem diameter (SD), chlorophyll A and B, total indices, stem dry mass (SDM), leaf dry mass (DML), shoot dry mass (SSDM), root dry mass (RDM), shoot dry mass/root dry mass (SSDM/RDM), total dry mass (TDM), and height/diameter (H/SD). The use of hydrogels increased water availability in the dystrocohesive Yellow Oxisol and reduced the effect of water deficit in *Eucalyptus urograndis*. A dose of 3.0 g L<sup>-1</sup> of the hydrogel provided better growth and phytomass production in regard to *Eucalyptus urograndis* when the initial soil moisture level was approximately field capacity.

**Keywords:** Water deficit; Hydrogel doses; Dystrocohesive Yellow Oxisol

## RESUMO

Embora avanços tecnológicos tenham ocorrido no setor florestal brasileiro, ainda não há, uma padronização quanto à quantidade de água a aplicar nas diferentes etapas de desenvolvimento das plantas, e de doses de condicionadores de umidade do solo, visando a redução do déficit hídrico em solos sob cultivo do *Eucalyptus urograndis*. Diante disso, objetivou-se avaliar o uso do hidrogel em *Eucalyptus urograndis* associado a níveis de umidade do Latossolo amarelo distrocoeso. O estudo foi conduzido em casa de vegetação da Universidade Federal do Recôncavo da Bahia. Os tratamentos foram constituídos por quatro níveis de umidade no solo (50, 75, 100 e 125%), a partir da água disponível no solo, e quatro doses de hidrogel (0; 1,5; 3,0 e 4,5 g L<sup>-1</sup>), em delineamento inteiramente casualizado em esquema fatorial 4 x 4, com 16 tratamentos e 4 repetições. As variáveis avaliadas foram: altura (H), diâmetro do caule (DC), índices de clorofila A, B e total, massa seca do caule (MSC), massa seca de folhas (MSF), massa seca da parte aérea (MSPA), massa seca de raízes (MSR), massa seca parte aérea/massa seca raiz (MSPA/MSR), massa seca total (MST) e altura/diâmetro (H/DC). O uso de hidrogel aumenta a disponibilidade de água em Latossolo Amarelo distrocoeso e reduz o efeito do déficit hídrico na cultura. A dose de 3,0 g L<sup>-1</sup> de hidrogel proporciona melhor crescimento e produção de fitomassa do *Eucalyptus urograndis*, quando o nível de umidade inicial do solo está em torno da capacidade de vaso.

**Palavras-chave:** Déficit hídrico; Doses de hidrogel; Latossolo Amarelo distrocoeso

## 1 INTRODUCTION

The use of species of the *Eucalyptus* genus in Brazil is for meeting the demand in the timber sector. In this context, the participation of the state of Bahia, Northeast Region of Brazil, in the production and processing of eucalyptus has increased considerably, starting in the extreme south of the state in the 1970s. Subsequently, the planting areas expanded to the northern region of the state in the transition zone between the Atlantic Forest and Caatinga biomes, where charging conditions are less developed than in the extreme south of Bahia.

Water is one of the most limiting factors for plant growth. When the water supply is below the capacity of the pot or field, a water scarcity condition can occur, which constitutes a limiting factor for plant metabolism. Under the conditions of water stress, stomatal opening is affected by the water content of the soil and plants (ALTURA and ACEVEDO, 2020). Plants close their stomata to prevent water loss through transpiration, which compromises photosynthetic activity and a series of other processes in plants (FLEXAS *et al.*, 2014; TOMBESI *et al.*, 2018; RODRIGUEZ-DOMINGUEZ and BRODRIBB, 2020; ALTURA and ACEVEDO, 2020).

Reducing the adverse effects of soil water variations in the field, such as water deficit, can be achieved through the use of some management practices, such as: soil cover, which contributes to increasing the soil's water retention capacity and decreased evaporation (PENG *et al.*, 2020); improving the chemical conditions of the soil profile aiming to deepen the root system of plants (VÁZQUEZ *et al.*, 2020) and the use of soil moisture conditioners, such as hydrogel (AZEVEDO *et al.*, 2006; NAVROSKI *et al.*, 2016; FARAG *et al.*, 2017 and TEIXEIRA *et al.*, 2019).

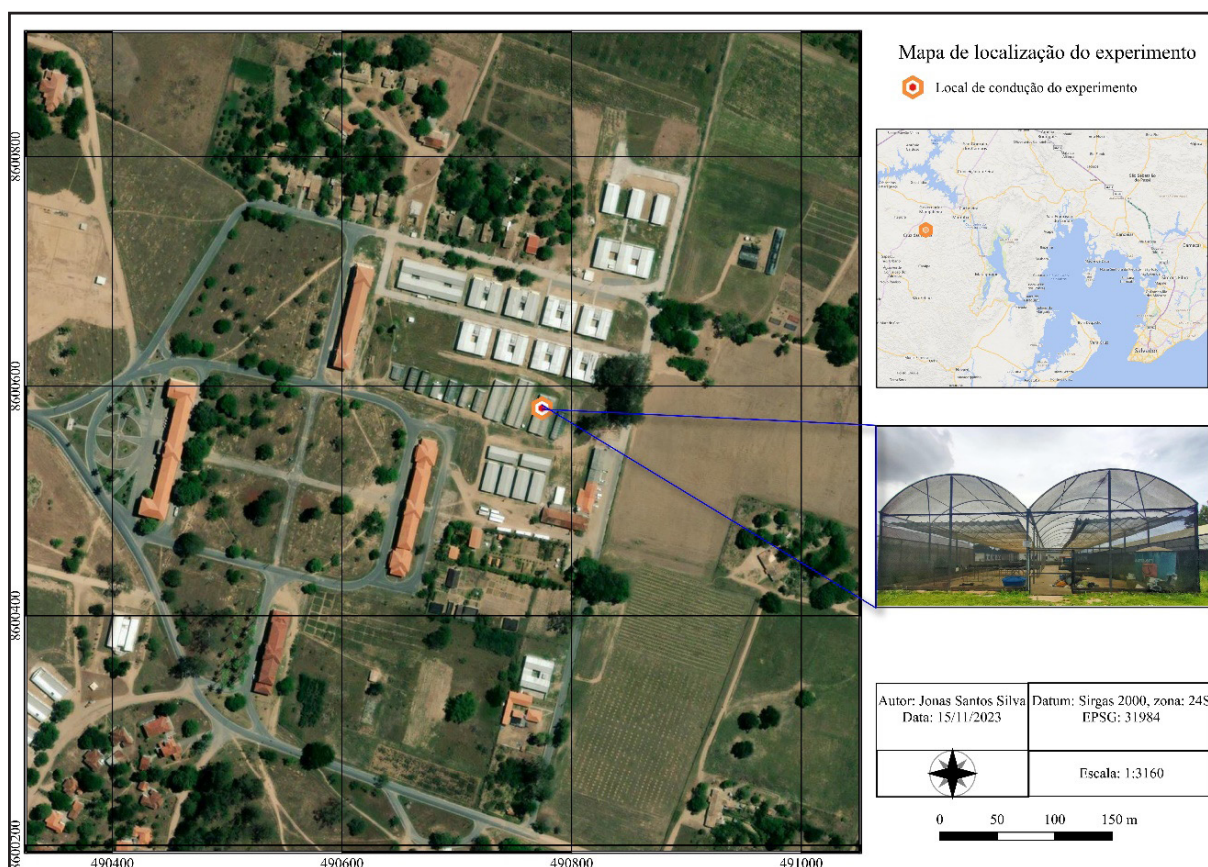
Hydrogels are water-absorbing polymers that can absorb variable amounts of water or other fluids while maintaining their original shape. These polymers are formed via hydrophilic polymeric networks that are physically or chemically cross-linked (LIU *et al.*, 2020). As they enable water retention, their release to the plants occurs gradually, which tends to increase the efficiency of irrigation and, consequently, improve the use of water by the plants. The greater retention of water by the hydrogel is very important for improving soil moisture conditions, mainly in regions with a wide variation in rainfall conditions, such as the northeast region of Brazil, with a climate that can vary from semi-arid, which corresponds to 60% of its total area with rainfall ranging from 600 to 700 mm year<sup>-1</sup>, to a humid climate, with rainfall that can reach more than 1,200 mm year<sup>-1</sup> (SANTOS *et al.*, 2010). In Eucalyptus cultivation, hydrogels have provided an increase in water content in the soil and delayed the symptoms of water stress, increasing the survival rate of *Eucalyptus urograndis* plants in nursery conditions in Laje, Santa Catarina (DIONÉIA *et al.*, 2021).

In view of this, although there is great technological support and investments in the forestry sector in the state of Bahia, there is still no standardization, even in the largest companies in the sector, regarding the amount of water which needs to be applied in the different stages of development of forestry crops, especially in the subsequent field planting (SILVA *et al.*, 2015), in which the soil water conditions have proven to be more restrictive in areas of crop expansion. In view of the above, the objective of this study was to evaluate the use of hydrogels in *Eucalyptus urograndis* associated with humidity levels in the dystrocoeso Yellow Oxisol.

## 2 MATERIALS AND METHODS

The experiment was conducted in a greenhouse under 45% shade at the Center for Agricultural, Environmental and Biological Sciences at the Federal University of Recôncavo da Bahia (CCAAB/UFRB) between October 2019 and January 2020, located under coordinates 39°05 '28"W and 12°41'50.44"S and altitude of 226 meters (Figure 1).

Figure 1- Location map of the experiment



Source: Authors (2023)

According to the Köppen classification, the climate of the region is as (Alvares *et al.*, 2014), which is tropical hot and humid, with a dry season in summer, mainly from September to February, and a rainy season in winter with average rainfall. annual temperature of 1,224 mm, distributed between the months of March and August, varying from 900 to 1,300 mm, with 80% relative humidity and an average annual temperature of 24.5°C.

For the study, *Eucalyptus urograndis* plants of clonal origin, produced in tubes, were used. Seedlings were standardized by measuring clone height and stem diameter. Subsequently, the plants were transported to polyethylene pots with a capacity of 5 dm<sup>3</sup>, filled with 4.2 dm<sup>3</sup> of dystrocohesive Yellow Oxisol material collected in the layer between 0 and 0.20 m deep, in the Cruz das region. Almas, BA, being previously dried, crumbled, and passed through a sieve with a 4 mm diameter mesh.

The physicochemical analyses of the soil and pot capacity of the dystrocohesive Yellow Oxisol are shown in Table 1. The definition of the basic fertilizer for planting *Eucalyptus urograndis* plants was based on Ribeiro *et al.* (1999) in order to define the following doses: 0.90 g of urea, 17.89 g of simple superphosphate and 0.69 g of potassium chloride per plant. The doses of urea and potassium chloride were divided into two applications: one at the time of transplanting the seedlings into pots and the other 30 days after setting up the experiment in a greenhouse.

Table 1 – Physicochemical analysis of the soil and potting capacity of the dystrocohesive Yellow Oxisol from the Coastal Tablelands of Bahia, Northeast Brazil

pH	<sup>1</sup> P (Mehlich)	K <sup>+</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Al <sup>3+</sup>	H=Al	SB	
H <sub>2</sub> O	mg dm <sup>-3</sup>			-----	cmolc dm <sup>-3</sup> -----			
4.4	0.004	3.91	0.7	0.6	0.5	1.9	1.31	
V	m	CTC (t)	CTC (T)	MO	VC	Texture		
--%--	---	cmolc dm <sup>-3</sup> --		dag m <sup>-3</sup>	%	Sand	Silt	Clay
40.81	27.62	1.81	3.21	1.43	16.83	35	10	55

Source: Authors (2023)

In where: <sup>1</sup>P (Mehlich); SB, sum of bases; V, base saturation; m, aluminum saturation; CTC (t), effective cation exchange capacity; CTC (T), potential cation exchange capacity; MO, organic matter; VC, vessel capacity.

The treatments consisted of four soil moisture levels (50, 75, 100 and 125%), defined based on the soil's potting capacity (0.1685 m<sup>-3</sup>), and these were determined according to Aguiar Netto *et al.* (1999) and Casaroli and Van Lier (2008). The four doses

of the hydrogel were 0.0; 1.5; 3.0 and 4.5 g L<sup>-1</sup>) with a dose of 3.0 g L<sup>-1</sup> being the one recommended by the manufacturer. The treatments, humidity levels, and hydrogel doses were arranged in a completely randomized design in a 4 × 4 factorial scheme constituting 16 treatments with four replicates.

The hydrogel was hydrated with water half an hour before transplanting the seedlings in varying concentrations according to the doses of hydrogel and soil moisture levels. After applying each dose of hydrogel, the vessels were weighed to obtain a weight equivalent to that of the pre-established treatments. With a daily irrigation shift, the soil moisture levels in the pots were maintained based on the difference between the weight of the set defined for each treatment and the weight of this set during the evaluation on the day in question.

The plants were kept in pots for 60 days. During this period, the following variables were evaluated: plant height (H), with the aid of a ruler graduated in mm; stem diameter (SD), with a caliper graduated in mm; and indices of chlorophyll A, B, and total, with a Clorofilog electronic chlorophyll meter, model CFL 1030. For stem dry mass (SDM), leaf dry mass (DML), shoot dry mass (SSDM) and root dry mass (RDM), the plants were separated into roots, stems and leaves and taken to a forced ventilation greenhouse for 72 hours at 65°C. From the values of these variables, the following mathematical relationships were calculated: aerial part dry mass/root dry mass (SSDM/RDM) and height/diameter (H/SD).

In order to perform the statistical analyzes the SISVAR Program version 5.6 (Ferreira *et al.*, 2014) was used. The F test was used at 5% probability and, subsequently, the regression analysis was carried out. The maximum points of the curves of the analyzed factors were found through the derivative of the regression equation for the curves.

### 3 RESULTS AND DISCUSSIONS

For plant height (H), the individual effects of soil moisture levels and hydrogel doses were selected, as well as interactions between treatments ( $p < 0.01$ ), whereas for stem ceramics (SD), there were only individual treatment effects ( $p < 0.01$  (Table 2).

Table 2 – Source of the variations and significance levels in *Eucalyptus urograndis* variables under the effect of soil moisture levels and hydrogel doses

Factor	QMRES		P value (*=5% e **= 1%)		
	(%)	Moisture (M)	Hydrogel (H)	(L X U)	CV (%)
H	10.712	0.000**	0.000**	0.000**	5.16
DC	0.004	0.000**	0.000**	0.226	10.50
Chlorophyll A	16.223	0.929	0.013*	0.149	12.12
Chlorophyll B	8.521	0.426	0.760	0.496	26.02
Total chlorophyll	45.32	0.174	0.026*	0.282	15.15
DML	6.198	0.087	0.000**	0.257	20.25
SDM	1.0346	0.165	0.020*	0.712	23.88
RDM	1.0775	0.649	0.002**	0.184	22.40
SSDM	9.8641	0.159	0.000**	0.547	18.97
TDM	12.346	0.188	0.000**	0.266	16.58
Rel. H/D	158.543	0.252	0.002**	0.826	12.27
Rel. MSPA/MSR	1.046	0.263	0.764	0.878	27.52

Source: Authors (2023)

In where: QMRES = mean square error (%); CV = Coefficient of variation (%).

The variables chlorophyll A and total chlorophyll index, dry matter production of leaves (DML), stems (SDM), aerial parts (SSDM), roots (RDM), total (TDM), and H/SD ratio presented only individual effects. of hydrogel doses, both ( $p < 0.05$ ) for chlorophyll A and total and ( $p < 0.01$ ) for other variables. No effects of the treatments were observed on chlorophyll B or the SSDM/RDM ratio. The fact that most variables were not significant for soil moisture levels suggests that the hydrogel suppressed the effects of initial soil moisture conditions on the cultivation of *Eucalyptus urograndis*.

For H, it appeared that the doses of 0.0 and 4.5 g L<sup>-1</sup> were significant ( $p < 0.01$ ), with the dose of 4.5 g L<sup>-1</sup> providing greater growth, with a maximum of 69.17 cm plant<sup>-1</sup>,

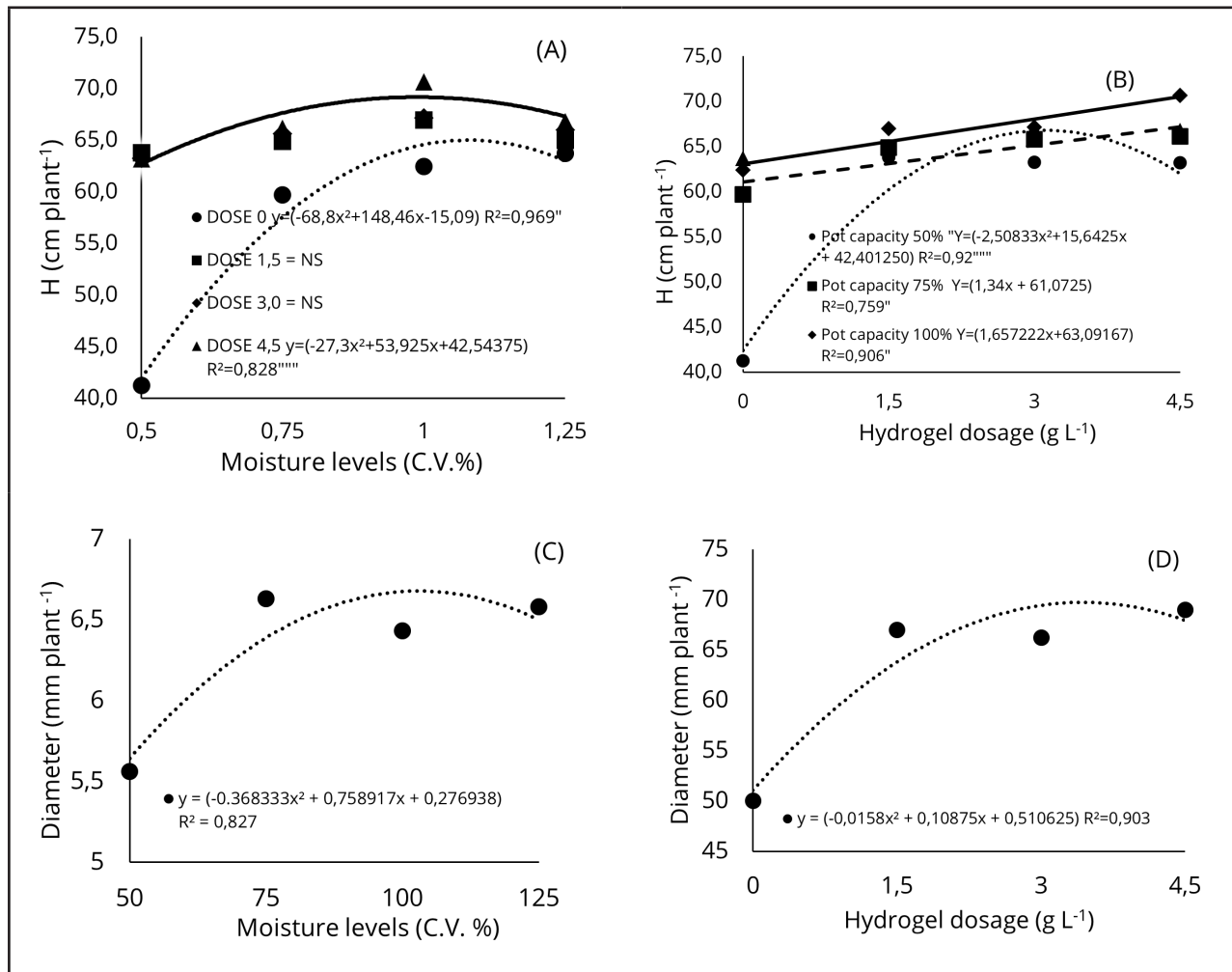
at the soil moisture level corresponding to 100% of the pot capacity (VC) (Figure 2 a). It is noteworthy that when evaluating the behavior of humidity levels as a function of hydrogel doses (Figure 2 b), it appears that humidity levels were only significant when they varied between 50 and 100% VC, with linear behavior for 75 and 100% VC, and quadratic behavior for 50% VC. This shows that when the soil moisture was lower than the VC, hydrogel doses alleviate the effect of water deficit, especially at 50% VC, which contributed to improved plant development. The hydrogel allowed the cultivation substrate to have greater water retention capacity, favoring the photosynthetic activity of the plant.

The SD exhibited quadratic behavior for soil moisture levels and hydrogel doses (Figures 1 c, d, respectively). For the humidity levels, the maximum estimated SD was 6.6 mm at an estimated humidity of 102%, which was close to the VC. Sasse and Sands (1996), when evaluating the behavior of *Eucalyptus globulus* clones depending on soil moisture levels and substrate types, found a significant difference in SD, with a lower value occurring in plants under greater water stress, as verified in the present study. Water stress limits growth in the height and diameter of the stem because of reduced cell expansion, resulting in poor formation of the cell wall, which indirectly results in reduced production of growth regulators (BUTRINOWSKI *et al.*, 2013). Furthermore, water deficits can affect stomatal function and water characteristics, such as water potential and xylem hydraulic conductivity (ALTURA and ACEVEDO, 2020).

For the hydrogel doses, the highest SD of 6.9 mm occurred at the dose 3.0 g L<sup>-1</sup> (Figure 2 d). This shows that regardless of soil moisture levels, the use of hydrogel improved plant growth in SD when compared to the treatments without the use of the hydrogel, as it reduced water loss from percolation irrigation, improved aeration and soil drainage, and reduced nutrient losses through leaching. Navroski *et al.* (2015) found that the SD was lower in *Eucalyptus dunnii* plants that received hydrogel doses lower than 4.5 g L<sup>-1</sup>.



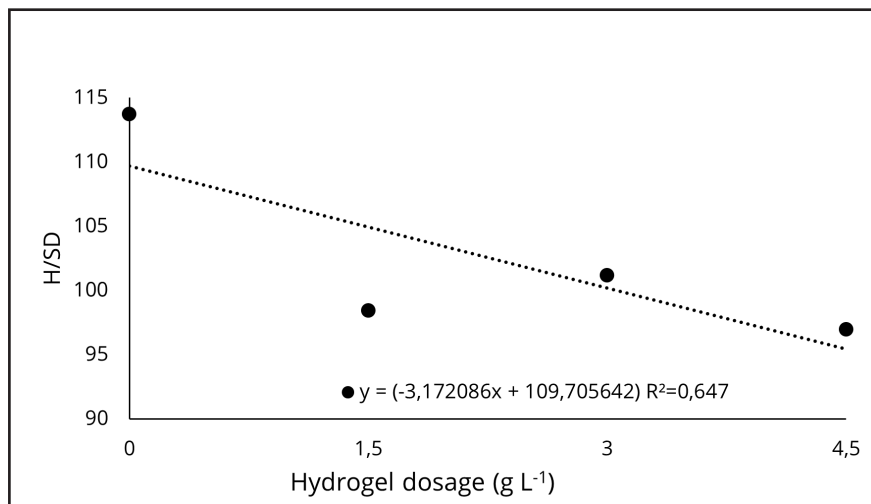
Figure 2 – Plant height (H) as a function of soil moisture levels (a) and hydrogel doses (b); stem diameter (SD) as a function of humidity levels (c) and hydrogel doses (d) in *Eucalyptus urograndis* plants under the effect of hydrogel doses



Source: Authors (2023)

For the H/SD ratio (Figure 3), a decreasing linear behavior was observed for the hydrogel doses. Better quality plants have a lower H/SD ratio, as they tend to have better balance, thus avoiding a greater risk of tipping over in the field (ARÁUJO *et al.*, 2020). Thus, plants that received the highest doses of the hydrogel suffered less water deficit and showed better development.

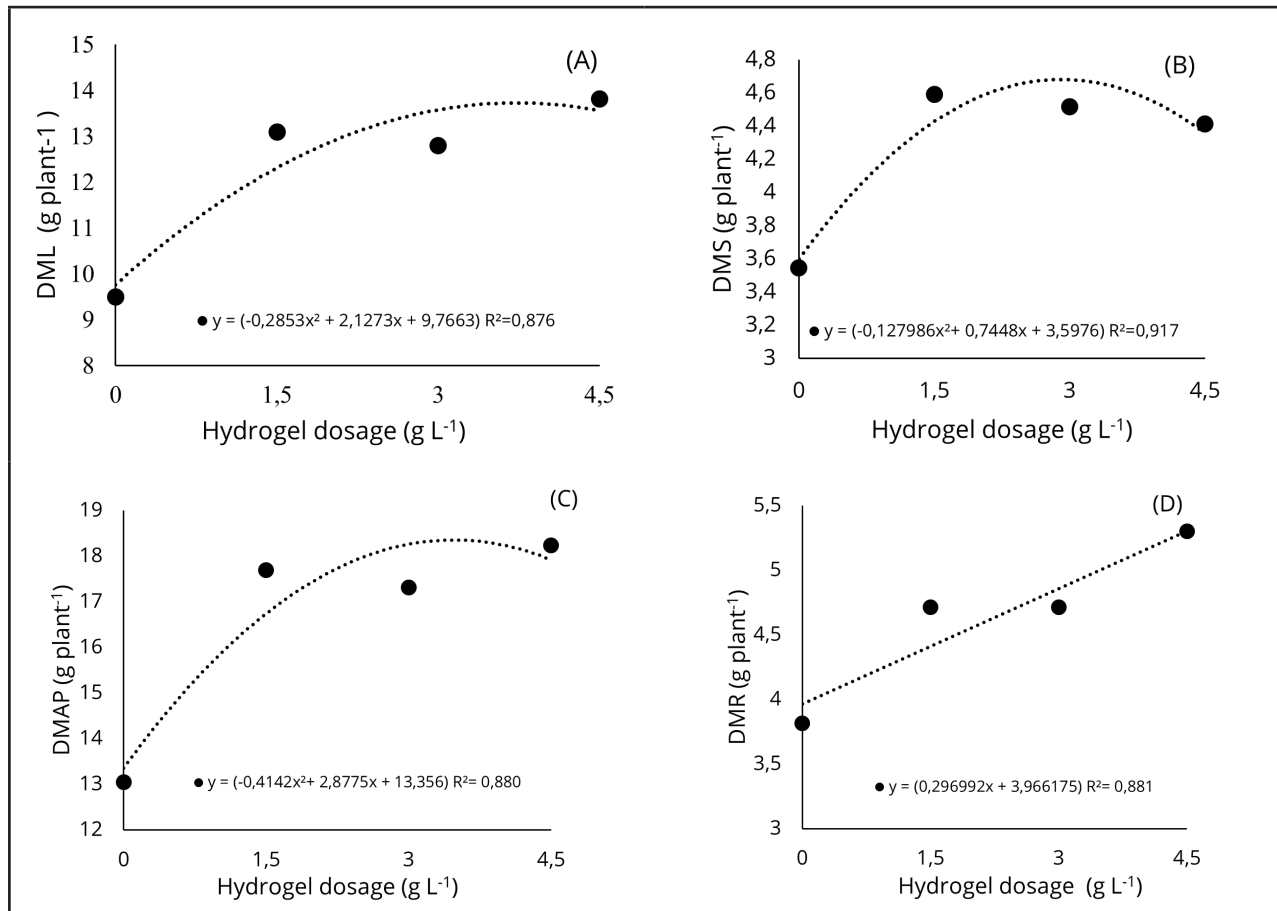
Figure 3 – H/SD relationship in *Eucalyptus urograndis* plants under the effect of the doses of the hydrogel



Source: Authors (2023)

For the dry masses of leaf (DML), stem (SDM), aerial part (SSDM), root (RDM) (Figure 4), and total (TDM) (Figure 5), there was an individual effect of hydrogel doses, with quadratic behavior for DML, SDM, SSDM, and TDM (Figures 4, b, c, and d, respectively) and a linear increase in RDM (Figure 3 d). In terms of phytomass, maximum values of 14.28 were verified for DML, SDM, SSDM and TDM; 4.68; 18.35 and 23.03 g plant<sup>-1</sup>, respectively, when the estimated hydrogel doses were 3.7; 2.91; 3.47 and 3.71 L<sup>-1</sup>, respectively. The gain from using the hydrogel in relation to seedlings without treatment justifies the use of the polymer mainly under conditions of high temperatures and low soil humidity because of its ability to absorb and store water in the soil for a long period and to enable conditions suitable for plant development. Fellipe *et al.* (2015) also evaluated the influence of the hydrogel and water management on *Eucalyptus benthamii* and they observed that its use, regardless of irrigation time, provided greater growth in the dry mass of the roots and aerial parts of plants.

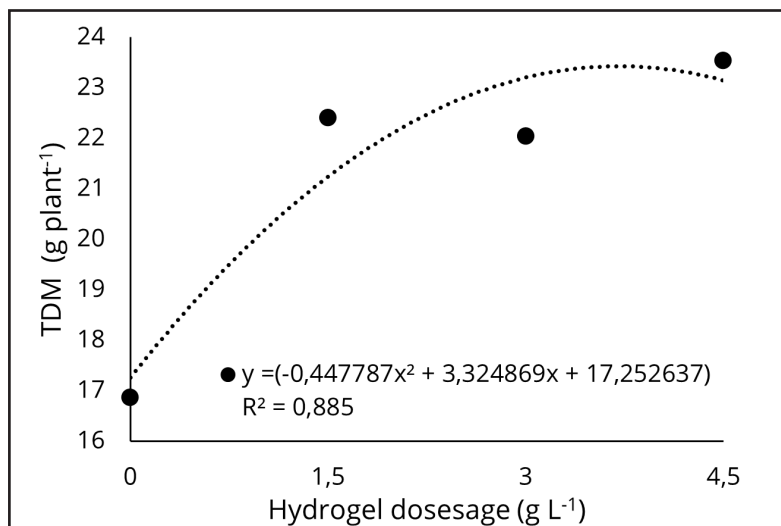
Figure 4 – Dry masses of leaves (a), stem (b), aerial part (c), roots (d) of *Eucalyptus urograndis*, as a function of doses of hydrogel



Source: Authors (2023)

For MSR, an increase in the root production was observed depending on the hydrogel dose, which was beneficial to the culture (Figure 4 d). For *Eucalyptus dunnii* this effect was also verified with the use of a hydrogel (NAVROSKI *et al.*, 2015) and according to the authors, a greater production of RDM is important when seeking sustainability of the crop in the field, because of the importance of the roots in the development of plants. This is due to the fact that the greater the root growth, the greater the plant growth and survival capacity in the field. The greatest growth of *Eucalyptus dunnii* seedlings was obtained with 3 g L<sup>-1</sup> of hydrogel (Navroski *et al.*, 2015). Eloy *et al.* (2013), when evaluating the quality of *Eucalyptus grandis* plants, indicated that a dose of 4.0 g L<sup>-1</sup> of the hydrogel provided greater root dry mass, probably because of the greater availability of water and nutrients provided by the hydrogel, which was also reported by Felipe *et al.* (2021) for *Eucalyptus urograndis*.

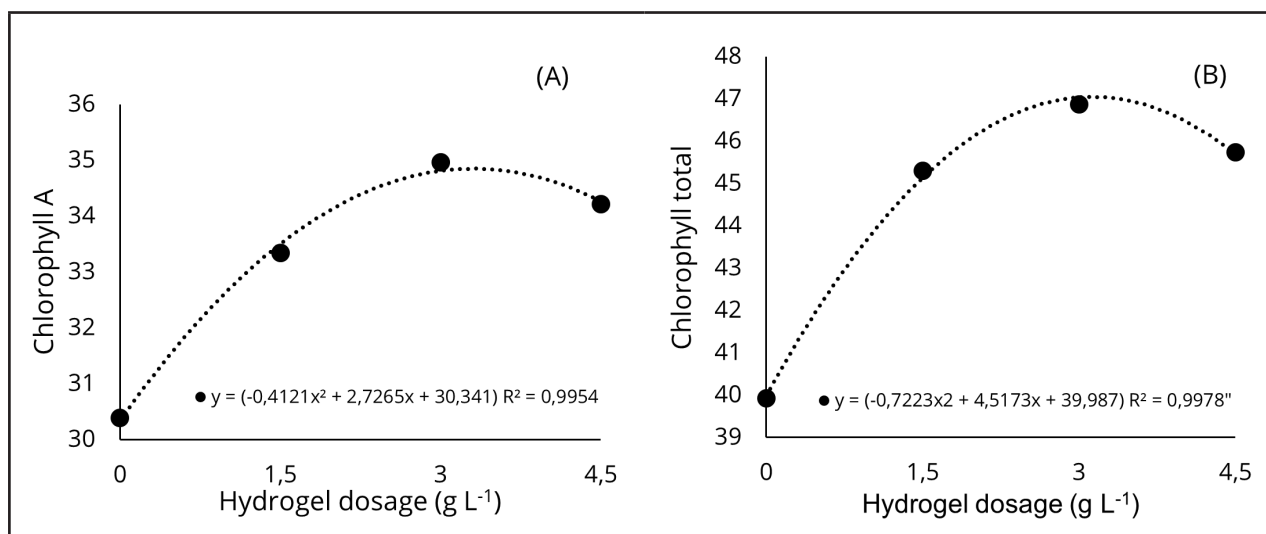
Figure 5 – Total dry mass of *Eucalyptus urograndis* (TDM), as a function of hydrogel doses



Source: Authors (2023)

The levels of chlorophyll A and total (Figures 6 a and b, respectively) were influenced by the hydrogel dose ( $p < 0.05$ ). For both variables, quadratic behavior was observed, with the maximum dose of  $3.0 \text{ g L}^{-1}$  providing greater photosynthetic activity.

Figure 6 – Chlorophyll A (a) and total chlorophyll (b) indices in *Eucalyptus urograndis* under the effect of humidity and doses of hydrogel



Source: Authors (2023)

The higher chlorophyll index at a dosage of 3.0 g L<sup>-1</sup> shows that the hydrogel has the capacity to maintain nutrients available in the soil solution for a longer time, owing to the increase in the adsorption capacity of the soil, with the subsequent release of nutrients into the soil solution (Figure 6). According to Sita *et al.* (2005), hydrogels can adsorb nutrients from soil solutions, such as nitrogen and magnesium, which directly participate in photosynthetic activity. According to Mendes *et al.* (2011), the chlorophyll index can increase or decrease in plants, depending on the species under study. According to Silva *et al.* (2017), the reduction in chlorophyll levels in plants under water deficit or excess conditions can be explained by the oxidative stress which is caused by the photo-oxidation of pigments and thus generates the degradation of chlorophyll molecules.

Under experimental conditions, *Eucalyptus urograndis* plants treated with the hydrogel and grown in a dystrocohesive Yellow Oxisol showed a delay in water stress symptoms for all of the biometric variables evaluated. This resulted in greater growth and phytomass production when compared with plants without a hydrogel, as this positively influenced the storage and availability of water for the plant in the soil, especially when humidity levels occurred less frequently. However, it is important to emphasize that hydrogels cannot replace regular irrigation systems.

## 5 CONCLUSIONS

The application of 3.0 g L<sup>-1</sup> hydrogel in dystrocohesive Yellow Oxisol increased water availability for the plants studied, reducing the effect of water deficit in *Eucalyptus urograndis*. This dose is most effective in promoting the growth and production of phytomass when the soil has an initial humidity near the pot's capacity.

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