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Mesquite (*Prosopis spp.*) Water Uptake under Different Simulated Drought Conditions

Mohamed A. M. ABD ELBASIT*1) 2), Hiroshi YASUDA1), Kiyotsugu YODA3), Ahmed M. ELDOMA4), Hiroshi NAWATA5), Buho HOSHINO6) and Magzoub K. MAGZOUB2)

Abstract: The Mesquite plant has been introduced to several parts of the world in order to control land degradation and to stabilize sand dunes. Mesquite has performed well in several locations due to its tolerance to different environmental stresses. However, mesquite is now considered one of the most invasive species in the world. In this study, we attempt to investigate the impact of drought on mesquite water uptake and to select plant indices that can be used to compare the mesquite's performance under drought conditions with that of Sudanese indigenous species.

Key Words: Growth chamber, Invasive plant species, Land degradation, Water stress

1. Introduction

Mesquite (*Prosopis spp.*), an ever green plant, performs ecological, economical, and hydrological roles in desert environments. The mesquite has been classified as a phreatophytic plant since its unusually long roots give it access to constantly saturated water reservoirs. The mesquite has been introduced to several arid parts of the world in order to rehabilitate the degraded lands and stop the continuous encroachment of the desert. In Sudan, the mesquite was planted in Khartoum in 1917, and has since been established in additional regions of the country (Babiker, 2006). Currently, mesquite is classified as a major non-indigenous (alien species) weed in Sudan. The mesquite pant has been shown to have two mechanisms enabling survival under harsh, arid conditions: phreatophytism and drought resistance. These two mechanisms support mesquite during prolonged drought conditions and allow it to compete successfully with the natural indigenous species. Consequently, mesquite displaces indigenous plant communities, affects agricultural practices, and disturbs the eco-hydrological system in the invaded areas.

An understanding of the mesquite water uptake mechanism could be important from an ecosystem and water conservation point of view. Evaporation from vegetation is generally the second largest component of water balance (Calder, 1999). For this reason, vegetation plays key roles in the interaction between surface and sub-surface hydrological systems (Le Maitre *et al*., 1999).

The evaporation from phreatophytic plant species can be directly related to diurnal water table fluctuations and may limit water resources (Tromble, 1977). The phreatophytic mechanism of the mesquite has been investigated by various researchers (e.g. Tromble, 1977; Giordano *et al*., 2011). In this study, the drought resistance mechanism will be investigated due to its importance in mesquite expansion in arid environments. The main objectives of this study are to study the response of mesquite plants to different drought levels and to identify some plant parameters that can be compared to those of the indigenous species in Sudan and other arid environments.

2. Materials and Methods

2.1 Growth chamber and environmental monitoring

A laboratory experiment was carried out at the Arid Land Research Center at Tottori University under a controlled growth chamber system. The growth chamber used in this study has an area equal to 6 m^2. The top and side walls were transparent to allow natural sun-light to penetrate **(Fig. 1)**. The chamber is equipped with a computer system which controls the temperature, humidity, and wind speed with 95+% accuracy. Air temperature, relative humidity, and wind speed of the chamber were fixed on 33ºC, 0.4, and 0.9 $m\ s^{-1}$, respectively. The air temperature (T) and relative humidity (RH) were monitored at 10-minute intervals. The solar radiation (R) was monitored using a solar radiation sensor (PYR, Decagon Devices, Washington, US), and reading were given every 10 minutes (Fig. 1).

The reference evapotranspiration (ET) at the growth

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* Corresponding Author: mbasit@alrc.tottori-u.ac.jp; m_abdelbasit@hotmail.com

1) Arid Land Research Center, Tottori University, Japan

2) Desertification Research Institute, National Center for Research, Khartoum, Sudan

3) Faculty of Science and Engineering, Ishinomaki Senshu University, Japan

4) Collage of Forestry Science, Sudan University of Science and Technology, Khartoum, Sudan

5) Research Institute for Humanity and Nature (RIHN), Japan

6) Department of Biosphere and Environmental Sciences, Rakuno Gakuen University, Japan

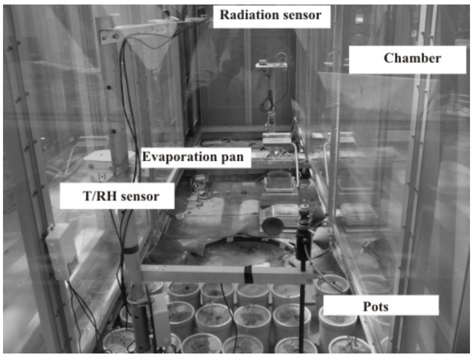

Fig. 1. Growth chamber.

chamber was evaluated using a 21 cm diameter steel pan filled with water and placed on a digital scale connected to a note book computer. The pan evaporation (E_p) was adjusted to evaluate the ET_o using the following procedures:

1. The evaporation from the steel pan was converted to a Class A evaporation pan.

$$E_p = k_{sp} \times E_{sp} \qquad (1)$$

where E_p is Class A water evaporation, E_{sp} is the small pan evaporation, and k_{sp} is the small pan coefficient.

2. The Class A evaporation has been converted to ET_o using relationship reported by Snyder (1992).

$$ET_o = k_p \times E_p \qquad (2)$$

where ET_o is reference evapotraspiration (mm day^{-1}), k_p is the Class A evaporation pan coefficient. According to Doorenbos and Pruitt (1977), the pan coefficient is a function of upwind fetch distance (F), mean daily wind speed (U_2), and mean daily relative humidity (RH_{mean}).

2.2. Pots and seedling Preparation

The pot had a diameter of 25 cm with a height of 30 cm. The pots were filled with dune sand. Four drought treatments were used: 100, 70, 50, 25% ($ET_{1.0}$, $ET_{0.7}$, $ET_{0.5}$, and $ET_{0.25}$, respectively) of the potential evapotraspiration evaluated by the pan evaporation. Each treatment was repeated three times. In addition to the 12 pots of mesquite plants, three pots filled by only sand were placed within the mesquite pots to determine the soil evaporation. The 15 pots were arranged in block experimental design. The mesquite seeds were collected from Khartoum state, Sudan. The seeds were treated using mechanical (sand paper) and chemical (using sulfuric acid and water) techniques to break the dormancy. Germination was induced using a small incubator for three weeks under 27ºC temperature and artificial light. After three weeks, the seedlings were transplanted to the pots and the initial weight was recorded.

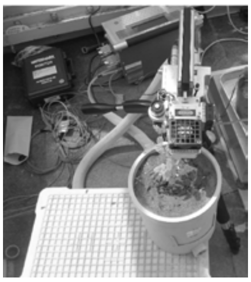

Fig. 2. Photosynthesis device

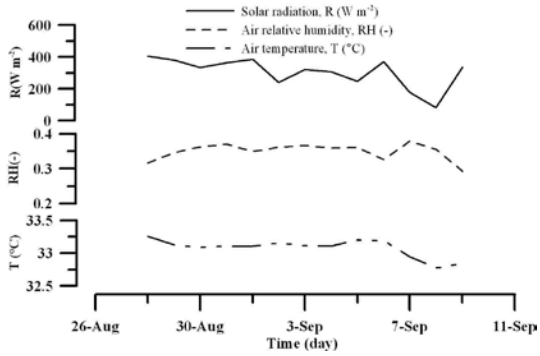

Fig. 3. Environmental parameters.

The weights of the pots were recorded daily prior to daily irrigation, and water lost through transpiration (T_r) was calculated. The amount of water added through irrigation was determined based on the average water evaporation form the pan. The number of leaves and the height of the plants were recorded two times during the experiment. The experiment was continued for two weeks. The mesquite photosynthesis (A), stomata conductance (g_s), intercellular carbon dioxide (C_i), and leaf transpiration ($T_{r(L)}$) were measured using Photosynthesis System LI-COR, LI 6400 (**Fig. 2**).

3. Results and Discussion

Figure 3 shows the T, RH, and R fluctuations during the experimental period. The results showed that the temperature and humidity were effectively controlled in the chamber. However, there was some variation in the solar radiation due to some cloudy days during the experimental period. The pan evaporation was used as basis for irrigation determination and was found to be highly correlated with solar radiation (**Fig. 4**). Although the R is not included in Doorenbos and Pruitt (1977) and Snyder (1992) equations, it showed highly impacted on pan evaporation under the chamber conditions.

3.1 Drought impact on mesquite transpiration

The mesquite transpiration has been calculated from the pots' daily weight (T_r). The mesquite T_r decreased with the increase of the drought level (**Fig. 5**). The relative decrease in

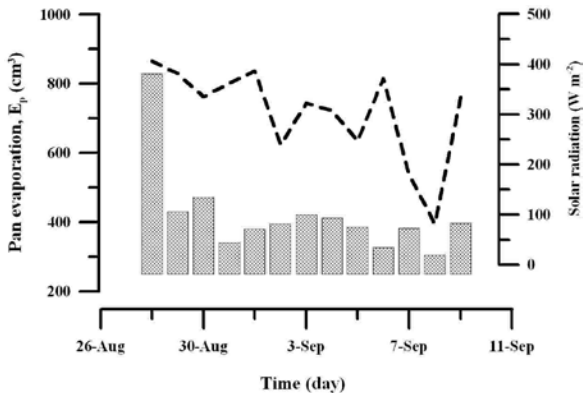

Fig. 4. Relationship between pan evaporation and solar radiation.

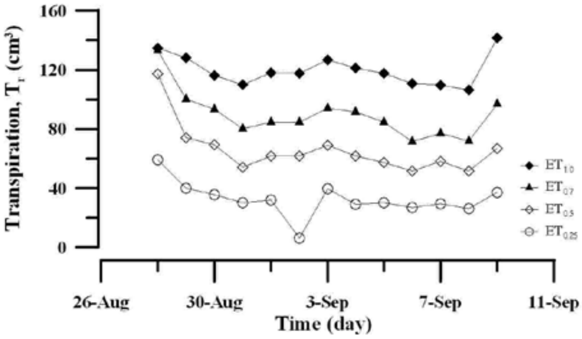

Fig. 5. Mesquite transpiration.

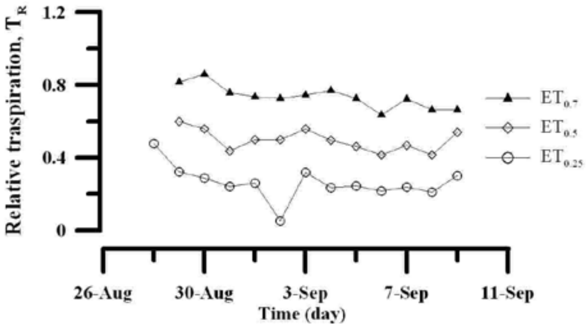

Fig. 6. Relative transpiration.

transpiration was found to be associated with drought levels (**Fig. 6**), which is a good indicator that mesquite is well able to adapt to water stress conditions.

There are two water uptake mechanisms that promote mesquite survival under drought conditions. The transpiration efficiency (T_E) was evaluated based on the transpiration calculated from the pots' weight and mesquite growth (**Fig. 7**). The plant growth was evaluated using the increase in leaf number ($T_{E(LN)}$) and plant height ($T_{E(Hi)}$).

The mesquite T_E increased linearly until the drought level reached $ET_{0.5}$ and then decreased in $ET_{0.25}$ level. The increase in T_E can be attributed to the decrease in the amount of water consumed by mesquite in drought level $ET_{0.7}$ and $ET_{0.5}$ while the plant was able to continue its physiological activities efficiently. This can also be confirmed by the T_E calculated based on the mesquite photosynthesis ($T_{E(A)}$) under different drought conditions (**Fig. 7**). The decrease in T_E occurred in level $ET_{0.25}$ can be attributed to leaf defoliation in this level, although the efficiency of photosynthesis still equalled the $ET_{0.7}$ level (Fig. 7).

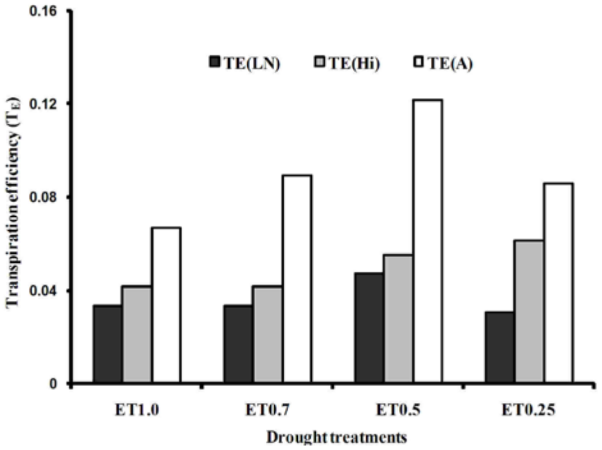

Fig. 7. Transpiration efficiency.

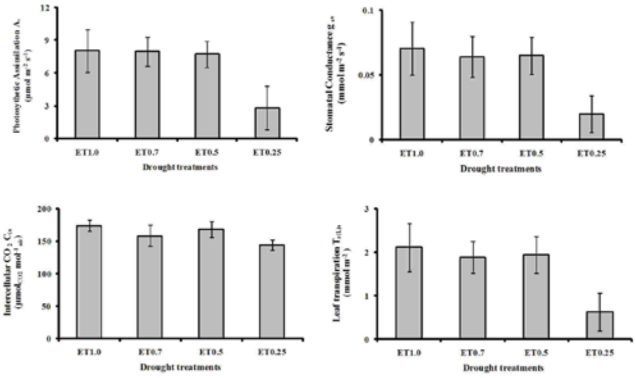

Fig. 8. Photosynthetic parameters.

3.2 Leaf level drought impact evaluation

The leaf A, g_s, C_i, and $T_{r(L)}$ were evaluated under different drought levels (**Fig. 8**). The A, g_s, C_i, and $T_{r(L)}$ were similar at $ET_{1.0}$, $ET_{0.7}$, and $ET_{0.5}$. On the other hand, the $ET_{0.25}$ resulted in a marked decrease in A, g_s, and $T_{r(L)}$ (**Fig. 8**).

The C_i decreased slighly under $ET_{0.25}$. The intrinsic water use efficiency (WUE_i) represents an indicator or a measurement for the photosynthetic water use efficiency (Letts *et al*., 2010). The mesquite showed high intrinsic water use efficiency under drought treatments compared to non-stressed plants (**Fig. 9**).

The mesquite also showed high WUE_i in all treatments as compared to *Acacia* sp. (e.g. *Acacia senegal*) under different cropping systems (Mohamed, 2005). Based on this result, the WUE_i of mesquite plant under drought conditions was higher than *Acacia sp*. under non-stressful conditions. The WUE_i can be used as an index for evaluation and screening of the best species for degraded land rehabilitation (Raddad and Luukkanen, 2006). The trend for the WUE_i was, generally, increased efficiency with drought treatment, which is in

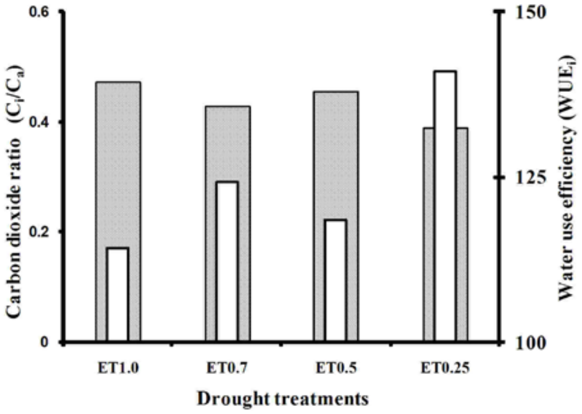

Fig. 9. Intrinsic water use efficiency.

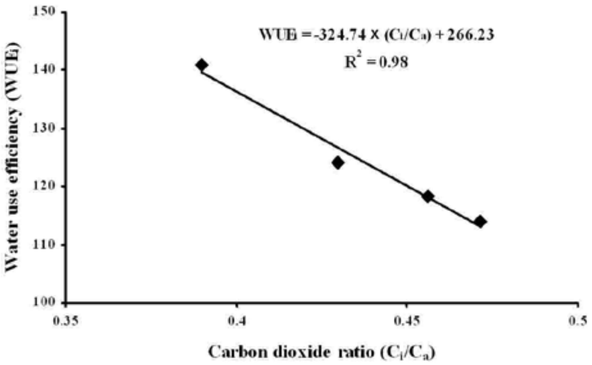

Fig. 10. Relationship between intrinsic water use efficiency and CO_2 ratio.

agreement with previous reported results on other plant species (Blum, 2005). The ratio between the intercellular and atmospheric CO_2 (C_i/C_a) decreased with increasing drought conditions (**Fig. 9**). The relationship between the WUE_i and C_i/C_a can be described by a negative linear relationship (**Fig. 10**).

4. Conclusions

The response of mesquite to different drought levels was investigated. The mesquite showed high adaptability to different drought levels during a short experimental period of time. Although the water supply was decreased by 75%, the mesquite survived with high transpiration and water use efficiencies. The intrinsic water use efficiency was high compared to *Acacia* sp., which gives a good explanation for the expansion of mesquite in the Sudan. Also, a significant relationship was found between the intrinsic water efficiency and the intercellular and atmospheric CO_2 ratio. In this study, several plant parameters were identified for use in comparing the performance of mesquite under drought conditions with indigenous species. The WUE_i can be considered as an efficient index to be used for this purpose.

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