

## Photochemical efficiency and growth of two provenances of *Acacia senegal* (gum arabic) tree seedlings under drying soil

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### ABSTRACT

This study was conducted to assess the impacts of water stress on diurnal photochemical efficiency of PSII and morphology of seedlings of *A. senegal* from two different 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) and all data were collected for these seedlings. The results revealed that there was midday depression with evening recovery of effective photochemical efficiency of PSII ( $\Delta F/F_m'$ ) and maximum photochemical efficiency of PSII ( $F_v/F_m$ ) 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  $\Delta F/F_m'$  and electron transport for both provenances and inverse relationship between air temperature and  $F_v/F_m$  for P1 were established. Cyclic droughts affected negatively on the morphology of seedlings for both provenances as the height, stem diameter, and leaf number of water stressed seedlings was reduced substantially compared to well-watered. P1 seems to have 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 has 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 cope 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 Abdalkreem., 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).

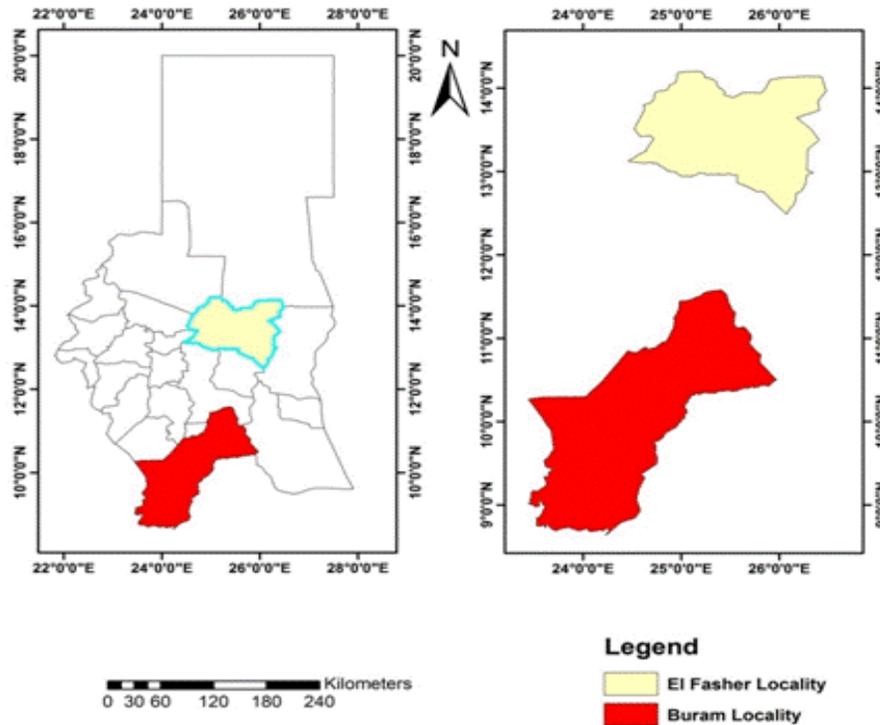
Many studies have shown that photosystem II photochemistry is very sensitive to water and other environmental stresses in wheat plants (Lu and Zhang 1999), *Prosopis juliflora* (Shirke and Pathre, 2003), in oak tree species (Siam *et al.*, 2008) and mango tree (Weng *et al.*, 2010). It has been mentioned 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: S

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 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.

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**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 (°C)	Rainfall/year (mm)
El Fasher	North Darfur	Sand	13°-14°N	25° – 26°E	10° – 45°C	75 – 500
Buram	South Darfur	Clay	10°-11°N	24° – 25°E	20° – 40°C	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 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 ( $\Delta F/F_m'$ ):**

To assess  $\Delta F/F_m'$ , 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 60° with the leaf plane. The light-exposed leaves were placed in leaf clip holder 2030-B to measure  $\Delta F/F_m'$ .  $\Delta F/F_m'$  was determined by pressing START and calculated as  $Yield = (F_m' - F)/F_m' = \Delta F/F_m'$  where  
 $F_m'$  = maximal fluorescence yield  
 $F$  = minimal fluorescence yield

The relative electron transport rate (ETR) was calculated concurrently with fluorescence yield by the formula:  $ETR = yield \times PAR \times 0.5$ . 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 ( $F_v/F_m$ ):**

The maximum quantum yield of PSII of dark –adapted leaf ( $F_v/F_m$ ) was measured following  $\Delta F/F_m'$  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 ( $F_v/F_m$ ) was calculated by  $(F_m - F_o)/F_m = F_v/F_m$ . Where  $F_m$  and  $F_o$  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 were started on the first day of water treatment application. Six measurements were performed starting from 9<sup>th</sup> January over the period of 45 days. The ruler was used in height measurement and vernier caliper (141-103Caliper, 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

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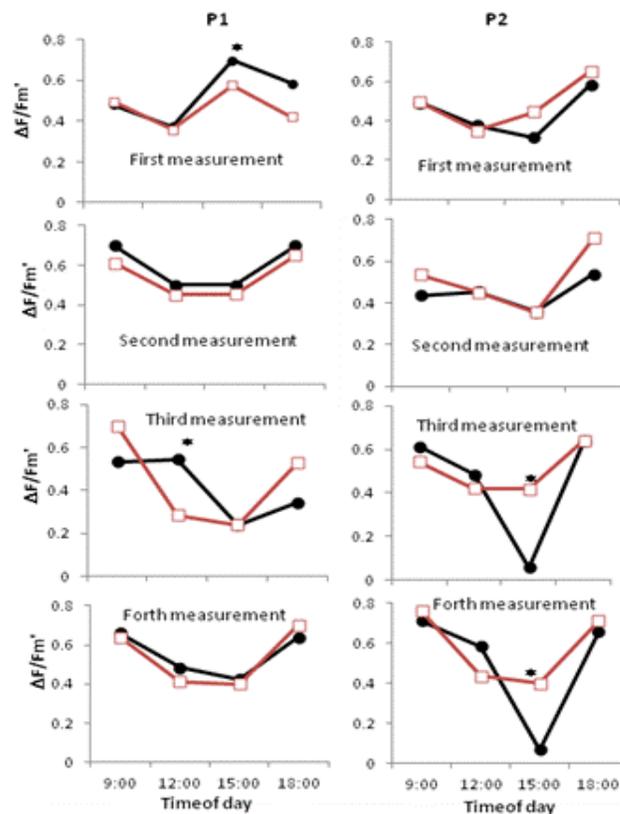
differences of means at 5% level ( $P \leq (0.05)$ ) were applied. The relationships between means of different variables established using linear regression of Microsoft excel program.

### RESULTS

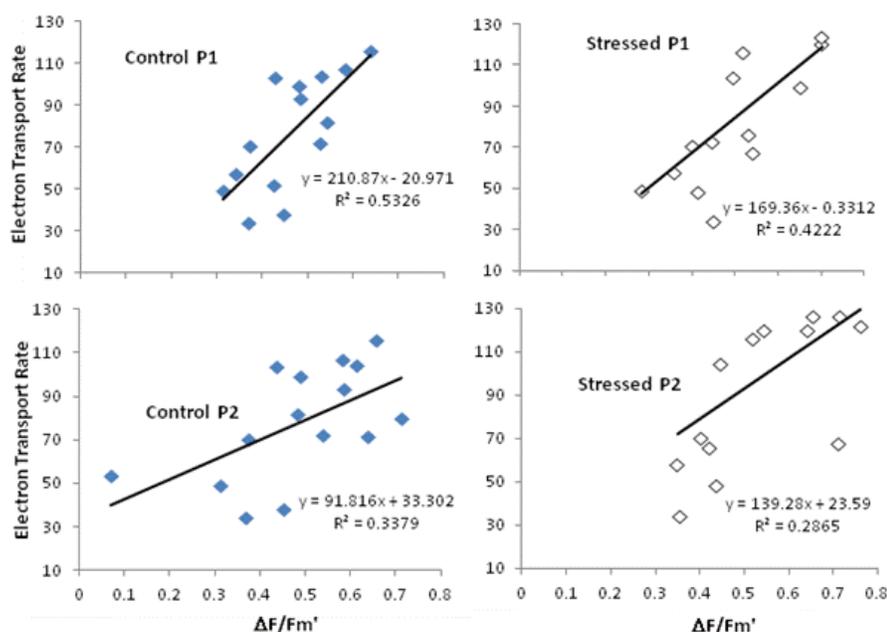
#### 1. Photosystem II photochemical efficiency

##### 1.1. Effective quantum yield of PSII ( $\Delta F/F_m'$ )

The results revealed that there was midday depression of  $\Delta F/F_m'$  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  $\Delta F/F_m'$  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  $\Delta F/F_m'$  declined with 86% and 83% relative to stressed on 2<sup>nd</sup> and 3<sup>rd</sup> measurements respectively at afternoon (15:00). Afternoon depression of  $\Delta F/F_m'$  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).



**Fig. (2). Diurnal patterns of effective photochemical efficiency of photosystem II ( $\Delta F/F_m'$ ) 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 (\*).**



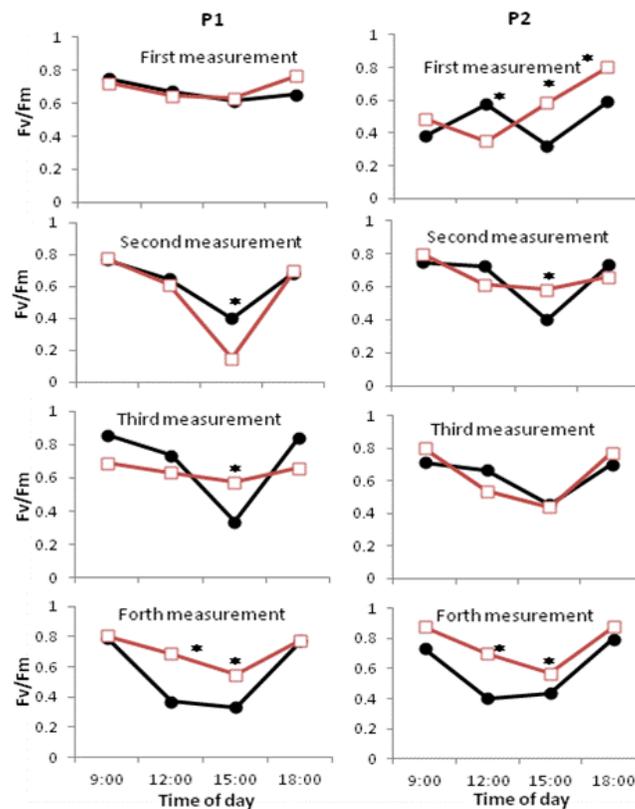
**Fig. (3). Relationship between effective photochemical efficiency of photosystem II ( $\Delta F/F_m'$ ) and electron transport rate of control and stressed seedlings of two provenances: El Fasher (P1) and Buram (P2).**

### 1.2. Maximum photochemical efficiency of PSII (Fv/Fm)

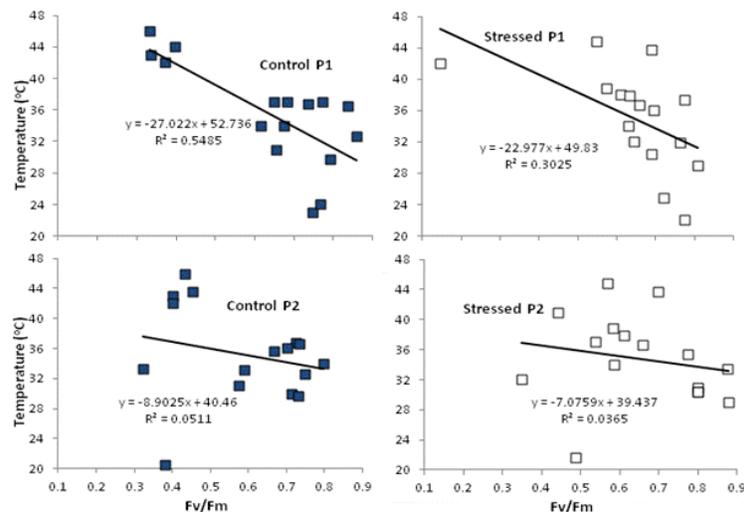
Fv/Fm displayed decreasing patterns from morning hours (9:00) to afternoon hours (15:00) in both treatments' seedlings for both provenances (Fig. 4). However, the Fv/Fm recovered in the evening hours (18:00) to values similar to morning hours throughout three week measurement course. Substantial afternoon 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.

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**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).

## 2. 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 third measurement up to the end of experimental course. El Fasher provenance exhibited significantly greater height than Buram from onset of the second and fourth 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, 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

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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

#### 1. 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  $\Delta F/F_m'$  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  $\Delta F/F_m'$ . The assumption was partially supported by substantial direct correlation between  $\Delta F/F_m'$  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  $\Delta F/F_m'$  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  $\Delta F/F_m'$  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 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 ( $F_v/F_m$ ) 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  $F_v/F_m$  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 these 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.

## 2. 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-Klaue, 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-Klaue *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 senegal* 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.

## CONCLUSION

The results revealed that seedlings of both provenances and treatments were capable to resume their  $\Delta F/Fm'$  and Fv/Fm at the evening to values similar as the morning hours throughout

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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.

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## Photochemical efficiency and growth of two provenances of *Acacia senegal* (gum arabic) tree seedlings under drying soil

أثر تجفيف التربة على الكفاءة الكيميوضوئية والنمو لشتلات 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 الضوئي والنمو المورفولوجي لشتلات شجرة الهشاب من مصدرين جغرافيين متباينين (الفاشر و برام). زُرعت الشتلات 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) وتم تجميع كل بيانات الدراسة من هذه الشتول. أظهرت الدراسة وجود إنخفاض بمنتصف النهار واستعادة في فترات المساء للمعدل الفعلي ( $\Delta F/F_m'$ ) والأقصى ( $F_v/F_m$ ) للكفاءة الكيميوضوئية لشتلات كلا المصدرين على إمتداد فترة إجراء قياسات الدراسة، الأمر الذي يعكس قدرة الشتلات 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 الإلكترونات لشتلات المصدرين وعلاقة عكسية في شتلات الفاشر بين درجة حرارة الجو والكفاءة الكيميوضوئية القصوى. الجفاف الدوري أثر سلباً على مورفولوجيا الشتلات في المصدرين، حيث تناقص الطول، قطر الساق وعدد الأوراق في الشتلات المعرضة للإجهاد المائي بفارق معنوي مقارنة بتلك ذات الري المستمر. بناءً على الخصائص المورفولوجية غان شتلات الفاشر تبدو أكثر ملائمة لعمليات التشجير في البيئات الجافة مقارنة بتلك من برام.

**الكلمات الدالة:** شجرة الهشاب، المصدر الجغرافي للبذور، الأستشعاع الكلوروفيلي، النمو، الجفاف الدوري