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Comparsion of Ecophysiological Responses of *Acacia raddiana* and *Acacia nilotica* During Seedling Establishment in Extreme Arid Conditions

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THE PRESENT investigation involves the studies of physiological responses of *A. raddiana* (savi) Brenan and *A. nilotica* (L.) seedlings under extreme arid conditions.

Experiments were performed in a hyper arid environment to study the effects of drought stress using different water regimes at 12%, 9%, 6%, 4% and 2%. Photosynthesis and transpiration rate were measured under full Photosynthetic Active Radiationrange (0-2500µmols^{-1}m^{-2}) and instantaneous water use efficiency was calculated.

A. raddiana and *A. nilotica* showed maximum photosynthesis rate under 4% and 12% soil moisture content, respectively at high Photosynthetic Active Radiation levels, maximum transpiration rate of *A. raddiana* recorded at 4% soil moisture content and at 9% soil moisture content in *A. nilotica* at highest Photosynthetic Active Radiation. The maximum instantaneous water use efficiency was noticed in *A. raddiana* at 12% soil moisture content, while *A. nilotica* showed maximum instantaneous water use efficiency at 6% soil moisture content at high Photosynthetic Active Radiation level.

A. raddiana acted as water spender ideal desert plant at high Photosynthetic Active Radiation. Other wise *A. nilotica* maximised photosynthesis rate and minimised transpiration rate giving maximum instantaneous water use efficiency at high Photosynthetic Active Radiation and low soil moisture content levels.

Keywords: Desert plant, Drought stress, Instantaneous water use efficiency, Photosynthetic active radiation, Photosynthesis, Transpiration rate.

Abbreviations: Pn: Photosynthesis rate, *E*: Transpiration, *WUE*: Instantaneous water use efficiency, *PAR*: Photosynthetic active radiation and *SMC*: Soil moisture content.

Introduction

Drought stress is the most prevailing environmental factor restricting plant production (Bray, 1997) and there are continuous changes in climate which arising in severe drought conditions (Dai, 2012; Basu et al., 2016). The effect of drought stress is recognized as a decline in photosynthesis and growth at all plant regimes, and it is concerned with changes in carbon and nitrogen metabolism (Cornic & Massacci, 1996; Mwanamwenge et al., 1999; Yordanov et al., 2003). The reduction of drought stress related to stomatal closure in response to low soil water content, which leads to the minimized of intake of CO_2 (Chaves, 1991; Cornic, 2000; Flexas et al., 2004; Ahmad et al., 2011). Plants in arid environments have developed physiological mechanisms to resist drought stress (Fahmy & Ouf, 1999; Kozlowski & Pallardy, 2002; Elfeel & Al-namo, 2011).

Desert plant species withst and extreme environmental conditions such as water deficit stress but keeping their metabolism active by the

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regulation of the osmotic and water relations in order to survive (Khan & Beena, 2002; Abdellah, 2009).

A. raddiana grows in all Egyptian deserts except that of Sinai and Cataract islands, while *A. nilotica* grows in the, lower stream parts of wadis connected Eastern and Western Desert Nile valley with Nile region, Cataract islands and oases of the western desert (Boulos, 1999; Springuel, 2006). *A. raddiana* used as Gums extracted from the plant are used for jaundice, Bark is used as disinfectant, and Seeds used as antidiarrheal, while *A. nilotica* used as Gum exudates from the tree antidiarrheal. Stem bark extract used as antiamoebic, antispasmodic, hypotensive. Fruits used for diarrhea; fruits used as Fevers (Boulos, 1999; Springuel, 2006). Both species considered as threatened due different man activities such as cutting trees for fuel wood and drought fluctuations (El Bahaa, 2012; Marshall et al., 2012; New, 1984; Sinclair et al., 2008).

Aim of the current research was to reveal the physiological mechanisms of *A. raddiana* and *A. nilotica* to resist the combination of drought stress and high irradiance during seedling establishment which in turn help in the restoring and cultivation of both endangered endemic species.

Materials and Methods

Seed collection and growing conditions

Seed collection from Desert Garden, Aswan University Campus, Aswan, Egypt in 2015. Seed dormancy of impermeable seed coat of *A. raddiana* and *A. nilotica* was breaked through a pre-germination treatment by immersing seeds in concentrated sulphuric acid (95%) for 10min to weaken seed coat (Danthu et al., 1992; Ndour, 1997; Zetta et al., 2017) then washed with tap water. Seeds were sown directly into plastic pots of 30cm in diameter and 20cm deep with four 1.5mm-holes at the bottom. Soil used in experiment was clay: sand (1:2) (Taher et al., 2006). The experiment was carried out for 16 weeks old of *A. raddiana* savi and *A. nilotica* (L.) under a different *SMC* from 12% (3% above field capacity) to 2% (almost dry). The soil moisture content in pots is measured and monitored by Model 5910A Soil moisture Meter (KIMBLE Glass, Inc.) (Sheded & Radwan, 2008).

Gas exchange measurements

Measurements of the photosynthesis and transpiration rate were performed by using infrared gas analyzer (IRGA, CI-340) handheld photosynthesis system (CID Bio-Science, Inc.) and measured in *PAR* range (0-2500μ mols^{-1}m^{-2}) by module CI-301LA. Six Homogenous replica seedlings of *A. raddiana* and *A. nilotica* were selected and marked for the measurements of gas exchange along different watering regime. *WUE* was determined using the following formula:

Instantaneous Water Use Efficiency= The current net CO_2 assimilation rate (*Pn*)/ the current transpiration Rate (*E*) (Silva et al., 2013).

Data analysis

Two-way analysis of variance was carried out using MINITAB 12 statistical software, INC USA.

Two-way ANOVA compares means in groups of two different factors (*SMC* and *PAR*). Each variation term again has an associated number of degrees of freedom (DF) Total: N-1 (N= 55 obs.) Factor A: Soil Moisture Content % and Factor B: Photosynthetic Active Radiation. Sum of Squares (SS)= Variation due to this factor Mean Square (MS)= Sum of squares/ DF Hypothesis tests for the importance of each factor in the model: F-Tests measure the amount of variation explained by each factor relative to the variation associated with the errors (Minitab Inc., 1998).

Results

Maximum *Pn* of 7.07μ molm^{-2}s^{-1} was recorded in *A. raddiana* seedlings kept at 4% *SMC* (Fig 1-d) at 2000μmolm^{-2}s^{-1} (*PAR*). On the other hand, maximum *Pn* of 4.02μmol m^{-2}s^{-1} was recorded in *A. nilotica* seedlings (Fig 2-a) at 12% *SMC* at 2500μmol m^{-2}s^{-1} (*PAR*). Other wise negative values of *Pn* were recorded in *A. raddiana* seedlings (-0.3, -0.36μmol m^{-2}s^{-1}) at 9% *SMC* and (-1.9, -1.48μ mol m^{-2}s^{-1}) at 2% *SMC* at *PAR* ranged from 0 to 250μmol m^{-2}s^{-1}. On the other hand, *Pn* of *A. nilotica*'s seedlings showed negative values (-0.78μmol m^{-2}s^{-1}) at 12% *SMC*, (-1.33, -1.23μmol m^{-2}s^{-1}) at 9% *SMC* and (-0.92μ mol m^{-2}s^{-1}) at 2% *SMC* and *PAR* ranged from 0 to 250μmol m^{-2}s^{-1}. From two-way analysis of variance (Tables 1 and 2), *Pn* in *A. raddiana* and *A. nilotica* showed significant changes attributed to differences in both *SMC* and *PAR*, where: $F=8.68$; $P<0.0001$, $F=12.84$; $P<0.0001$, $F=3.93$; $P<0.05$ and $F=8.61$; $P<0.0001$, respectively.

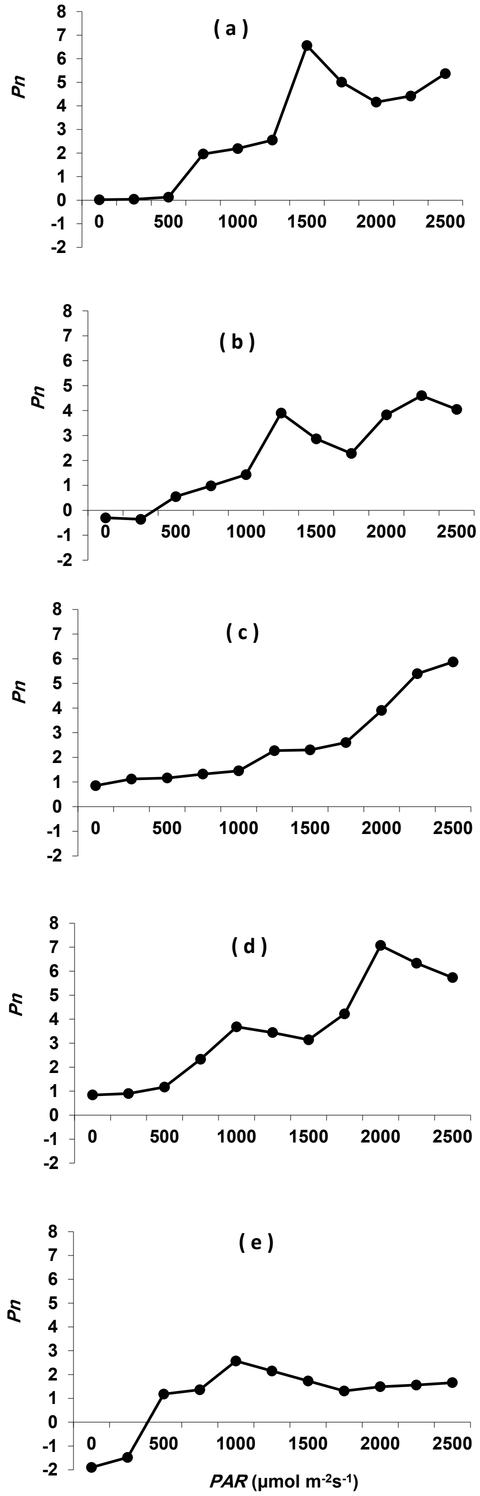

Fig. 1a-e. Photosynthesis rate *Pn* (µmol $m^{-2}s^{-1}$) of *Acacia raddiana* under water depletion (12%, 9%, 6%, 4% and 2%) and at photosynthetic active radiation (PAR) ranged from 0 to 2500 (µmol $m^{-2}s^{-1}$), F=8.68; P<0.0001, F=12.84; P<0.0001, respectively.

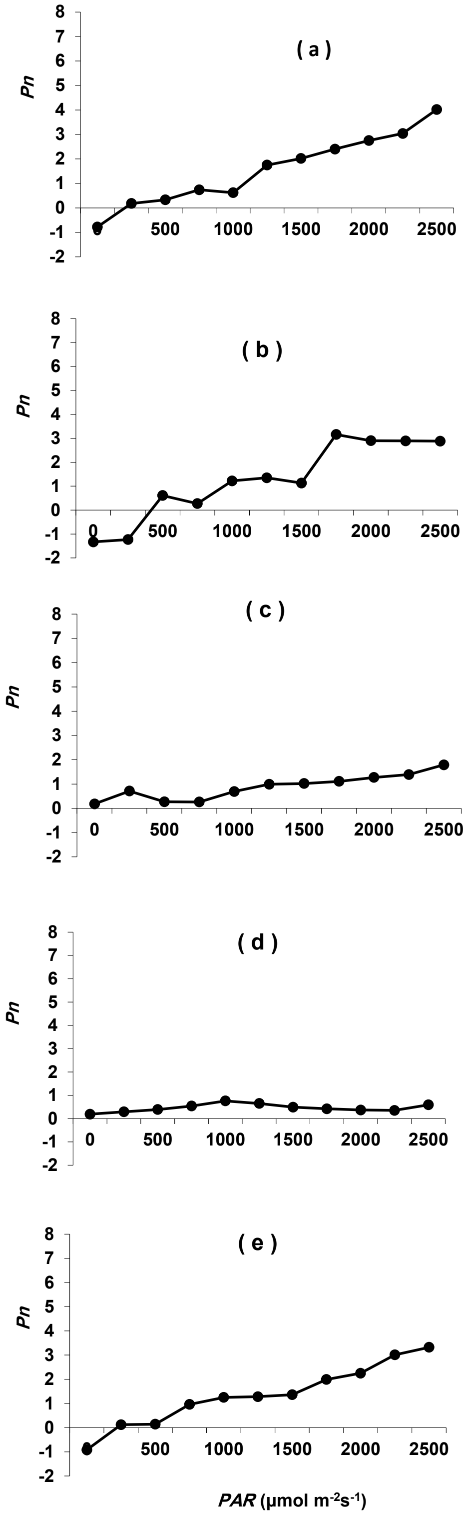

Fig. 2a-e. Photosynthesis rate (µmol $m^{-2}s^{-1}$) of *Acacia nilotica* under water depletion (12%, 9%, 6%, 4% and 2%) and at photosynthetic active radiation (PAR) ranged from 0 to 2500 (µmol m-2s-1), F=3.93; P<0.05, F=8.61; P<0.0001, respectively.

TABLE 1. Two-way analysis of variance of photosynthesis rate *(Pn)*, Transpiration *(E)* and instantaneous water use efficiency *(WUE)* of *Acacia raddiana* under different soil moisture contents (%) and at full range of photosynthetic active radiation (PAR).

Analysis of variance of *Acacia raddiana*'s photosynthesis rate (*Pn*) versus *SMC* and *PAR*.					
Source	**DF**	**SS**	**MS**	**F**	**P**
SMC	4	37.95	9.49	8.68	0.000
PAR	10	140.32	14.03	12.84	0.000
Error	40	43.71	1.09		
Total	54	221.98			
Analysis of variance of *Acacia raddiana*'s transpiration (*E*) versus *SMC* and *PAR*.					
Source	**DF**	**SS**	**MS**	**F**	**P**
SMC	4	2.1504	0.5376	10.12	0.000
PAR	10	2.2942	0.2294	4.32	0.000
Error	40	2.1239	0.0531		
Total	54	6.5685			
Analysis of variance of *Acacia raddiana*'s*WUE* versus *SMC* and *PAR*.					
Source	**DF**	**SS**	**MS**	**F**	**P**
SMC	4	13.974	3.493	5.28	0.002
PAR	10	64.106	6.411	9.69	0.000
Error	40	26.454	0.661		
Total	54	104.534			

TABLE 2. Two-way analysis of variance of photosynthesis rate (*Pn*), Transpiration (*E*) and instantaneous water use efficiency (*WUE*) of *Acacia nilotica* under different soil moisture contents (%) and at full range of photosynthetic active radiation (*PAR*).

Analysis of variance of *Acacia nilotica* 's photosynthesis rate (*Pn*) versus *SMC* and *PAR*.					
Source	**DF**	**SS**	**MS**	**F**	**P**
SMC	4	8.231	2.058	3.93	0.009
PAR	10	45.101	4.510	8.61	0.000
Error	40	20.945	0.524		
Total	54	74.276			
Analysis of variance of *Acacia nilotica* 's transpiration (*E*) versus *SMC* and *PAR*.					
Source	**DF**	**SS**	**MS**	**F**	**P**
SMC	4	4.7358	1.1840	32.15	0.000
PAR	10	1.1368	0.1137	3.09	0.005
Error	40	1.4730			
Total	54	7.3456			
Analysis of variance of *Acacia nilotica* 's *WUE* versus *SMC* and *PA*R.					
Source	**DF**	**SS**	**MS**	**F**	**P**
SMC	4	126.23	31.56	13.11	0.000
PAR	10	114.69	11.47	4.76	0.000
Error	40	96.28	2.41		
Total	54	337.20			

A. raddiana exhibited maximum *E* of 2.73mmol m^{-2}s^{-1} at 4% *SMC* (Fig 3-d) at highest *PAR* (2500µmol m^{-2}s^{-1}). On the other hand, *E* in *A. nilotica* seedlings gave maximum of 1.68mmol m^{-2}s^{-1} at highest *PAR* (2500µmol m^{-2}s^{-1}) kept at 9% *SMC* (Fig. 4-b). From two-way analysis of variance (Tables 1 and 2), *E* significant changes of *A. raddiana* and *A. nilotica* were attributed to differences in both *SMC* and *PAR*, where: F=10.12; P<0.0001, F=4.32; P<0.0001, F=32.15; P<0.0001, and F=3.09; P<0.01, respectively.

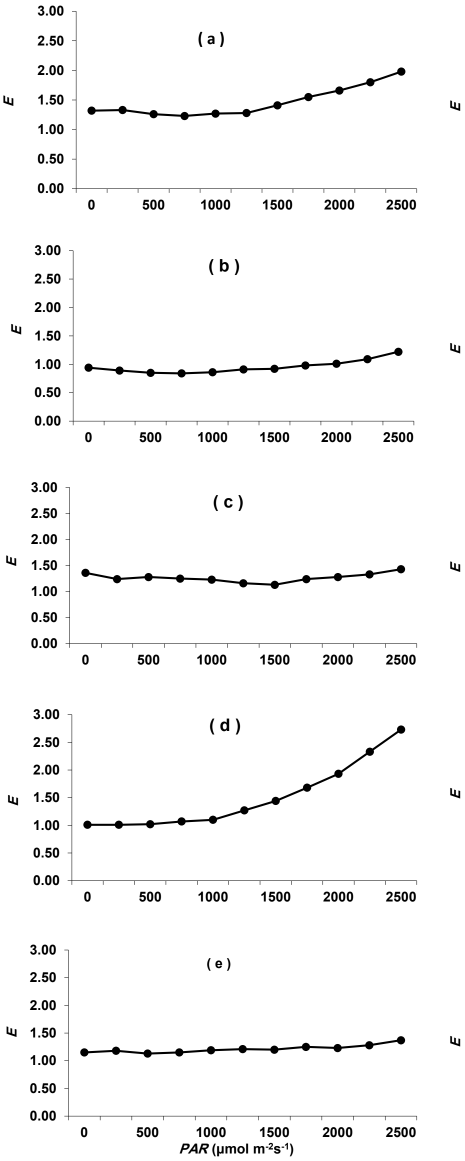

Fig. 3a-e. Transpiration rate E (mmol m^{-2}s^{-1}) of *Acacia raddiana* under water depletion (12%, 9%, 6%, 4% and 2%) and at photosynthetic active radiation (PAR) ranged from 0 to 2500 (µmol m^{-2}s^{-1}), F=10.12; P<0.0001, F=4.32; P<0.0001, respectively.

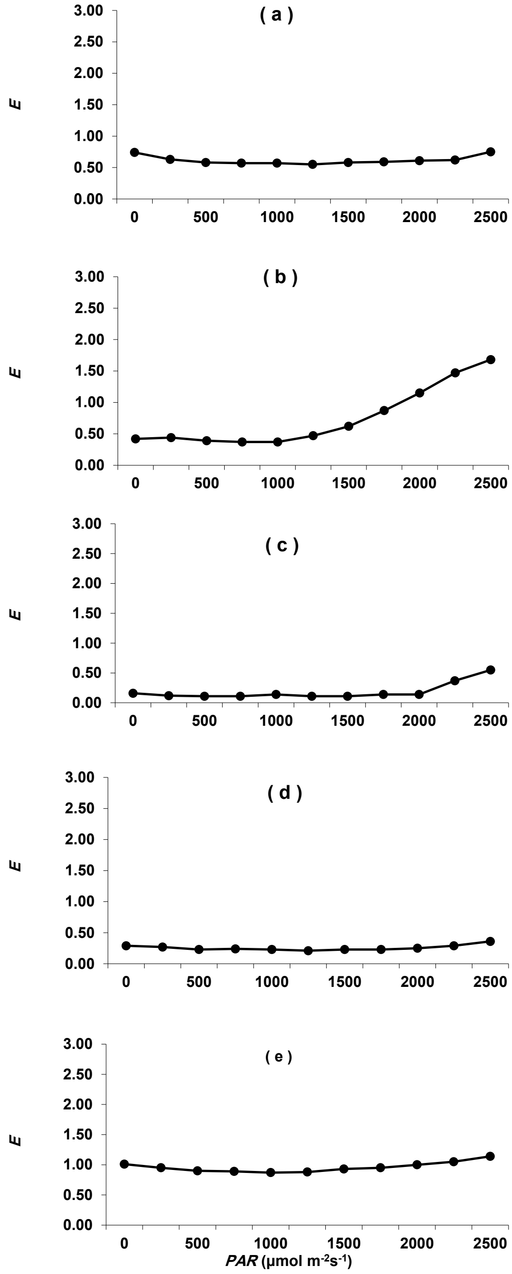

Fig. 4a-e. Transpiration rate (mmol m^{-2}s^{-1}) of *Acacia nilotica* under water depletion (12%, 9%, 6%, 4% and 2%) and at photosynthetic active radiation (PAR) ranged from 0 to 2500 (µmol m^{-2}s^{-1}), F=32.15; P<0.0001, F=3.09; P<0.01, respectively.

The maximum *WUE* (4.7µmolm^{-2}s^{-1}/mmol m^{-2}s^{-1}) was recorded in *A. raddiana* seedlings kept at 12% watering regime (Fig 5-a) at *PAR* of 1500µmol m^{-2}s^{-1}. *A. nilotica* exhibited maximum *WUE* of 9.3µ molm^{-2}s^{-1}/mmol m^{-2}s^{-1} at 6% *SMC* (Fig. 6-c) at 1500µmolm^{-2}s^{-1} (*PAR*). From two-way analysis of variance (Tables 1 and 2), *WUE* changes of *A. raddiana* and *A. nilotica* showed significant changes attributed to differences in both *SMC* and *PAR*, where: F=5.28; P<0.01, F=9.69; P<0.0001, F=13.11; P<0.0001, and F=4.76; P<0.0001, respectively.

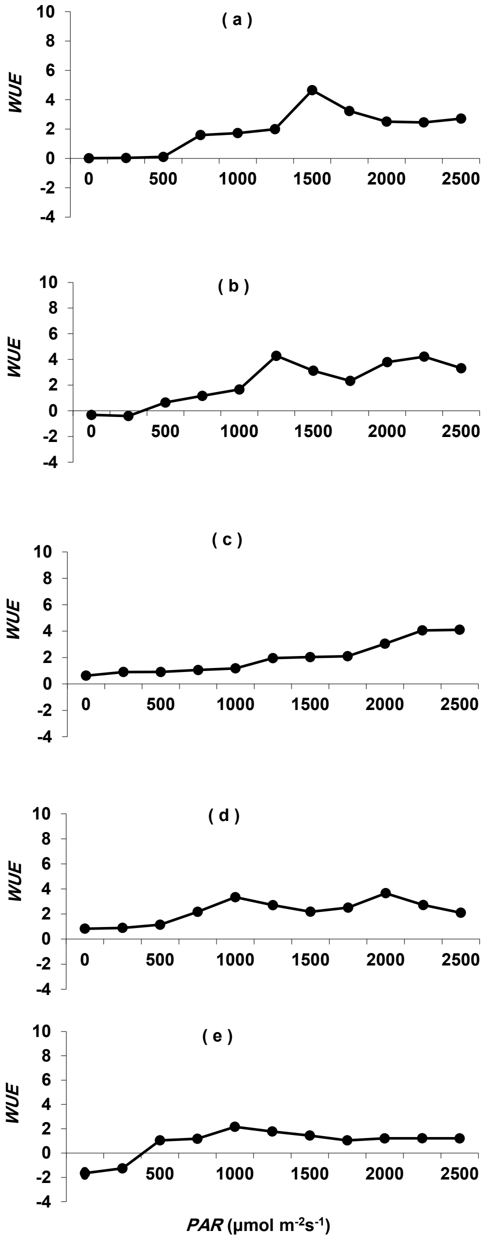

Fig. 5 a-e. Water use efficiency (µmol m^{-2}s^{-1}/ mmol m^{-2}s^{-1}) of *Acacia raddiana* under water depletion (12%, 9%, 6%, 4% and 2%) and at photosynthetic active radiation (PAR) ranged from 0 to 2500 (µmol m^{-2}s-^{1}), F=5.28; P<0.01, F=9.69; P<0.0001, respectively.

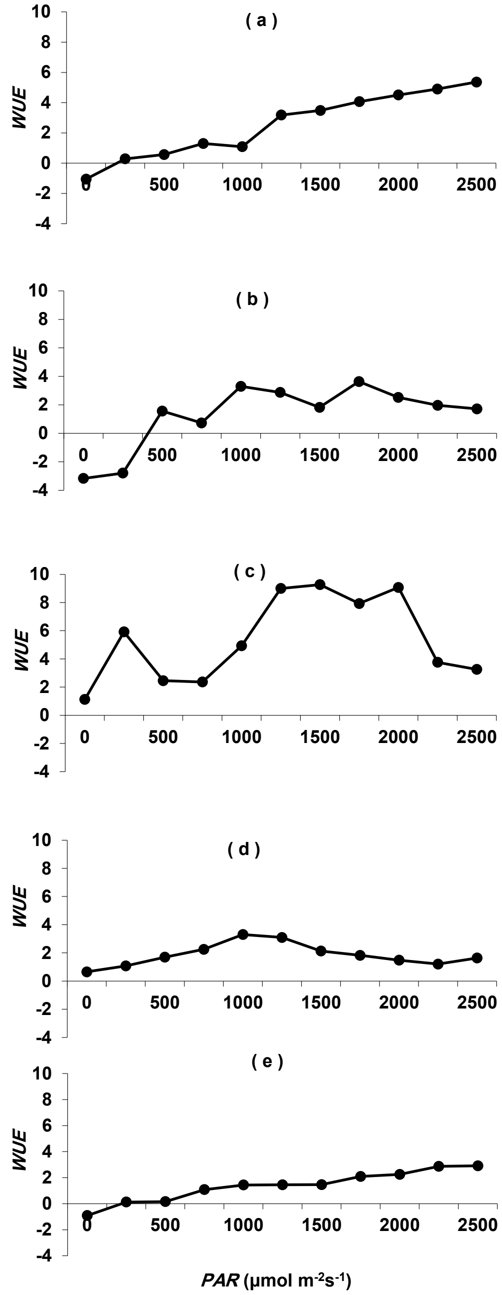

Fig. 6a-e. Water use efficiency (µmol m^{-2}s^{-1}/ mmol m^{-2}s^{-1}) of *Acacia nilotica* under water depletion (12%, 9%, 6%, 4% and 2%) and at photosynthetic active radiation (PAR) ranged from 0 to 2500 (µmol m^{-2}s^{-1}), F=13.11; P<0.0001, F=4.76; P<0.0001, respectively.

Discussion

During this study, *A.raddiana* and *A. nilotica* exhibited different high tolerance mechanisms to drought. Many authors found that drought tolerance is characterized by high productivity via maximizing assimilation in relation to the amount of water availability (Jones, 1992; Radwan, 2007). *A. raddiana* and *A. nilotica* showed maximum *Pn* under 4% and 12% *SMC,* respectively at high *PAR* levels. One of the main physiological responses of plant to soil dryness is minimize in leaf conductance to water for keeping sufficient turgor in plant tissues (Nunes et al., 1989; Radwan, 2008). Negative *Pn* values were noticed in both *A. raddiana* and *A. nilotica* seedlings under low *PAR* (0 to 250µmol $m^{-2}s^{-1}$) accompanied with water depletion. Jones (2014) stated that negative *Pn* values associated with dark respiration, in order to produce energy during plant growth. Drought promoted stomatal closure (Flexas et al., 2004), shoot and root growth in desert plants (Bageat-Triboulot et al., 2007; Radwan et al., 2007). Drought stress affects photosynthesis rate due to the minimized CO_2 availability resulted from stomatal closure (Flexas et al., 2006; Chaves et al., 2009; Osakabe et al., 2014). Reduced gas exchange of leaf minimized transpiration in leaf and carbon assimilation (Parolin, 2001; Baraloto et al., 2007; Wang et al., 2017). Under limited water supply or high evaporation, plants exhibit different strategies for survival and growth (Jones, 2004; Tambussi et al., 2007; El Atta et al., 2012).

According to this study's results, *A. raddiana* showed high transpiration rates at 4% watering regime. In drought conditions plants attain survival mechanisms by decrease the potential dry matter productivity through decreasing total photosynthesis by stomatal closure. The main effects of drought stress in plants are declined leaf size, stem elongation, water use efficiency (*WUE*) (Li et al., 2009; Farooq et al., 2009; Farooq et al., 2012).

The ideal desert plants tends to exhibit optimum balance between water conservation and productivity mechanisms depending on the aridity of the environment, productivity of plants in dry environments is enhanced by maximizing assimilation and minimizing water evaporated in relation to water availability to improve *WUE* (Sambatti & Caylor, 2007; Jones, 2014).The photosynthetic water use efficiency (*WUE*) is associated with the plant's optimum water use (Robinson et al., 2001; Larcher, 2003; Novriyanti et al., 2012).

The result of stomatal closure is minimizing transpiration rate, which leads to the improvement of water use efficiency (Lawson & Blatt, 2014; Tshikunde et al., 2018). The highest *WUE* value related with the increment in drought tolerance with trees growing in arid areas (Smith & Nowak, 1990; Otieno et al., 2005), which agree with the current study's results that the maximum *WUE* was noticed in *A. raddiana* at 12% *SMC*, while *A. nilotica* showed maximum *WUE* at 6% *SMC* at high *PAR* level. The plant's capability to absorb higher carbon concentrations for including high photosynthetic rates maintenance, and water loss is limited via the control of the stomatal aperture and closure (Flexas et al., 2013; De Santana et al., 2015; Liu et al., 2016), and plants able to absorb carbon and maintain photosynthetic activities (Roel et al., 2011; Broeckx et al.,2014; Dos Santos et al., 2017).

Desert plants adopt a powerful defense mechanism by minimize water loss through reduction of stomatal conductance and the dynamic photoinhibition under high irradiance (Rossi et al., 1999; Pinheiro & Chaves, 2011). *A. raddiana* acted as water spender ideal desert plant at high *PAR* and in response to water depletion and *A. nilotica* maximized *Pn* and minimized *E* giving maximum *WUE* at high *PAR* and low *SMC* levels.

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مقارنة الاستجابات الفسيولوجية البيئية للطلح والسنط النيلى أثناء تكون الشتلة تحت تأثير ظروف الجفاف القاسية

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تتضمن هذه الدراسة الاستجابات الفسيولوجية البيئية للطلح والسنط النيلى أثناء تكون الشتلة تحت تأثير ظروف الجفاف القاسية. وتمت هذه التجربة في ظروف بيئية قاحلة لدراسه تأثيرات الاجهاد المائي حيث تم تطبيق نظام ري يبدأ من محتوي مائي للتربة بنسبة 12% ، آخذاً في التناقص تدريجيا كالتالي 9%، 6%، 4%، 2%. و تم قياس كلا من البناء الضوئي و النتح وكفاءة إستخدام الماء اللحظية المحسوبة، تحت مدى (صفر- 2500 ميكرومول م$^{-2}$ ث$^{-1}$) من إشعاع البناء الضوئي النشط. وقد لوحظ أن القيمة العظمي للبناء الضوئي في شتلات الطلح عند 4% محتوي مائي للتربة، ولوحظت القيمة العظمي للبناء الضوئي في شتلات السنط النيلى عند 12% محتوي مائي للتربة، وذلك عند اقصي درجات أشعاع البناء الضوئي النشط. كما تم تسجيل أعلى قيم للنتح في شتلات الطلح عند 4% محتوي مائي للتربة و في شتلات السنط النيلي عند 9% محتوي مائي للتربة و ذلك عند اقصى درجات إشعاع البناء الضوئي النشط. وقد لوحظت أعلى قيمة لكفاءة إستخدام الماء اللحظية في شتلات الطلح عند 12% محتوي مائي للتربة، كما أظهرت شتلات السنط النيلي اعلى قيمة لكفاءة إستخدام الماء اللحظية 6% و ذلك عند اقصى درجات اشعاع البناء الضوئى النشط. وقد اظهرت شتلات الطلح صفات النبات الصحراوي النموذجي عند الدرجات العالية لإشعاع البناء الضوئي النشط، و اظهرت شتلات السنط النيلي معدل بناء ضوئي عالي و معدل نتح منخفض، مما ضاعف من كفاءة إستخدام الماء اللحظية عند مستوي عالي من اشعاع البناء الضوئي النشط و مستويات محتوي مائي منخفض للتربة.