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EFFECTS OF WATER DEFICIT ON GROWTH AND PHYSIOLOGY OF YOUNG *CONOCARPUS ERECTUS* L. AND *FICUS BENJAMINA* L. SAPLINGS

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Abstract

A greenhouse experiment was conducted to investigate the effects of water deficit on growth and physiological parameters of *Ficus benjamina* and *Conocarpus erectus*. The results revealed that all growth parameters such as plant height, stem diameter, no. of leaves, no. of branches and chlorophyll contents significantly decreased under water deficit condition. Interestingly, although leaf, stem and total biomass production and allocation decreased significantly under water deficit, but root biomass production and allocation increased significantly. Similarly, stomatal conductance to water vapor decreased significantly and CO_2 assimilation rate remained similar to control under water deficit condition. Resultantly, a significant increase in water use efficiency was evident in both species under water deficit condition. These results suggested that, in spite of a significant decrease in biomass production, young *Conocarpus erectus* and *Ficus benjamina* can tolerate water deficit which is due to sustained CO_2 assimilation rate and increase in root biomass.

Introduction

The debate on climate change has evolved on to assess, mitigate and adapt to its impacts. This acceptance is based on evidence presented by the scientific community through intensive monitoring of changes in terrestrial systems and predictive modeling (IPCC 2013). Climate change does not merely imply increased average global temperature; other effects include lower frequency of heavy precipitation events and higher frequency of longer drought spells. Resultant scenario favors loss of biodiversity, redistribution and shrinkage of species ecological zones and decrease in productivity (Babst *et al.* 2013). In the last decade, regions around the globe have faced the negative impact of drought where United Nations Organization (UNO) reported that 2.18 billion hectors of lands were affected by water deficit in the world (Stuart *et al.* 2011). Globally, forest research has made immense progress in determining how drought affects species growth and productivity. Drought is one of the major abiotic factors to reduce the morphological, physiological and growth performances of plant (Lahlou and Ledent 2005). Morphological adaptation in different plant parts such as leaves, stems and roots are the potential indicators to assess the tolerance and adaption capacity of a species under water stress condition (Rasheed *et al.* 2015, Rasheed and Delagrange 2016). Drought reduces stomatal conductance and ultimately photosynthesis activities of a plant (Peguero-Pina *et al.* 2009). Therefore, it is crucial to make additional research on species in order to evaluate their adaptability under water stress to improve biomass production and ensure sustainable forestry. Pakistan has mostly arid and semiarid climates and about 7.8 million ha of land is facing drought stress, which has become a serious

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threat to forest productivity and cover (Aslam *et al.* 2002). The rapid decline of forest cover in Pakistan call for an urgent need of planting water stress tolerant species (Aslam *et al.* 2002). However, production sustainability of tree plantations will depend on the capacity of tree species to adapt to their future environment. Therefore, evidencing intraspecific phenotypic plasticity for morphological and physiological traits can be very useful in determining specie's capability to adapt to various abiotic stresses especially water deficit (Chaves *et al*. 2002). *Conocarpus erectus* L. (buttonwood) belongs to a family *Combretaceae*. It is an evergreen shrub/tree found in tropical and subtropical regions of the world (Hegazy *et al*. 2008), and is capable of growing on stony land, hammocks and salty areas. *Ficus benjamina* L. is native to India, China, Southeast Asia, Malaysia, the Philippines, south pacific and northern part of Australia (Riffle 1998). It is mostly found in urban area and is particularly used for ornamental purposes and to mitigate urban pollution (Dominí and Benítez 2004). *Conocarpus erectus* L. and *Ficus benjamina* L. were selected as target species to investigate the effects of water deficit on plants growth and physiology due to their good growth rates and tolerance capacity in the arid and semiarid climates. The main objective of this study was to evaluate the effects of water deficit on the growth, morphological and physiological parameters of *Conocarpus erectus* and *Ficus benjamina.*

Materials and Methods

The experiment was set up in a greenhouse at the Department of Forestry & Range Management, University of Agriculture Faisalabad Pakistan (31° 26' N, 73° 06' E) for a period of 90 days. The temperature in the greenhouse was maintained at 28°C with a photoperiod of 15 hrs, light at 28°C and dark period of 9 hrs dark at 21°C, and relative humidity at around 56 %. Three-month-old healthy seedlings were collected from the nursery of Department of Forestry & Range Management. Total 40 plants of *Conocarpus erectus* and *Ficus benjamina* seedlings (20 of *Conocarpus erectus* (10 pants control ,10 plants treatment)*;* 20 of *Ficus benjamina* (10 pants control ,10 plants treatment) were planted into plastic pots (34 cm diameter, 24 cm depth). Plastic pots were filled with peat sand mixture (2v/1v). Each pot was filled with 15 kg of dried soil. NPK fertilizer (15 % N, 5% P_2O_5, 5% K_2O) was added at a rate of 5 g/kg of soil to overcome nutrient deficiency. All the pots were rotated to avoid micro-climatic variations during the growth period. Pots under control condition were watered back to 80% of field capacity and pots under water deficit treatment were water back to 40% of the field capacity (Anjum *et al.* 2017). The stress treatment was regularly monitored by a moisture meter TRIME-EZ/-IT (IMKO Micromodultechnik GmbH, Germany). Plant height (cm), stem diameter (mm) at the collar, number of leaves and number of branches were measured manually from each individual throughout the experiment. Individuals in each treatment were harvested and divided into leaves, stem and roots and subsequently placed in the oven at 75°C for 72 hrs till constant weight. The chlorophyll contents were measured on a fully mature and well-lit leaf produced during the stress treatment by using chlorophyll meter (FT GreenLlc Wilmington DE 19801 US.). One fully mature, well-lit leaf per individual per species was selected to measure gas exchange parameters using CIRAS-3 (PP- System, Amesbury, USA) and net CO_2 assimilation rate (A, μmol m^{-2} s^{-1}), stomatal conductance (g_s, mol m^{-2} s^{-1}) and transpiration rate (E, mol m^{-2} s^{-1}) were measured under light intensity of 1200 μmol m^{-2} s^{-1} provided by red blue LEDs. Airflow through the cuvette was maintained at 500 ml/min. Water use efficiency (WUE) was calculated as a ratio between A and g_s. All the traits were analyzed using ANOVA for species, treatment and interaction effect. The significant differences between treatments were compared using *Post-Hoc* Tukey HSD test. All means were expressed along with their SE and all tests and correlations were taken significant at $p < 0.05$. All statistical tests were performed in STATICTICA software, version 8.1, USA.

Results and Discussion

Overall, species and interaction effects remained insignificant for almost all the traits related to growth, biomass production/allocation and leaf gas exchange parameters. Therefore, the result section mainly focusses on the treatment effect. Water deficit negatively affected almost all the growth parameters (plant height, stem diameter, no. of leaves, no. of branches) and chlorophyll contents of both tree species. The results showed that under water stress, minimum plant height and diameter was noted in *Ficus* species (7.77 cm and 3.60 mm, respectively; Fig. 1). The *Conocarpus* species performed better under water stress treatment showing a decrease of 47.4% in plant height, 36.6% in stem diameter, 61.5% in number of leaves and 9.64% in chlorophyll contents while *Ficus* showed a decrease of 60.7% in plant height, 34.9% in stem diameter, 55.9% in number of leaves, and 10.1% in chlorophyll contents. From the results it can be concluded that the *Conocarpus* species performed better under water stress and *Ficus* was found more sensitive to water stress. Under water stress, all the growth parameters decreased as compared to the control condition of both species. Our results were in consonance with the decrease in the stem height evidenced in *S. lycopersicum* species under moisture deficit (Aderolu 2000). Similarly, Kirnak *et al.* (2001) also reported similar findings where plant height and shoot length of the seedlings decreased under limited supply of water than in control condition. The

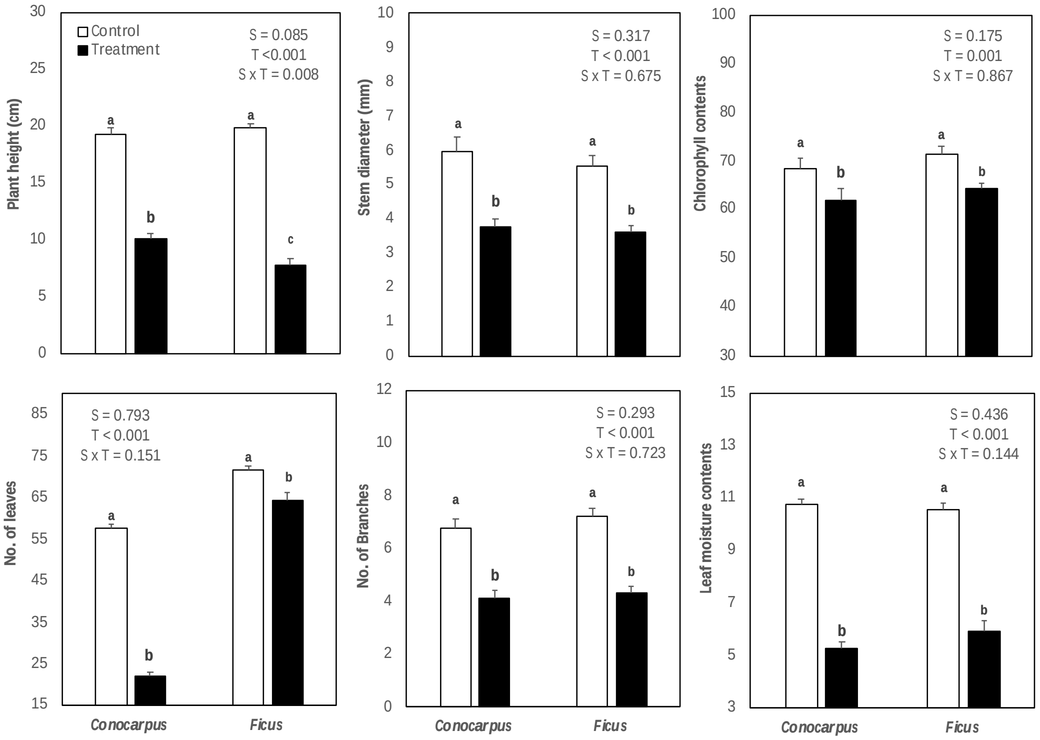

Fig 1. Growth parameters like plant height, stem diameter, chlorophyll contents, no. of leaves, no. of branches and leaf moisture contents were studied during the experiment. Data was analyzed using two-way ANOVA for species (S), treatment (T) and interaction (S × T) effect and P values are given. Each bar represents means along with their SE. (Control 80 FC, treatment 40% FC).

reduction in plant height under limited supply of soil moisture have been observed due to decrease in turgor pressure, that influenced cell division and expansion subsequently biomass production depends upon both cell growth and development. Mwai (2002) described that cell growth and development is a procedure that depends upon three phases; cell division, enlargement and differentiation. Similar results where growth was decreased in drought-treated seedlings compared with the controls have been reported from previous study on 11 species including *Q. robur* and *Q. pyrenaica* Wild (Valladares and Sanchez-Gomez, 2006). In *Populus* trees, limited supply of water also resulted in inhibitory growth effects (Yin *et al.* 2005).

Leaf and stem biomass production as well as allocation decreased significantly under increasing water stress in both species, however root biomass production as well as allocation increased significantly in both species under water stress. The leaf biomass obtained for *Conocrpus* and *Ficus* decreased under well-water as compared to water stress where a slight decrease in *Conocrpus* (13.9 %) and a higher decrease in *Ficus* (17.8 %) was evidenced. However, stem dry weight of both species decreased in a similar fashion (*Conocrpus* 35.2% and *Ficus* 33.0 %). Interestingly root dry weight of both species were found insignificant different from each other under both conditions (Table 1). Root biomass of both species significantly increased under water stress treatment as compared with well water condition. Root biomass showed an increase of 20.0 % in *Concarpus* and an increase of 11.3 % in *Ficus,* respectively. Total biomass of *Ficus* seedlings was negatively influenced by drought stress, but *Ficus* species was less affected (a decrease of 21.7 % in *Conocarpus* and a decrease of 18.7 % in *Ficus* was evidenced). R : S ratio significantly increased under drought stress treatment in both species (Table 1). Root morphology determines the ability of the plant to explore soil and water resources. To sustain the uptakes and to reduce the water transpiration, seedlings in water stress environment normally reduces their plant height and leaf area, and increase the root length, leading to increase their root: shoot ratio (Yin *et al.* 2005). The increase of R : S ratio is a common response under different stress types (Flexas *et al.* 2014). The previous reports have demonstrated that the tree adaptation under drought environment usually have larger R : S ratio and longer roots system as compared to those which are not suitable under dry environmental condition (Hartmann 2011). So, trees adjusting to water stress tends to deepen their root system, thus sustaining water uptake, while at the same time less water loss from their leaves or other parts. Similar results have been evidenced in forest plants where they respond to drought by improving their root-to-shoot ratio and increasing root length (Poorter *et al.* 2012).

The gas exchange parameters of two species showed variation in their results. The ANOVA (Table 2) shows that significant treatment effect was evidenced in stomatal conductance however CO_2 assimilation rate remained similar under water stress treatment. Resultantly, water use efficiency (WUE; the ratio between CO_2 assimilation rate and stomatal conductance) increased significantly in response to drought stress. Furthermore, WUE increased by 51.1 % in *Conocarpus* and 55.2 % in *Ficus* species under water stress condition (Table 2). Similar results have been reported in previous studies where WUE was improved under drought environment (Liu *et al.* 2005; Rasheed *et al.* 2015). Reduction in photosynthesis is a usual plant response to water shortage that results in reduction in plant growth and development (Manes *et al.* 2006; Ghanbary *et al.* 2017). Under water deficit condition, the plants reduce stomatal conductance and under severe cases prevent the entry of CO_2 into the leaves and has substantial influence on the growth condition, morphological structure and physiology and biochemistry of plants. Previous studies have pointed out that stomatal closure is one of the first responses to drought stress that causes a decline in the rate of photosynthesis (Flexas *et al.* 2014). In this study, the rate of photosynthesis and the stomatal conductance of both seedlings declined in response to drought stress. It is well known that the decrease in water potential and maintenance of water relations is one of the plant

Table 1. Means (SE ±) of growth, biomass production and allocation parameters studied during the experiment. Data were analyzed using two-way ANOVA for species (S), treatment (T) and interaction (S × T) effect. Each value represents mean along with their SE and significant p-values are set in bold.

Traits	*Conocarpus*		*Ficus*		p values		
	Control (80% FC)	Treatment (40 % FC)	Control (80% FC)	Treatment (40 % FC)	S-effect	T-effect	S × T-effect
Leaf biomass (g)	6.91 ± 0.19 a	4.98 ± 0.18 b	6.71 ± 0.11 a	4.5 ± 0.23 b	P = 0.076	**P < 0.001**	P = 0.468
Stem biomass (g)	3.72 ± 0.27 a	2.41 ± 0.16 b	3.30 ± 0.23 a	2.21 ± 0.67 a	P = 0.127	**P < 0.001**	P = 0.580
Root biomass (g)	4.05 ± 0.24 a	4.86 ± 0.18 b	4.65 ± 0.29 b	5.18 ± 0.26 a	P = 0.075	P = 0.011	P = 0.583
R : S ratio	0.38 ± 0.012	0.65 ± 0.022	0.46 ± 0.024	0.77± 0.02	P = 0.066	**P < 0.001**	P = 0.148
Total biomass (g)	15.66 ± 0.36a	12.26 ± 0.33b	14.66 ± 0.36a	11.91 ± 0.43b	P = 0.608	**P < 0.001**	P = 0.651
Leaf biomass allocation (%)	47.21 ± 1.56a	40.61 ± 0.79b	46.03 ± 1.58a	37.81 ± 1.22b	P = 0.148	**P < 0.001**	P = 0.550
Stem biomass allocation (%)	25.13 ± 1.37a	19.58 ± 1.07b	22.36 ± 1.15a	18.66 ± 0.61b	P = 0.100	**P < 0.001**	P = 0.400
Root biomass allocation (%)	27.65 ±1.67b	39.80 ± 1.47a	31.60 ± 1.54b	43.51 ± 1.23a	**P = 0.015**	**P < 0.001**	P = 0.937

Significant p < 0.05.

Table 2. Means (SE ±) of physiological parameters studied during the experiment. Data were analyzed using two-way ANOVA for species (S), treatment (T) and interaction (S × T) effect. Each value represents mean along with their SE and significant p-values are set in bold.

Traits	*Conocarpus*		*Ficus*			P-values	
	Control (80% FC)	Treatment (40 % FC)	Control (80% FC)	Treatment (40 % FC)	S-Effect	T-Effect	S x T-effect
CO_2 assimilation rate	10.1 ± 0.51a	9.2 ± 0.62 b	7.2 ± 0.82 a	6.3 ± 0.85 b	**p < 0.001**	p = 0.072	p = 0.457
Stomatal conductance	0.253 ± 0.024	0.18 ± 0.028	0.195 ± 0.016	0.114 ± 0.018	p = 0.062	**p < 0.001**	p = 0.324
Transpiration rate	8.02 ± 0.39 a	3.34 ± 0.32 b	7.74 ± 0.45 a	4.32 ± 0.29 b	p = 0.068	**p < 0.001**	p = 0.534
Water use efficiency	39.92 ± 3.38 b	51.11 ± 3.38 a	39.92 ± 5.28 b	55.26 ± 4.45 a	p = 0.481	**p < 0.001**	p = 0.465

Significant p < 0.05.

strategies in response to water limitation, which finally helps develop tolerance to drought stress. The higher WUE is a direct response to the reduction in stomatal conductance prior to the reduction in CO_2 assimilation rate. This is a typical response observed in other plants when exposed to mild moisture deficit (El-Sharkawy 2007). However, others (Díaz-López *et al.* 2012) described synchronized decreased of stomatal conductance and net CO_2 assimilation rate.

Conclusion

The results showed that both species respond in a similar way to water stress effect as species effect was found insignificant for almost all parameters. However, treatment effect was found significant where almost all parameters showed a decrease under water stress except for root biomass and CO_2 assimilation rate. Resultantly root biomass allocation percentage also showed a significant increase in both species. Therefore, it is concluded that both species can tolerate water stress which is derived by sustained CO_2 assimilation rate and a higher water use efficiency and biomass allocation to the roots that can help plants to survive under water stress conditions.

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