African Journal of Biotechnology Vol. 9 (1), pp. 036-040, 4 January, 2010
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2010 Academic Journals

Full Length Research Paper

Effect of soil water stress on yield and proline content of four wheat lines

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Accepted 10 August, 2009

This field study was conducted to evaluate the effect of drought stress after anthesis on proline accumulation and wheat yield during 2008 at Moghan region. Four lines of bread wheat (N-82-9, N-83-5, N-84-12 and N-85-20) were evaluated into contrasting water regimes (well-watered and drought stressed after anthesis). The trial was carried out in a 4 × 2 factorial experiment based on complete block design with 3 replications. Proline content, total soluble sugar (TSS), seed yield, straw yield, harvest index (HI), 1000 kernel weight, ear length, plant height and tiller number were studied. The SAS software package was used to analyze all the data and means were separated by the least significant difference (LSD) test at P < 0.01. Results showed that proline content and TSS increased by water stress. Seed and straw yield decreased 25% approximately, if water stress occurred after anthesis stage. The highest seed yield observed in line N-82-9 and lowest observed in line N-85-20 under water stress. Under control condition (None stress), line N-82-9 had high seed yield, straw yield, HI and 1000 kernel weight.

Key words: Water stress, *Triticum aestivum*, yield, proline, TSS.

INTRODUCTION

Water deficit is one of the main abiotic factors that affect spring wheat planted in subtropical regions. 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, 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). Water availability mostly affects growth of leaves and roots, photosynthesis and dry mater accumulation (Blum, 1996). 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 have 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). Compatible solutes are overproduced under osmotic stress aiming to facilitate osmotic adjust-ment (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 osmoprotectants (Yancey, 1994). It has been shown that proline also have a key role in stabilizating cellular proteins and membranes in presence of high concentrations of osmoticum (Yancey, 1994 and Errabii et al., 2006).

Zlatev and Stoyanov (2005) suggested that proline accumulation of plants could be only useful as a possible drought injury sensor instead of its role in stress tolerance mechanism. However, Vendruscolo et al. (2007)

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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.
Temp (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

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. 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). 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). Katerji et al. (2009) reported that drought affected the plant water status during the ear formation and flowering stages. It reduced the grain (37%) and straw (18%) yield. Giunta et al. (1993) find that wheat yield decreased from 25 - 85% under drought stress.

Wheat is the second important crop on the globe, whose research in this aspect of importance for food quality, safety and yield in field.

MATERIALS AND METHODS

This field study was conducted to evaluate the effect of drought stress after anthesis on proline accumulation and wheat yield during 2008 at Moghan conditions. 4 lines of bread wheat (N-82-9, N-83-5, N-84-12 and N-85-20) were evaluated in to contrasting water regimes (well-watered and drought stressed after anthesis). The trial was carried out in a 4 × 2 factorial experiment based on complete block design with 3 replications. To impose drought stress, plants was not irrigated after anthesis.

Moghan is located in the north-west of Iran (Lat 39°, 39' N; Long 47°, 49' E and elevation 50 m) with mediterranean climate, mean 30 years averages of 299 mm rainfall per year, 14.6°C temperature.

According to soil analysis carried out prior to sowing, the soil texture was a clay-loam with EC = 2.03 dsm^{-1}, pH = 8.08, O.C (%) = 0.994, soil P_2O_5 = 4 ppm, K_2O = 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/cm^3. 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.

Proline content (µm/g fresh weight), total soluble sugar (TSS), seed yield, straw yield, harvest index (HI), 1000 kernel weight, ear length, plant height and tiller number were studied. The proline content and TSS were measured by method of Irigoyen et al. (1992). The plant material (flag leaves of different wheat lines) was harvested during grain filling stage.

Data given in percentages were subjected to arcsine transformation before statistical analysis. The SAS software package was used to analyze all the data and means were separated by the least significant difference (LSD) test at $P < 0.01$.

RESULTS AND DISCUSSION

Analysis of variance has been presented in Table 2. According to variance table, proline content, total soluble sugar (TSS), seed yield, straw yield, HI and 1000 kernel weight affected significantly by water stress. But plant height, ear length and tiller number did not affected significantly by water stress. There were significant differences between cultivars and all adjectives affected by cultivalrs exception plant height. All adjectives had significant defference between stress × cultivar exception plant height and tiller number (Table 2).

Means has been presented in Tables 3, 4 and 5. According to Figure 1, proline content increased significantly by stress from 5.03 to 20.60 µm/g fresh weight, compared by control. Many reports proved this. High proline content in wheat and other plants after water stress has been reported by Tatar and Gevrek (2008), Vendruscolo et al. (2007), Errabii et al. (2006), Shao et al. (2006), Zlatev and Stoyanov (2005), Wang et al. (2003), Wang and Li (2000), Yancy (1994) and Patel and Vora (1985).

TSS content increased by water stress also (Figure 2). Compatible solutes such as TSS and proline have a key role in drought tolerance.

According to Table 3, seed yield, straw yield and 1000 kernel weight decreased by water stress, compared with control. But HI (%) increased. It have been widely reported that plant yield decreased under water stress (Tatar and Gomer, 2008; Kameli and Losel, 1996).

According to Table 3, seed yield, straw yield and 1000

Table 2. Results of variance analysis.

S.V	d.f	Proline	TSS	Seed yield	Straw yield	Harvest index	1000 kernel weight	Plant height	Ear length	Tiller no.
Block	2	1.366	11.56	25714.0	129249.7	1.22	4.84	90.84	0.00	0.16
Factor (A)	1	1465.5**	88129.4**	16070430 **	33727714.7**	4.42 *	94.01 **	74.48 n.s	0.09 n.s	1.98 n.s
Factor (B)	3	288.8 **	3405.2 **	1644332.7 **	6603054.3 **	66.3 **	26.06 **	25.88 n.s	1.07 **	8.49 **
A.B	3	233.1**	2778.4**	1345105.4 **	3512132.4 **	5.93 **	78.34 **	24.38 n.s	4.21 **	1.71 n.s
Error	14	66.036	331.55	47342.90	95326.97	0.88	4.884	28.34	0.128	0.61

**, * Significantly different at the 0.01 and 0.05 probability levels, respectively.
n.s = non-significant difference.

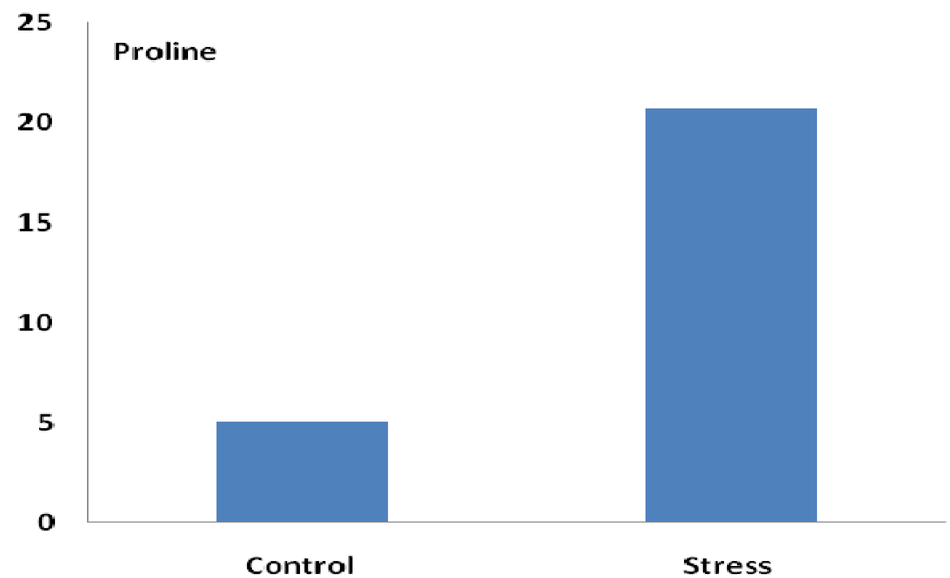

Figure 1. Effect of water stress on proline content.

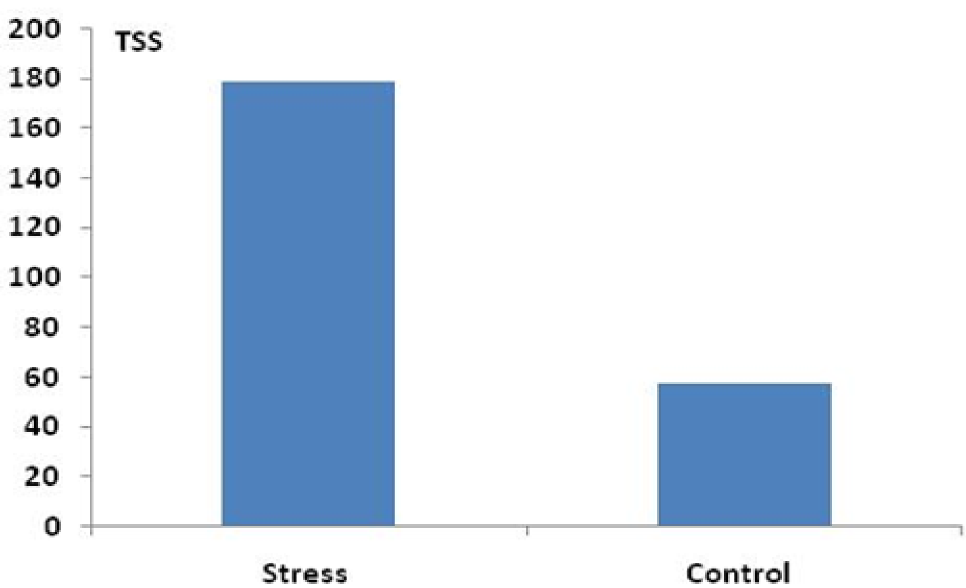

Figure 2. Effect of water stress on total soluble sugar content.

Table 3. Mean wheat yield, HI and 1000 kernel weight as affected by water stress.

Parameter	Proline (μm/g)	TSS (μm/g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	1000 Kernel weight (g)
Stress	20.66	178.90	4575	5943	46.77	33.17
Control	5.031	57.70	6211	8314	42.92	37.12

Table 4. Mean wheat cultivar yield and other studied adjectives.

Cultivar	Proline (μm/g)	TSS (μm/g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	1000 Kernel weight (g)	Ear length (cm)	Tiller no.
N-82-9	12.6 ab	108.3 ab	6105 a	7804 a	43.9 b	37.37 a	9.18 b	6.63 b
N-83-5	14.8 a	89.5 b	5155 bc	8227 a	38.6 c	32.38 b	9.65 ab	8.75 a
N-84-12	7.4 b	141.1 a	4885 c	6060 b	44.6 ab	35.02 ab	9.45 ab	6.61 b
N-85-20	16.6 a	134.3 a	5428 b	6424 b	46.3 a	35.82 ab	10.18 a	6.05 b
LSD (0.01)	5.28	44.26	529	750.4	2.2	2.4 ($P < 0.05$)	0.869	1.89

Numbers in the columns followed by the same letters are not significantly different at $P < 0.01$.

Table 5. interaction effects of stress × cultivare on studied adjectives.

Treatment	Cultivar	Proline (μm/g)	TSS (μm/g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	1000 Kernel weight (g)	Ear length (cm)
Stress	N-82-9	21.2 b	157.9 b	4988 d	6391 cd	43.9 b	30.7 c	8.2 c
	N-83-5	23.9 ab	125.8 b	4397 e	6877 c	39.0 c	30.3 c	10.0 ab
	N-84-12	9.9 c	224.4 a	4711 de	5965 d	44.1 b	37.2 b	10.5 a
	N-85-20	27.5 a	207.5 a	4204 e	4540 e	48.1 a	34.5 bc	10.0 ab
Control	N-82-9	4.0 d	58.6 c	72212 a	9217 a	43.9 b	44.0 a	10.1 ab
	N-83-5	5.7 cd	53.3 c	5913 c	9577 a	38.2 c	34.5 bc	9.3 b
	N-84-12	4.7 cd	57.8 c	5059 d	6155 cd	42.1 b	32.9 bc	8.4 c
	N-85-20	5.7 cd	61.1 c	6652 b	8308 b	44.5 b	37.1 b	10.4 a
LSD (0.01)		5.28	44.26	529	750.4	2.2	5.37	0.87

Numbers in the columns followed by the same letters are not significantly different at $P < 0.01$.

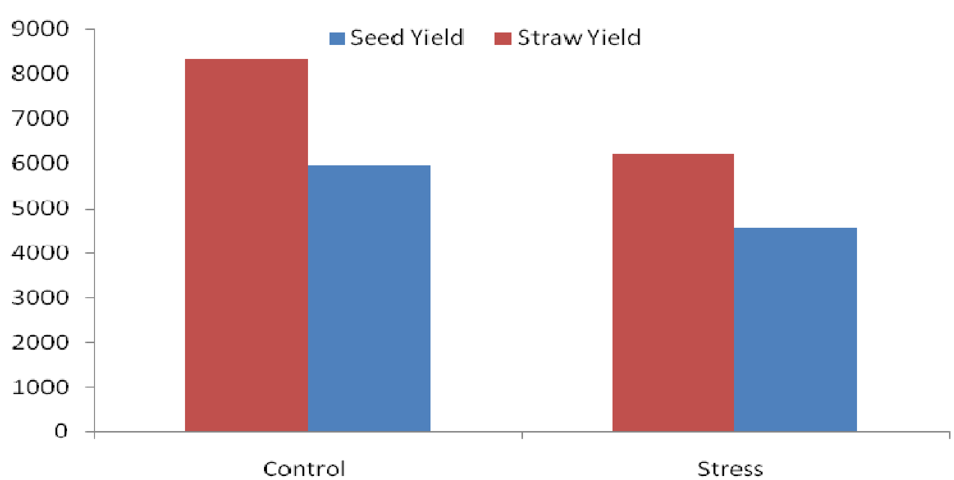

Figure 3. Effect of water stress on seed and straw yield (kg/ha).

kernel weight decreased by water stress, compared with control. But HI (%) increased. It have been widely reported that plant yield decreased under water stress (Tatar and Gomer, 2008; Kameli and Losel, 1996).

Results showed that seed and straw yield decreased 25% approximately, if water stress occurred after heading stage (Figure 3).

Wheat lines had different potential yield under water stress. The highest seed yield and 1000 kernel weight (g) observed in line N-82-9 and lowest observed in line N-84-12 (6105 and 4885 kg/ha respectively). Interaction effects showed that line N-82-9 had high seed yield, straw yield, HI, 1000 kernel weight under control condition (None stress) (Table 5). According to Table 5, line N-82-9 has a high seed yield at control and stress condition. Therefore this line is suitable for Moghan region and next agronomic and improvement projects must be focused on this line.

REFERENCES

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 in drought resistance. 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, vol. 218(4571): 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.

Giunta F, Motzo R, Deidda M (1993). Effect of drought on yield and yield components of durum wheat and triticale in a Mediterranean environment. Field Crops Res. 33(4): 399-409

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 JJ, Emerich DW, Sanchez-Diaz M (1992). Water stress induced changes in concentrations of proline and total soluble sugars in modulated alfalfa (*Medicago sativa*) plants, Physiol. Plant. 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.

Katerji N, Mastrorilli M, Hoornc J.W, Lahmerd FZ, Hamdyd A, Oweise T (2009). Durum wheat and barley productivity in saline–drought environments. Euro. J. Agron. 31(1): 1-9.

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 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 proline 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. of 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.