PHOTOCHEMICAL EFFICIENCY AND GROWTH OF TWO PROVENANCES OF *ACACIA SENEGAL* (GUM ARABIC) TREE SEEDLINGS UNDER DRYING SOIL

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ABSTRACT

A study was conducted to assess the impacts of water stress on diurnal photochemical efficiency of PSII and morphology of seedlings of two *A. senegal* provenances (El Fasher, P1 and Buram, P2). Seedlings were grown at the nursery of the Department of Forestry and Range Sciences, University of Al-Fashir, North Darfur, Sudan. Fifty-four seedlings per provenance were selected and divided into well-watered (W) and water-stressed (D) where all data were collected on these seedlings.

The results revealed that there was midday depression with evening recovery of effective photochemical efficiency of PSII (ΔF/Fm’) and maximum photochemical efficiency of PSII (Fv/Fm) in all seedlings throughout the measurement course reflecting the capability of both provenances to keep intact photosynthetic apparatus for more than nineteen days under drying soil. Substantial direct correlation between ΔF/Fm’ and electron transport for both provenances and inverse relationship between air temperature and Fv/Fm for P1 was established. Cyclic droughts affected negatively the morphology of seedlings for both provenances as the height, stem diameter, and leaf number of water stressed seedlings were reduced substantially compared to well-watered. P1 seems greater morphological growth compared to P2 hence El Fasher’s provenance tends to be more appropriate for plantations in arid environments.

Keywords: *Acacia senegal*, provenances, chlorophyll fluorescence, growth, cyclic drought.

INTRODUCTION

Acacia senegal (L. Willd) is multipurpose small tree belonging to family Mimosaceae flourishes in Sahel zone of Africa extending from Senegal to the Red Sea (Von Maydell, 1990; Vogt, 1995; Hussein 2006; Mulumba *et al.*, 2011). Its wood is highly valued by rural populations as fuel for firewood and charcoal (Larwanou *et al*., 2010; Kassa *et al*., 2010). *A. senegal* is characterized by active root nodules for nitrogen fixing capacity, and hence maintenance of soil stability and fertility (Beyene, 1993; Mulumba *et al*., 2011). The species produces nearly 90% of the renowned commercial gum arabic (Von Maydell, 1990). About 80%- 90% of world gum arabic exports come from Sudan where the tree locally known as hashab thus, contributes to a national economy and the revenues of the farming communities (Eisa *et al*., 2008; Larwanou *et al*., 2010; Mohammed *et al*., 2016). *A. senegal* survives in areas of low rainfall (100 to 800 mm per annum) and withstands dryer period of 8 to 11 months with high daily temperatures (Kassa *et al.*, 2010; Pancholy *et al*., 2014). Therefore, the tree species have been used for desertification, sand dune fixation and wind erosion control in degraded lands (Vogt, 1995).

However, during the last decades many factors especially insufficient and variability of rainfall have imposed pressures on the growth and production of *A. senegal* forests in Sudan. Reforestation and natural regeneration of hashab are facing frequent failure due to mortality of seedlings in the field during prolonged dry periods. Drought impacts are exacerbated worldwide threatening plant survival and crop production hence the life of million of people (UNEP, 2007; Allen *et al*., 2010; FAO, 2012; IPCC, 2013; Reyer *et al*., 2015; Lina and Eloisa, 2018; Polle, *et al*., 2019; Adetumbi *et al.,* 2020). Therefore, test of various geographical seed sources (provenances) and silvicultural techniques of *Acacia senegal* seedlings must be sought for better coping of transplanted seedlings with harsh conditions of the field. Concurrent understanding of young seedling growth and capacity of photosynthetic machinery under water stress conditions likely provides us information to select the appropriate genotypes for plantation in dry lands. It has been reported that the assessment of plant morphogenesis at early stages of life provides necessary indicators for subsequent performance of species under arid environments (Johnson, 1980; Kramer and Boyer, 1995; Merine *et al*., 2015; Siam and Abdal Kreem., 2019). In an Ecophysiological context, the measurement of chlorophyll fluorescence tends to be a useful technique in quantification the effect of stresses on photochemical efficiency of PSII (Klughammer and Schreiber, 2008; Lambers *et al*., 2008). Photosystem II is a specialized protein complex that uses light energy to oxidize water, releasing the molecular oxygen into the atmosphere, and release the reduced plastoquinone into the photosynthetic membrane (Govindjee *et al*., 2010).

Many studies have shown that photosystem II photochemistry is very sensitive to water and other environmental stresses in wheat plants (Lu and Zhang 1999), *Prosopis juliflora* (Shirke and Pathre, 2003), in oak tree species

(Siam *et al.*, 2008) and mango tree (Weng *et al*., 2010). It has been mentioned that, investigation on photosynthetic capacity of plants under field conditions may remain incomplete unless augmented with some fluorescence analysis (Maxwell and Johnson, 2000). However, according to our knowledge no studies have been conducted on the impacts of environmental stresses on the photochemical efficiency of PSII of *A. senegal* seedlings.

Therefore, this study aims to assess seedling chlorophyll fluorescence and morphology of socioeconomically important woody *Acacia senegal* trees from two diverse seed sources. Specific objectives were: To examine the photochemical efficiency of photosystem II of two provenances of *Acacia senegal* seedlings under different water regimes and to assess the height, stem diameter and leaf number of seedlings under cyclic water stress.

MATERIALS AND METHODS

Seed procurement: Seeds of *Acacia senegal* were collected from two different geographical areas (provenances) in western Sudan: El-Fasher - North Darfur and Buram - South Darfur Fig (1). Seeds were kindly donated by Forest National Corporation authorities in both localities. El Fasher and Buram provenances were assigned as P1 and P2 respectively. North Darfur classified as dry arid region, the precipitation ranges between 75- 600 mm/year (Table 1) and the temperature ranges between 10– 45 °C (MSF, 2015). Whereas the South Darfur is classified as Savanna region, the

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precipitation range between 500 -1200 mm/year and the temperature ranges between 20–40 °C (MSN, 2015). The soil type of P1 is sand and of P2 is clay.

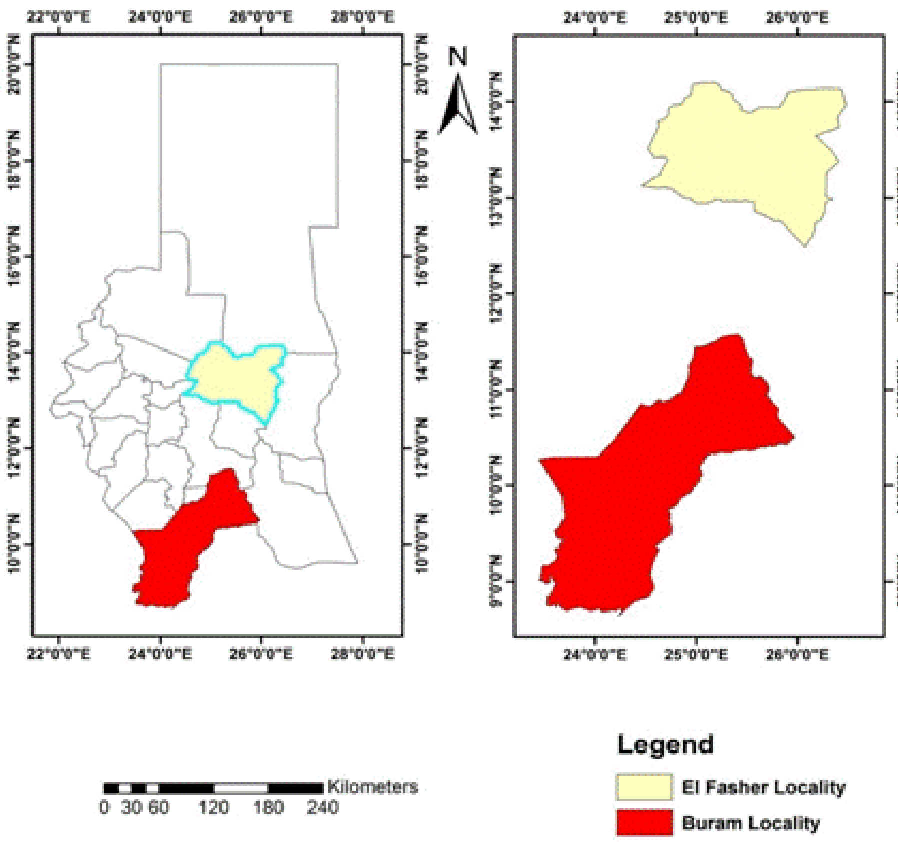

Fig. (1): Map shows geographical locations of *Acacia senegal* seed sources (El Fasher and Buram)

Table (1): Geographical locations and climatic variables of *Acacia senegal* seed sources

Provenance	State	Type of Soil	Latitudes	Longitudes	Temperature (ºC)	Rainfall/year (mm)
El Fasher	**North Darfur**	**Sand**	**13º-14ºN**	**25º – 26ºE**	**10º – 45ºC**	**75 – 500**
Buram	**South Darfur**	**Clay**	**10º-11ºN**	**24º – 25ºE**	**20º – 40ºC**	**500 – 1200**

Seedling establishment: Two hundred seeds per provenance were sown in 100 polyethylene bags (10 cm in width and 20 cm in length) in the nursery of the Department of Forestry and Range Sciences, University of Al-Fashir, North Darfur State, Sudan. The bags were filled with a soil mixture (2 silt: 1 sand) and placed under partial shade and kept watered in regular over six weeks. After 43 days from sowing, the seedlings were transplanted from small bags into large polythene bags (20 cm in diameter and 45 cm in height) filled with similar soil mixture. Each large bag contained one seedling. The bags were placed under partial shade for a week and then transferred to full sun light on open yard. After one week acclimation period 54 seedlings per provenance were selected and divided into two groups: one was kept well watered (control, W) and the other group subjected to water stress (stressed, D). The stressed seedlings were subjected to 6 drought cycles: for two days, four days, five days, seven days, ten days and fourteen days respectively. The experiment was arranged in a randomized complete block design in three replicates (9 seedlings / replicate / provenance / treatment). All chlorophyll

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fluorescence and morphological measurements were collected on these seedlings.

Photosystem II (PSII) photochemical efficiency: After forty two days of the application of drying cycles, both control and water stress seedlings were exposed to continuous nineteen drying days. Four days of photochemical efficiency of PSII (Chlorophyll fluorescence) measurements over the period of two weeks were carryout. The variables of photochemical efficiency of PSII were measured using Portable Chlorophyll Fluorometer (MINI-PAM, Walz GmbH, Effeltrich, Germany) as follow:

Effective quantum yield of PSII (ΔF/Fm’): To assess ΔF/Fm’, 3 seedlings/ provenances/ replicates/ treatments were selected randomly and measured four times per day at three hours interval (9:00, 12:00, 15:00, and 18:00). The first measurement was commenced on day five from the beginning of continuous drying, the second measurement on day nine, the third measurement on day eleven and the fourth measurement on day nineteen. Mini –Pam was supported by optional leaf clip holder 2030-B. Twelve millimeter distance between sample leaf surface and fiber optics was taken. The fiber optics formed 60º with the leaf plane. The light-exposed leaves were placed in leaf clip holder 2030-B to measure ΔF/Fm’. ΔF/Fm’ was determined by pressing START and calculated as:

Yield = (Fm'-F)/Fm' = ΔF/Fm'

Where,

Fm' = maximal fluorescence yield

F = minimal fluorescence yield

The relative electron transport rate (ETR) was calculated concurrently with fluorescence yield by the formula: ETR = yield x PAR x 0.5. Where PAR = photosynthetic active radiation of leaf. PAR was monitored by micro-quantum sensor held by optional leaf holder 2030-B.

Maximum quantum yield of PSII (Fv/Fm): The maximum quantum yield of PSII of dark –adapted leaf (Fv/Fm) was measured following ΔF/Fm' measurement. Fifteen dark leaf clip (DLC-8) were attached to leaves to prevent light access for at least 20 minutes as adaptation period. With dark leaf clips the fiber optics were positioned at right angle with respect to the leaf surface at the distance of 7mm. The photochemical efficiency of PSII (Fv/Fm) was calculated by (Fm-Fo)/Fm = Fv/Fm). Where Fm and Fo represent maximal and minimal fluorescence of dark adapted leaf respectively. A temperature (T) around the leaf was concurrently measured by thermocouple mounted in leaf clip holder.

Assessment of seedlings morphology: Four seedlings/ provenance/ replicate/ treatment were selected to assess height, stem diameter and leaf number on week basis. After one week from transplanting to large polythene bags described above the measurements of morphological characteristics

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were started on the first day of water treatment application. Six measurements were performed starting from 9^{th} January over the period of 45 days. The ruler was used in height measurement and vernier caliper (141-103 Caliper, Element Company, Egypt) was used in stem diameter measurement. The leaves were counted to determine their number per each measurement.

Statistical analysis: Variable differences among provenance and within provenance were assessed by analysis of variances (ANOVA) using Statistical Package for Social Science (SPSS). Significant differences of means at 5% level ($P \leq (0.05)$ were applied. The relationships between means of different variables established using linear regression of Microsoft excel program.

RESULTS

Photosystem II photochemical efficiency:

Effective quantum yield of PSII (ΔF/Fm'): The results revealed that there was midday depression of ΔF/Fm' in control and stressed seedlings of both provenances Fig (2). In the first and third measurement course significant differences were detected between two sets of seedlings of El-Fasher. Whereas its well-watered seedlings maintained significantly higher ΔF/Fm' than stressed at 15:00 and 12:00 on the first and the third day of measurement respectively. On the other hand, with the progression of soil drying control seedlings of Buram ΔF/Fm' declined with 86% and 83% relative to stressed

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on 2nd and 3rd measurements respectively at afternoon (15:00). Afternoon depression of ΔF/Fm' in control seedlings of Buram was also significant relative El-Fasher provenance. Seedlings of two provenances exhibited direct substantial relationships between electron transfer rate (ETR) and effective photochemical efficiency of photosystem II of light exposed leaves Fig (3).

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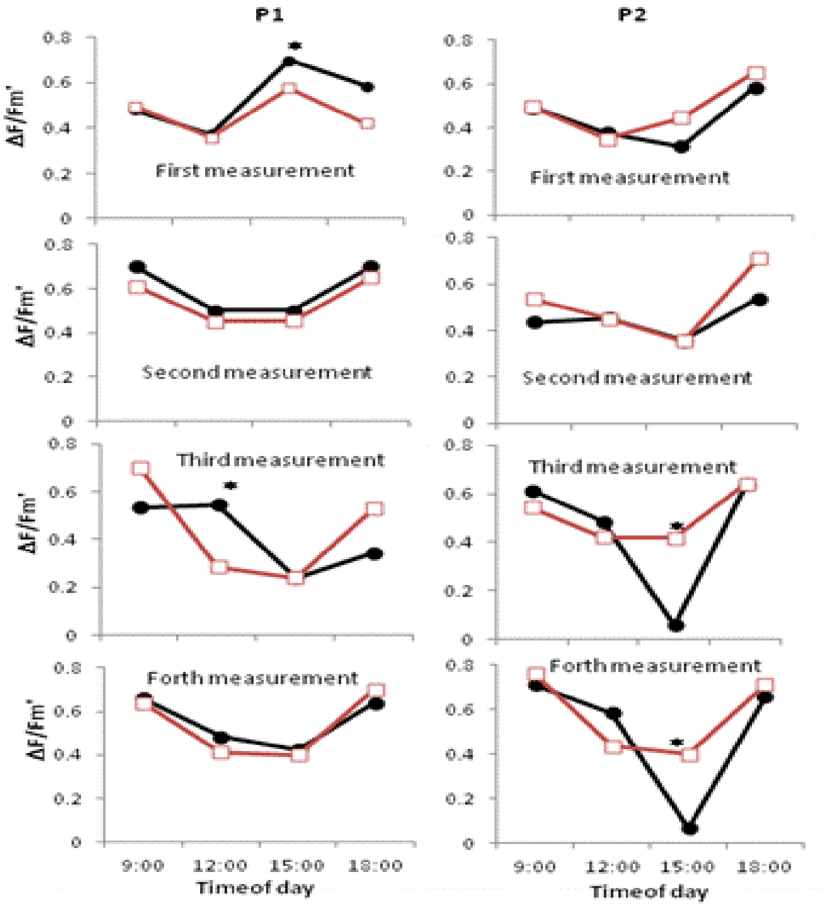

Fig. (2): Diurnal patterns of effective photochemical efficiency of photosystem II (ΔF/Fm') of the seedlings of two provenances: El Fasher (P1) and Buram (P2) in different dates

Filled circles and open squares represent control and stressed seedlings respectively. Points are means of three seedlings at given date. Statistically significant differences at ($p \leq 0.05$) between control and stressed seedlings were indicated by asterisk (∗).

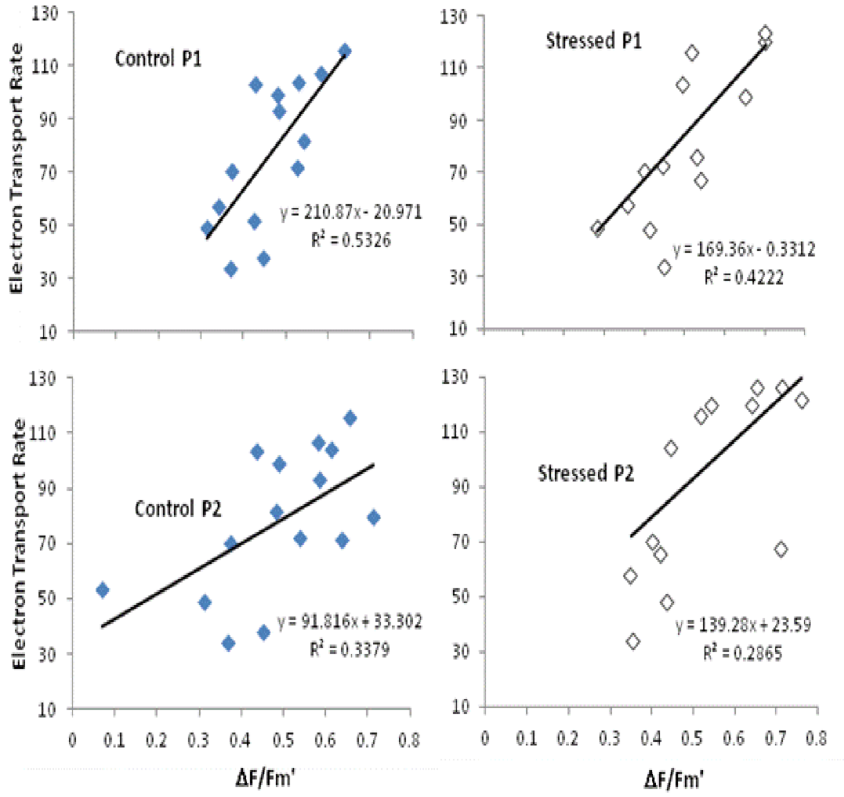

Fig. (3): Relationship between effective photochemical efficiency of photosystem II (ΔF/Fm') and electron transport rate of control and stressed seedlings of two provenances: El Fasher (P1) and Buram (P2)

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Maximum photochemical efficiency of PSII (Fv/Fm): Fv/Fm displayed decreasing patterns from morning hours (9:00) to after- noon hours (15:00) in both treatments' seedlings for both provenances Fig (4). However, the Fv/Fm recovered in the evening hours (18:00) to values similar to morning hours throughout three-week measurement course. Substantial afternoon Fv/Fm decline of stress seedlings relative to control was detected during second day of measurements in El-Fasher provenance. Conversely, Buram provenance exhibited substantial afternoon Fv/Fm decrease in control seedlings compared to stress seedlings, during the first and second day of measurements. Well-watered seedlings of Buram recorded significantly greater midday Fv/Fm in the first day relative to water stress.

The depression of the control seedlings compared to the stress seedlings was significant for El-Fasher during the third measurement and for both origins during the last measurement. In case of gradual drying of the soil, the Fv/Fm values were reduced to about 0.6 and 0.4 for stressed and control seedlings respectively at midday and at afternoon for the two origins. Nevertheless, seedlings recovered their Fv/Fm values to above 0.80 at evening. The maximum photochemical efficiency of PSII was established inverse relationship with leaf temperature Fig (5). The correlation was substantial in both sets of seedlings of El Fasher provenance.

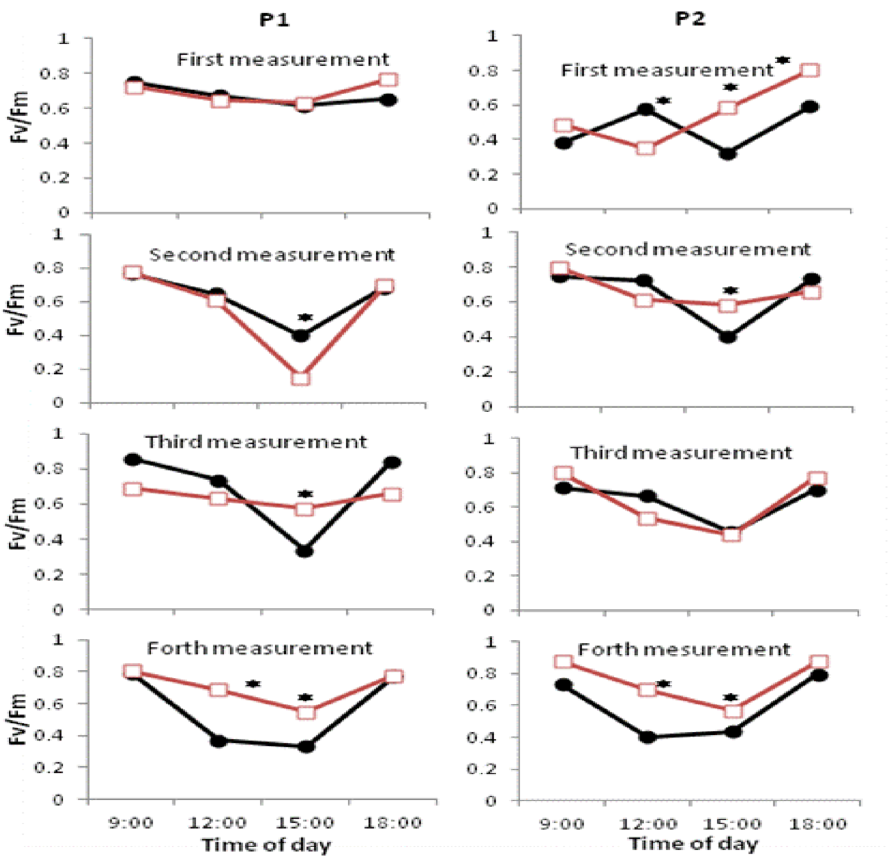

Fig. (4): Diurnal patterns of maximum photochemical efficiency of photosystem II (Fv/Fm) of the seedlings of two provenances: El Fasher (P1) and Buram (P2) in different dates

Filled circles and open squares represent control and stressed seedlings respectively. Points are means of three seedlings at given date. Statistically significant differences at ($p \leq 0.05$) between control and stressed seedlings were indicated by asterisk (∗).

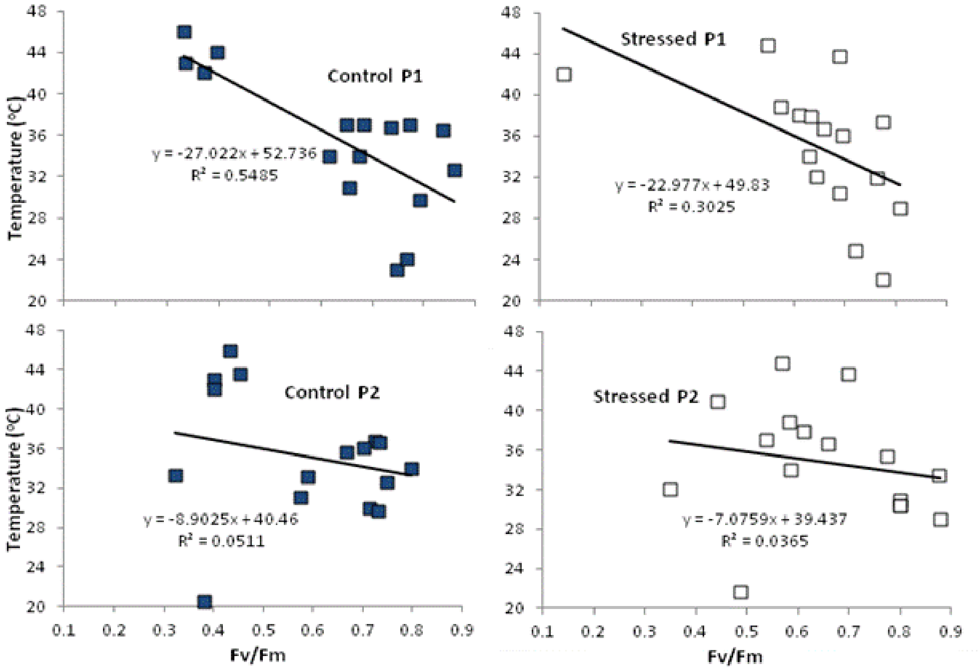

Fig. (5): Relationship between maximum photochemical efficiency of photosystem II (Fv/Fm) and leaf temperature of control and stressed seedlings of two provenances: El Fasher (P1) and Buram (P2)

Morphological characteristics: The results of height, stem diameter and leaf number measurements showed significant differences between water treatments and between provenances (Table 2). Control seedlings of El-Fasher exhibited significantly taller height than water stress in the fourth, fifth, and sixth day of measurements. Moreover, well-watered seedlings of Buram displayed substantially greater height than stressed seedlings since the

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third measurement up to the end of experimental course. El Fasher provenance exhibited significantly greater height than Buram from onset of the second and forth measurements in stressed and control seedlings respectively till the end of measurement course.

Table (2): Height, stem diameter and leaf number of two provenances of *Acacia senegal* seedlings

Week	Water treatment	El Fasher			Buram		
		Height (cm)	Stem diameter (mm)	Leaf number	Height (cm)	Stem diameter (mm)	Leaf number
First	control	14.4	2.6A	7.0	14.3	1.8B	6.9
	stressed	14.3	2.6A	7.0	14.1	1.8B	6.8
Second	control	15.2	2.8A	8.5	14.5	2.3B	8.5a
	stressed	15.0A	2.7A	8.5A	14.3B	2.3B	6.5bB
Third	control	15.9	3.2A	8.9	15.6a	2.8aB	8.9a
	stressed	15.8A	3.1A	8.9A	14.4bB	2.5bB	4.0bB
Forth	control	17.5aA	3.9aA	10.4	16.0aB	3.1aB	10.4a
	stressed	16.7bA	3.5bA	10.4A	15.2bB	2.7bB	4.0bB
Fifth	control	18.3aA	4.3aA	10.4	17.0aB	3.3aB	10.41a
	stressed	17.3bA	3.6bA	10.4A	16.0bB	2.9bB	3.8bB
Sixth	control	19.0aA	5.0aA	14.7aA	18.0aB	4.6aB	13.0aB
	stressed	18.3bA	4.5bA	13.4bA	16.5bB	3.0bB	3.6bB

Note: The differences between treatments within provenance at column level are indicated by letters of lower case, while between provenances at row level are indicated with capital letters. Significant differences ($P \leq 0.05$) at each sampling week for the same variable are indicated by different letters. Values are means of three replicates.

The results of study revealed significantly higher stem diameter of control seedlings compared to stressed ones in both provenances starting from third and fourth measurements up to the end of measurements for P2 and P1

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respectively. The seedlings of El Fasher were maintained substantially higher stem diameter than Buram provenance throughout the experimental course. With exception of last measurement, even stressed seedlings of El Fasher exhibited substantially greater diameter than control Buram. In leaf appearance well-watered seedlings of Buram showed significantly higher number of leaves than stressed seedlings since the second measurement up to the end of measurement course. Meanwhile, control seedlings of El-Fasher displayed substantially higher number of leaves relative to its stressed seedlings only in sixth measurement. Moreover, control seedlings of P1 exhibited significantly higher leaf number than control P2 only in the last measurement. On the other hand, seedlings of P1 maintained significantly greater number of leaves than stressed P2 from second week up to the end of measurement.

DISCUSSION

Photochemical efficiency of PSII: The midday and afternoon decline of light exposed photochemical efficiency of PSII observed in this study might be attributed to temporary coping responses to some prevailing environmental stresses and/or to internal alteration during the day. Because, the seedlings of both provenances and treatments were capable to recover their ΔF/Fm’ at the evening hours (18:00) to values similar as the morning (9:00) time. Various external factors such as increased vapor pressure deficit

(Shirke and Pathre, 2003; Siam *et al*., 2008), excessive light (Lu and Zhang, 1999; Quiles and Lopez, 2004; Weng *et al*., 2010; Roach and Krieger-Liszkay, 2014), decreased ETR (Oquist and Chow, 1992; Jia *et al*., 2013; Li *et al*, 2017), increased heat dissipation energy (Mathur and Jajoo, 2014), mineral concentration (Pena-Olmos and Casierra-Posada, 2013;), and elevated initial and decreased maximum chlorophyll fluorescence (Maxwell and Johnson, 2000) causes reduction in ΔF/Fm'. The assumption was partially supported by substantial direct correlation between ΔF/Fm' and ETR found in this study. This relationship is concordant with the statement that good correlations between ETR and photosynthetic are very usual as the ETR trend represents the whole leaf gas exchange and chlorophyll fluorescence patterns (Lambers *et al*., 2008). Photosystem II activity down-regulation during prevalence of daytime stresses is accompanied with decreased ETR and quantum yield (Mathur and Jajoo, 2014).

Thus, transitional decline of ΔF/Fm' shown in this study would possibly imply protective effects for photosynthetic machinery. The reversible decrease of diurnal photochemical efficiency of PSII often indicates photoprotection mechanism for photosystem II against excess solar radiation (Werner *et al*., 1999; Tozzi *et al*., 2013). Buram afternoon decline in ΔF/Fm' with about 86% and 83% for control relative to stressed seedlings under progressive soil drying during second and third measurements presumably reflects that repeated drought cycles have conferred better coping

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mechanisms with environmental stresses for this provenance. It has been found that PSII water-stressed leaf display increased resistance to environmental stresses compared to well-watered plants (Lu and Zhang, 1999).

Regard to evening recovery of dark adapted leaf quantum yield (Fv/Fm) to similar values as morning hours throughout soil drying course could indicate the capability of all seedlings of both provenance to maintain safe photosynthetic apparatus for more than nineteen days. These results accord the report that, dark leaf photochemical efficiency of PSII of some *Quercus* tree and wheat plant species was decreased in stressful conditions and resumed to optimum values in the reasonable times (Siam *et al*. 2008; Mathur and Jajoo, 2014; Xu *et al.,* 2020). The optimal values of Fv/Fm in unstressed leaves of higher plants range between 0.75 and 0.85 (Fleck *et al*., 1998; Lambers *et al*., 2008). Values lower than these often reflect the state of photoinhibition when the plants are exposed to stresses (Filella *et al*., 1998). The midday and afternoon decline detected in Fv/Fm likely refers to environmental stresses that plants were experiencing during the daytime. The assumption is corroborated by inverse relationship between air temperature and Fv/Fm (R^2 = 0.55 and 0.30) in control and stress P1 seedlings respectively. However, the transitional Fv/Fm depression in P2 might occurred due to factors other than temperature stress as long as theses two variables are weakly correlated (R^2 = 0.05 and 0.04) in control and stressed seedlings respectively. The resistance mechanisms of trees exposed to field conditions are often overruled by interactive effects of variables and combination of natural stresses (Polle *et al*., 2019). In general the maintenance of PSII capability in light exposed and dark adapted leaves for more than nineteen days soil drying in both provenances may qualify them for afforestation programs in dry prone environments. However further investigations still remain urgent before concrete conclusions are made.

Seedlings morphology: It is apparent that, repeated drought cycles were affected negatively on growth of seedlings of both provenances. Consequently, the height, stem diameter, and leaf number of stressed seedlings were reduced substantially compared to well-watered seedlings. The phenomenon will confirm the statement that, recurrent droughts led to substantial decrease of *Typha latifolia* shoot and root growth (Li *et al*., 2004). Growth is governed by water which cause plants to become larger or cells to become more numerous (Larcher, 1980; Park, 1990; Kramer and Boyer, 1995; Johnsen and Major, 1999; Fotelli *et al*., 2000). However it is worth to mention that, water irrigation intervals induce drought tolerance in many plant genotypes (Siam and Khalil, 2002; ElAwady *et al*., 2017; Abdullah and Siam, 2017). The maintenance of similar number of leaves by El Fasher W+ and W seedlings throughout the first five weeks attested in present study perhaps indicates an inherent adaptation properties of this ecotype to intermittent precipitation prevails in its geographical origin. It has been reported that some provenances of *Azadirachta indica* and acacia species have shown adaptation responses to moisture stress associated with their original habitats (Kundu and Tigerstedt, 1999; Wujeska-Klause, 2015).

Furthermore, bigger height, diameter and leaf number shown by El-Fasher in both treatments compared to Buram seedlings might be attributed to genetic performance traits. Wide range of genetic variations was detected among *A. senegal* provenances in Sudan (Mohammed *et al*., 2016). Plants from xeric sites are expected to perform better growth because of their phenological, physiological and structural characteristics relative to plants from mesic sites when all together exposed to identical water stress (Kubiske and Abrams, 1992; Khalil and Siam, 2003; McDowell *et al*., 2008; Wujeska-Klause *et al*., 2015). Xeric plants possess mechanisms enable them to avoid detrimental effects of drought and maintain productivity under limited water resources (Rambal and Leterme, 1987). Therefore, identifying superior genotypes better adapted to stressful environments would be of great interest in tree selection for dryland afforestation (Sarr *et al*., 2017). *Acacia senagal* variations in height, basal diameter and number of branches have been given primary importance in tree selection for restoration and agroforestry in Sudan (Raddad, 2007). Accordingly, in the current study El-Fasher provenance seems better than Buram in term of morphological growth hence more appropriate for plantation in arid and degraded lands.

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CONCLUSION

The results revealed that seedlings of both provenances and treatments were capable to resume their ΔF/Fm' and Fv/Fm at the evening to values similar as the morning hours throughout the experimental course. The maintenance of safe PSII of leaves for more than nineteen days soil drying may qualify both provenances for plantation activities in dryer environments. Repeated drying cycles were affected negatively on growth of stem height, diameter and leaf number of seedlings of both provenances. El Fasher has shown higher growth attributes in both treatments relative to Buram. Thus, El-Fasher provenance seems better than Buram in term of morphological growth hence more appropriate for plantation in arid areas.

REFERENCES

Abdullah, N.A.A., and Siam, A.M.J. (2017): Variation of two provenances of *Acacia senegal* in seed characteristics and dry matter allocation of seedlings under water stress. Sudan Journal of Desertification Research 9(1): 14-28.

Adetumbi, J.A.; Manga, M.; Jallow, D.; Akintoye, N.A. and Omodele, T. (2020): Assessment of agro-ecological influence on the seed quality of groundnut (Arachis *hypogaea*) in the Gambia. Ghana Jnl Agric. Sci. 55(2): 59-69.

Allen, C.D.; Macalady, A.K.; Chenchouni, H.; Bachelet, D.; McDowell, N.; Vennetier, M.; Kitzberger, T.; Rigling, A.; Breshears, D.D.; Hogg, E.H. et al. (2010): A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest Ecology and Management 259: 660-684. doi:10.1016/j.foreco.2009.09.001.

Beneye, M. (1993): Investing in *Acacia senegal* –Lessons from the Sudanese experience to Eritrea. African Arid Lands -Working Paper Series No. 4/93:1- 14.

Eisa, M. A.; Roth, M. and Sama, G. (2008): *Acacia senegal* (Gum Arabic Tree): Present role and need for future conservation / Sudan. Paper thesis. Chair of Forest Zoology, Technische Universität Dresden, Institute of Forest Botany and Forest Zoology, Tharandt, Germany, 1-5.

El Awady, M.N.; Altellaw, F.M.; Kishk, Y.F.; Albagoury, Kh.T. and El Sarraf, A.M. (2017): Drip irrigation effect on sunflower oil production in the sandy soil. JES, Institute of Environmental Studies and Research, Ain Shams University 40 (3): 65-94.

FAO. (2012): Adaptation to climate change in semi-arid environments: Experience and lessons from Mozambique. Environment and Natural Resource Management series 19, FAO, Rome, Italy.

Filella, I.; Llusia, J.; Pinol, J. & Penuelas, J. (1998): Leaf gas exchange and fluorescence of *Phillyrea latifolia, Pistacia lentiscus* and *Quercus ilex* saplings in severe drought and high temperature conditions. Environmental and Experimental Botany 39: 213-220.

Fleck, I.; Hogan, K.P.; LLorens, L.; Abadia, A. & Aranda, X. (1998): Photosynthesis and photoprotection in *Quercus ilex* resprouts after fire. Tree Physiology 18: 607-614.

Fotelli, M.N.; Radoglou, K.M. & Constantinidou, H.-I.A. (2000): Water stress response of seedlings of four Mediterranean oak species. Tree Physiology 20, 1065-1075.

Govindjee, G.; Kern, J.F.; Messinger, J. & Whitmarch, J. (2010): Photosystem II. https://onlinelibrary.wiley.com/doi/full/10.1002/9780470015902.a0000669.pub2. Last accessed: Wed, 8th May 2019.

Hussein, S. G. (2006): Afforestation in Arid Lands with Particular reference to the Sudan. 1st ed., Khartoum University Press, Khartoum, Sudan.

IPCC. (2013): Climate Change: the physical science basis. Working group1 contribution to fifth assessment report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/2018/03/WGIAR5_SummaryVolume_FINAL.pdf. Last accessed Tue, 23rd July 2019.

Jia, H.; Forster, B.; Chow, W.; Pagson, B. and Osmond, C.B. (2013): Decreased photochemical efficiency of photosystem II following sunlight exposure of shade-grown leaves of Avocado: because of, or in spite of, two kinetically distinct xanthophylls cycles. Plant Physiology 161: 836-852.

Johnson, D. A. (1980): Improvement of perennial herbaceous plants for drought-stressed western rangelands. In: Turner, N. C. and Kramer, P. J. (Editors). Adaptation of plants to water and high temperature stress. Wiely, New York. pp.: 419-433.

Johnsen, K.H. and Major, J.E. (1999): Shoot water relations of mature black spruce families displaying a genorype X environment interaction in growth rate. I. Family and site effects over three growing seasons. Tree Physiology 19: 367-374.

Kassa, A.; Alia, R.; Tadesses, W.; Pando, V. and Bravo, F. (2010): Seed germination and viability in two African Acacia species growing under different water stress levels. African Journal of Plant Sciences 4(9): 353-359.

Khalil, A.A.M. and Siam A.M.J. (2003): Effect of soil drying on water relations and growth of four provenances of *Acacia senegal* seedlings. U. of K. Journal of Agricultural Sciences 11(1): 117-132.

Klughmmer, C. and Schreiber, U. (2008): Complementary PSII quantum yields calculated from simple fluorescence parameters measured by PAM Fluorometry and the Saturation Pulse methods. PAM Application Notes, 1: 27-35.

Kramer, P.J. and Boyer, J.S. (1995): Water relations of plants and soils. Academic press, San Diego.

Kubiske, M.E. & Abrams, M.D. (1992): Photosynthesis, water relations, and leaf morphology of xeric versus mesic *Quercus rubra* ecotypes in central Pennsylvania in relation to moisture stress. Canadian Journal of Forest Research 22: 1402-1407.

Kundu, S.K. and Tigerstedt, P.M.A. (1999): Variation in net photosynthesis, stomatal characteristics, leaf area and whole plant phytomass production among ten provenances of neem (*Azadirachta indica*). Tree Physiology 19: 47-52.

Lambers, H. Chapin III, F.S. and Pons. T.L. (2008): Plant Physiological Ecology. 2nd edition, Springer, New York, USA.

Larcher, W. (1980): Physiological plant ecology. 2nd edition, Springer-Verlag, Berlin.

Larwanou, M.; Raebild, A.; Issa, R. and Kjaer, E.D. (2010): Performance of *Acacia senegal* (L.) Willd provenances in dryland Savannah of Niger. *Silvae Genetica* 59(5): 210-218.

Li, J.; Cang, Z.; Jiao, F.; Bai, X.; Zhang, D. and Zhai, R. (2017): Influence of drought stress on photosynthetic characteristics and protective enzymes of potato at seedling stage. J. Saudi Soci. Agric. Sci. 16: 82-88.

Li, S.; Pezeshki, S.R. and Goodwin, S. (2004): Effects of soil moisture regimes on photosynthesis and growth in cattail (*Typha latifolia*). *Acta Oecologica* 25: 17-22.

Lina A., and Eloisa L. (2018): How do young cucti (seeds and seedlings) from tropical xeric environments cope with extended drought period ?. Journal of Arid Environments 154: 1-17.

Lu, C., and Zhang, J. (1999): Effects of water stress on photosystem II photochemistry and its thermostability in wheat plants. Journal of Experimental Botany 50(336): 1199-1206.

Mathur, S. and Janjoo, A. (2014): Alteration of photochemical efficiency of photosystem II in wheat plant on hot summer day. Physiol. Mol. Biol. Plants 20(4): 527-531.

Maxwell, K. and Johnson, G.N. (2000): Chlorophyll fluorescence – a practical guide. Journal of Experimental Botany 51(345): 659 - 668.

McDowell, N.; Pockman, W.T.; Allen, C.D.; Breshears, D.D.; Cobb, N. Kolb, T.; Plaut, J.; Sperry, J.; West, A.; Williams, D.G. and Yepez, E.A. (2008): Mechanisms of plant survival and mortality during drought: why do some plants survive while others succumb to drought? New Phytologist 178: 719-739.

Merine, A.K.; Rodriguez-Garcia, E.; Alia, R.; Pando, V. and Bravo, F. (2015): Effects of water stress and substrate fertility on the early growth of *Acacia senegal* and *Acacia seyal* from Ethiopian Savanna woodlands. Trees, 29: 593-604.

Mohammed, S.S.M.; Mohammed, M.M.; Essam El-din, W.; Basher, E.H.; Murat, A. and Mustafa, Y. (2016): Characterization of phenotypic variability of Sudanese gum arabic tree *Acacia senegal var. senegal* using multiprimer random amplification of polymorphic DNA (RAPD). International Journal of Genetics and Genomics 4(3):20-23.

MSF. (2015): Meteorological Station of El Fasher Report, North Darfur State, Sudan.

MSN. (2015): Meteorological Station of Nyala Report, South Darfur State, Sudan

Mulumba, J.W.; Lwasa, J. and Atieno, F. (2011): Distribution of *Acacia senegal* (*L.*) *Willd*. (*Fabaceae*) in Uganda and its relationship to climatic factors. African Journal of Ecology 49: 261-266.

Oquist, G. and Chow, W.S. (1992): On the relationship between the quantum yield of photosystem II electron transport as determined by chlorophyll fluorescence and the quantum yield of Co_2-dependent O_2 evolution. Photosynthesis Research 33: 51-62.

Pancholy, A.; Jindal, S. K. and Pathak, P. (2014): Association of growth related seedling traits under arid environment of western Rajasthan. J. Enviro. Biol. 36(4):941-6.

Park, Y.M. (1990): Effects of drought on two grass species with different distribution around coastal sand-dunes. Functional Ecology 4: 735-741.

Pena-Olmos, J. and Casierra-Posada, F. (2013): Photochemical efficiency of photosystem II (PSII) in broccoli plants (Brassica oleraraceae var italica) affected by excess ion. ORINOQUIA 17(1): 15-22.

Polle, A.; Chen, S.L.; Eckert, C. and Harfouche, A. (2019): Engineering drought resistance in forest trees. Frontiers in Plant Science 9(1875):1-18. Doi: 10.3389/fpls.2018.01875.

Quiles, M.J. and Lopez, N.I. (2004): Photoinhibition of photosystem I and II induced by exposure to high light intensity during oat plant growth: Effects on the chloroplast NADH dehydrogenase complex. Plant Science 166: 815-823.

Raddad, E.A.Y. (2007): Eco-physiological and genetic variation in seedlings traits and in first-year field performance of eight *Acacia senegal* provenances in the Blue Nile, Sudan. New Forests 34: 207-222.

Rambal, S. and Leterme, J. (1987): Change in above ground structure and resistance to water uptake in *Quercus coccifera* along rainfall gradient. In: Tenhunen, J.D.; Catarino, F.M.; Lange, O.L. and Oechel, W.C. (Editors). Plant response to stress. NATO ASI series G: Ecol. Sci. 15, Berlin. pp.191-200.

Reyer, C.P.; Brouwers, N.; Grant, R.F; Brook, B.W.; Ramming, A.; Epila, J; Holmgren, M.; Langerwisch, F.; Leuzinger, S.; Lucht, W.; Medlyn, B.; Pfeifer, M.; Steinkamp, J.; Vanderwel, M.C.; Verbeeck, H. and Villela, D.M. (2015): Forest resilience and tipping points at different spatio-temporal scales: approaches and challenges. Journal of Ecology 103(1): 5-15.

Roach, T. and Krieger-Liszkay A. (2014): Regulation of electron transport and photoinhibition. Current Protein & Peptide Science 15(4): 351-362.

Sarr., M.S.; Seiler, J.R. & Sullivan, J. (2017): Growth and physiology of *Senegalia senegal* (L.) Britton seedlings as influenced by seed origin and salinity and fertility treatments. Forests 8(388): 1-15.

Shirke, P.A. and Pathre, U.V (2003): Diurnal and seasonal changes in photosynthesis and photosystem2 photochemical efficiency in *Prosopis juliflora* leaves subjected to natural environment stress. Photosynthetica 41(1): 83-89.

Siam, A.M.J. and Khalil, A.A.M. (2002): The effect of drought conditioning on water relations and growth of *Acacia senegal* (L.Willd) seedlings. JONARES, 3(1): 43-50.

Siam A.M.J.; Radoglou K. M.; Noitsakis B. and Smiris P. (2008): Physiological and growth responses of three Mediterranean oak species to different water availability regimes. Journal of Arid Environments 72: 583-592.

Siam, A.M.J. and Abdel Kareem, I.H. (2019): Diurnal photosystem II photochemical efficiency and biomass partitioning of *Acacia mellifera* and *Acacia laeta* seedlings under drying soil. Kastam. Univ. J. For. Fac. 19(1): 82-94.

Tozzi, E.S.; Easlon, H.M. and Richards, J.H. (2013): Interactive effects of water, light and heat on photosynthesis in Fremon cottonwood. Plant, Cell and Environment 36(8): 1423-1434.

UNEP. (2007): Sudan: post conflict environmental assessment. United Nations Environment Program, Nairobi, Kenya.

Vogt, K. (1995): Common trees and shrubs of dryland Sudan. SOS Sahel International, London, UK.

Von Maydell, H-J. (1990): Trees and shrubs of the Sahel: Their characteristics and uses. Verlag Josef Margraft, GTZ, Germany.

Weng, J.; Jhuang, L.; Lin, R. and Chen, H. (2010): Relationship between photochemical efficiency of photosystem II and the photochemical reflectance index of mango tree: merging data from different illuminations, seasons and leaf colors. Tree Physiology 30: 469-478.

Werner, C.; Correia, O. and Beyschlag W. (1999): Two different strategies of Mediterranean macchia plants to avoid photoinhibitory damage by excessive radiation levels during summer drought. Acta Oecologica 20(1):15-23.

Wujeska-Klause, A.; Bossinger, G. and Tausz, M. (2015): Seedlings of two acacia species from contrasting habitats show different photoprotective and anti-oxidative responses to drought and heat waves. Annals of Forest Science 72(4): 403-414.

Xu Q.; Ma X.; Lv T.; Bai M.; Wang Z. and Niu J. (2020): Effects of water stress on fluorescence parameters and photosynthetic characteristics of drip irrigation in rice. Water, 12(1):289, doi:10:3390/w12010289.

أثر تجفيف التربة على الكفاءة الكيميوضوئية والنمو لشتول شجرة الهشاب (الصمغ العربي) من بذور مصدرين جغرافيين متباينين

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المستخلص

تم إجراء هذه الدراسة لتقييم أثر الإجهاد المائي على نمط الكفاءة الكيميوضوئية اليومي للجهاز الضوئي٢ والنمو المورفولوجي لشتول شجرة الهشاب من مصدرين جغرافيين متباينين (الفاشر و برام). زُرعت الشتول بمشتل قسم علوم الغابات والمراعي بجامعة الفاشر، شمال دارفور، السودان. أختيرت أربع وخمسون شتلة من كل مصدر وقُسمت إلى مجموعتين (مجموعة تروى بانتظام ومجموعة معرضة للإجهاد المائي المكرر) حيث تم جمع كل بيانات الدراسة من هذه الشتول.

أظهرت الدراسة بأن هنالك إنخفاض بمنتصف النهار واستعادة في فترات المساء للمعدل الفعلي (ΔF/Fm’) والأقصى (Fv/Fm) للكفاءة الكيميوضوئية لشتول كلا المصدرين على إمتداد فترة إجراء قياسات الدراسة، الأمر الذي يعكس قدرة الشتول في الحفاظ على سلامة أجهزة البناء الضوئي لأكثر من تسعة عشرة يوماً تحت تجفيف التربة. توجد علاقة طردية مباشرة بين الكفاءة الكيميوضوئية الفعلية ومعدل نقل الالكترونات لشتول المصدرين وعلاقة عكسية في شتول الفاشر بين درجة حرارة الجو والكفاءة الكيميوضوئية القصوى. الجفاف الدوري أثر سلباً على مورفولوجيا الشتول في المصدرين، حيث تناقص الطول، قطر الساق وعدد الأوراق في الشتول المعرضة للإجهاد المائي بفارق معنوي مقارنة بالشتول ذات الري المستمر. بناءً على الخصائص المورفولوجية شتول الفاشر تبدو أكثر ملائمة لعمليات التشجير في البيئات الجافة مقارنة بمصدر برام.

الكلمات الدالة: شجرة الهشاب، المصدر الجغرافي للبذور، الأستشعاع الكلوروفيللي، النمو، الجفاف الدوري.