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Water use efficiency and consumption in different Brazilian genotypes of *Jatropha curcas* L. subjected to soil water deficit

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ABSTRACT

In order to quantify the water use efficiency and water consumption during the early growth of *Jatropha curcas* L., three genotypes were grown in pots under greenhouse conditions, and subjected to two watering regimes: irrigated (substrate matric potential (Ψ_m) of −9.8 to −7.4 kPa) and water deficit (Ψ_m = −98.6 to −33.5 kPa). Independent of watering regime, the genotypes did not differ on the variables analyzed. Despite the reduction of substrate water content in water deficit treatment, no significant decrease ($p < 0.05$) of leaf water potential (Ψ_w) was observed, which suggests some water redistribution from the succulent stems of *J. curcas*. The values of net photosynthetic rate (*A*), stomatal conductance (*gs*), and transpiration (*E*) were reduced to 80, 90 and 85%, respectively, as compared to control plants. Moreover, drought led to 78% reduction in hydraulic conductance (K_L). At the end of the experiment, the average water consumption in water deficit plants was 27% lower than in control plants. Drought-induced decrease in biomass production led to reduction of water use efficiency of biomass ($WUE_{Biomass}$). However, due to the more significant effect on *gs* and *E* than *A* at 66 DAIT, intrinsic (*A*/*gs*) and instantaneous efficiency (*A*/*E*), water use increased 50% and 27%, respectively. The results showed that there was no intergenotypic variation for the traits evaluated, and that the reduction of water availability in the substrate proved to be an effective technique in the increase of photosynthetic efficiency of water use in plants of *J. curcas*, reducing water consumption in this species.

1. Introduction

The species *Elaeis guineensis*, *Acrocomia aculeata*, *Ricinus communis*, *Glycine max*, and *Jatropha curcas* are among the main energetic cultures, i.e., potential sources of oil for production of biodiesel, specially the last one, which has high levels of oil [1], develops in low-pluviosity areas [2], and presents no conflicts with the food sector [3].

The species *J. curcas* L., of the family Euphorbiaceae, popularly known as physic nut, widely distributed in tropical

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regions, is an evergreen tree and shrub of fast growth with oil content in the seeds that is easily converted into biofuel, ranging from 33 to 38% of its dry mass [1,4]. In Brazil, with the advent of the Brazilian Biodiesel Program (Programa Brasileiro de Biodiesel) and the emergence of a large demand for vegetable oils, *J. curcas* has been touted as an alternative for raw material. This choice is based on the expectation that the plant has low production cost and is resistant to water stress, which would be a significant advantage especially in the semi-arid region of Brazil [5]. It is expected that its cultivation can provide, effectively, a source of raw material for the biodiesel industry [3,6].

With the increasing global aridity as a consequence of the scenario of global climate changes, water deficiency emerges as one of the major limitations for agricultural production worldwide [7]. Water scarcity imposes abiotic stresses such as drought and salinity, which are among the most important factors limiting plant capacity and productivity throughout the world [8]. Water deficit impacts on many physiological processes in plants, generally increasing stomatal resistance, reducing transpiration and, hence, the supply of CO_2 for conducting the process of photosynthesis [9]. Primarily, moderate water stress tends to reduce stomatal conductance, before reducing the photosynthetic rate [10]; thus, the plant can assimilate more molecules of CO_2 for each unit of transpired water, being more efficient in the use of the available water [11]. The water use efficiency (WUE) is associated with this ability of the plant to absorb higher concentrations of carbon (implying maintenance of high photosynthetic rates) limiting water loss through the control of stomatal aperture and closure [12].

We hypothesized that (1) water use efficiency of biomass in *Jatropha curcas* can be manipulated through controlled soil water restriction and (2) different genotypes show distinct responses in terms of WUE. Therefore, this study aimed to: i) assess whether the genotypes respond differently to moderate water deficit; ii) evaluate the effects of regulated water deficit on morphological variations, water relations and leaf gas exchange in the genotypes; iii) measure the water use efficiency, quantifying biomass production and water consumption during the studied period; and iv) examine the feasibility of the regulated water deficit technique in increasing water use efficiency.

2. Material and methods

2.1. Biological material and cultivation conditions

The experiment was conducted in a greenhouse at the campus of Santa Cruz State University (UESC), next to the urban area of the municipality of Ilhéus, state of Bahia, in Brazil (14°47′00″ S, 39°02′00″ W), from July 6, 2011 to November 14, 2011.

The seeds of *J. curcas* of the genotypes CNPAE 126, 137, and 139, from the active genebank of EMBRAPA – Agroenergia were left to germinate in pots (six seeds per pot), each containing 50 L of a soil: sand mixture (2:1) (Table 1), previously fertilized according to chemical analysis of the substrate. After 15 days of germination, a trimming was carried out, leaving only one plant per pot. Immediately, the pots were covered with aluminum foils in order to reduce soil water evaporation, and the treatment of the water deficit was initiated for a period of 108 days. During all the experimental period, the control plants were maintained irrigated next to field capacity (−9.8 and −7.4 kPa). The other plants were maintained under deficit irrigation, with range of water deficit between −98.6 and −33.5 kPa. The values for substrate matric potential (Ψ_m) for each treatment during the experimental period were estimated through an equation derived from the soil water retention curve.

Table 1 – Variation of photosynthetically active radiation (PAR – mol m^{-2} day^{-1}), temperature (Tair - °C) e relative humidity (RH - %) of the air, inside the greenhouse during the experimental period. Values are mean (±standard error of the mean), maximum and minimum daily.

	Mean	Maximum	Minimun
PAR	12 (0.6)	24	5
T	25 (0.2)	28	22
RH	77 (1.4)	96	53

During the experiment, the photosynthetically active radiation (PAR) was monitored with quantum sensors S-LIA-M003. Air temperature (T) and relative humidity (RH) were monitored with microcomputed smart sensors Hobo H8 Pro Series (Onset, USA). These variables were measured and stored permanently by the data collectors Hobo Micro Station Data Logger (Onset, USA) (Table 1).

2.2. Water relations

The water status of the plants was evaluated upon 66 days after imposition of treatment (DAIT) through measurements of the leaf water potential (Ψ_w). The measurements of Ψ_w were performed before sunrise (predawn water potential) and at midday, utilizing the pressure chamber PMS1000 (PMS Instrument Company, USA).

The hydraulic conductance was estimated 66 DAIT by using the formula: $[K_L = (gs \times VPD)/(\Psi_{pd} - \Psi_{md})]$, in which *gs* is the stomatal conductance for water vapor, *VPD* is the vapor pressure deficit of water between leaf and air, Ψ_{pd} e Ψ_{md} are the predawn and midday water potentials, respectively [13]. In order to estimate K_L, *gs* and *VPD* were measured at midday along with the measurements of Ψ_{md}.

2.3. Leaf gas exchanges

At 20, 30, 40, 55, and 66 DAIT, gas exchanges were evaluated in completely mature leaves with the portable photosynthesis measurement system Li-6400 (Li-Cor, USA). The net photosynthetic rate (*A*), stomatal conductance (g_s), transpiration (*E*), ratio between the internal and external concentrations of CO_2 (C_i/C_a), were always measured from 08:30 to 11:30 h, under artificial saturating light photon flux of 1000 μmol m^{-2} s^{-1} and atmospheric concentration of CO_2 (C_a) of 380 μmol mol^{-1}.

2.4. Growth variables

In the end of the experiment, at 108 DAIT, a measuring tape was utilized to measure the height of the plant as the distance