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Scientific Article

Production of *Mimosa caesalpiniifolia* benth seedlings using a water-absorbing polymer and different water regimes

Polímero hidroabsorvente na produção de mudas de sabiá sob diferentes turnos de rega

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ABSTRACT − *Mimosa caesalpiniifolia* Benth is an arboreous species native to the Caatinga commonly utilized for restoration of degraded areas. One factor that can affect its development is water shortage. This denotes the importance of searching for alternatives for improving these plant's tolerance to water shortage, such as the use of water-absorbing polymers known as hydrogels. In this context, the objective of this study was to evaluate the production of *M. caesalpiniifolia* seedlings under different hydrogel rates and water regimes. The experiment was conducted at the Forest Nursery of the Federal University of Campina Grande, Patos, PB, Brazil. Seeds were sown in 2-liter pots made from halved polyethylene terephthalate bottles, containing a substrate consisted of soil and cattle manure (2:1 v v^{-1}). A completely randomized design with four replications was used, in a 4×2 factorial arrangement consisted of four hydrogel rates in the substrate (0, 1, 2, and 3 g L^{-1}) and two water regimes (daily irrigation and irrigation every 2 days). The following parameters were evaluated at the end of the experiment (75 days after sowing): number of leaves per plant, stem base diameter, plant height, root length, shoot and root dry weights, water relative content, chlorophyll content, gas exchanges, and Dickson quality index. Most of parameters presented no statistically significant difference; however, the hydrogel rate of 2 g L^{-1} resulted in increased production of *M. caesalpiniifolia* seedlings, whereas the absence of hydrogel resulted in longer roots, regardless of the water regime.

Keywords: Caatinga. Hydrogel. Substrate.

RESUMO − *Mimosa caesalpiniifolia* Benth é uma espécie arbórea nativa da caatinga comumente utilizada em programas de recuperação de áreas degradadas. Um fator que pode afetar seu desenvolvimento é a falta de água. Assim, é fundamental buscar alternativas que aumentem a tolerâncias das plantas a falta d'água, desse modo uma dessas alternativas é o uso dos polímeros hidroabsorventes. Neste contexto, o objetivo foi avaliar doses do polímero hidrorretentor sob diferentes turnos de rega na produção de mudas de sabiá. O experimento foi conduzido no Viveiro Florestal da Universidade Federal de Campina Grande, campus de Patos. As sementes foram semeadas em garrafas PET (Polietileno Tereftalato) de 2 litros cortadas ao meio, contendo os substratos solo e esterco bovino, na proporção 2:1. Foi utilizado o delineamento inteiramente casualizado, em esquema fatorial 4 x 2, sendo 04 doses do hidrogel (0, 1g, 2g e 3g por litro de substrato) e dois turnos de rega (irrigação diária). Ao término do experimento (75 dias) foi avaliado número de folhas, diâmetro do colo, altura de planta, crescimento do sistema radicular, massa seca da parte aérea, massa seca do sistema radicular, teor relativo de água (TRA), teor de clorofila e trocas gasosas, além do Índice de Qualidade de Dickson (IQD). Quase todas as vaiáveis não se deferiram estatisticamente, mas ao término do experimento, conclui-se que a dose 2g de hidrogel promove maiores incrementos na produção de mudas de sabia e ausência de hidrogel promove maior crescimento do sistema radicular independente do turno de rega.

Palavras-chave: Caatinga. Hidrogel. Substrato.

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INTRODUCTION

Mimosa caesalpiniifolia Benth is an arboreous species native to the Caatinga biome in Brazil, where it is known as sabiá. Its rapid growth makes it a promising species for use in programs aimed at the restoration of degraded areas and for reforestation. Additionally, this species has high protein and energy values, making it suitable for multiple uses, including as forage plants and for stake and charcoal production. Consequently, this species has been in high demand, but still not properly explored.

Drought is one of the most characteristic aspects in the Northeast region of Brazil. This is not only due to water shortage but also due to poor rainfall distribution in time and space (SILVA, et al., 2017). This denotes the importance of seeking alternatives for promoting plant growth and improve the plants' tolerance to water shortage in this region. The use of silicon (SANTOS et al., 2022), *Azospirillum brasiliense*-based inoculants (PAIVA et al., 2021), and salicylic acid (GOMES et al., 2023) are among the alternatives used for this purpose.

Soil conditioners known as water-absorbing polymers or hydrogels are among the available technologies for supplying water to plants; they have been widely used in agriculture, resulting in higher water retention during the germination process of maize crops (CASSOL; FANTINEL; SILVA, 2020) and in improved quality of passion fruit (FERNANDES; ARAÚJO; CAMILE, 2015), jalapeño pepper (PINTO; SANTANA; GODINHO, 2015), and citrus (FERREIRA et al., 2014) seedlings. These hydrogels consist of powders that forms a transparent gel through which the roots develop, increasing the number of root hairs and, consequently, the contact surface, releasing water to the plant according to its needs; consequently, this decreases the number of daily irrigations needed or the interval between irrigations for improving plant development (LOPES et al., 2010). Hydrogels are not toxic to the soil, as their residues generate water, carbon dioxide, and ammonium dioxide, causing no pollution to the environment (VILARINHO, 2017).

Hydrogels have been used in the production of seedlings of forest species, mainly those native to the Cerrado biome, for growing these seedlings transplanted to the field. Their effects can vary depending on the specific needs of each species, the production system used, and the hydrogel characteristics and rates (AZEVEDO et al., 2016). However, well-documented scientific information on the use of hydrogels for growing forest species native to the Caatinga is still limited. In this context, the objective of this study was to evaluate the production of *M. caesalpiniifolia* seedlings under different hydrogel rates and water regimes.

MATERIAL AND METHODS

Study area characterization

The experiment was conducted at the Forest Nursery of the Academic Unit of Forest Engineering of the Federal University of Campina Grande (UFCG), Patos, PB, Brazil (7° 03'34.76"S and 37°16'27.29"W), from November 2021 to February 2022.

The region's climate is Bsh, hot and dry, according to the Köppen classification, with two well-defined seasons: a rainy season in the winter and a dry season in the summer. The region presents a mean annual rainfall depth of 600 mm, a mean annual temperature of 30 °C, and a mean relative air humidity of approximately 55% (ALVARES et al., 2014).

Experiment implementation and conduction

Seeds at full maturation stage were collected from *Mimosa caesalpiniifolia* trees at the Health and Rural Technology Center of UFCG (Patos, PB, Brazil) in September 2021, and sown in 2-liter pots made of halved polyethylene terephthalate bottles, containing a substrate consisted of soil and cattle manure (2:1 v v^{-1}). All plants were treated with a hydrogel (Biogel Aqua Plus; Biossementes®, Ilhéus, Brazil) at rates corresponding to the treatments, except the control plants.

The experiment was conducted in a completely randomized design with four replications, in a 4×2 factorial arrangement consisting of four hydrogel rates in the substrate (0, 1, 2, and 3 g L^{-1}) and two water regimes (daily irrigation - WR1; and irrigation every 2 days - WR2) reaching 80% field capacity, totaling 8 treatments, with one plant per plot. In the treatments containing the hydrogel, the dry product was applied to each pot and uniformly mixed into the substrate.

The amount of water applied to the pots at the beginning of the treatments was standardized to determine the soil field capacity. The plants were irrigated once a day, maintaining substrate moisture close to 100% of the container retention capacity, which was determined by submerging the pot containing only soil in water until saturation for 24 hours; it was then removed and subjected to intense leaching and weighed when leaching stopped. Thus, this value corresponded to the substrate weight at 100% field capacity, which was used as the basis for determining the water level evaluated (80%), as the method proposed by Ramos (2017). The pots were placed in a greenhouse covered with a 50% shade screen, with a spacing of 0.70 × 0.60 cm.

The following parameters were evaluated at the end of the experiment (75 days after sowing): number of leaves per plant, stem base diameter (mm), plant height (cm), root length (cm), shoot and root dry weights (g), water relative content, chlorophyll content, gas exchanges, and Dickson quality index. Additionally, substrates from the treatments were subjected to chemical analysis at the Soil and Water Laboratory of UFCG to assess nutritional contents (N, P, K, Ca, and Mg).

Plant growth evaluation

Plant growth was assessed biweekly for number of leaves per plant (NLP), stem base diameter (SBD), plant height (PH), and chlorophyll content.

SBD (mm) was measured just below the insertion of the cotyledonary leaf using a digital caliper. PH (cm) was measured from the base of the plant to the apical meristem using a graduated ruler. NLP was determined by counting true leaves in each plant.

Plants were sectioned at the stem base, separating aerial part and roots, at the end of the experiment. These plant materials were washed in running water, placed in paper bags, and left to dry in a forced air circulation oven at 65 °C until reaching a constant weight. Subsequently, the samples were weighed on a precision scale to determine shoot and root dry weights (SDW and RDW, respectively) and total dry weight (TDW), expressed as grams (g).

Gas exchange parameters were determined in healthy, fully expanded leaves between 10:00 a.m. and 11:00 a.m. using a portable photosynthesis Infrared Gas Analyzer (IRGA) (model LCpro-SD; ADCBioScientific Ltd., Hoddesdon, UK). The photosynthetically active radiation (PAR) of the device was set to 1200 µmol m^{-2} s^{-1}. The parameters assessed were leaf temperature, transpiration rate (mmol of H_2O m^{-2} s^{-1}), stomatal conductance (mol of H_2O m^{-2} s^{-1}), photosynthetic rate (µmol of CO_2 m^{-2} s^{-1}), and intercellular CO_2 concentration (mol mol^{-1}).

Water relative content evaluation

Leaf samples were collected to determine the relative water content (RWC). A healthy leaflet was taken from each plant, weighed to obtain fresh weight (FW), placed in a plastic container, kept in the refrigerator for 72 hours (temperature ± 5 °C), and then weighed again to determine the turgid weight (TW). Subsequently, the samples were dried in an oven at 65 °

C for 72 hours and weighed to obtain the dry weight (DW). RWC was calculated using the formula proposed by Weatherley (1950): $RWC = [(FW - DW) / (TW - DW)] \times 100$.

Leaf area estimation

Leaf area (LA) was determined based on the measurement of length and width of three leaves with different ages. Leaf length and width data were used to determine LA, using the following formula: $LA = 1.4755 \times LW$, where LW is the mean of the product of length (L) by width (W), according to Ribeiro et al. (2021). Temperature data were collected daily at the same time as irrigation, using a sensor installed inside the greenhouse.

Seedling quality evaluation

The Dickson Quality Index (DQI) was obtained using the formula: $DQI = [TDW / (HDR + SRR)]$, where HDR is the PH to SBD ratio and SRR is the SDW to RDW ratio (DICKSON et al., 1960).

Statistical analysis

The data obtained were subjected to analysis of variance to detect possible effects of the treatments on the analyzed variables, using the SISVAR program (FERREIRA, 2014). Quantitative data were subjected to regression analysis, while the means of qualitative data were compared using the Tukey's test at a 5% significance level ($p<0.05$).

RESULTS AND DISCUSSION

Plant growth

Considering the plant growth parameters evaluated at four different periods (Table 1), the effect of the interaction between the factors (hydrogel rates and water regimes) was significant ($p<0.05$) only for number of leaves per plant (NLP) at 60 days after emergence (DAE). The hydrogel rate factor had significant effect ($p<0.05$) on plant height (PH) and stem base diameter (SBD) at 45 DAE, whereas the water regime factor had significant effect on NLP at 15 DAE ($p<0.01$) and PH at 30 DAE ($p<0.05$).

Table 1. Means of number of leaves per plant (NLP), plant height (PH), and stem base diameter (SBD) of *Mimosa caesalpiniifolia* seedlings grown under different hydrogel rates in the substrate and two different water regimes (WR1 and WR2), evaluated at different periods (days after emergence - DAE).

	NLP		PH (cm)		SBD (mm)	
15 DAE						
Hydrogel rate	WR1	WR2	WR1	WR2	WR1	WR2
0 g L^{-1}	3.5a	3.5a	8.8a	8.8a	1.14a	1.16a
1 g L^{-1}	3.0a	3.0a	7.9a	8.1a	1.15a	1.18a
2 g L^{-1}	3.0b	3.8a	8.3a	8.9a	1.18a	1.18a
3 g L^{-1}	3.0b	3.8a	9.0a	8.1a	1.17a	1.23a
30 DAE						
Hydrogel rate	WR1	WR2	WR1	WR2	WR1	WR2
0 g L^{-1}	5.75a	5.5a	16.8a	16.3a	1.92a	1.85a
1 g L^{-1}	5.25a	5.25a	14.8a	15.8a	1.89a	1.97a
2 g L^{-1}	5.75a	6.00a	16.1a	18.5a	1.87a	2.12a
3 g L^{-1}	5.25a	5.75a	18.0a	15.4b	1.90a	1.80a
45 DAE						
Hydrogel rate	WR1	WR2	WR1	WR2	WR1	WR2
0 g L^{-1}	8.0a	7.5a	25.5a	26.5a	2.84a	2.8a
1 g L^{-1}	8.0a	7.3a	28.0a	26.8a	2.80a	3.0a
2 g L^{-1}	8.5a	8.3a	30.1a	30.5a	3.07a	3.2a
3 g L^{-1}	8.0a	8.0a	30.4a	26.9a	2.85a	2.8a
60 DAE						
Hydrogel rate	WR1	WR2	WR1	WR2	WR1	WR2
0 g L^{-1}	10.5a	10.0a	41.0a	39.0a	3.7a	3.9a
1 g L^{-1}	11.0a	9.8b	41.8a	39.5a	4.0a	3.9a
2 g L^{-1}	10.8a	10.8a	40.5a	41.0a	4.1a	4.2a
3 g L^{-1}	10.0a	11.0a	43.3a	42.0a	4.2a	4.3a

WR1 = daily irrigation; WR2 = irrigation every 2 days. Means followed by the same letter, comparing water regimes within each hydrogel rate, are not significantly different from each other by the Tukey's test ($p \leq 0.05$).

NLP at 15 DAE was higher for the water regime with irrigation every 2 days (WR2) compared to that found for daily irrigation (WR1) when using hydrogel rates in the substrate of 2 and 3 g L^{-1}. PH at 30 DAE was higher for WR1 than for WR2 when using the hydrogel rate of 3 g L^{-1}. NLP at 60 DAE was higher for WR1 than for WR2 when using the hydrogel rate of 1 g L^{-1} (Table 1).

NLP, PH, and SBD were negatively affected by hydrogel rates, mainly in the treatments with low water availability (WR2). However, no significant difference was found among treatments, except for NLP at 15 DAE (WR2 and hydrogel rate of 1 g L^{-1}) and 60 DAE (WR2 and hydrogel rates of 2 and 3 g L^{-1}), and PH at 45 DAE (WR2), which can be attributed to the water stress. According to Larcher (2006), the first and most sensitive response to water deficit is a decrease in turgidity, resulting in stomatal closure and decreased photosynthesis and cell elongation.

Furthermore, water deficit is the most limiting factor for plant growth and development, compromising seedling development over all vegetative stages, from seed germination to the induction of floral bud drop (CARVALHO et al., 2014). However, the use of hydrogels can minimize the adverse effects of water stress on seedlings by reducing water losses from seedlings subjected to irrigation on alternate days. These results are consistent with those reported by Chirino, Vilagrosa and Vallejo (2011), who evaluated *Quercus suber* seedlings and found higher efficiency against water deficit effects when using a mixture of commercial substrate with a high hydrogel rate.

PH at 45 DAE in WR1 showed a linear increasing response to response to hydrogel rates; thus, the highest PH (30.4 cm) was found for the highest hydrogel rate (3 g L^{-1}). The PH found in the WR2 (45 DAE) showed a quadratic response, reaching the highest mean (28.95 cm) for a rate of 1.8 g L^{-1} (Figure 1a). SBD at 45 DAE in WR2 showed a quadratic response to hydrogel rates, reaching the highest mean (3.145 mm) for the rate of 1.5 g L^{-1}, whereas the SBD data in WR1 did not fit any regression model, showing an overall mean of 2.9 mm (Figure 1b).

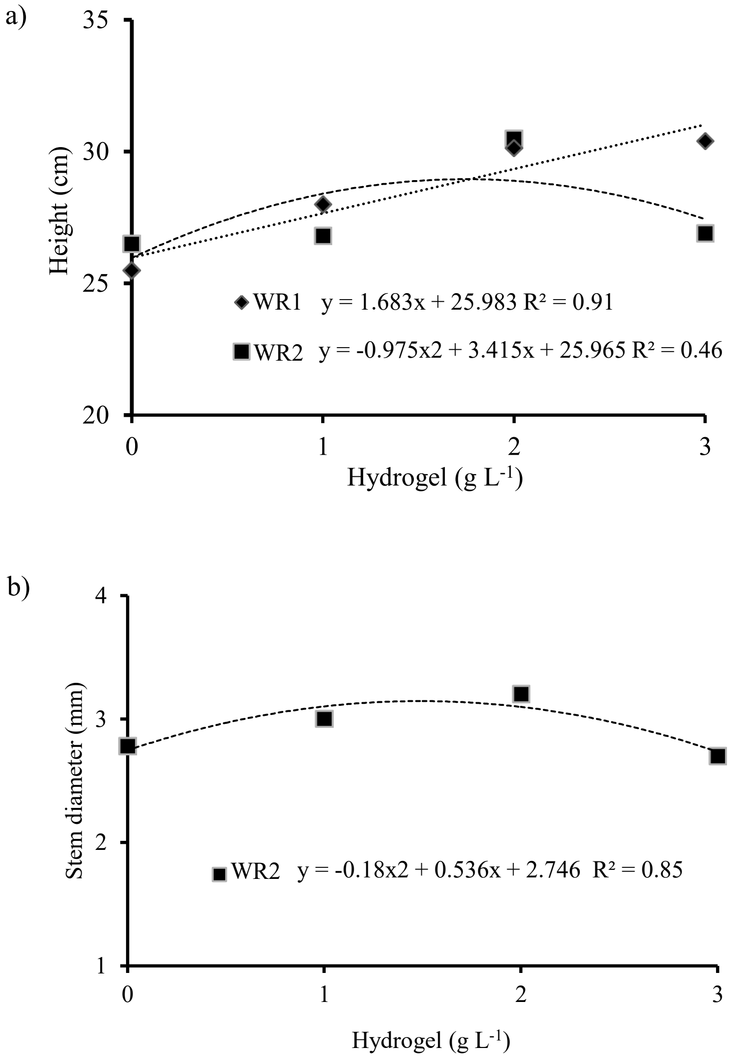

Figure 1. Plant height (PH) and stem base diameter (SBD) assessed at 45 days after emergence of *Mimosa caesalpiniifolia* seedlings subjected to different hydrogel rates in the substrate and water regimes (WR1: daily irrigation; WR2: irrigation every 2 days).

NLP in WR1 at 60 DAE showed the highest and lowest means (10.978 and 10 leaves, respectively) for hydrogel rates of 1.24 and 3 g L^{-1}, respectively; the highest and lowest mean NLP (11 and 9.7 leaves, respectively) in WR2 were found for the hydrogel rates of 3 and 0 g L^{-1}, respectively (Figure 2).

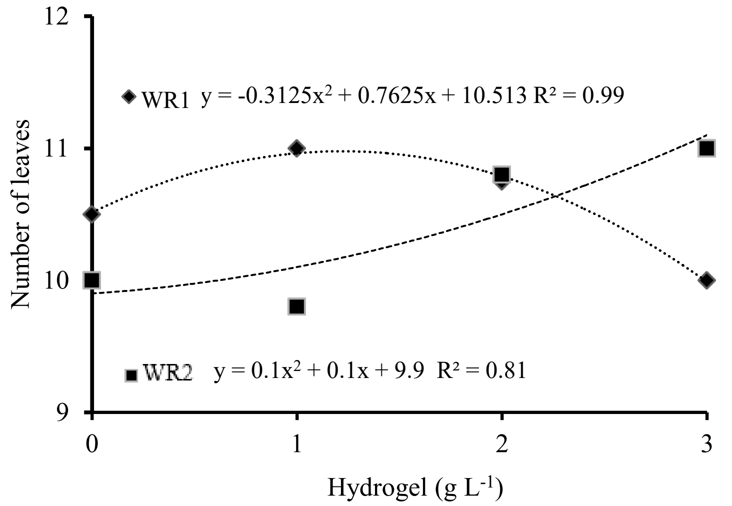

Figure 2. Number of leaves per plant (NLP) assessed at 60 days after emergence of *Mimosa caesalpiniifolia* seedlings subjected to different hydrogel rates in the substrate and water regimes (WR1: daily irrigation; WR2: irrigation every 2 days).

Seedling growth was affected by the water regimes, mainly when combined with the evaluated hydrogel rates. PH, SBD, and NLP means were similar between the water regimes. This result can be attributed to the effect of hydrogel on soil water retention capacity (YÁÑEZ-CHÁVEZ et al., 2014).

Studies on the use of hydrogels as soil conditioners are relatively recent, but have generally shown mitigating effects of water stress on plants, contributing to the development of more resistant and high-quality seedlings. Similarly, Nascimento (2021) found that the incorporation of a hydrogel into the soil favored the initial development of *M. caesalpiniifolia* seedlings. Additionally, the application of hydrogel to clayey soil increased soil water storage by up to 17% (MENDONÇA et al., 2013).

Final evaluations

The evaluation at the end of the experiment (75 days after sowing - DAS) showed no significant effect of the interaction between the factors for any of the evaluated parameters (Table 2). Regarding the effect of individual factors, root length was significantly affected ($p<0.01$) by hydrogel rates; the water regime factor had no significant effect on any of the parameters.

Table 2. Means of number of leaves per plant per plant (NLP), plant height (PH), stem base diameter (SBD), root length (RL), robustness index (PH to SBD ratio; PH/SBD), shoot dry weight (SDW), root dry weight (RDW), total dry weight (TDW), SDW to RDW ratio (SDW/RDW), and Dickson quality index (DQI) of *Mimosa caesalpiniifolia* seedlings grown under different hydrogel rates in the substrate (H) and water regimes (WR1 and WR2).

	NLP		PH (cm)		SBD (mm)		RL (cm)		PH/SBD	
H	WR1	WR2	WR1	WR2	WR1	WR2	WR1	WR2	WR1	WR2
0 g L^{-1}	12.5a	11.5a	46.5a	46.0a	4.9a	4.6a	37.0a	45.1a	0.20a	0.24a
1 g L^{-1}	12.3a	12.0a	46.6a	46.7a	5.0a	4.8a	25.5a	25.1a	0.20a	0.17a
2 g L^{-1}	12.8a	11.5a	46.0a	47.4a	4.9a	4.8a	25.6a	20.0a	0.15a	0.18a
3 g L^{-1}	11.8a	12.5a	49.0a	48.0a	4.7a	4.6a	23.4a	23.0a	0.21a	0.15a
H	SDW (g)		RDW (g)		TDW (g)		SDW/RDW		DQI	
	WR1	WR2	WR1	WR2	WR1	WR2	WR1	WR2	WR1	WR2
0 g L^{-1}	5.06a	4.08a	0.94a	0.99a	5.99a	5.06a	6.4a	4.4a	1.09a	1.16a
1 g L^{-1}	4.95a	5.10a	0.96a	0.85a	5.91a	5.94a	5.2a	6.3a	1.11a	0.97a
2 g L^{-1}	5.3a	4.80a	0.78a	0.83a	6.07a	5.61a	8.8a	5.8a	0.90a	0.95a
3 g L^{-1}	4.9a	4.90a	1.04a	0.74a	5.97a	5.65a	4.8a	6.7a	1.21a	0.83a

WR1 = daily irrigation; WR2 = irrigation every 2 days. Means followed by the same letter, comparing water regimes within each hydrogel rate, are not significantly different from each other by the Tukey's test ($p\leq0.05$).

The evaluated parameters showed no significant different means; however, high Dickson quality indices (DQI) were found.

DQI is a comprehensive and widely used indicator of forest seedling quality, as it combines robustness index and biomass distribution balance of seedlings (DA ROS et al., 2018). Moreover, the higher the DQI, the better the seedling quality and the greater the likelihood of survival in the field (ABREU et al., 2014). The DQI values found in the present study are consistent with those reported by Marques et al. (2006) and Nascimento (2021) for *M. caesalpiniifolia* seedlings.

Root length (RL) in WR1 water regime reached the highest mean (36.3 cm) in the absence of hydrogel, whereas the lowest mean (23.19 cm) was found for a hydrogel rate of 2.4 g L^{-1}. RL in WR2 showed similar trend: the highest and lowest means (45.1 and 19.13 cm) were found for the hydrogel rates of 0 and 2.2 g L^{-1}, respectively (Figure 3).

The highest hydrogel rates negatively affected root system growth of *M. caesalpiniifolia* seedlings. This may be attributed to an intense contact between roots and hydrogel from germination onwards, which hindered root growth due to a large amount of hydrogel in the root environment (NASCIMENTO, 2021).

Marques, Cripa, and Martinez (2013) evaluated 240-day-old coffee plants grown under a superabsorvent polymer rate of 3 g L^{-1} and found reduced root development compared to the rate of 2 g L^{-1}, as excess polymer in the soil formed clumps, affecting the plants' root system.

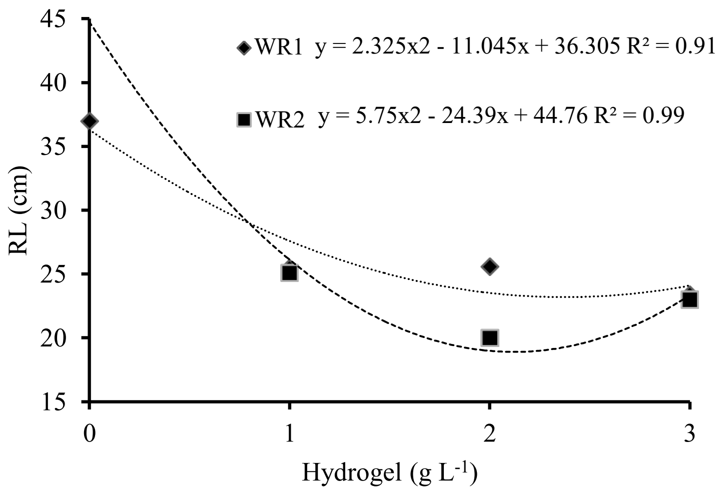

Figure 3. Root length (RL) of *Mimosa caesalpiniifolia* seedlings grown under different hydrogel rates in the substrate and water regimes (WR1: daily irrigation; WR2: irrigation every 2 days).

Gas exchange

Similarly, the effect of the interaction between the factors was not significant for any of the evaluated gas exchange parameters (Table 3). Regarding the effects of individual factors, hydrogel rates significantly affected intercellular CO_2 concentration (*Ci*) ($p<0.01$), whereas water regimes significantly affected *Ci* and transpiration rate (*E*) ($p<0.01$), as well as photosynthetic rate (*A*) ($p<0.05$).

Ci, E, and *A* showed significant different means between water regimes (Table 3). *Ci* showed significantly higher means in the treatments with WR1 and hydrogel rates of 0 and 2 g L^{-1}. Plants in WR2 had significantly higher *E* compared to those in WR1, showing the highest means for the hydrogel rates of 0 g and 1 g L^{-1}. The treatments without hydrogel and subjected to WR2 resulted in significant higher *A* than that with WR1; however, the mean *A* values tended to be higher for WR2, decreasing as the hydrogel rate was increased in the substrate.

Pessoa, Freire, and Costa (2017) assessed gas exchanges in young *Handroanthus impetiginosus* plants subjected to water deficit and found decreases in *A* for non-irrigated compared to irrigated plants. Scalon et al., (2011) reported that *A* can be affected by stomatal limitations caused by changes in stomatal opening, resistance to CO_2 influx, biochemical reactions, and inhibition of Rubisco activity.

The highest and lowest *Ci* (251.9 and 169.67 mol mol^{-1}) in WR1 were found for plants subjected to the hydrogel rates of 0 and 3 g L^{-1}, respectively. Regarding the treatments with WR2, the highest *Ci* (177.3 mol mol^{-1}) in the hydrogel rate of 2 g, decreasing to 155.7 mol mol^{-1} for the hydrogel rate of 3 g L^{-1} (Figure 4). Pessoa, Freire, and Costa (2017) assessed the progressive suspension of irrigation in *H. impetiginosus* plants and found higher *Ci* in non-irrigated plants compared to those under irrigation, attributing this result to stomatal closure, which reduced photosynthesis, resulting in lower carboxylation and consequently lower CO_2 accumulation. Additionally, Machado et al. (2005) reported that decreases in *Ci* can reduce photosynthesis due to lower CO_2 concentration, which is essential for Rubisco activity.

Table 3. Means of leaf area (LA), water relative content (WRC), intercellular CO_2 concentration (*Ci*), transpiration rate (*E*), stomatal conductance (*gs*), photosynthetic rate (*A*), water use efficiency (WUE), and intrinsic water use efficiency (WUEi) of *Mimosa caesalpiniifolia* seedlings grown under different hydrogel rates (H) and water regimes (WR1 and WR2).

	LA		WRC		*Ci*		*E*	
H	WR1	WR2	WR1	WR2	WR1	WR2	WR1	WR2
0 g L^{-1}	9.4a	7.9a	0.93a	0.95a	251.9a	175.3b	4.54b	9.3a
1 g L^{-1}	7.5a	7.5a	0.94a	0.91a	209.0a	174.3a	6.73b	9.4a
2 g L^{-1}	6.7a	7.0a	0.94a	0.93a	223.3a	177.3b	6.97a	8.0a
3 g L^{-1}	7.2a	7.5a	0.94a	0.94a	169.7a	155.7a	6.5a	7.0a

	gs		*A*		WUE		WUEi	
H	WR1	WR2	WR1	WR2	WR1	WR2	WR1	WR2
0 g L^{-1}	0.56a	1.12a	18.15b	39.63a	4.0a	4.3a	32.65a	39.4a
1 g L^{-1}	0.87a	0.78a	30.10a	36.86a	4.6a	3.9a	36.20a	47.3a
2 g L^{-1}	0.69a	0.50a	25.57a	29.29a	3.7a	3.6a	37.20a	60.0a
3 g L^{-1}	0.87a	0.35a	29.70a	27.30a	4.5a	3.9a	72.20a	78.7a

WR1 = daily irrigation; WR2 = irrigation every 2 days. Means followed by the same letter, comparing water regimes within each hydrogel rate, are not significantly different from each other by the Tukey's test ($p \leq 0.05$).

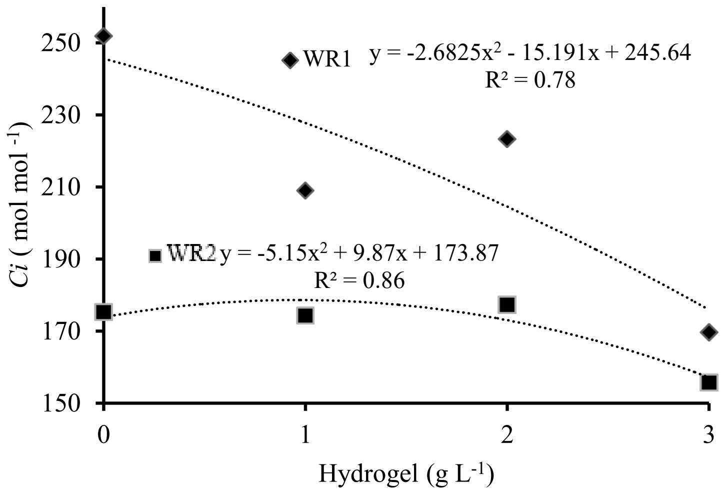

Figure 4. Intercellular CO_2 concentration (*Ci*) in *Mimosa caesalpiniifolia* seedlings grown under different hydrogel rates in the substrate and water regimes (WR1: daily irrigation; WR2: irrigation every 2 days).

Few studies on the effects of hydrogel application on plant physiology are found in the literature, mainly regarding forest species of the Caatinga biome. Nascimento (2021) analyzed the effect of hydrogel rates and application methods on gas exchanges in *M. caesalpiniifolia* seedlings and found lower *A*, *E*, and *gs* in plants grown without hydrogel compared to those treated with polymer rates; this result was attributed to the retention and slow release of water to plants by superabsorbent polymers. These results are consistent with those found in the present study.

Soil nutrient evaluation

The evaluation of nutrient contents in the substrates at the end of the experiment showed a significant effect ($p<0.05$) of the interaction between hydrogel rates and water regimes. The interaction between had significant effect ($p<0.05$) on pH. However, the effect of individual factors was significant ($p<0.01$) for Sodium (Na) contents. No significant effect was found for the other nutrients: potassium (K), calcium (Ca), and magnesium (Mg).

The lowest substrate pH was found for the treatment with WR1 and hydrogel rate of 0 g L^{-1}, significantly differing from the other treatments. Sodium (Na) contents were significantly lower in treatments subjected to WR1 at all hydrogel rates (0, 1, 2, and 3 g L^{-1}) compared to treatments in WR2 (Table 4).

Data of pH fitted to a quadratic model, with the highest levels (6.89 and 6.8) found for hydrogel rates of 2.35 and 1 g L^{-1} in WR1 and WR2, respectively (Figure 5).

Na data showed a linear increasing response, with the highest levels (1.8 and 3.1 cmolc dm^{-3}) found for the hydrogel rate of 3 g L^{-1} in WR1 and WR2, respectively (Figure 6).

Table 4. Means of potential hydrogen (pH) and calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) contents in the substrates used for growing *Mimosa caesalpiniifolia* seedlings under different hydrogel rates (H; L^{-1}) and water regimes (WR1 and WR2).

	pH		Ca ($cmol_c\ dm^{-3}$)		Mg ($cmolc\ dm^{-3}$)		K ($cmolc\ dm^{-3}$)		Na ($cmolc\ dm^{-3}$)	
H	WR1	WR2	WR1	WR2	WR1	WR2	WR1	WR2	WR1	WR2
0 g L^{-1}	6.6b	6.8a	14.23a	13.97a	4.4a	4.9a	0.53a	0.35a	0.97b	2.1a
1 g L^{-1}	6.9a	6.8a	13.4a	14.10a	4.8a	4.3a	0.41a	0.35a	1.2b	2.6a
2 g L^{-1}	6.8a	6.8a	13.7a	14.50a	3.9a	4.5a	0.39a	0.35a	1.4b	2.9a
3 g L^{-1}	6.9a	6.7a	13.2a	14.10a	4.9a	4.5a	0.33a	0.34a	1.8b	3.1a

WR1 = daily irrigation; WR2 = irrigation every 2 days. Means followed by the same letter, comparing water regimes within each hydrogel rate, are not significantly different from each other by the Tukey's test ($p \leq 0.05$).

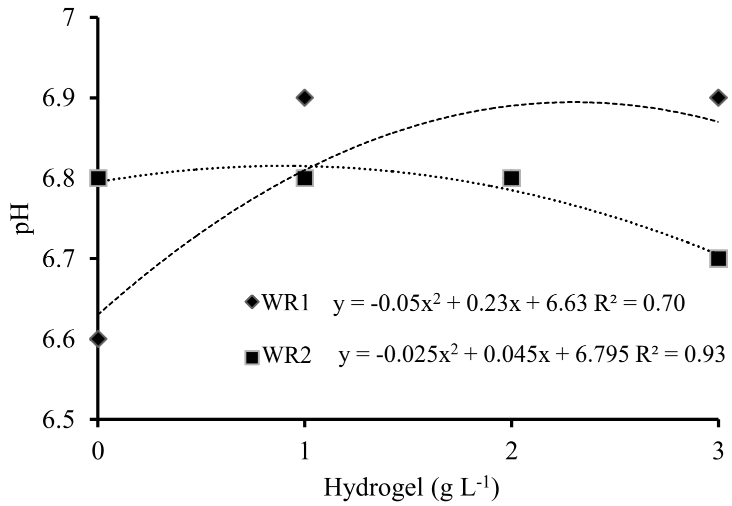

Figure 5. Potential hydrogen (pH) in substrates used for growing *Mimosa caesalpiniifolia* seedlings under different hydrogel rates (H) and water regimes (WR1: daily irrigation; WR2: irrigation every 2 days).

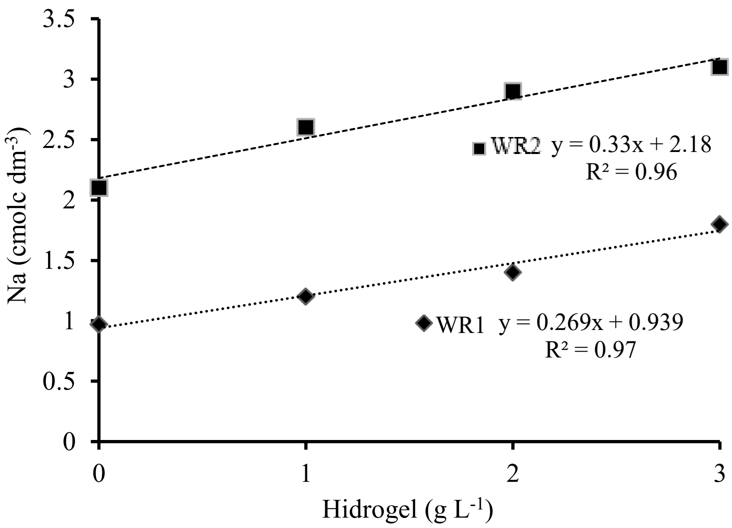

Figure 6. Sodium (Na) contents in substrates used for growing *Mimosa caesalpiniifolia* seedlings under different hydrogel rates (H) and water regimes (WR1: daily irrigation; WR2: irrigation every 2 days).

Considering the importance of pH and Na content in the soil, the results showed adequate levels of these parameters for plant nutrition. Moreover, the lower the water availability, the higher the salt accumulation, probably from water. However, Al-Jabari, Ghyadah, and Alokely (2019) reported that the action of polymers depends on several factors such as soil pH, temperature, texture, and salinity level, indicating that the results found in the present study may be inconclusive.

CONCLUSION

A rate of 2 g L^{-1} of water-absorbing polymer (hydrogel) in the substrate resulted in higher production of *Mimosa caesalpiniifolia* seedlings.

The absence of hydrogel resulted in longer roots, regardless of the water regime used.

Irrigation every two days, combined with absence of hydrogel, resulted higher photosynthetic rate and intercellular CO_2 concentration.

The application of hydrogel in the substrate, regardless of the rate, combined with Irrigation every two days, resulted in *M. caesalpiniifolia* plants presenting similar stomatal responses to those irrigated daily.

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