African Journal of Agricultural Research, Vol. 5 (4) pp. 286-289, 18 February, 2010
Available online at http://www.academicjournals.org/AJAR
ISSN 1991-637X © 2010 Academic Journals

*Full Length Research Paper*

# Influence of water deficit stress on wheat grain yield and proline accumulation rate

**H. Maralian[1*], A. Ebadi[2], Didar[1], T. R and B Haji-Eghrari[1]**

[1]Department of Plant Productions, Moghan Junior College of Agriculture, University of Mohaghegh Ardabili, Parsabad, Ardabil, Iran.
[2]Department of agronomy, University of Mohaghegh, Ardabili, Ardabil, Iran.

Accepted 30 November, 2009

**The study of physiological responses of different wheat varieties to water stress could be a useful tool to understanding of the mechanisms of drought resistance. This field study was conducted to evaluate the effect of water deficit stress on proline accumulation rate and wheat grain yield at Iran in 2008. A bread wheat (line N84-12) was evaluated by contrasting irrigation regimes (well-watered (control condition), water deficit stress before tillering stage (T1) and after heading stage (T2). The experiment was carried out using a randomized complete block design (RCBD) with three replications. To impose water deficit stress, plants wasn't irrigated before T1 and after heading T2. The analysis of variance showed that water deficit stress significantly affected grain yield, straw yield, proline accumulation rate and harvest index (HI) in P≤0.01. The highest proline accumulation rate was observed under T2 condition and grain yield was decreased by water deficit stress compared with control condition.**

**Key words:** Water deficit stress, proline accumulation rate, grain yield, wheat.

## INTRODUCTION

Drought stress remains an ever-growing problem that severely limits crop production worldwide and causes important agricultural losses particularly in arid and semi-arid areas (Boyer et al., 1982). The percentage of drought affected land areas more than doubled from the 1970s to the early 2000s in the world (Isendahl and Schmidt, 2006).

For the purpose of crop production, yield improvement, developing of drought tolerant varieties is the best option (Siddiqe et al., 2000). Therefore physiological and biochemical approaches have a great importance in order to understand the complex responses of plants to water deficiency and develop rapidly new varieties. Water availability mostly affects growth of leaves and roots, photosynthesis and dry mater accumulation (Blum, 1996). One of the initial responses of plants to water stress is the decrease of leaf elongation rate and closing of stomata in order to reduce water consumption via transpiration. Generally, the plants accumulate some kind of organic and inorganic solutes in the cytosol to raise osmotic pressure and thereby maintain both turgor and the driving gradient for water uptake (Rhodes and Samaras, 1994). Among these solutes, proline is the most widely studied (Delauney and Verma, 1993). The beneficial roles of proline in conferring osmotolerance have been widely reported (Kishor et al., 1995; Bajji et al., 2000).

It has been widely reported that plant cells achieve their osmotic adjustment by the accumulation of some kind of compatible solutes such as proline, betaine and polyols to protect membranes and proteins (Delauney and Verma, 1993). Consequently, there occurs an osmotic re-inflow of water into the cells. Compatible solutes are overproduced under osmotic stress aiming to facilitate osmotic adjustment (Hasegawa et al., 2000; Shao et al., 2005; Zhu, 2000). These compounds accumulated in high amounts mainly in cytoplasm of stressed cells without interfering with macromolecules and behaved as osmo-protectants (Yancey, 1994). It has been shown that proline also have a key role in stabilizing cellular proteins and membranes in presence of high concentrations of osmoticum (Rudolph et al., 1986; Yancey, 1994; Errabii et al., 2006). Zlatev and Stoyanov (2005) suggested that proline accumulation of plants could be only useful as a

*Corresponding author. E-mail: h_maralian@yahoo.com. h_maralian@uma.ac.ir. Tel: 00989141548667. Fax: 00984527463417.

**Table 1.** Mean temperature (ºC), rainfall (mm), relative humidity (%) and no. of days below zero of site from sowing to harvest (2007-2008).

| Month | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. |
|---|---|---|---|---|---|---|---|---|---|
| Temperature (ºC) | 17.6 | 9.1 | 4.7 | -0.8 | 3.7 | 13.2 | 16.8 | 9.3 | 23.7 |
| Rainfall (mm) | 30 | 41.2 | 31.5 | 19.4 | 17.4 | 11.3 | 6.5 | 37.1 | 28.1 |
| Relative Humidity (%) | 76.3 | 81.5 | 82.8 | 81.2 | 71 | 62.5 | 67.5 | 67.2 | 57.7 |
| No. of Days Below Zero | 0 | 4 | 14 | 25 | 17 | 2 | 0 | 0 | 0 |

**Table 2.** Results of variance analysis.

| S.V. | M.S | | | | |
|---|---|---|---|---|---|
| | df | Proline | Seed yield | Straw yield | HI |
| Replication | 2 | 3.85 | 1878.78 | 81370.33 | 0.845 |
| Stress | 2 | 353.61 ** | 6452661.78 ** | 10651122.33 ** | 67.69 ** |
| Error | 4 | 3.54 | 58340.94 | 97196.67 | 0.608 |

Abbreviations: **- significantly different at the 0.01 probability level.

possible drought injury sensor instead of its role in stress tolerance mechanism. However, Vendruscolo et al. (2007) found that proline is involved in tolerance mechanisms against oxidative stress and this was the main strategy of plants to avoid detrimental effects of water stress.

Tatar and Gevrek (2008) and Kameli and Losel (1996) showed that wheat dry mater production, Relative water content (RWC) decreased and proline content increased under drought stress. However they reported that RWC was a reversible decrease, which recovered quickly after re-watering. Siddiqe et al. (2000) reported that there was a positive relation between RWC and photosynthetic rate. Higher proline content in wheat plants after water stress has been reported by Vendruscolo et al. (2007) and Patel and Vora (1985). Increasing amount of proline was also established in several stress conditions such as salinity (Poustini et al., 2007), cold (Charest and Phan, 1990) and U.V (Tian and Lei, 2007) in wheat. In addition, drought is also related to acid stress, alkaline stress, pathological reactions, senescence, growth, development, cell circle, UV-B damage, wounding, embryogenesis, flowering, signal transduction and so on (Capell et al., 2004). Proline content is closely with plant anti-drought, especially under soil water deficits. Many reports from crops and other plants have proved this (Wang and Li, 2000; Wang et al., 2003; Errabii et al., 2006; Shao et al., 2006). Wheat is the second important crop on the globe, whose research in this aspect of importance for food quality, safety, and yield in field.

The effect of water deficit stress on proline accumulation rate, grain and straw yields of wheat was investigated in this study.

## MATERIALS AND METHODS

This field study was conducted to evaluate the effect of water deficit stress on proline accumulation rate and wheat yield at Iran (Moghan locality) in 2008. A bread wheat (line N84-12) was evaluated in to contrasting irrigation regimes (well-watered (control condition), water stress before tillering stage (T1) and after heading stage (T2). The experiment was carried out using a randomized complete block design (RCBD) with three replications.

Moghan is located in the north-west of Iran (39º 39' N; 47º 49' W and 50m above sea level) with Clay-Loam soil (Table 1), relative humidity (63.1%), mean annual temperature (14.6℃) and rainfall in the study area is distributed with an annual mean of 275 mm. This study was carried out at the experimental farm of the agricultural faculty, University of Mohaghegh Ardabil. According to soil analysis carried out prior to sowing, the soil texture was a Clay-Loam with EC=2.03dsm-1, PH= 8.08, O.C (%) = 0.994, Soil P2O5 = 4 ppm, K2O = 379 ppm N= 0.109, Field Capacity = 21% W/W, Wilting Point = 10% W/W and the Volume weight of the soil was 1.21 g.cm3. Climate temperature and rainfall from sowing to harvest are presented in Table 1.The experiment field received 80 $kg.ha^{-1}$ of $P_2O_5$. Nitrogen at a rate of 150 kg/ha was applied, in the form of urea, the first half of which during disk harrowing and the remaining half used when the plants were at heading stage.

In this study, plant density was 350 plants per $m^2$ and Plots were hand sown on 10 March 2008 using a template to produce 10 rows of plants 12 cm apart. Seeds were sown 4 cm deep and 3 cm apart within rows. Two seeds were sown in each position and the plots thinned to the desired plant population when the seedlings reached the first leaf fully emerged stage. Weeds were removed by hand.

Grain yield, straw yield, proline content and harvest index (HI) were studied. The proline content was measured by method of Irigoyen et al. (1992). The plant material (flag leaf) was harvested for proline content.

## RESULTS AND DISCUSSION

Results of analysis of variance table showed that water deficit stress affected significantly the proline accumulation rate, grain yield, straw yield and HI (Table 2). Results of mean comparison showed that stress at heading increased leaf proline content, while it was not increased significantly at tillering stage compared with control (Figure 1). Tatar and Gevrek (2008) reported same results. Higher proline

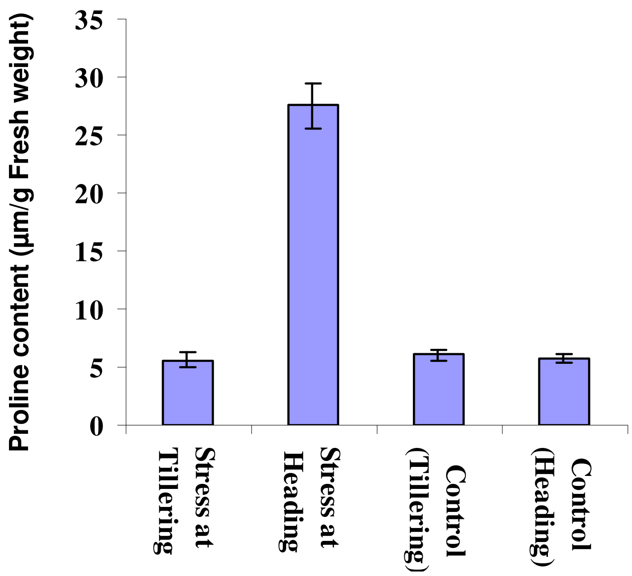


**Figure 1.** Effect of water deficit stress on proline accumulation rate.

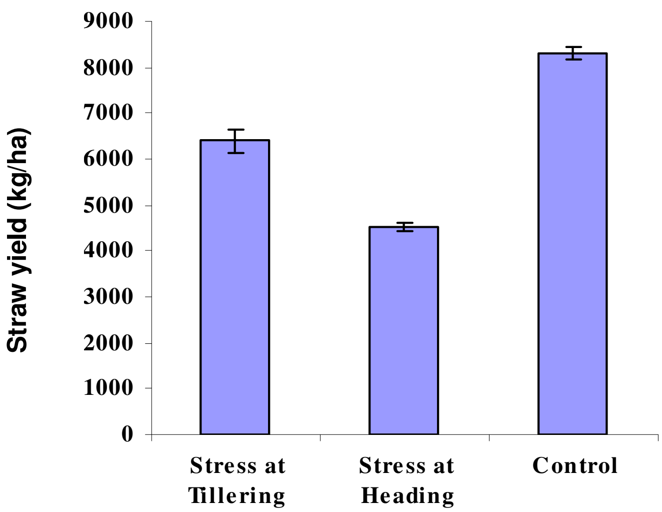


**Figure 2.** Effect of water deficit stress on grain yield.

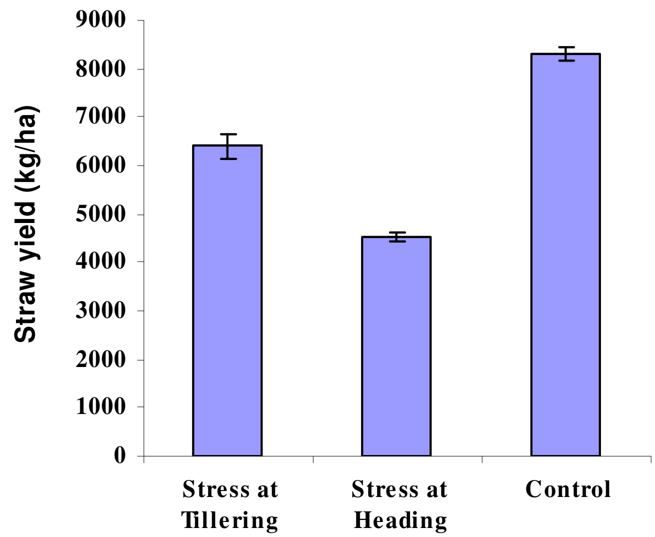


**Figure 3.** Effect of water deficit stress on straw yield.

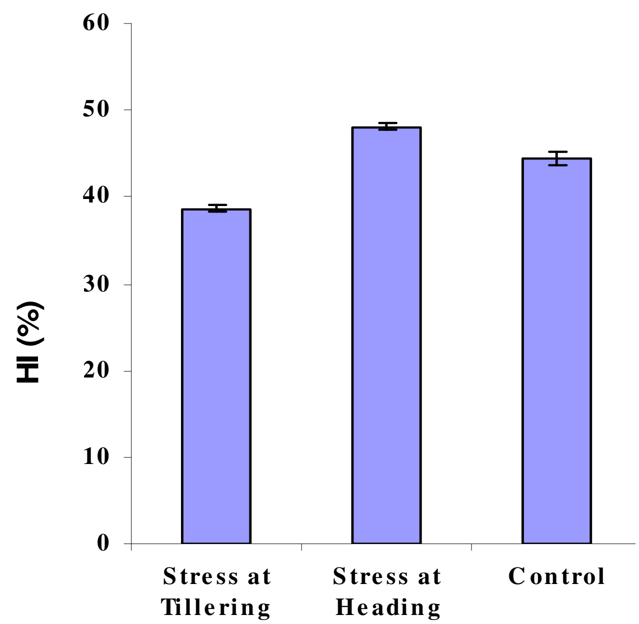


**Figure 4.** Effect of water deficit stress on HI.

content in wheat plants after water stress has been reported by Errabii et al. (2006), Patel and Vora (1985) and Vendruscolo et al. (2007). Results showed that proline content is closely linked with water stress. Many reports from crops and other plants have proved this (Wang and Li, 2000; Wang et al., 2003; Errabii et al., 2006; Shao et al., 2006). Seed yield reduced by water stress compared with control. If water stress occurs at tillering or heading stages, the seed yield decreased more than 37% (Figure 2). Ahmadi and Sio-se Mardeh (2004) reported that wheat grain yield reduced 34%.

The maximum straw yield was obtained at control condition, but it was reduced by stress (Figure 3). Stress at heading stage reduced straw yield more than tillering stage. Tatar and Gevrek (2008) and Kameli and Losel (1996) showed that wheat dry mater production decreased and proline content increased under drought stress. Closure of stomata and decrease in $CO_2$ concentration as an initial response to water stress inhibited dry mater production due to limitation of photosynthesis (Ready et al., 2004). The highest harvest index was obtained when water stress occurred at heading stage (Figure 4).

According to these results, we conclude that tillering and heading stages were sensitive to water stress and yield decreased more than 37% compared with control. Therefore wheat plants must be irrigated at these stages to obtain high seed yield at Moghan condition.

## REFERENCES


Ahmadi A, Sio-Se Mardeh A (2004). The Effects of Water Stress on SolubleCarbohydrates, Chlorophyll and Proline Contents of four Iranian Wheat Cultivares under Different Moisture Regimes. Iranian J. Agric. Sci. 35(3): 753-763.

Bajji M, Lutts S, Kinet JM (2000). Physiological changes after exposure to and recovery from polyethylene glycol-induced water deficit in callus cultures issued from durum wheat (*Triticum durum* Desf.) cultivars differing i*n drought resi*stance. J. Plant. Physiol. 156: 75-83.

Blum A (1996). Crop response to drought and the interpretation of adaptation. J. Plant Growth Regul. 20(2): 135-148.

Boyer JS (1982). Plant productivity and environment. Science 218: 443-448.

Capell T, Bassie L, Christou P (2004). Modulation of the polyamine biosynthetic pathway in transgenic rice confers tolerance to drought stress, PNAS 101(26): 9909–9914.

Charest C, Phan CT (1990). Cold acclimation of wheat (*Triticum aestivum*): Properties of enzymes involved in proline metabolism. Physiol. Plant 80(2): 159-168.

Delauney AJ, Verma DPS (1993). Proline biosynthesis and osmoregulation in plants. Plant J. 4: 215-223.

Errabii T, Gandonou CB, Essalmani H, Abrini J, Idaomar M, Skali-Senhaji N (2006). Growth, Proline and ion accumulation in Sugarcane callus cultures under drought-induced osmotic stress and its subsequent relief. Afr. J. Biotechnol. 5(6): 1488-1493.

Hasegawa P, Bressan RA, Zhu JK, Bohnert HJ (2000). Plant cellular and molecular responses to high salinity. Annu. Rev. Plant Mol. Biol. 51: 463-499.

Irigoyen J, Emerich DW, Sanchez-Diaz M (1992). Water stress induced changes in concentrations of proline and total soluble sugars in nodulated alfalfa (*Medicago sativa*) plants. Physiologia Plantarum. 84(1): 55-60.

Isendahl N, Schmidt G (2006). Drought in the Mediterranean-WWF policy proposals. A. WWF Report, Madrid.

Kameli A, Losel DM (1996). Growth and sugar accumulation in durum wheat plants under water stress. New Phytol. 132(1): 57-62.

Kishor PBK, Hong Z, Miao GH, Hu CAA, Verma DPS (1995). Overexpression of [delta]-Pyrroline-5-Carboxylate synthetase increases proline production and confers osmotolerance in transgenic plants. Plant Physiol. 108(4): 1387-1394.

Patel JA, Vora AB (1985). Free proline accumulation in drought-stressed plants. Plant and Soil 84(3): 427-429.

Poustini K, Siosemardeh A, Ranjbar M (2007). Proline accumulation as a response to salt stress in 30 wheat (*Triticum aestivum* L.) cultivars differing in salt tolerance. Genet. Resour. Crop. Evil. 54(5): 925-934.

Rhodes D, Samaras Y (1994). Genetic control of osmoregulation in plants. In cellular and molecular physiology of cell volume regulation. Stronge K. Boca Raton: CRC Press pp. 347-361.

Shao HB, Chen XY, Chu LY, Zhao XN, Wu GY, Yong B, Zhao CX, Hu ZM (2006). Investigation on the relationship of proline with wheat anti-drought under soil water deficits. Colloids and surfaces. B: Biointerfaces 53(1): 113-119.

Shao HB, Liang ZS, Shao MA (2005). Changes of anti-oxidative enzymes and MDA content under soil water deficits among 10 wheat (*Triticum aestivum* L.) genotypes at maturation stage, Colloids Surf. B: Biointerfaces 45(1): 7–13.

Siddique MRB, Hamid A, Islam MS (2000). Drought stress effects on water relations of wheat. Bot. Bul. Acad. Sin. 41(1): 35-39.

Tatar O, Gevrek MN (2008). Influence of water stress on prolin accumulation, lipid peroxidation and water content of wheat. Asian J. Plant Sci. 7(4): 409-412.

Tian XR, Lei YB (2007). Physiological responses of wheat seedlings to drought and UV-B radiation, effect of exogenous sodium nitroprusside application. Russian J. Plant Physiol. 54(5): 676-682.

Vendruscolo ACG, Schuster I, Pileggi M, Scapim CA, Molinari HBC, Marur CJ, Vieira LGC (2007). Stress-induced synthesis of proline confers tolerance to water deficit in transgenic wheat. J. Plant. Physiol. 164(10): 1367-1376.

Wang JR, Li SX (2000). Effect of water-limited deficit stress in different growth stages on winter wheat grain yields and their yield constituents, Acta Bot. Boreal-Occident Sin. 20(2): 193–200.

Wang WX, Vinocur P, Altman A (2003). Plant responses to drought, salinity and extreme temperatures: towards genetic engineering for stress tolerance. Planta 218(1): 1–14.

Yancey PH (1994). Compatible and counteracting solutes. In Cellular and Mol. Physiol. Cell Volume. Edited by Strange K. Boca Raton: CRC Press pp. 81-109.

Zlatev Z, Stotanov Z (2005). Effect of water stress on leaf water relations of young bean plants. J. Central Eur. Agric. 6(1): 5-14.

Zhu JK (2000). Salt and drought stress signal transduction in plants, Annu. Rev. Plant Biol. 53: 247–273.