

Full Length Research Paper

The impact of drought stress on photosynthetic quantum yield in *Haloxylon aphyllum* and *Haloxylon persicum*

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The impact of periodic drought stress on photosynthesis changes was examined in *Haloxylon aphyllum* and *Haloxylon persicum*. Parameters F_0 , F_v/F_m , the chlorophyll content and chlorophyll a/b ratio were measured. Drought stress factor was considered as lack of irrigation of potted-seedlings of two *Haloxylon* species in periods 0, 2, 4, 6... 26 and 28 days, and each drought period were repeated six times. Species factor included *H. aphyllum* and *H. persicum*. Drought stress significantly ($p=0.01$) reduced chlorophyll content and maximum quantum yield of photosynthesis (F_v/F_m ratio) but increased the Chl a/b ratio. Both the species are susceptible to drought stress.

Key words: Haloxylon, photosynthesis, stress, drought, fluorescence.

INTRODUCTION

Drought stress is one of the most important abiotic stresses in the arid and semi-arid regions that cause a wide variety of physiological and biochemical changes that inhibit plant growth and development from germination to productivity and disturb photosynthesis (Mekhaldi et al., 2008; Misra et al., 2002). Photosynthesis is the most important process in biological system defining the limits of biomass production (Sofi et al., 2006), and is the main physiological parameter in drought stress process that is affected by drought (Arabzadeh, 2009; Satisha et al., 2007; Misra et al., 2002). Drought stress (Arabzadeh, 2009) and light are important factors in photosynthesis function of plants (Iqbal, 2003b).

There is a considerable difference between C_3 and C_4 plants in terms of drought resistance. C_4 plants have high photosynthetic capacity so that photosynthesis of the plants are dominant compared with their respiration in poor light or in low pressure of CO_2 . The plants are also able to consume enough water for photosynthesis in dry habitats (Cornic and Miginiac, 1983).

Drought stress with creation of structural changes in

tilacoide membranes (Soares et al., 2008) has an indirect effect on photosynthetic electron transport chain (Kana et al., 2008). Other mechanisms that are involved on the photosynthetic processes reduction in conditions of water stress are ionic disorders of stroma (Kana et al., 2008). The studies show that a significant strong relationship was between relative water content (RWC) and photosynthesis rate, so that RWC reduction from 95 to 90% reduced the rate of photosynthesis up to 50% (Kramer, 1983).

Chlorophyll is the basic catalyst of photosynthesis that as green pigments exists in all plant tissues that do photosynthesis (Masinovsky et al., 1992). Composition of chlorophyll is relatively unstable that at the time of extraction should be prevented from its decomposition (Masinovsky et al., 1992).

It is well established that PS II play a key role in photosynthetic response to drought and unfavorable environmental conditions (Misra et al., 2011, 2012). Photochemical efficiency of PS II (F_v/F_m) was reduced in stipa (Balaguer et al., 2002), in pigweed (Osmond and Grace,

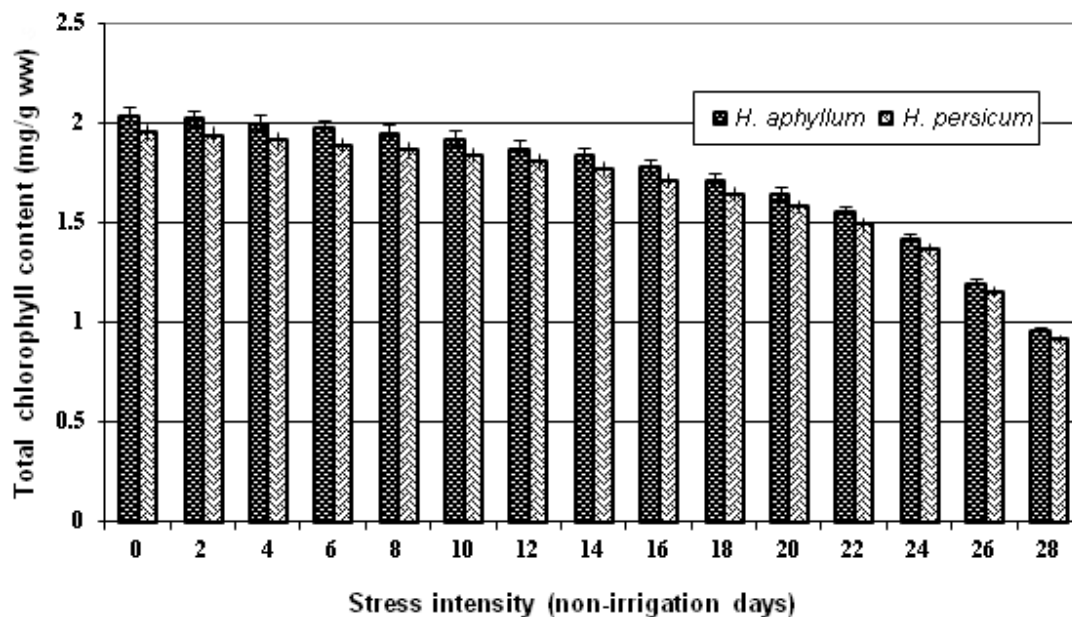


Figure 1- The impact of drought stress on changes mean of total chlorophyll (mg/g ww) in branchlets of *Haloxylon aphyllum* and *Haloxylon persicum*

1995), in *Clusia minor* (De Mattos et al., 1999), in banana (Thomas and Turner, 2001) and many plants under drought stress (Misra et al., 2002, 2012). The maximum quantum yield of photosynthesis (Fv/Fm ratio) ratio is taken as a parameter for the study of chloroplast development under normal and stress conditions (Misra et al., 2001a, b, 2006, 2012).

In the present report, the changes in the maximum quantum yield of photosynthesis were studied (Fv/Fm ratio) in two species of *Haloxylon* to assess their susceptibility to water stress.

MATERIALS AND METHODS

Induction of drought stress to seedlings of two *Haloxylon* species

After taking a month to comply with greenhouse conditions, annual seedlings from seeds of two *Haloxylon* species were treated with periodic drought stress at 0, 2, 4, 6...26 and 28 days of non-irrigation. It means that no water was given in these days. After 28 days without irrigation, the remaining plants were watered to saturation. This experiment was repeated 11 cycles (periodic stresses). In each experiment, five plants in each treatment were stratified.

Experimental design type

The experiment was in a randomized complete design, and data was analyzed using two-way analysis of variance; and comparison of averages was made by using Duncan's test.

Measurement of chlorophyll fluorescence

Chlorophyll fluorescence measurements were performed using Fluorimeter (PAM: H. Walz GmbH, Effeltrich, Germany); and then

Fv/Fm parameter was calculated as follows (Van Kooten and Snel, 1990):

$$Fv/Fm = (Fm - Fo)/Fm$$

Measurement of chlorophyll content

In this study, the amount of chlorophyll in the branchlets was measured by the method of Arnon (Arnon, 1949) extracting the pigment in 80% acetone as given below:

$$\text{Chlorophyll a (mg/ml)} = (0.0127 \times OD_{663}) - (0.00259 \times OD_{645})$$

$$\text{Chlorophyll b (mg/ml)} = (0.0229 \times OD_{645}) - (0.00469 \times OD_{663})$$

$$\text{Chlorophyll total (mg/ml)} = (0.00805 \times OD_{663}) - (0.02031 \times OD_{645})$$

RESULTS

Effect of drought stress on chlorophyll content

The total chlorophyll content of both *Haloxylon* species was affected by water deficit (drought stress). So that it declined from 2.041 mg/g (ww) in control to 0.96 mg/g (ww) in 28 days of non-irrigation treatment in *H. aphyllum*. The total chlorophyll content in *H. persicum* was reduced from 1.96 mg/g (ww) in control to 0.92 mg/g (ww) in 28 non-irrigation treatment too (Figure 1). Reduction speed of chlorophyll rate in both *Haloxylon* species was the function of stress intensity. So that reduction velocity of total chlorophyll rate increased with increasing stress.

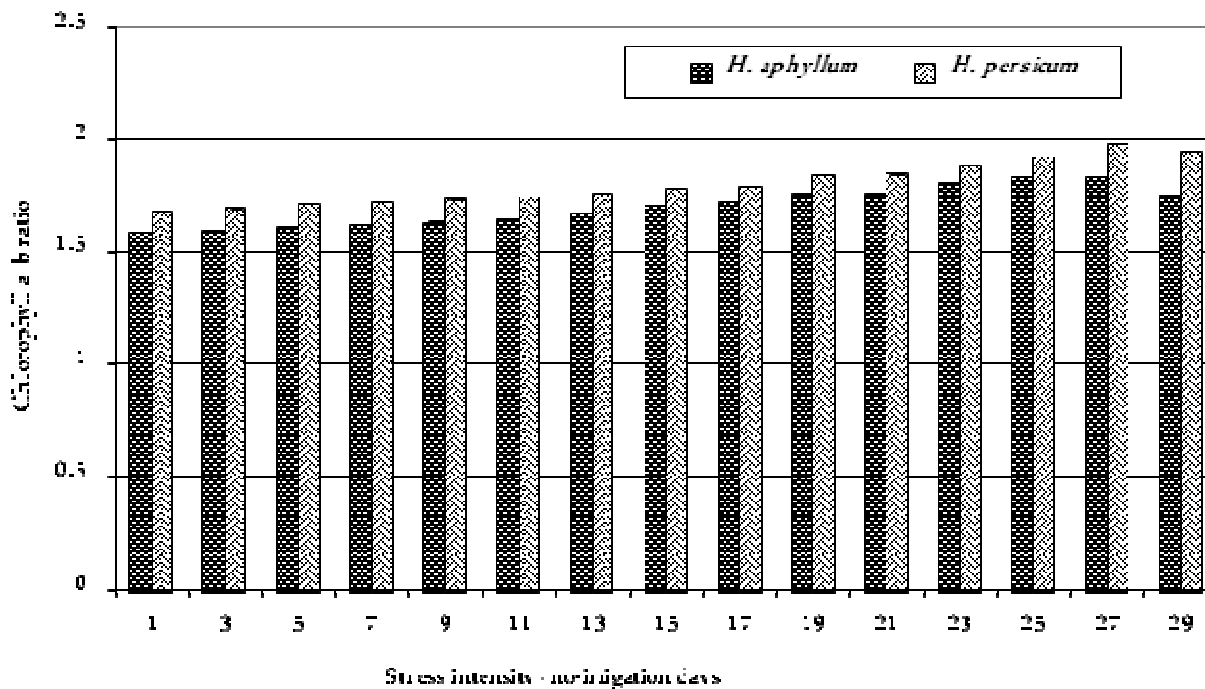


Figure 2- The impact of drought stress on changes mean of a/b ratio in branchlets of *Haloxylon aphyllum* and *Haloxylon persicum*.

Chlorophyll a/b ratio in both *Haloxylon* species increased proportional to the degree of water deficit (stress intensity) to 26 days of non-irrigation treatment. The ratio increased from 1.59 to 1.84 in *H. aphyllum* and from 1.68 to 1.98 in *H. persicum* (Figure 2). The changes trend was reversed from the 28 days of non-irrigation treatment so that the ratio decreased from 1.84 to 1.76 in *H. aphyllum*, and from 1.98 to 1.95 in *H. persicum*.

Effect of drought stress on the quantum efficiency of PS II (Fv/Fm)

Effects of drought stress on Fv/Fm had same trend in both *Haloxylon* species (Figure 3). So those with increasing stress levels were reduced. The rate decreased from 0.734 at zero stress to 0.681 at 28 days of non-irrigation stress in *Haloxylon aphyllum*, and from 0.715 to 0.685 in *Haloxylon persicum*. Reducing effect of drought stress on the Fv/Fm was intensified from 8 days of non-irrigation treatment in both *Haloxylon* species.

DISCUSSION

Drought stress in plants occurs when the plant's water intake is less than its loss. This may be due to excessive water loss or loss absorption or both (Erwin et al., 2007). Water potential and osmotic potential with the loss of turgidity, stomata closure and reduction of growth are

specific symptoms of water stress. The high intensity of water stress severely reduces photosynthesis, disrupts physiological processes, stops the plant growth, and eventually the plant dies (Singh and Patel, 1996; Misra et al., 2002).

This study shows that the chlorophyll content of assimilating shoots of both species of *H. aphyllum* and *H. persicum* decreased under water stress conditions (Figures 1 and 2). The phenomena of chlorophyll loss in drought conditions have been reported in many plants (Balaguer et al., 2002; Steinberg et al., 1990). Reduction of leaf chlorophyll content which is under drought stress reduces photosynthetic efficiency in the plants. The plants that are able to maintain their chlorophylls can also have higher photosynthesis (Arabzadeh, 2009).

According to survey results (this study) and studies of other researchers (Balaguer et al., 2002; Steinberg et al., 1990), it can be admitted that increase drought stress is a major factor in the breakdown of chlorophyll, and is an essential obstacle in the process of making new chlorophylls. In this study, chlorophyll content under drought stress decreased in all treatments in both *Haloxylon* species (Table 1), but the ratio of chlorophyll a/b increased.

Chlorophyll fluorescence is considered as a strong indicator of photosynthesis and as a decisive factor in stress physiology (Misra et al., 2001, 2006, 2012).

Photochemical reaction of PS II to drought was different in drought stress conditions and in the various species. The parameters of photosynthesis in both *Haloxylon* species, the control treatment (no stress) and 28 days of

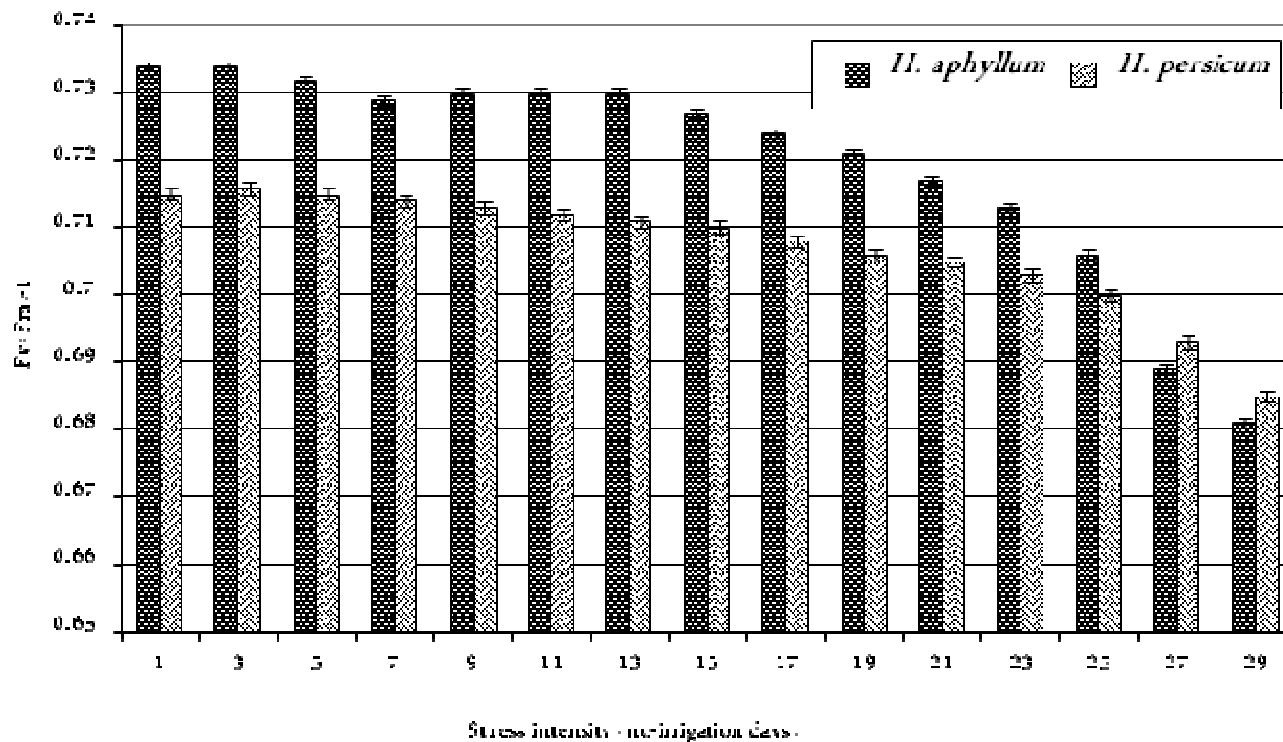


Figure 3. The impact of drought stress on the maximum quantum efficiency (Fv/Fm) in branchlets of *Haloxylon aphyllum* and *Haloxylon persicum*.

Table 1. Comparison of photosynthetic parameters in both control and 28 days of non-irrigation in two species of *Haloxylon aphyllum* and *Haloxylon persicum*.

<i>Haloxylon aphyllum</i>			<i>Haloxylon persicum</i>			Non-irrigation days
Total Chl. (mg/g ww)	Chl. a/b ratio	Fv/Fm	Total Chl.	Chl. a/b ratio	Fv/Fm	
2.041	1.590	0.734	1.959	1.684	0.715	0
0.961	1.754	0.681	0.920	1.949	0.685	28
**	**	**	**	**	**	Significant level

**Means significant at level 1%; Chl., chlorophyll.

non-irrigation treatment (the most severe stress treatment) are shown in Table 1. This table shows that the difference between these two treatments was significant at the 99% level in all studied parameters in both *Haloxylon* species.

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REFERENCES

- Arabzadeh N (2009). The examination of dryness induction effect in growth, some of physiological relations (parameters of water relations), physiological changes and increasing of drought tolerance range in *Haloxylon persicum* and *H. aphyllum*, Thesis submitted for degree of Ph.D in plant physiology. Department of Biology Sciences, Teacher Training (Tarbiyat Moallem) University of Tehran.
- Arnon D (1949). Copper enzymes in isolated chloroplasts, polyphenol oxidases in *Beta vulgaris*, *Plant Physiol. J.* 24:1-15.
- Balaguer L, Pugnaire FI, Martinez-Ferri E, Armas C, Valladares F, Manrique E (2002). Ecophysiological significance of chlorophyll loss and reduced photochemical efficiency under extreme aridity in *Stipa tenacissima* L., *Plant Soil J.* 240:343-352.
- Cornic G, Miginiac E (1983). Nonstomatal inhibition of net CO₂ uptake by abscisic acid in *parbits nil*. *Plant Physiol.* 73:529-533.

- De Mattos EA, Herzog B, Luttge U (1999). Chlorophyll fluorescence during CAM-phases in *Clusia minor* L. under drought stress. *Exper. Bot.* 50(331):253-261.
- Erwin HB, Fettig S, Knake C, Hartig K, Bhattarai T (2007). Specific and unspecific responses of plants to cold and drought stress. *Biosci. J.* 32:501-510.
- Iqbal RM (2003b). Equilibration study to determine procedure for determining net photosynthesis and photon flux densities response curves. *Asian J. Plant Sci.* 2(15):1083-1087.
- Kana R, Kotabova E, Prasil O (2008). Acceleration of plastoquinone pool reduction by alternative pathways precedes a decrease in photosynthetic CO₂ assimilation in preheated barley leaves. *Physiologia Plantarum*, Oxford, UK: Blackwell Publishing Ltd (133)4:794-806.
- Kramer PJ (1983). *Water relation of plants*, Orlando, Florida, Academic Press, Inc.
- Masinovsky Z, Lozovaya GI, Sivash AA (1992). Some aspects of the early evolution of photosynthesis. *Adv. Space Res.* 12(4):199-205.
- Mekhaldi A, Benkhalifa M, Belkhdja M (2008). The effect of salinity on gas exchange on different developmental stages of mung bean (*Vigna radiata* L. Wilczek). *Intl J. Bot.* 4(3):269-275.
- Misra AN, Srivastava A, Strasser RJ (2001a). Utilisation of fast Chlorophyll *a* fluorescence technique in assessing the salt/ion sensitivity of mung bean and brassica seedlings. *J. Plant Physiol.* 158:1173-1181
- Misra AN, Srivastava A, Strasser RJ (2001b). Fast chlorophyll *a* fluorescence kinetic analysis for the assessment of temperature and light effects: A dynamic model for stress recovery phenomena. *Photosynthesis PS2001*. CSIRO Publ., Melbourne, Australia S3-007.
- Misra AN, Biswal AK, Misra M (2002). Physiological, biochemical and molecular aspects of water stress responses in plants, and the biotechnological applications. *Proc. Nat. Acad. Sci.* 72(2):115-134.
- Misra AN, Latowski D, Strzalka K (2006). The xanthophylls cycle activity in kidney bean and cabbage leaves under salinity stress. *Russian J. Plant Physiol.* 53:102-109.
- Misra AN, Misra M, Singh R (2011). Nitric oxide ameliorates stress responses in plants. *Plant Soil Environ.* 57(3):95-100.
- Misra AN, Misra M, Singh R (2012). Chlorophyll fluorescence in plant biology. *Biophysics*. (Ed. Misra A N) ISBN 979-953-307-290-5.
- Osmond CB, Grace SC (1995). Perspective on photoinhibition and photorespiration in the field: quint essential ineffectiveness of the light and dark reactions of photosynthesis. *J. Expt. Bot.* 46:1351-1362.
- Satisha J, Prakash GS, Bhatt RM, Kumar PS (2007). Physiological mechanisms of water use efficiency in grape rootstocks under drought conditions. *Int. J. Agric. Res.* 2(2):159-164.
- Soares AS, Driscoll SP, Olmos E, Harbinson J, Arrabaca MC, Foyer CH (2008). Adaxial/abaxial specification in the regulation of photosynthesis and stomata opening with respect to light orientation and growth with CO₂ enrichment in the C₄ species *Paspalum dilatatum*. *New phytologist Oxford, UK: Blackwell Publishing Ltd* 2008 Jan., v. 177(1):186-198.
- Sofi P, Rather AG, Zargar MY (2006). Breaking yield barriers in rice: Remodeling photosynthesis. *Am. J. Plant Physiol.* 1(2):113-126.
- Steinberg SL, Miller JC, McFarland MJ (1990). Dry matter partitioning and vegetative growth of young peach trees under water stress. *Australian J. Plant Physiol.* 17:6-23.
- Thomas DS, Turner DW (2001). Banana (*Musa sp.*) leaf gas exchange and chlorophyll fluorescence in response to soil drought, shading and lamina folding. *Sci. Horticult.* 90:93-108.
- Van Kooten O, Snel JFH (1990). The use of chlorophyll fluorescence nomenclature in plant stress physiology. *Photosynthesis Res.* 25:147-150.