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Growth components and gas exchange in *Tecoma stans L.* plants under water stress

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Abstract

The reduction in water availability has significant effects on plant physiology and morphology, leading to changes in metabolism that impair the plant establishment in the field. This study aimed to evaluate the effects of water stress on morphophysiological traits of *Tecoma stans* (L.) Juss. ex Kunth seedlings. The experimental design was conducted in a completely randomized design, with four irrigation intervals: daily irrigation (control), and irrigation intervals of 5, 10, and 15 days. Plant height and leaf number were measured weekly after the 15th day after transplanting and the root length, dry matter, and biomass allocation in different plant organs were determined after 60 days. Gas exchange measurements were also assessed. *Tecoma stans* showed significant response to water stress due to the extended irrigation intervals, showing a significant reduction in plant height, leaf number, dry matter (stem, leaves, roots, and total dry matter). Photosynthetic rates ranged from 1.8 μmol m^{-2} s^{-1} under the longest irrigation interval to 13.6 μmol m^{-2} s^{-1} in plants irrigated daily, with transpiration rates following a similar behavior. The highest gas exchange rates were observed under daily irrigation. The most significant negative effects on photosynthesis, transpiration, and particularly stomatal conductance were observed in plants irrigated under intervals of 10 and 15 days.

Keywords: photosynthesis, phytomass, yellow trumpetbush, water availability

Introduction

Tecoma stans (L.) Juss. ex Kunth belongs to the Bignoniaceae family and is commonly known as Yellow trumpetbush. Due to its striking flowering display, it is widely used as an ornamental plant and is commonly found throughout Brazil. The species produces a high quantity of viable seeds, which are mainly wind dispersed during the dry season (Rojas Rodríguez & Torres-Córdoba, 2012). This ecological flexibility has placed *T. stans* as one of the most significant invasive plant species in Brazil (Cipriani et al., 2014).

Climate change accelerates the drying rate of soils with vegetation, leading to an earlier onset of drought stress in plants (Fischer & Knutti, 2015). The variation in the duration of dry periods and the total annual precipitation modulates forest types, as consecutive dry years reduce biomass accumulation, highlighting the significant impact of climatic conditions (Poorter et al., 2016; Spannl et al., 2016).

The water deficit in soil affects plant species under various conditions, leading to morphological and physiological changes. This problem highlights the importance of the development of strategies to ensure the proper functioning of structural, metabolic, and biochemical processes, which together may confer drought adaptation and/or tolerance of plants to such harsh conditions. In addition, understanding of the morphophysiological responses to drought is essential for a holistic perception of the tolerance mechanisms in trees under water stress (Nascimento et al., 2019).

The period, intensity, and duration significantly influence the plant water stress (Saint Pierre et al., 2012). Plants have evolved numerous mechanisms to delay and tolerate water stress, including adaptations in growth and development, such as the expansion of the root system, leaf abscission, stomatal closure, increased resistance

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to water flow, and enhanced wax deposition on leaves (Osakabe et al., 2014; Meena et al., 2017). Additionally, a reduction in leaf water potential, loss of turgor, and decreased cell growth are also key response mechanisms in plants under water stress (Jaleel et al., 2009).

Studies on *T. stans* under water-restricted conditions is of great value as it may contribute to the understanding of the effects of drought periods on the adaptation mechanisms of these plants during their propagation and establishment. This knowledge can facilitate the development of viable management practices, improving the control of expansive populations, reducing the loss of local biodiversity, and preventing potential habitat destruction.

Therefore, considering the lack of information on the growth and physiological behavior of this species under water deficit conditions, this study aimed to evaluate the effect of water stress on the morphophysiology of *Tecoma stans* (L.) Juss. ex Kunth seedlings.

Materials and methods

The experiment was conducted in a greenhouse at the Centro de Ciências Agrárias of the Universidade Federal da Paraíba (CCA-UFPB), located in Areia, Paraíba, Brazil. The area is located in the Brejo de Altitude region, at the coordinates: latitude 6° 57' 42'' South, longitude 35° 41' 43'' West, and altitude of 573 meters. According to the Köppen classification, the predominant climate in the region is of the As' type, with hot, dry summers and rainfall in the winter (ALVAREZ et al., 2013).

The *T. stans* seedlings were produced from seeds randomly collected from different individuals distributed within the UFPB forests. The harvest fruits were brown in color and were near the point of spontaneous seed release. To extract the seeds, the fruits were manually processed, and the seeds were germinated in plastic trays with dimensions of 0.49 x 0.33 x 0.07 cm, containing topsoil, with emergence occurring three days after sowing.

The seedlings were transplanted into pots of 6 L containing soil when they reached five centimeters in height and had at least one pair of true leaves. The soil physical and chemical characteristics are shown in **Table 1** (EMBRAPA, 2017).

The experiment was conducted in a completely randomized block design with four watering regimes [daily watering (control), watering every 5 days, watering every 10 days, and watering every 15 days], with 8 replications, represented by one plant per pot. The irrigation regimes were implemented starting 30 days after planting, and were provided equally to all plants, using a single volume without a drainage layer, to keep the soil moisture close to field capacity, using the direct gravimetric method (Bernardo, 2006).

Plant height was measured weekly 30 days after planting, from the basal of the plant to the top insertion of the last expanded leaf, with a millimeter ruler. The number of leaves was determined by counting the leaves on all plants in each treatment. At the end of the experiment (60 days), the dry mass of the aerial part, stem, and root was assessed. The seedlings from each treatment were harvested and separated into leaves, stems, and roots. The roots were washed with running water to remove all soil particles, dried with tissue paper, and placed in kraft paper bags. The samples were dried in a forced-air circulation oven at 65°C until a constant weight was reached. The dry matter of the leaves, stems, and roots was then weighed. The dry matter of plants was used to calculate the biomass allocation partitioning to the leaves, stems, and roots according to Benincasa (2003).

Gas exchange measurements included the stomatal conductance (gs - mol m^{-2} s^{-1}), net CO_2 assimilation rate (A - μmol CO_2 m^{-2} s^{-1}), transpiration (E - mmol H_2O m^{-2} s^{-1}), internal CO_2 concentration (Ci - μmol CO_2 m^{-2} s^{-1}), water use efficiency (WUE: A/E), and intrinsic water use efficiency (iWUE). Measurements were taken between 10:00 and 11:00 a.m., using a portable infrared gas analyzer (IRGA model LI-6400XT, LI-COR®, Nebraska, USA) with an airflow rate of 300 mL min^{-1} and a coupled light source of 1200 μmol m^{-2} s^{-1}.

Data were submitted to residual normality and homogeneity of variances tests. For the analysis of variance, the F-test was applied, and when significant, the means were compared by Tukey's test at a 5%. The software Sisvar® was used for all analyses (Ferreira, 2019).

Results and discussion

The best plant height of T. stans (L.) Juss. ex Kunth plants was obtained when plants were irrigated daily, with the highest values (35.38 cm) being observed at 100 days (**Figure 1**A), followed by a decrease according to the irrigation intervals, with losses of 49.1%, 71.7%, and 75.4%, under irrigation intervals of 5, 10, and 15 days, respectively. The number of leaves (Figure 1B) followed the same pattern, with the highest number of leaves (14 leaves) under daily watering. Plants irrigated every 5, 10, and 15 days had 12, 6, and 8 leaves, a reduction of 14.3%, 57.1%, and 42.9%, respectively when compared to control (daily irrigation).

The reduction in height and the number of leaves in T. stans plants may be related to the reduction in cell turgor, which affects cell division and expansion, leading

Table 1. Physico-chemical properties of the soil used in the cultivation of *T. stans* in the study.

Soil chemical properties										
pH	P	K^+	Na^+	H^++Al^{+3}	Al^{+3}	Ca^{+2}	Mg^{+2}	SB	CTC	O.M
H_2O (1:2.5)	--- mg dm^{-3}---		------------------ $cmol_c$ dm^{-3}--------------------							g kg^{-1}
5.1	0.38	27.34	0.35	7.92	0.23	1.90	1.68	4.0	11.92	34.12

Physical properties			
Sand	Silt	Clay	Classe textural
2- 0.05 mm	0.05 – 0.002 mm	< 0.002 mm	
------------ g kg^{-1}-------------			
560	13	427	Sandy clay, Loamy sandy lay.

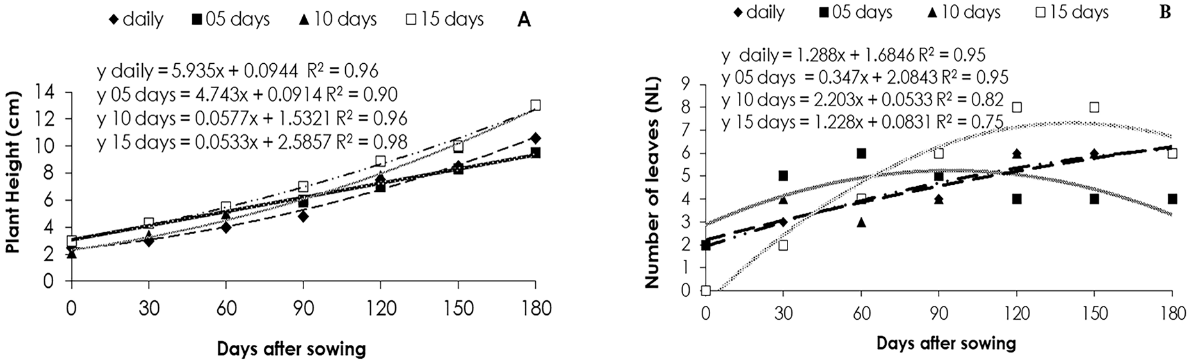

Figure 1. Plant height (A) and number of leaves (B) of *Tecoma stans* (L.) Juss. ex Kunth under different intervals of irrigation.

to morphophysiological changes (Peloso et al., 2017). Height growth is more sensitive to water stress, highlighting the need of water for the formation of new leaves and, especially, for their growth (FÁTIMA et al., 2018). This effect was observed in plants under 10 and 15-day watering intervals, where water stress impaired height growth and formation of leaves. Water restriction affects the growth and development of plants and other traits such as the number of nodes, plant height, internode length, and leaf area expansion, which have been proposed as indicators of tolerance to water stress (KU et al., 2013).

The root dry matter (RDM), stem (SDM), leaves (LDM), and total dry matter (TDM) were also higher in plants where water was provided daily, with reductions as the irrigation intervals increased, resulting in losses of approximately 50%, 90%, 85%, and 75% for RDM, SDM, LDM, and TDM, in those plants irrigated at every 15 days (**Figure 2**). The reduction in dry matter under water stress conditions may be explained by a lower photosynthetic rate, caused by reduced leaf development and expansion, leading to decreased light interception (Mathobo et al., 2017; Freitas et al., 2021).

Biomass allocation was also higher in the treatment with daily watering and watering every 5 days, both in the leaf, stem, and root. However, biomass allocation decreased when the plants were under water stress under watering every 10 and 15 days (**Table 2**). The biomass allocation showed in table 2 occur due to the decreases in the photosynthetic activity, induced by the reduction in stomatal conductance, affecting leaf formation, leaf area, and the high rate of degradation of photosynthetic pigments and leaf senescence, leading to low biomass accumulation in the plant organs (Matos et al., 2014).

Stomatal conductance (gs) was higher in plants irrigated daily (0.296 mol m^{-2} s^{-1}), with lower levels observed in the plants irrigated under intervals of every 5 (0.025 mol m^{-2} s^{-1}), 10 (0.01 mol m^{-2} s^{-1}), and 15 days (0.011 mol m^{-2}

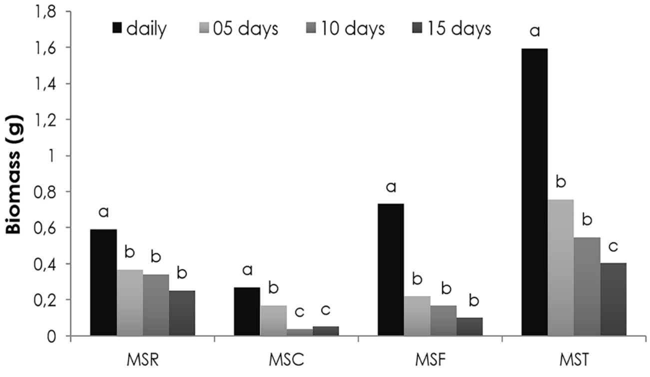

Figure 2. Root dry matter (RDM), stem (SDM), leaf (LDM), and total dry matter (TDM) of *Tecoma stans (L.) Juss. ex Kunth* under different irrigation intervals. Means followed by the same letter in the column are statistically similar according to the Tukey's test at 5%.

Table 2. Mean biomass allocation in leaves, stem, and roots of *Tecoma stans* (L.) Juss. ex Kunth under different irrigation intervals.

Treatments	Biomass alocation		
	Leaves	Stem	Roots
Daily irrigation	0.459a	0.223a	0.624a
5 days	0.307a	0.169a	0.622a
10 days	0.290b	0.129b	0.485ab
15 days	0.248b	0.068b	0.371b

s^{-1}) (**Figure 3**A). The same pattern was observed with the internal CO_2 (Ci), which was higher in plants irrigated daily (244.07 µmol mol^{-1}) and every five days (241.18 µmol mol^{-1}), with a reduction of 24.14% due to water availability in the soil (Figure 3B).

The stomata closure observed in the treatments under irrigation intervals of 5, 10, and 15 days is considered one of the first adjustments of plants to avoid water loss (LIU; SUAREZ, 2021), reducing the assimilation of CO_2, consequently reducing the internal CO_2 concentration (Ci).

Photosynthesis (A) and transpiration (E) decreased as water deficit became more severe, with values close to 0 (**Figures 4**A and 4B). Water deficit in plants generally leads to a decrease in the photosynthetic rate. Stomatal closure is another strategy to reduce the transpiration rate and maintain cell turgor (Giordano et al., 2021). This reduction in stomatal opening decreases stomatal conductance and limits CO_2 assimilation (Harrison et al., 2020).

The results observed in plants under water stress represent a strategy of plants to reduce water loss through transpiration, preventing dehydration of the tissues. This is also indicated by increases in internal carbon (Ci) values accompanied by increases in stomatal conductance (Gs). Consequently, the reduction in stomatal opening would be the main factor limiting photosynthetic performance, as greater stomatal opening allows more CO_2 diffusion into the stomatal chamber (Nascimento et al., 2011).

Leaf vapor pressure (LVP) increased gradually with water stress, particularly in the treatments under larger intervals, 10 and 15 days (**Figure 5**A). Air temperature (°C) reached 38°C in the treatments with irrigation intervals of 10 and 15 days (Figure 5B). Leaf temperature increased throughout the period, with a maximum value of 39°C being recorded in the irrigation interval of 15 days (Figure 5C).

The increase in vapor pressure was probably due to the increase in air temperature, and thus, the decrease in stomatal opening, causing a reduction in stomatal conductance and photosynthesis. At the same time, this led to increased water loss from the plant through transpiration, which may result in reduced primary productivity and increased plant mortality induced by drought (Grossiord et al., 2020).

Intrinsic water use efficiency (iWUE) and instantaneous water use efficiency (WUE) decreased with longer irrigation intervals, reaching values of 1.8 and 1.2 µmol CO_2 mol H_2O^{-1}, respectively, in plants under irrigation intervals of every 15 days (**Figures 6**A and 6B).

The decrease in these parameters can be explained by the increase in leaf vapor pressure and CO_2 concentration in the atmosphere, causing increased

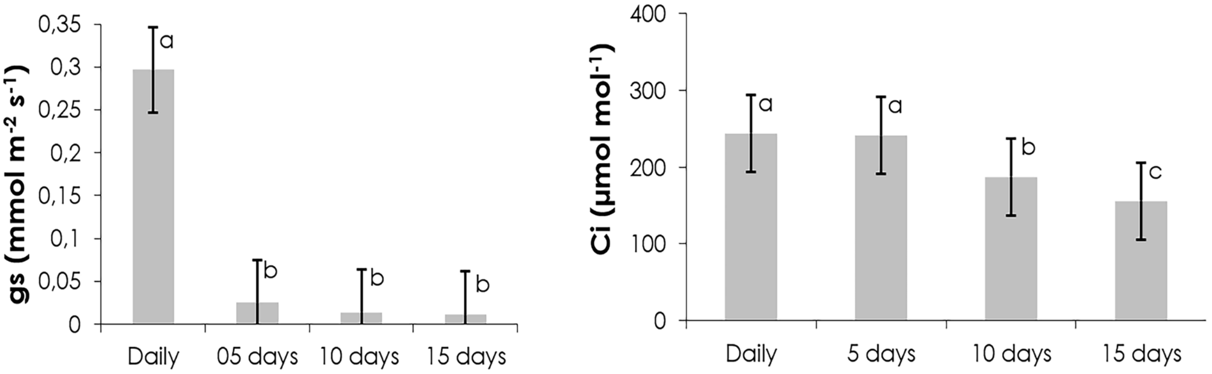

Figure 3. Stomatal conductance – gs (A) and internal CO_2 concentration – Ci (B) of *Tecoma stans* (L.) Juss. ex Kunth under different irrigation intervals.

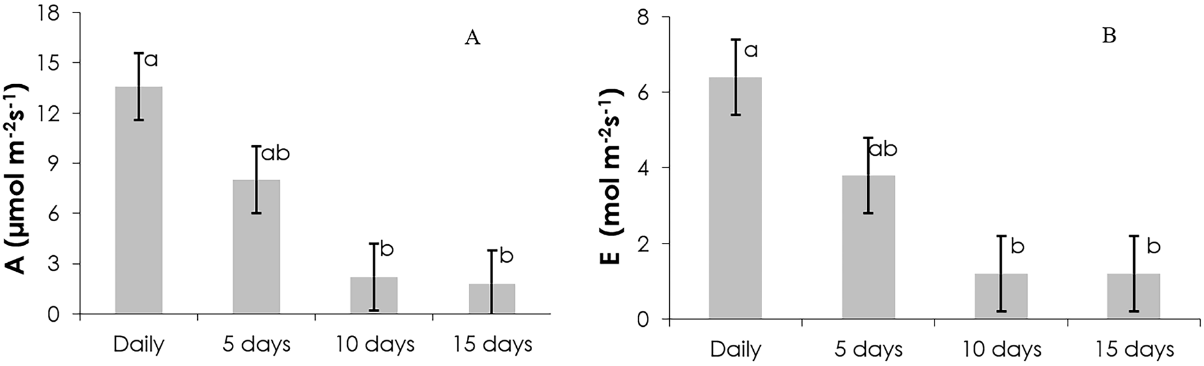

Figure 4. Photosynthesis – A (A), and transpiration – E (B) of *Tecoma stans* under different irrigation intervals.

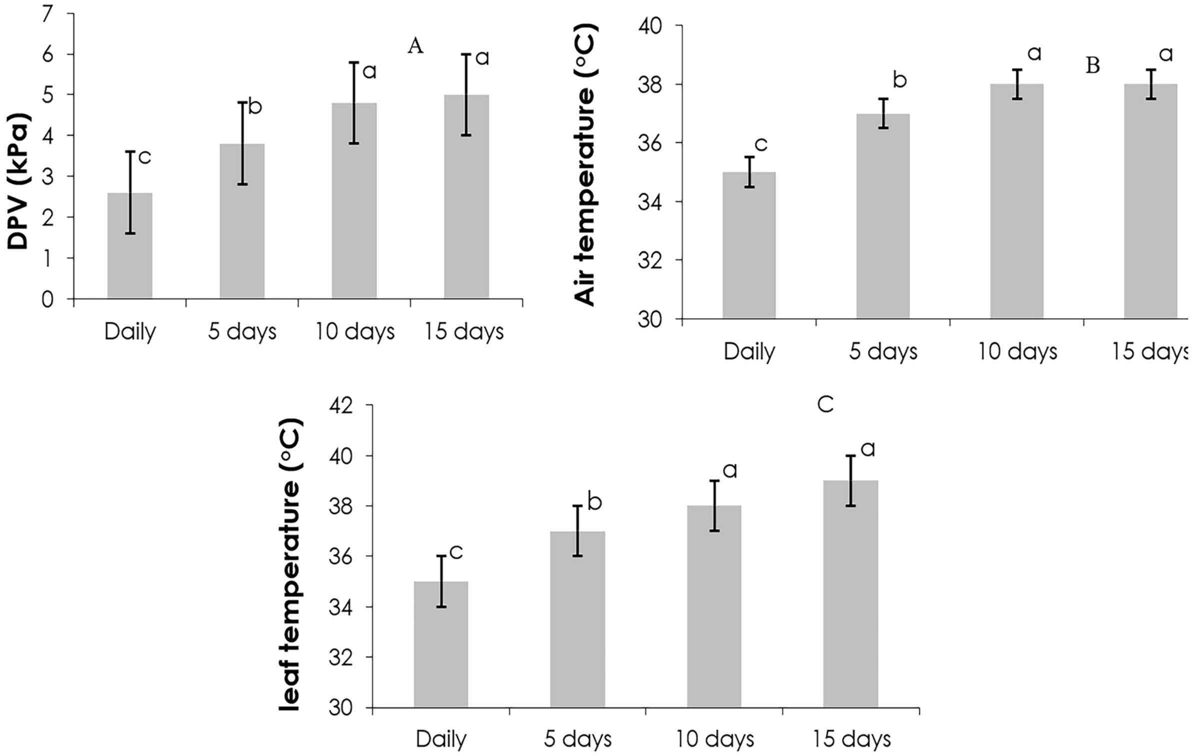

Figure 5. Leaf vapor pressure deficit – LVP (C), air temperature (D), and leaf temperature (E) of *Tecoma stans* under different irrigation intervals.

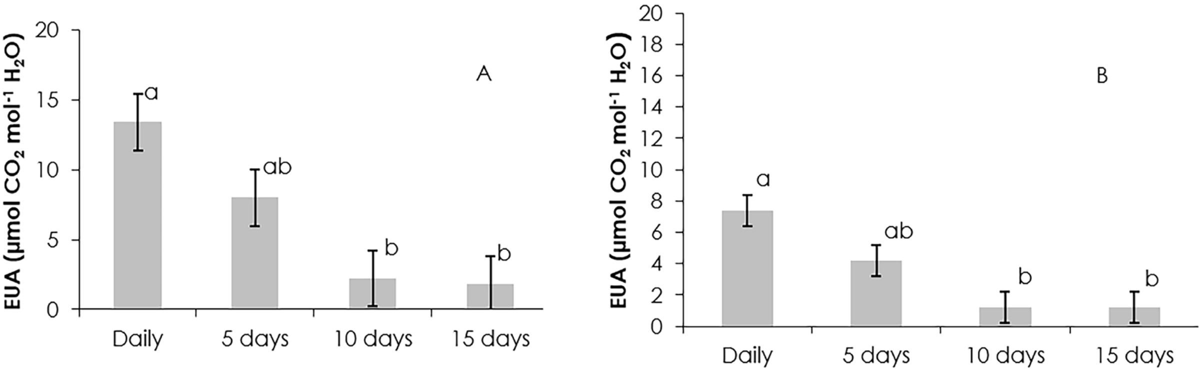

Figure 6. Intrinsic water use efficiency – iWUE (A) and instantaneous water use efficiency – WUE (B) of *Tecoma stans* plants under different irrigation intervals.

transpiration and decreased photosynthesis with stomatal closure (KNAUER et al., 2018). According to Taiz et al. (2017), plants can increase water use efficiency under water stress by reducing stomatal conductance, which affects the photosynthetic rate more intensely than the leaf transpiration rate. However, with severe water stress, water use efficiency is reduced (Mukherjee et al., 2010; Kuscu et al., 2014).

Conclusions

Young plants of *T. stans* can tolerate irrigation regimes of up to five days without compromising growth and physiological parameters. However, as the restriction increases, a severe reduction in the viability of establishing these plants is observed.

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