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EFFECT OF WATER STRESS ON YIELD AND YIELD COMPONENTS OF TWO WHEAT CULTIVARS

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ABSTRACT A field study was conducted at an Agricultural Research station, Azad University, Khorasgan, Isfahan, Iran, during 2006-2007 to evaluate the effect of irrigation regimes on grain yield components and grain yield of two wheat cultivars. In order to determine the most tolerant cultivar five drought tolerance indices comprising, adjusted based on grain yield under drought (Ys) and normal (Yp) conditions were used. A split plot layout with a randomized complete block design with four replications was used. Irrigation regimes (irrigation after 80 (I1), 100 (I2) and 120 (I3) mm cumulative evaporation from class A evaluation pan) were considered as the main plots and two wheat genotypes (M7318 and Line 4) as subplots. The (I1) and (I2) did not differ significantly for grain yield components, grain yield excepting total dry matter and peduncle length. Delay in irrigation from (I2) to (I3) significantly reduced grain yield components, grain yield and total dry matter. I2 has the maximum water used efficiency and harvesting index. The responses to irrigation regimes appeared to differ between the two wheat cultivars. M7318 gave the highest grain yield, grain weight and total dry matter. The responses to irrigation regimes appeared to differ between the two wheat cultivars. The calculated correlation coefficients reveal that TOL and SSI are superior criteria for selection of high yielding genotypes both under non-stress and stress conditions. The comparison of cultivars with above criteria indicated, line 4 is more tolerant than M7318. In conclusion, irrigation after 100 mm cumulative evaporation from class A evaporation pan with respect to water saving might be suitable for winter wheat production under condition similar to this experiment where irrigation water during spring is not abundant.

Keywords: Irrigation, Water stress, Yield, Yield components, Drought resistance indices.

INTRODUCTION Supplying food for some two billion people in the world currently suffer from hunger is an international issue that demands an international response. Many concerns have been expressed about supplying food in dry and semi-arid regions, where many developing and under developed countries located and drought is a major stress which is an important limiting factor. Iran is situated in a dry region of the world. In this country, precipitation is limited; so that the average annual precipitation is less than 300 mm. Most states in Iran have arid and semi-arid conditions. Unfortunately, the limited precipitation is confined mainly to cold and winter seasons, and cannot directly be used by plant cultivation areas. More over most of the rainfall only occurs for short period time, When there are not enough deep-rooted plants to use the available rainwater. According to world statistics, Iran ranks 7th from the point of view of area under irrigated cultivation. It has ten or more million hectares of dry farming. Continues sever recent droughts such as the one that occurred in the crop year 1999–2000 leads to 16.3 % and 19.3 % reduction in cultivated area and crop production, respectively.

Drought stress retards the formation of yield component that is most actively developing at the time of stress, consequently the ability of winter wheat plant to respond to changes in environmental condition can be characterized by limitations imposed by stress at different stages of growth and is reflected in number of spikes per square meter, number of kernels per spike, and kernel weight (Duggan and Fowler, 2006). Water stress occurring in the early vegetative phase decreased tiller production, and cause to reduction in number of spikes per square meter, In the same way, water deficit around anthesis may lead to a loss in yield by reducing spike and spikelet number and the fertility of surviving spikelets (Giunta et al., 1993). In addition, drought stress from anthesis to maturity reduces grain yield (Stone & Nicolas, 1994, 1995), through reduction in the rate and duration of grain filling (Sofield et al., 1974). The number of kernels per spike is the most affected yield component and this has been proposed as an important selection criterion for drought tolerance (Shpiler & Blum, 1986, 1991). Dencic et al., (2000) found that under drought stress conditions, number of sterile spikelets displayed negative direct effect, while grain weight per spike had a positive direct effect of yield. It has been reported that drought stress cause to reduction in biological yield and harvesting index in all studied genotype. There was evidence for an actual loss of dry matter in the final stage of maturation where plants were subjected to sever water stress. Emam and Ranjbaran (2007) showed under drought stress condition biological yield had the highest correlation with grain yield.

The plant response to drought stress is complex because it reflects over space and time the integration of stress effects and responses at all underlying levels of organization (Blum, 1996). Thus, drought indices which provide a measure of drought based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001). These indices are either based on drought resistance or susceptibility of genotypes (Fernandez, 1992). Drought resistance is defined by Hall (1993) as the relative yield of a genotype compared to other genotypes subjected to the same drought stress. Drought susceptibility of a genotype is often measured as a function of the reduction in yield under drought stress (Blum, 1988) whilst the values are confounded with differential yield potential of genotypes (Ramirez and Kelly, 1998). Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between the stress (Ys) and non-stress (Yp) environments and mean productivity (MP) as the average yield of Ys and Yp. Fischer and Maurer (1978) proposed a stress susceptibility index (SSI) of the cultivar. Fernandez (1992) defined a new advanced index (STI = stress tolerance index), which can be used to identify genotypes that produce high yield under both stress and non-stress conditions. Other yield based estimates of drought resistance are geometric mean (GM), mean productivity (MP) and TOL. The geometric mean is often used by breeders interested in relative performance since drought stress can vary in severity in field environment over years (Ramirez and Kelly, 1998). Clark et al. (1992) used SSI for evaluation of drought tolerance in wheat genotypes and found year-to-year variation in SSI for genotypes and their ranking pattern. In spring wheat cultivars, Guttieri et al. (2001) using SSI criterion suggested that SSI more than 1 indicated above-average susceptibility to drought stress. Golabadi et al. (2006) and Sio-Se Mardeh et al. (2006) suggested that selection for drought tolerance in wheat could be conducted for high MP, GMP and STI under stressed and non-stressed environments.

The object of this research was to determine the relationship among yield and yield components of two wheat cultivar under the applied drought stress treatment, in order to achieve the proper irrigation regime for area similar to studied condition and also specify the tolerated cultivar according to the stress indices.

Material and Methods This study was carried out under field conditions in Agricultural Research Station, Islamic Azad University, Khorasgan Branch, Isfahan, Iran with longitude 51/48' and latitude 32/40 during 2006-2007. The region is arid with mean annual rainfall of 110 mm. the soil in field from 0.0 to 40.0 cm below the surface was classified as sandy loam. Experimental design was arranged as s split plot with four replications. Irrigation treatments were applied from the elongation phase to ripening and were considered as the main plots, it consists irrigation after 80 (I_1), 100 (I_2) and 120 (I_3) mm cumulative evaporation from class A evaporation pan and winter wheat genotypes were allocated as subplots. Experimental materials were two winter wheat cultivar (M7318 and Line 4). The evaporation value was determined daily. Sowing was done in the first week of November that is recommended time for wheat in this region. The planting rate was 80 kg m^{-2} with an inter-row space of 20 cm. the fertilizing were 120 kg ha^{-1} ammonium phosphate before planting and 100 kg ha^{-1} nitrogen in two stage half before and half after planting used. Plant samples were taken from 0.1 m^{-2} of all subplots from middle of rows at harvesting stage and studied parameters included, the number of spikes per square meter, grain number spike^{-1}and 1000-grain weight were measured. In order to determine grain yield, biological yield and harvesting index all plots belong to each treatments harvested. Drought resistance indices were calculated using the following relationships:

$SSI = 1 - (Y_S / Y_p) / 1 - (\bar{Y}_S/\bar{Y}_P)$ (Fischer and Maurer, 1978)

Where Y_{si} is the yield of cultivar under stress, Y_{pi} is the yield of cultivar under irrigated condition, $\bar{Y}_S$ and $\bar{Y}_P$ are the mean yields of all cultivars under stress and non-stress conditions, respectively and $1 - (\bar{Y}_S/\bar{Y}_P)$ is the stress intensity.

$STI = \frac{Y_{Pi} \times Y_{Si}}{(\bar{Y}_P)^2}$ (Fernandez, 1992);

$GM = \sqrt{y_p \times y_s}$ (Fernandez, 1992);

$TOL = |y_p - y_s|$ (Hossain et al., 1990);

$MP = \frac{y_p - y_s}{2}$ (Hossain et al., 1990);

Data were analyzed using SAS (SAS institute, 1998, NC.) for analysis of variance and LSD test was employed for the mean comparisons.

Results

The number of spikes m^{-2} Among the applied treatments, maximum reduction in the number of spikes m^{-2} was recorded in I_3, but the difference between I_2 and I_1 was not significant (table.2). Due to less competition for absorbing water and nutrient among the plants in I_2 and I_1 drought stress cause no remarkable decrease in number of spikes per m^{-2}. Severe drought stress and strong competition among the plants in I_3 cause a significant reduction in number of spikes per m^{-2}. It seems that the mild drought stress in I_2 also promoted root extension and as result, supports plants to avoid stress and yield loss. Ali et al. (1999) also reported that in spring wheat, drought stress significantly decreased fertile spikes. These results are in close conformity with those of Mogabe et al. (2000) who established that water deficiency around anthesis may led to a decrease in number of spikes per m^{-2}. M7318 produced maximum number of spikes per m^{-2} but the difference between the genotypes was not significant (table.2). Genotype x treatment was not significant the regarding number of spikes per m^{-2} (table.2).

Grain number spike^{-1} Among the applied treatments, maximum number of grains per spike was recorded in I_1 (61 grains spike^{-1}) followed by I_2 (52 grains spike^{-1}) and a minimum number of 46 grains spike^{-1} was recorded in I_3 (table 1). Statical data analysis showed that the difference between I_1 and I_2 was not significant but the severe drought stress that occurred during the most sensitive plant growth period from double ridge to anthesis not only through reduction in spike length but also led to aborted spikelets and as result caused to remarkable decrease in number of grains per spike in I_3. Similar results have been reported by Giunta et al. (1993) and (Zhong-hu & Rajaram 1994) who found that number of grain spike^{-1} in wheat are most sensitive to water stress due to high remobilization of stored pre-anthesis assimilates. M7318 produced maximum number of grain spike^{-1} but the difference between the genotypes was not significant (table.1). Genotype x treatment was not significant the regarding number of grain spike^{-1} (table.1).

Table.1- Mean squares for yield components, grain yield and biological yield, harvesting index and water use efficiency of wheat genotypes.

source	df	spikes m^{-2}	Grain number	Grain weight	Grain yield	Biological yield	HI	WUE
Replication	3	646/93	5/1	23/46	309941/2	2121090/7	49	0/0032
Irrigation (I)	2	34790/54 **	393/12 **	99/75 **	62650586/6**	80055138/2 **	1941/8**	0/284 **
Error a	6	1453/43	6/6	5/91	397245/6	2117197/1	35/4	0/005
Genotype (G)	1	0/042	4/43	54/51 **	396159/9*	1808241/3	11/85	0/0001
G within I	2	1101/54	4/98	4/17	1203588/9 **	11485629/4*	40/018	0/0187 **
Error b	9	572/04	2/52	3/13	55924/6	1677791/7	16/22	0/00057

*: Indicates significance at p=0.05 **: Indicates significance at p=0.01

Table.2- Mean value for yield components, grain yield and biological yield, harvesting index and water use efficiency of wheat genotypes.

Treatment	Spikes m^{-2}	Grain Number	Grain Weight	Grain Yield	Biological Yield	HI	WUE
Irrigation							
80	549/5 ^{a}	37/15 ^{a}	35/66 ^{a}	6951/1 ^{a}	19030/8 ^{a}	36/69 ^{b}	0/55 ^{b}
100	521/88 ^{a}	34/2 ^{a}	35/003 ^{a}	6700/6 ^{a}	14890/9 ^{b}	45/78 ^{a}	0/74 ^{a}
120	424/00 ^{b}	23/81 ^{b}	29/24 ^{b}	2583/6 ^{b}	12817/7 ^{c}	20/1 ^{c}	0/367 ^{c}
Genotype							
M7318	498/5 ^{a}	32/15 ^{a}	34/8 ^{a}	5340/2 ^{a}	15854/3 ^{a}	33/34 ^{a}	0/552 ^{a}
Line-4	498/42 ^{a}	31/29 ^{a}	31/79 ^{b}	5083/3 ^{b}	15305/3 ^{b}	31/93 ^{a}	0/556 ^{a}

Within columns, means followed by same letter of same case are not different as determined by LSD multiple range test ($P<0.05$)

1000-grain weight Among the applied treatments, maximum 1000-grain weight was recorded in I$_1$ (35.66 g) followed by I$_2$ (35 g) and a minimum 1000-grain weight (29.24 g) was recorded in I$_3$ (table 2). Statical data analysis showed that the difference between I$_1$ and I$_2$ was not significant but the severe drought stress in I$_3$ caused to hasten leaf senescence and led to a great reduction in photosynthesis rate in the grain filling period in I$_3$. Siddique et al. (2000) has been reported, root absorption process and assimilate translocation also interrupted by drought stress and as result a mark decline in grain weight. Genotype differed significantly regarding this variable. M7318 due to forming more leaf area than line-4 might be led to maximum 1000-grain weight (table 1). Genotype x treatment was not significant the regarding 1000-grain weight (table 1).

Grain yield Among the applied treatments, maximum grain yield was recorded in I$_1$ (6951.1 kg^{-ha}) followed by I$_2$ (6700.6 kg^{-ha}) and a minimum grain yield (2583.6 kg^{-ha}) was recorded in I$_3$ (table 2). Statical data analysis showed that the difference between I$_1$ and I$_2$ was not significant but the severe drought stress in I$_3$ thru a decreased in grain weight, tiller, grain and spike number per square meter led to a considerable decreased in grain yield. It has been reported at the stress conditions, the amount and the rate of remobilization have an important role in grain filling process (Dehghanzade, 2006), but regarding to the negative effects on stem and spike length due to the severe stress in I$_3$, grain yield had been reduced accordingly. Pundy et al. (2001) observed, water deficit at any growth stage reduced grain yield. Giunta et al. (1993) also reported that water deficiency around anthesis may lead to a loss in yield by reducing number of spike and spikelet and the fertility of surviving spikelets. Genotype also differed significantly regarding this variable (table.1). M7318, due to having more fertile tiller and 1000-grain weight than Line-4, might be led to maximum grain yield (table.2). Genotype x treatment was significant the regarding this variable (table.1). As the Figure 1 show M7318 had higher grain yield than line-4 in I$_1$ and I$_2$ but at the severe stress condition (I$_3$) Line-4 result in maximum grain yield, it might be concluded that Line-4 has better stability for the grain yield under severe drought stress.

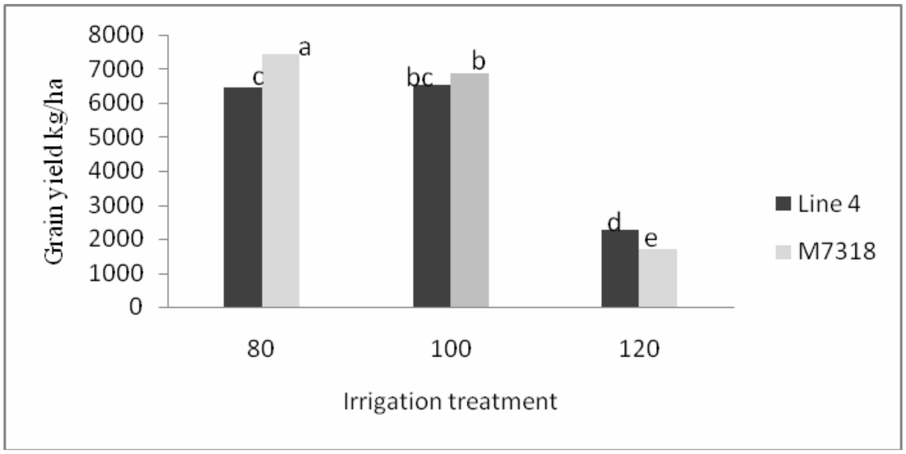

Figure.1- Interaction between Grain yield and Irrigation treatments

Biological yield Among the applied treatments, maximum biological yield was recorded in I_1 (19030.8 kg^{-ha}) followed by I_2 (14890.9 kg^{-ha}) and a minimum biological yield (12817.7 kg^{-ha}) was recorded in I_3 (table 2). Reduction in Leaf area index, plant length, number of spikes m-2, grain number spike-1 and grain weight due to the increase intensity of stress along the treatments, causing a steep decline in biological yield. It seems that drought accelerates leaf senescence, leading to a decrease in canopy size, loss in photosynthesis and reduced yields. Similar result regarding the reduction in dry weight due to drought stress was reported by Dehghanzade (2007) who found accelerated leaf senescence and leaf abscission are associated with drought in nature as a means to decrease canopy size and biological yield. M7318 produced maximum amount of biological yield but the difference between the genotypes was not significant (table.1). Genotype x treatment was significant the regarding this variable (table.1). As the figure.2 shows in I_1, genotypes was not showed significant difference in biological yield but in I_2 and I_3, M7318 and line-4 showed the maximum biological yield.

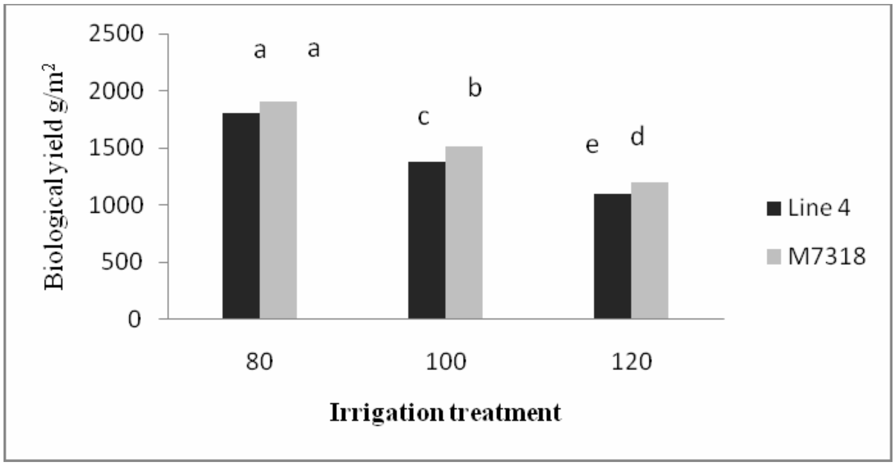

Figure.2- Interaction between Biological yield and irrigation treatments

Harvesting Index Among the applied treatments, maximum HI was recorded in I_2 (45.78%) followed by I_1 (36.69%) and a minimum HI (15.43%) was recorded in I_3 (table.2). Highest amount of dry matter due to non-stress condition in I_1 could not led to maximum HI, it seems that plants could not transferred the store assimilate to the yield components to increase the grain yield while in I_2, obtained store dry matter were utilized as way to increase the grain yield. The severe drought stress in I_3 thru a decreased in grain weight, grain and spike number led to a considerable decreased in the amount of grain yield and total dry matter so the HI value drastically dropped. Mojarad and Ghanadha (2007) also reported that drought stress after ear-formation decreased HI, despite a great biomass was accumulated before anthesis. Line-4 probably due to lower plant length than M7318 showed a higher value of HI, but the difference between the genotypes was not significant (table.1). Genotype x treatment was significant the regarding this variable (table.1).

Water Use Efficiency Among the applied treatments, maximum WUE was recorded in I_2 (0.74) followed by I_1 (0.55) and a minimum WUE (0.367) was recorded in I_3 (table.2). Applied higher amount of irrigation water in I_1 in compare with I_2 did not led to significant higher grain yield in I_1. Result showed that the produced dry matter in I_1 cause no considerable increase in grain yield while in I_2 mild stress did not cause to significant decrease in economical yield. Results indicated that, severe drought stress in I_3 cause to significant decline in economical yield. Genotypes were not showed significant difference regarding to variable (table.1). Genotype x treatment was significant the regarding this variable (table.1). As the figure.3 shows in I_1 and I_2 M7318 showed maximum value of WUE but under the severe drought stress in I_3 Line-4 showed the highest value of WUE, it might be concluded that Line-4 has better stability regarding to this variable under severe drought stress.

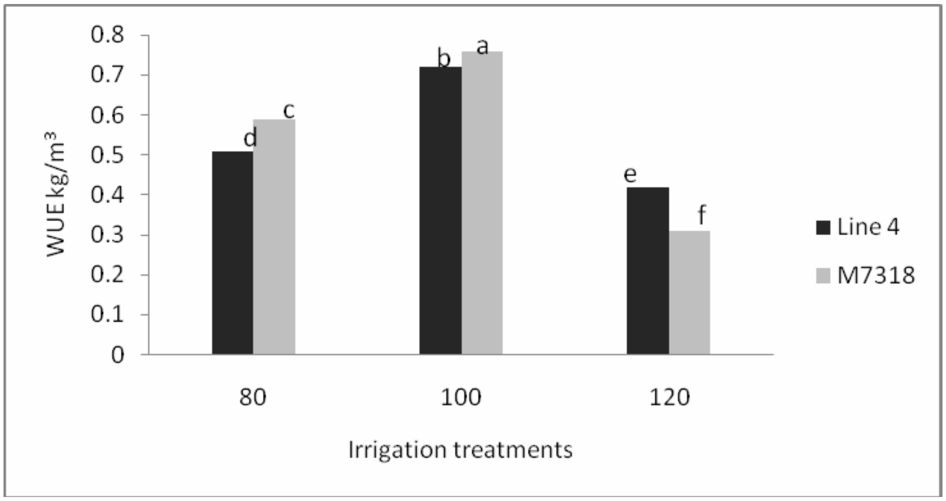

Figure.3- Interaction between WUE and irrigation treatments

Stress indices Resistance indices were calculated on the basis of genotype grain yield. Result of analyze of variance for the indices are given in table.3. Genotypes showed significant differences in grain yield and other treat under different moisture conditions (table.3). STI and GMP indicated a positive correlation with yield under non-stress condition. Among the calculated indices SSI and TOL which have a significant correlation with grain yield under stress and non-stress conditions were used to identify sensitive and tolerant genotypes. According to these two indices, Line-4 in compare with M7318 appeared to be more tolerant to drought stress (table.4). It seems that high potential yield under optimum conditions does not necessarily result in improved yield under stress conditions. These results are in agreement with those of Talebi et al. (2008)

who reported, indirect selection for a drought-prone environment based on the result of optimum conditions will not be efficient.

Table.3- Mean squares for measured stress indices value

TOL	MP	GMP	SSI	STI	df	source
98691/391	22999/09	21973/24	0/00001	0/00056	3	replication
4731824/221**	78657/85	154757/94	0/05862**	0/00375	1	Genotype
71887/862	36588/0652	24852/2	0/00037	0/00058	3	Error

*: Indicates significance at p=0.05 **: Indicates significance at p=0.01

Table.4- Mean value for measured stress indices value

TOL	MP	GMP	SSI	STI	Genotype
4198/4b	4368/2a	3829/6a	b 0/908	a 0/304	Line-4
5736/5a	4566/5a	3551/4a	a 1/079	a 0/2611	M7318

Within columns, means followed by same letter of same case are not different as determined by LSD multiple range test (P<0.05)

CONCLUSION In this study, although deficit irrigation in I_2 comparing with I_1 resulted in reduced grain yield but it causes to considerable increase in water use efficiency as well as harvesting index. On the other hand, under the non-stress condition M7318 comparing with Line-4 resulted in better grain yield while in stress condition Line4 showed better performance.

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