Water Use Efficiency of *Acacia seyal* (Del.) in extreme arid environment prevails in South-Western Desert, Egypt

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Received: 12/7/2020  
Accepted: 8/8/2020

Abstract:
The present investigation involves the studies of water use efficiency of *Acacia seyal* (Del.) 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%. Calculated instantaneous water use efficiency was measured under full Photosynthetic Active Radiation range (0-2500μmols⁻¹m⁻²). *Acacia seyal* showed maximum photosynthesis rate at 9% soil moisture content, and at high Photosynthetic Active Radiation levels. Maximum transpiration rate recorded at 9% soil moisture content at highest Photosynthetic Active Radiation. The maximum instantaneous water use efficiency was noticed at 4% soil moisture content at high Photosynthetic Active Radiation level. *Acacia seyal* maximized photosynthesis rate and minimized transpiration rate, giving maximum instantaneous water use efficiency at the high Photosynthetic Active Radiation and low soil moisture content levels.

Keywords: Drought stress, photosynthetic Active Radiation, photosynthesis, transpiration rate, water use, Riverian plant.

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 and 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 CO₂ (Chaves, 1991; Cornic, 2000; Flexas et al., 2004; Ahmad et al., 2011). Plants in arid environments have developed physiological mechanisms to resist drought stress (Kozlowski and Pallardy, 2002; Elfeel and Alnamo, 2011).

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Acacia seyal exists in the Nile region including the Delta, Valley and Faiyum; Nile banks and Islands (Boulos, 1999). Woods of Acacia seyal used as a fumigant, leaves and bark used for treating gastric ulcers, gum is extracted from the plant therapeutic significance against rheumatism, and pods are useful in feeding in livestock (Boulos, 1983). Acacia seyal considered as threatened due different man activities such as cutting trees for fuel wood and drought fluctuations (ElBahaa, 2012; Marshall et al., 2012; New, 1984; Sinclair et al., 2008).

The aim of the current research was to reveal the physiological mechanisms of Acacia seal to resist the combination of drought stress and high irradiance during seedling establishment which in turn help in the restoring and cultivation of endangered endemic species.

MATERIALS AND METHODS

Seed collection from Desert Garden, Aswan University Campus, Aswan, Egypt in May 2015, seed dormancy of impermeable seed coat of Acacia seyal was breaked through a pre-germination treatment by immersing seeds in concentrated sulphuric acid (95%) for 10 minutes 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 30 cm in diameter and 20 cm deep with four 1.5 mm-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 Acacia seyal (Del.) under a different SMC from 12% (3% above field capacity) to 2% (almost dry) to impose soil water depletion. The soil moisture content in pots is measured by Model 5910A Soil moisture Meter (KIMBLE Glass, Inc.) (Sheded and Radwan, 2008). 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 (0-2500μmol m⁻² s⁻¹) by module CI-301LA. Six homogenous seedlings were selected and marked for the measurements of gas exchange along different levels of SMC. WUE was determined using the following formula: Instantaneous Water Use Efficiency = the current net CO₂ assimilation rate (Pn)/ the current transpiration Rate (E) (Silva et al., 2013).

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 AND DISCUSSION

Maximum Pn of 3.66μmol m⁻² s⁻¹ was recorded in Acacia seyal seedlings kept at 4% SMC (Fig 1-b) at 2250μmol m⁻² s⁻¹ (PAR). Otherwise negative values of Pn were recorded in Acacia seyal seedlings (-0.72μmol m⁻² s⁻¹) at 12% SMC and (-0.25, -0.26, -0.27μmol m⁻² s⁻¹) at 9% SMC and (-0.87μmol m⁻² s⁻¹) at 6% SMC and (-0.85, -1.16, -1.77μmol m⁻² s⁻¹) at 4% SMC and (-1.58, -1.45, -1.15μmol m⁻² s⁻¹) at 2% SMC at PAR ranged from 0 to 500 μmol m⁻² s⁻¹. From two-way analysis of variance (Table 1), Pn in Acacia seyal showed significant changes attributed to differences in both SMC and PAR, where: F=3.66; P<0.01 and F=15.53; P<0.0001, respectively (Table 1.).

Acacia seyal exhibited maximum E of 1.45mmol m⁻² s⁻¹ at 9% SMC (Fig 2-b) at highest PAR (2500μmol m⁻² s⁻¹). From two-way analysis of variance (Table 1), E significant changes of
Acacia seyal were attributed to differences in both SMC and PAR, where: F=82.93; P<0.0001 and F=3.23; P<0.0001, respectively (Table 1.).

![Graphs](a)-(e)

Fig. 1a-e. Photosynthesis rate $P_n$ (µmol m$^{-2}$s$^{-1}$) of A. seyal 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=3.66; P<0.01 and F=15.53; P<0.0001, respectively.

The maximum WUE (30.8µmolm$^{-2}$s$^{-1}$/mmol m$^{-2}$s$^{-1}$) was recorded in Acacia seyal seedlings kept at 4% watering regime (Fig 3-d) at PAR of 1500µmol m$^{-2}$s$^{-1}$. From two-way analysis of variance (Table 1), WUE changes of Acacia seyal showed significant changes attributed to differences in both SMC and PAR, where: F=9.56; P<0.0001 and F=4.14; P<0.01, respectively (Table 1).

During this study, Acacia seyal 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). Acacia seyal showed maximum $P_n$ under 4% SMC 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 $P_n$ values were noticed in Acacia seyal seedlings under low PAR (0 to 500 µmol m$^{-2}$s$^{-1}$) accompanied with water depletion. Jones (2014) stated that negative $P_n$ values were 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 CO₂ 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, Acacia seyal showed high transpiration rate at 9% 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 plants tend 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 and 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).

Table (1) Two-way Analysis of Variance of Photosynthesis rate (Pn), Transpiration (E) and instantaneous water use efficiency (WUE) of A. seyal under different soil moisture contents (%) and at full range of photosynthetic active radiation (PAR).

| Source of variance of photosynthesis rate (Pn) versus phenological stages |
|---------------------------|-----------------|-----------------|-------|------|
| Source                  | DF | SS   | MS   | F   | P   |
| Phenology               | 3  | 47.01| 15.67| 4.77| 0.004|
| Error                   | 80 | 262.92| 3.29 |     |      |
| Total                   | 83 | 309.92|     |     |      |

| Source of variance of transpiration (E) versus phenological stages |
|---------------------------|-----------------|-----------------|-------|------|
| Source                  | DF | SS   | MS   | F   | P   |
| Phenology               | 3  | 0.10045| 0.03348| 4.75| 0.004|
| Error                   | 80 | 0.56335| 0.00704|     |      |
| Total                   | 83 | 0.66380|     |     |      |

| Source of variance of stomatal conductance (C) versus phenological stages |
|---------------------------|-----------------|-----------------|-------|------|
| Source                  | DF | SS   | MS   | F   | P   |
| Phenology               | 3  | 323.48| 107.83| 14.24| 0.000|
| Error                   | 80 | 605.58| 7.57 |     |      |
| Total                   | 83 | 929.06|     |     |      |

| Source of variance of instantaneous water use efficiency (WUE) versus phenological stages |
|---------------------------|-----------------|-----------------|-------|------|
| Source                  | DF | SS   | MS   | F   | P   |
| Phenology               | 3  | 727.6| 242.5| 4.30| 0.007|
| Error                   | 80 | 4514.3| 56.4 |     |      |
| Total                   | 83 | 5242.0|     |     |      |
Fig. 2a-e. Transpiration rate $E$ (mmol m$^{-2}$s$^{-1}$) of *A. seyal* under water depletion (12%, 9%, 6%, 4% and 2%) and at photosynthetic active radiation (PAR) ranged from 0 to 2500 (μmol m$^{-2}$s$^{-1}$), $F=82.93; P<0.0001$ and $F=3.23; P<0.0001$, respectively.

The result of stomatal closure is minimizing transpiration rate, which leads to the improvement of water use efficiency (Lawson and Blatt, 2014; Tshikunde et al., 2018). The highest WUE value related with the increment in drought tolerance with trees growing in arid areas (Smith and Nowak, 1990; Otieno et al., 2005), which agree with the current study’s results that the maximum WUE was noticed in *Acacia seyal* at 12% SMF 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).

Fig. 3a-e. Water use efficiency ($\mu$mol m$^{-2}$s$^{-1}$/ mmol m$^{-2}$s$^{-1}$) of A. seyal under water depletion (12%, 9%, 6%, 4% and 2%) and at photosynthetic active radiation (PAR) ranged from 0 to 2500 ($\mu$mol m$^{-2}$s$^{-1}$), F=9.56; P<0.0001 and F=4.14; P<0.01, respectively.

REFERENCES

Ahmad, A. S., Xiao-yu, X., Long-chang, W., Saleem, M. F., Man, C. and Lei, W. (2011) Morphological, physiological and biochemical responses of plants to drought stress. African Journal of Agricultural Research 6 (9): 2026-2032.

Bageat-Triboulot, M., Brosche, M., Renault, J., Jouve, L., Le Thiec, D., Fayyaz, P., Vinocur, B., Witters, E., Laukens, K., Teichmann, T., Altman, A., Hausman, J., Kangasjarvi, J. and Dreyer, E. (2007) Gradual soil depletion result in reversible changes of gene expression, protein profiles, ecophysiology, and growth performance in Populus euphratica, a poplar growing in arid regions. Plant Physiology (143): 876-892.
Baraloto, C, Morneau, F., Bonal, D., Blanc, L and Ferry, B. (2007) Seasonal Water Stress Tolerance and Habitat Associations within four Neotropical Tree Genera. Ecology: 88(2): 478-489.

Basu, S., Ramegowda, V., Kumar, A., and Pereira, A. (2016) Plant adaptation to drought stress. F1000Research, 5(F1000 Faculty Rev):1554.

Boulos, L. (1983) Medicinal Plants of North Africa. Reference Publications Inc., Algononae, Michigan, 286p.

Boulos, L. (1999) Flora of Egypt, Volume One: Azollaceae - Oxalidaceae. Al Hadara Publishing, Cairo.

Bray, E. A. (1997) Plant responses to water deficit. Trends Plant Sci., 2(2): 48-54.

Broeckx, L. S., Fichot, R., Verlinden, M.S. and Ceulemans, R. (2014) Seasonal variations in photosynthesis, intrinsic water-use efficiency and stable isotope composition of poplar leaves in a short-rotation plantation. Tree Physiology (34)7: 701-715.

Chaves, M. M. (1991) Effects of Water Deficits on Carbon Assimilation. Journal of Experimental Botany 42(1): 1-16.

Chaves, M. M., Flexas, J., and Pinheiro, C. (2009) Photosynthesis under drought and salt stress: regulation mechanisms from whole plant to cell. Annals of botany 103: 551-560.

Cornic, G. (2000) Drought stress inhibits photosynthesis by decreasing stomatal aperture-not by affecting ATP synthesis. Trends in Plant Science (5)5: 187-188.

Cornic, G., and Massacci, A. (1996) Leaf Photosynthesis Under Drought Stress. In: Baker N.R. (eds) Photosynthesis and the Environment. Advances in Photosynthesis and Respiration, Vol. 5. Springer, Dordrecht.

Dai, A. (2012) Increasing drought under global warming in observations and models. Nat. Clim. Chang. (3): 52-58.

Danthu, P., Roussel, J., Dia, M., and Sarr, A. (1992) Effect of different pretreatments on the germination of Acacia senegal seeds. Seed Science and Technology, International Seed Testing Association Ista pp.111-117.

De Santana, T. A., Oliveira, P. S., Silva, L. D., Laviola, B. G., Almeida, A. F., and Gomes, F. P. (2015) Water use efficiency and consumption in different Brazilian genotypes of Jatropha curcas L. subjected to soil water deficit. Biomass Bioenergy 75: 119-125.

Dos Santos, C. M., Endres, L., Ferreira, V., Silva, J. V., Rolim, E. V. and wanderley Filho, H. C. L. (2017) Photosynthetic capacity and water use efficiency in Ricinus communis (L.) under drought stress in semi-humid and semi-arid areas. Anais da Academia Brasileira de Ciências 89(4): 3015-3029.

El Atta, H. A., Aref, I. M., Ahmed, A. I. and Khan, P. R. (2012) Morphological and Anatomical response of Acacia ehrenbergiana Hayne and Acacia tortilis (Forssk.) Haynes subspp. raddiana seedlings to induced water stress. African Journal of Biotechnology (11)44: 10188-10199.

El Bahaa, A. M. (2012) Forest Genetic Resources Country Report Egypt. FAO.
Elfeel, A. and Al-Namo, M. L. (2011) Effect of imposed drought on seedlings growth, water use efficiency and survival of three arid zone species (Acacia tortilis subsp raddiana, Salvadora persica and Leptadenia pyrotechnica). Agric. Biol. J. N. Am. 2(3): 493-498.

Farooq, M., Hussain, M., Abdul Wahid and Siddique, K. H. M. (2012) Drought Stress in Plants: An Overview. Springer-Verlag Berlin Heidelberg.

Farooq, M., Wahid, A., Kobayashi, N., Fujita, D. and Basra, S. M. A. (2009) Plant drought stress: effects, mechanisms and management. Agron. Sustain. Dev. 29: 185-212.

Flexas, J., Niinemets, Ü., Gallé, A., Barbour, M. M., Centritto, M., Díaz-Espejo, A., Douthe, C., Galmés, J., Ribas-Carbo, M., Rodríguez, P. L., Rosselló, F., Soolanayakanahally, R., Tomas, M., Wright I. J., Farquhar, G. D. and Medrano, H. (2013) Diffusional conductances to CO2 as a target for increasing photosynthesis and photosynthetic water-use efficiency. Photosynthesis Research (117):1-3: 45-59.

Flexas, J., Bota, J., Cifre, J., Escalona, J. M., Galmés, J., Gulòas, J., Lefi El-Kadri, Martínez-Cañellas S. F., Moreno, M., Ribas-Carbó, M., Riera, D., Sampol, B. and Medrano, H. (2004) Understanding down-regulation of photosynthesis under water stress: future prospects and searching for physiological tools for irrigation management. Ann. appl. Biol. 144:273-283.

Flexas, J., Bota, J., Cifre, J., Escalona, J. M., Galmés, J., Henkle, M., Martínez-Cañellas, S. F., Moreno, M., Ribas-Carbó, M., RIERA, D. and Medrano, H. (2006) Decreased Rubisco activity during water stress is not induced by decreased relative water content but related to conditions of low stomatal conductance and chloroplast CO2 concentration. New Phytologist PP. 73-82.

Jones, H. G. (1992) Plants and Microclimate: A Quantitative Approach to Environmental Plant Physiology. 2nd Edition Cambridge University Press.

Jones, H. G. (2004) Irrigation scheduling: advantages and pitfalls of plant-based methods. Journal of Experimental Botany (Water-Saving Agriculture Special Issue) (55) 407: 2427–2436.

Jones, H. G. (2014) Plants and Microclimate: A quantitative approach to environmental Plant Physiology. 3rd Edition Cambridge University Press, New York, USA.

Kozlowski, T.T., and Pallardy, S.G. (2002) Acclimation and adaptive responses of woody plants to environmental stresses. The botanical review 68 (2): 270-334.

Larcher, W. (2003) Physiological plant ecology: ecophysiology and stress physiology of functional groups, 4th edition, Springer-verlag Berlin Heidelberg, New York.

Lawson, T, and Blatt, M. R. (2014) Stomatal size, speed, and responsiveness impact on photosynthesis and water use efficiency. Plant physiology 164 (4): 1556-1570.

Li Z., Wakao S., Fischer B. B. and Niyogi K. K. (2009) Sensing and responding to excess light. Annu. Rev. Plant Biol. 60: 239-260.

Liu, E. K., Mei, X. R., Yan, C. R., Gong, D. Z. and Zhang, Y. Q. (2016) Effect of water stress on photosynthetic characteristics, dry matter translocation and WUE in two winter wheat genotypes. Agricultural Water Management 167: 75-85.
Marshall, A. R., Platts, P. J., Gereau, R. E., Kindeketu, W., King’ethe, S. and Marchant, R. (2012) The genus Acacia (Fabaceae) in East Africa: distribution, diversity and the protected area network. Plant Ecology and Evolution 145 (3): 289-301.

Minitab Inc. (1998) Users Guide 2: Data Analysis and Quality tools Release 12:12, Minitab Inc.

Mwanamwenge, J., Loss, S. P., Siddique, K. M. H. and Cocks, P. S. (1999) Effect of water stress during floral initiation, flowering and podding on the growth and yield of fababean (Vicia faba L.). Europ. J. Agron. 11: 1-11.

Ndour, P. (1997) Comportement de quelques espèces du genre Acacia en condition de stress hydrique et salin simulé. DEA: Biologie végétale, Université Cheikh Anta Diop, Dakar Sénégal.

New, T. R. (1984) A biology of Acacias. Oxford, Oxford University Press.

Novriyanti, E., Watanabe, M., Makoto, K., Takeba, T., Hashidoko, Y., and Koike, T. (2012) Photosynthetic nitrogen and water use efficiency of Acacia and Eucalypt seedlings as afforestation species. Photosynthetica 50 (2): 273-281.

Nunes, M. A., Catarino, F. and Pinto, E. (1989) Strategies for acclimation to seasonal drought in Ceratonia siliqua leaves. Physiol. Plant. 77: 150-156.

Osakabe, Y., Osakabe, K., Shinozaki, K. and Tran, L. (2014) Response of plants to water stress. Frontiers in Plant Science 64: 445-458.

Otieno, D. O, Schmidt, M. W., Adiku, S., and Tenhunen, J. (2005) Responses of Acacia tortilis and Acacia xanthophloea to seasonal changes in soil water availability in the savanna region of Kenya. Journal of Arid Environments (62)3: 377-400.

Parolin, P. (2001) Morphological and physiological adjustments to waterlogging and drought in seedlings of Amazonian floodplain trees. Oecologia 128: 326-335.

Radwan, U. A. A. (2007) Photosynthetic and leaf Anatomical characteristics of the drought resistant Balanites aegyptiaca (L.) Del. Seedlings. American-Eurasian J. agric. and Environ. Sci. 2 (6): 680-688.

Radwan, U. A. A. (2008) Tolerance Evaluation of Hyoscyamus muticus L. Seedlings to Radioactive Heat Load and Gradual Soil Moisture Depletion. American-Eurasian J. agric and Environ. Sci. 3 (1): 106-113.

Radwan, U. A., Springuel, I., Sheded, M. G. and Taher, M. A. (2007) Ecophysiological characteristics as a tool to evaluate drought tolerance of Acacia raddiana (savi) Brenan and Acacia ehrenbergiana Hayne seedlings. Bull. Fac. Sci., Cairo Univ. 75 (C): 107-126.

Robinson, D. E., Wagner, R. G., Bell, F. W. and Swanton, C. J. (2001) Photosynthesis, nitrogen-use efficiency, and water-use efficiency of jack pine seedlings in competition with four boreal forest plant species. Can. J. Forest Res. 31: 2014-2025.

Roel, J. W., Wanek, B. W. and Hietz, P. (2011) Stable carbon isotopes in tree rings indicate improved water use efficiency and drought responses of a tropical dry forest tree species. Trees 25: 103-113.
Sambatti, J. B. M., and Caylor, K. K. (2007) When is breeding for drought tolerance optimal if drought is random. New Phytologist 175: 70-80.

Sheded, M. G. and Radwan, U. A. A. (2008) Plant Water Relations as an Indicator of Drought Tolerance of Senna species in the Egyptian Nubia. World Applied Sciences Journal 3(3): 382-390.

Silva, M. D., Jifon, J. L., Dos Santos, C. M., Jadoski, C. J. and Da Silva, J. A. G. (2013) Photosynthetic Capacity and Water Use Efficiency in Sugarcane Genotypes Subject to Water Deficit During Early Growth Phase. Braz. Arch. Biol. Technol. 56 (5): pp. 735-748.

Sinclair, A. R. E., Hopcraft, J. G. C., Olff, H., Mduma, S., Galvin, K. A., and Sharam, G. J. (2008) Historical and future changes to the Serengeti ecosystem. In: Sinclair, A. R. E., Packer, C., Mduma, S. A., Fryxell, J. M. (Eds.) Serengeti III: Human Impacts on Ecosystem Dynamics. 7-46. Chicago, University of Chicago Press.

Smith, S. D. and Nowak, R. S. (1990) Ecophysiology of Plants in the Intermountain Lowlands. Plant Biology of the Basin and Range pp. 179-241.

Taher, M. A., Springuel, I., Sheded, M. G. and Radwan, U. A. (2006) Transpiration rate, Stomatal Conductance and Stem Water Potential of Acacia raddiana Savi and Acacia ehrenbergiana Hayne in response to Different Watering Regime and Photosynthetic Photon Flux Density (PPFD). J. Union Arab Biol. Cairo, Ecology, Taxonomy, Flora and Cytogenetics Vol. (16B) PP. 1-16.

Tambussi, E. A., Bort, J. and Araus, J. L. (2007) Water use efficiency in C3 cereals under Mediterranean conditions: A review of physiological aspects. Ann. Appl. Biol. 150: 307-321.

Tshikunde, N. M., Odindo, A., Shimelis, H. and Mashilo, J. (2018) Leaf gas exchange and water use efficiency of dry land wheat genotypes under water stressed and non-stressed conditions. Acta Agriculturae Scandinavica, Section B - Soil and Plant Science PP. 738-748.

Wang, S., Callaway, R. M., Zhou, D. and Weiner, J. (2017) Experience of inundation or drought alters the responses of plants to subsequent water conditions. Journal of Ecology 105: 176-187.

Yordanov, I., Velikova, V., and Tsoniev, T. (2003) Plant Responses to Drought and Stress Tolerance. Bulg. J. Plant Physiol. Speical Issue, 187-206.

Zetta, H. B., Amrani, S. and Nacer, A. (2017) Effects of pre-germination treatments, salt and water stresses on the germination of Acacia ehrenbergiana Hayne and Acacia seyal Del. (Mimosoideae): two Algerian native species. Applied Ecology and Environmental Research 15(4): 355-368.