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Full Length Research Paper

Evaluation of 10 wheat cultivars under water stress at Moghan (Iran) condition

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Water deficit is one of the main abiotic factors that affect yield and yield component of wheat planted in arid and semi-arid regions. This study was conducted to evaluate the effect of water stress on wheat yield and yield component during 2008 at Moghan conditions. The objective of this study was to evaluate the effects of water stress on seed yield and yield components of ten wheat cultivars and lines that differ in adoption to drought stress. Ten bread wheat lines and cultivars were evaluated with contrasting water regimes {well-watered (as control) and water stress}. The trial was carried out in a complete block design based on factorial arrangement with three replications. Grain yield, ear number/m^2, seed number per ear, 1000 kernel weight, ear length and plant height were studied. Analysis of variance showed that seed yield, ear number, grain number per ear, 1000 kernel weight and plant height was affected significantly by water stress, but ear length was not affected by water stress. The highest seed yield was observed in Chamran cultivar. Seed yield has a positive-significant correlation with ear number/m^2, 1000 kernel weight, grain number/ear and plant height.

Key words: Water stress, wheat, yield, yield component.

INTRODUCTION

Water stress in wheat changes the patterns of plant growth and development. Depressed water potential suppresses cell division, organ growth, net photosynthesis, protein synthesis and alters hormonal balances of major plant tissues (Gusta and Chen, 1987). Wheat (*Triticum aestivum* L.) is commonly grown in drought-prone environments where grain yields are limited by low seasonal rainfall. 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 doubled from the 1970s to the early 2000s in the world (Isendahl and Schmidt, 2006). Growers in these regions rely on wheat varieties selected for improved yield under drought. In arid and semiarid regions with Mediterranean climate, wheat crops usually encounter drought during the grain filling period. Wheat quality was controlled not only by genetic factors, but also by environmental conditions, especially the supply of water and fertility in soil that can change wheat quality under normal cropping condition (Triboi et al., 2003). Dadashi (2002) reported that protein content increased under drought stress. Jinyin et al. (2002) reported that the content of total protein in seeds increased by 5 to 13% in different water deficit treatments, as compared to control. Drought stress at grain filling period reduces grain yield, dramatically (Ehdaie and Waines, 1996).

For the purpose of crop production and yield improvement, development 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). One of the initial responses of plants to water stress is the decrease of leaf elongation rate and closing of stomata in order to

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Figure 1. Parsabad location in Iran.

reduce water consumption via transpiration. 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). Compatible solutes are overproduced under osmotic stress, aiming to facilitate osmotic adjustment (Hasegawa et al., 2000; Shao et al., 2005; Zhu, 2000). 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. 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) and Johari-pireuvatlou (2010) find that wheat yield decreased from 25 to 85% under drought stress. Moisture stress influences both yield and end-use quality of wheat. Water stress in wheat changes the patterns of plant growth and development. Depressed water potential suppresses cell division, organ growth, net photosynthesis, protein synthesis, and alters hormonal balances of major plant tissues (Gusta and Chen, 1987). In selecting improved cultivars, plant breeders attempt to incorporate tolerance to moderate levels of water stress. Although, stress typically depresses grain yield (Hsiao, 1973); it can elevate the value of other components of economic yield, such as quantity of grain protein (Guttieri et al., 2000).

Above-optimal temperatures and drought are common during kernel filling in wheat growing areas of the world with a Mediterranean climate, including Moghan region (Shackley and Anderson, 1995). However, it is often difficult to distinguish the main cause of yield reduction when both stresses overlap, as there are many apparent similarities in the response of kernel filling to drought and heat. Drought following heading has little effect on the rate of kernel filling, but its duration (time from fertilization to maturity) is shortened and kernel dry weight at maturity is reduced (Khanna-Chopra et al., 1994; Wardlaw and Willenbrink, 2000). Yang et al. (2001) reported that water deficits enhanced the senescence by accelerating loss of leaf nitrogen and chlorophyll and increased lipid peroxidation. At maturity, 75 to 92% of pre-anthesis C^{14} stored in the straw was reallocated to grains in water-deficit treatments, 50 to 80% higher than the amount in well-watered treatments, indicating that water deficits promoted remobilization. The peak values of abscisic acid (ABA) in both leaves and grains under water-deficit treatments were 63 to 144% higher than those under well-watered treatments. The elevated ABA level correlated with the degree of earlier leaf senescence, the C^{14} partitioning into grains and the carbon remobilization. The activities of both acid invertase (INV) and sucrose synthase (SS) in grains were also enhanced by water deficits at the midstage of grain fill (Yang et al., 2001). Maralian et al. (2010) reported that seed yield reduced with water stress as compared with the control. If water stress occurred at tillering or heading stages, the seed yield decreased more than 37%. Ahmadi and Sio-se Mardeh (2004) reported that wheat grain yield reduced by 34%. The maximum straw yield was obtained with control condition, but it was reduced by stress. Stress at heading stage reduced straw yield more than tillering stage (Maralian et al., 2010).

Wheat is the second important crop in the globe (first in Iran). Its research is important for food quality, safety and yield in the field. This study was conducted to evaluate the response of yield and yield component of wheat genotypes to moisture-deficit.

MATERIALS AND METHODS

This field study was conducted to evaluate the effect of water stress on wheat yield and yield component during 2008 at Moghan conditions. Ten bread wheat lines and cultivars were evaluated in contrast to water regimes {well-watered (as control) and water stress}. The trial was carried out in complete block design based on factorial arrangement with three replications. To impose water stress, plants was not irrigated after planting.

Parsabad is located in the north-west of Iran (Lat 39°, 39' N; Long 47°, 49' E and elevation 50 m) with mean 30-year averages of 275 mm rainfall per year and 14.6°C temperatures. Parsabad location in Iran is shown in Figure 1.

According to soil analysis carried out prior to sowing, the soil texture was a clay-loam with EC = 1.08 dsm^{-1}, pH = 7.65, O.C (%) = 0.854, soil P_2O_5 = 11 ppm, K_2O = 383 ppm N = 0.109, field capacity

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

Month	October	November	December	January	February	March	April	May	June
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
Number of days below zero	0	4	14	25	17	2	0	0	0

Table 2. Results of variance analysis.

S.V.	Mean of square						
	d.f	Seed yield	Ear number/m^2	Grain/Ear	1000 kernel weight	Ear length	Plant height
Replication	2	2788292.9	1210.2	8.8	3.2	0.376	8.52
Factor A	1	73648760.4**	39680.8**	380.0**	821.4**	0.001	9176.1**
Factor B	9	1427026.0	2733.0	1075.7**	66.3**	5.39**	150.1**
AB	9	1135308.6	2070.0	391.8*	6.25	0.111	60.5**
Error	38	1099798.4	4283.9	581.2	3.15	0.124	15.9

**, * Significantly different at 0.01 and 0.05 probability levels, respectively.

= 23% w/w, wilting point = 11% w/w and the volume weight of the soil = 1.33 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 was applied 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 14 December 2007 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 were thinned to the desired plant population when the seedlings reached the first leaf fully emerged stage. Weeds were removed by hand.

Grain yield (kg/ha), ear number/m^2, seed number per ear, 1000 kernel weight (g), ear length (cm) and plant height (cm) were studied.

RESULTS AND DISCUSSION

Analysis of variance is presented in Table 2. According to the variance table, seed yield, ear number, grain number per ear, 1000 kernel weight and plant height was affected significantly by water stress, but ear length was not affected by water stress. There were significant differences between cultivars, except seed yield and ear number.

Interaction effect of stress × cultivar was not significant on seed yield, ear number, 1000 kernel weight and ear length (Table 2). Mean seed yield and yield component of wheat cultivars is presented in Table 3. According to Table 3, Chamran cultivar and N-84-10 had the highest and lowest seed yield among cultivars, respectively. Plant height reduced under water stress in all cultivars (Table 4). According to table 5, Niknejhad cultivar has the highest reduction (from 101 to 63 cm) under water stress among cultivars.

Seed yield decreased under water stress by approximately 39% as compared to the control (Figure 2). Many reports and researches proved this. 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. Nayyar and Walia (2004) reported that genotype (C306) had higher levels of ABA, osmolytes, water content and grain weight and number during stress, indicating its better ability for osmoregulation as compared with the susceptible genotype. They found that the tolerant genotype showed higher content of ABA, proline, glycine betaine, total sugars, reducing sugars and had higher water content in its flag leaf and grains than the susceptible genotype, which contained more of glycine betaine and potassium but had lower ABA and water content in its flag leaf and grains.

Maralian et al. (2010) reported that if water stress occurred at tillering or heading stages, the seed yield decreased more than 37%. Drought and high temperature during anthesis period reduce the storage capacity of cereal grains by decreasing the number of endosperm cells and/or the number of amyloplasts initiated (Jones et al., 1996). It can reduce the final kernel size by limiting the rate and duration of filling process, causing earlier physiological maturity (Gupta et al., 2001; Vishwanathan and Khanna-Chopra, 2001). Kernel number is also

Table 3. Mean yield of wheat cultivar and other studied parameters.

Cultivar	Seed yield (kg/ha)	Grain Number/Ear	1000 kernel weight (g)	Ear length (cm)	Plant height
Zagros	4538	35.7^{f}	46.3^{a}	8.5^{de}	80.8^{ab}
Niknajhad	4167	44.3^{cd}	38.0^{e}	9.0^{b}	81.8^{ab}
Kohdasht	4677	42.0^{de}	44.2^{b}	10.2^{a}	82.8^{a}
Shiroodi	4523	35.3^{f}	44.5^{b}	8. 6^{cd}	71.0^{d}
Chamran	5405	40.2^{e}	38.8^{de}	8.2^{e}	75.8^{c}
N-78-14	4505	44.0^{cd}	40.8^{c}	8.9^{b}	78.5^{bc}
N-80-6	4070	46.0^{abc}	36.3^{f}	9.2^{b}	81.2^{ab}
N-81-18	5382	44.7^{bcd}	39.2^{de}	7.0^{f}	83.3^{a}
N-83-3	5038	48.0^{a}	39.7^{cd}	7.1^{f}	83.8^{a}
N-84-10	4056	47.3^{ab}	37.8^{ef}	8.8^{bc}	70.2^{d}
LSD *(0.01)*	---	2.738	1.521	0.301	3.416

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

Table 4. Interaction effects of stress × cultivar on plant height.

Stress											Non-stress									
Cultivar	Zagros	Niknajhad	Kohdasht	Shiroodi	Chamran	N-78-14	N-80-6	N-81-18	N-83-3	N-84-10	Zagros	Niknajhad	Kohdasht	Shiroodi	Chamran	N-78-14	N-80-6	N-81-18	N-83-3	N-84-10
(Cm)	73	63	71	63	66	66	68	69	70	58	89	101	95	79	86	91	95	97	97	82
(%)	18	38	25	20	23	27	28	29	28	30	← Plant height reduction under stress (%)									

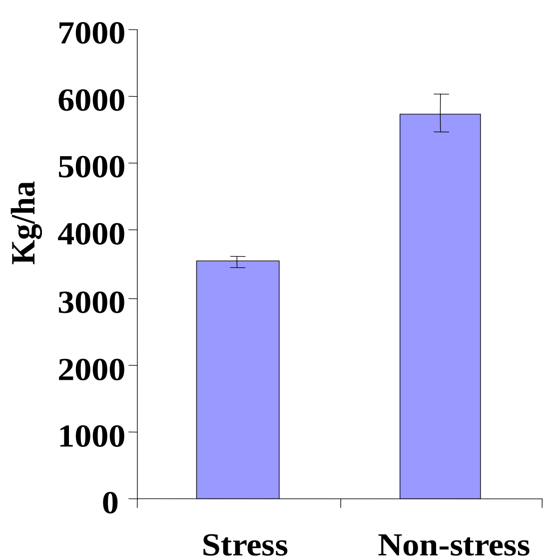

Figure 2. Effect of water deficit stress on seed yield.

reduced in proportion to the inhibition of photosynthesis by water deficit (Schussler and Westgate, 1991). Saini and Westgate (2000) reported that water stress initially affected kernel development, resulting in a decrease in sink potential of kernel, and during the linear fill or its later stages of development, it inhibited the enzyme activity directly, thereby causing premature desiccation.

Decrease in ear number/m^2, grain number/ear, 1000 kernel weight, ear length and plant height reduced seed yield in this study (Figures 2 and 3). Correlation coefficients between seed yield and yield components are presented in Table 5. According to Table 5, seed yield has a positive-significant correlation with ear number/m^2, 1000 kernel weight, grain number/ear and plant height, and plant height has the highest correlation with seed yield. Simane et al. (1993) found that the number of kernels per spike and kernel weight had significant, positive and direct effects on grain yield under moisture stress conditions, as well as under well-watered conditions. The authors reported that the number of grains

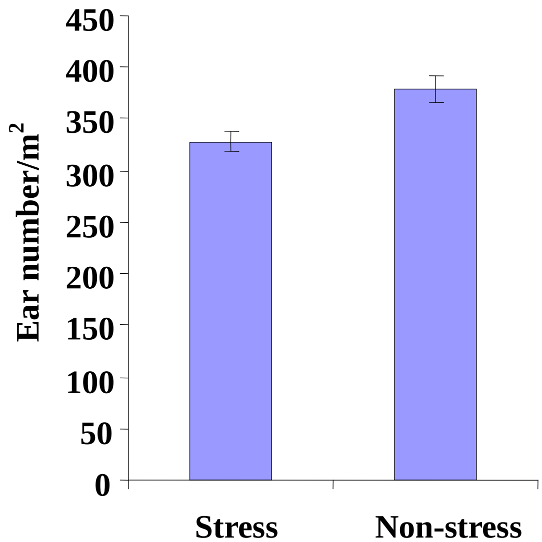

Figure 3. Effect of water deficit stress on ear number/m^2.

Table 5. Correlation coefficients between seed yield and yield components.

Parameter	Seed yield	Ear number/m^2	1000 kernel weight	Grain/Ear	Ear length	Plant height
Seed yield	1.00					
Ear number/m^2	0.441**	1.00				
1000 kernel weight	0.553**	0.272*	1.00			
Grain/Ear	0.358**	-0.001	-0.036	1.00		
Ear length	-0.124	0.083	0.086	-0.068	1.00	
Plant height	0.728**	0.343**	0.617**	0.521**	-0.033	1.00

**, *: Correlation is significant at the 0.01 and 0.05 probability level, respectively.

per spike had the most significant effect on yield.

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