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Response of Different Growth Stages of Wheat to Moisture Tension in a Semiarid Land

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Abstract: This investigation was done in order to study the response of grain yield and yield components of bread wheat cultivars to drought stress in western Iran in 2008-2009. The main plots were levels of drought stress (full irrigation, stress at early stem elongation, flowering and grain filling stages) and subplots were five cultivars (Chamran, Dez and Verinak). The results indicated that the effect of drought on grain yield and yield components was significant. Drought stress at all growth stages induced reducing grain yield and yield components. Drought stress at stages of stem elongation, flowering and grain filling stages induced 32%, 32% and 35% reduce in grain yield, respectively. Stress at stem elongation stage had the highest sensitivity than other growth stages. Also, The most and least number of spikes/m^2 were observed in full irrigation and Chamran cultivar and in stress at stem elongation stage and Dez cultivar, respectively. As a result, we can use Verinak cultivar for conditions which irrigation is not possible or water deficit occurs in same regions of western iran.

Key words: Wheat · Drought stress · Grain yield · Yield components

INTRODUCTION

Wheat (*Triticum aestivum*, L.) is one of the main cereal crops, cultivated to demands of the population for human feeding [1]. Drought stress influenced on plant growth, tiller improvement, photosynthesis, number and size of grain [2]. Ali *et al* stated that grain yield, number of grains per spike and grain weight under irrigated conditions were more than incomplete irrigation [1]. Result of other experiment showed that number of spike/m^2, 1000-grain weight, weight of grain per spike were most important variable which affect on yield under drought stress condition. Based on these results, it is assume that under dry condition, number of spike/m^2, 1000-weight, number of grains per spike can develop wheat grain. Zhang and Oweis reported that the sensitive growth stages of wheat to soil water deficits were from stem elongation to booting, followed by anthesis and milking [4]. Stone and Nicholas found that the reduction to be more severe when the water stress occurred at early stages of grain filling rather than at later stages [5]. Water stress occurring at any during reproductive growth can result a drastic change in seed yield, the worst time to water stress on many grain crops in during stem elongation and flowering [6]. The early senescence induced by a moderate water-deficit during grain filling can enhance the remobilization of stored assimilates and accelerate grain filling [7, 8]. Gonzalez *et al* concluded that under drought stress conditions, number of spikes/m^2 had more effective role in reducing yield than other yield components [9]. Akram *et al* reported that drought tension increased spikelet unproductively and decreased 1000-grain weight and economical yield of grain [10]. Singh reported that deficit water affects on plant phonology by reducing growth period [11]. Kheiralla *et al* reported that under different irrigation conditions and deficit moisture, grain yield, number of spikes per square meter, number of grains per spike and 1000-grain weight were be changed [12]. Kobota *et al.* showed that severe water tension compared mild stress decreased size and

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weight of grain in result of reducing retransferring assimilation, significantly [13]. Reports of Van Heerden and Laurie and Liu *et al* indicated that lower soil moisture might inhibit photosynthesis and decrease translocation of assimilates to the grain which lowered grain weight [14,15]. The increase of water stress intensity progressively reduced the number of kernel per spike. As the water stress was imposed at jointing stage, the lowest number of spikes per unit area was obtained. Also when water stress imposed at anthesis, the lowest number of kernel per spike was obtained (26 kernels per spike) [16]. The reduction of tillers production under lower soil moisture levels might be the fact that under water stress, plants were not able to produce enough assimilates for inhibited photosynthesis. It might be also happened for less amount of water uptake to prepare sufficient food and inhibition of cell division of meristematic tissue [17]. The depression in these growth parameters as results of water deficits may be attributed to the loss of turgor which affects the rate of cell division and enlargement. In this concern, Kramer and Boyer reported that the growth of plants is controlled by rates of cell division and enlargement and by the supply of organic and inorganic compounds required for the synthesis of new protoplasm and cell walls [18]. Therefore, the object of this experiment was to determine the variability of grain yield and yield components of wheat as affected by drought stress in different growth stages.

MATERIAL AND METHODS

In order to evaluating grain yield and yield components in wheat cultivars as affected by drought stress, an experiment performed in western Iran with coordinates of 33°07′ N and 46°10′ E and 155 m height of sea level. Experimental form was as split plot design by randomized complete blocks design with three replications. Treatments were levels of drought stress (control, irrigation in stem elongation, flowering and grain filling stages) as the main plots and three cultivars (Chamran, Dez and Verinak) as subplots. Sowing rate was based on 400 plants per square meter. Planting date was at 21 December 2008. Main and subplot spacing were 2 m and 50 cm, respectively. Length of plots was 4 m and each cultivar planted on six lines by 20 cm plant spacing. Sampling was by omitting two outer rows and edge of plots. Number of spikes counted in one square meter, number of grains per spike from 10 spikes and 1000-grain weight determined by weighting of 1000 grains in three replications for each plot. Protein percent was determined using Kjeldhal procedure. Also harvest index calculate by dividing grain yield by biological yield. Data analyzed using MSTATC and SAS programs.

RESULTS AND DISCUSSION

Number of Spikes/m^2: Results indicated that the effect of drought stress on number of spikes/m^2 was significant at $p<0.01$ (Table 2). Full irrigation and stress treatments at stem elongation stage had the highest and the lowest number of spikes/m^2, respectively (Table 3). Stress at stem elongation stage has high sensitivity, because this stage is the most determined factor for yield components. Also, in this stress condition, number of spikes/m^2 had 77.7 spikes/m^2 less than control. This indicated the importance of irrigation at the beginning of stem elongation. Day an Intapal suggested that water stress in beginning of stem elongation induced decreasing number of spikes and 1000-grain weight [19]. Results of this study showed that the effect of moisture during forming and late growth stage which is coincident with stem elongation stage has important role in enhancing wheat grain yield. Number of fertile tillers that resulted in number of spikes/m^2 is determined at stem elongation stage. At this stage, number of spikes/m^2 was reduced due to reduction of received water, then drought stress at flowering and grain filling stages didn't effect on number of spikes/m^2 (Table 3). Irrigation at primary stages of growth of wheat cultivars could effect on productivity of tillers and more produced spike. But after this stage, number of fertile tillers was originated and irrigation at flowering and grain

Table 1: Mean rainfall values during the years of experiment and 5 year means in Ilam, Iran

	Rainfall(mm)	
	2004-2007	2008-2009
Sep-Oct	0	15
Oct-Nov	0	0
Nov-Dec	66.8	56.8
Dec-Jan	23.1	60
Jan -Feb	56.8	15.8
Feb- Mar	38.2	24.4
Mar - Apr	60.9	3.8
May- Apr	3	12
May- Jun	22.6	4.4
Jun-Jul	0	0
Jul -Aug	0	0
Aug-Sep	0	0
Total	214.6	192.2

Table 2: Analysis variance of measured parameters

		MS						
S.O.V	df	Grain yield	Number of spike/m^2	Grain per spike	1000 grain weight	Harvest index	Biological yield	Protein percent
Replication	2	8956751.3	3147.02	1016.02	291.8	3.08	67529555.1	1.8
Irrigation	3	4212891.6**	6888.2*	235*	116.4	45.8*	8037396.5*	3.2^{ns}
Error a	6	368147.2	1095.69	34.36	38.5	4.7	1853296.5	0.99
Cultivars	3	3704758.3**	4284.5**	261.02**	115.8**	36.08**	12630701.7**	2.09^{ns}
Interaction	6	523147.2*	1837.08*	48.2**	17.1*	13.7*	790158.8^{ns}	0.80^{ns}
Error b	16	190737.5	633.8	10.23	5.6	4.2	1933707.05	1
CV%		9.8	7.54	7.1	7.1	5.4	12.6	8.32

*: Significant at 0.05 level, **: Significant at 0.01 level, ^{ns}: No significant difference

Table 3: Mean comparisons of the main effects

Treatment	Grain yield (Kg ha^{-1})	Number of spike /m^2	Grain per spike	1000 grain weight (g)	Harvest index(%)	Biological yield (Kg ha^{-1})	Protein percent (%)
Irrigation							
I_1	5450a	367.2a	51.7a	37.3a	41.6a	13008.8a	11.3b
I_2	4123.3b	289.5c	43.3b	33ab	36.8b	11022b	12.3ab
I_3	4106.6b	332.2bc	39.6c	32.3ab	36.7b	10983.3b	12.2ab
I_4	4023.3b	335.7ab	43.6b	28.5b	37.3ab	10983b	12.7a
Cultivars							
C_1	4897.5a	349.2a	40.3c	35a	39.9a	12370.6a	12.4a
C_2	3813.3b	312.6b	49.5a	29.2b	36.4b	10331.6b	12.3a
C_3	4566.6a	339.1a	43.9b	34.1b	39a	11550ab	11.6a

Mean which have at least once common letter are nit significant different at the 5%level using (DMRT)

I_1, I_2, I_3 and I_4 =Full irrigation, Stress in stem elongation, flowering and grain filling stages, respectively

C_1, C_2 and C_3= Chamran, Dez and Verinak respectively.

Table 4: Mean comparisons of the interaction effect

Treatment	Grain yield (Kg ha^{-1})	Number of spike/m^2	Grain per spike	1000 grain weight (g)	Harvest index (%)	Biological yield (Kg ha^{-1})	Protein percent (%)
I_1C_1	6533.3a	423.3a	42.3cd	42.3a	45a	14766.6a	12.03a
I_1C_2	4700bc	325bcd	63.3a	31.3def	39.6b	11793.3bc	11.9a
I_1C_3	5116.6b	353.3bc	49.6b	38.3ab	40.3b	12466.6ab	9.9b
I_2C_1	4533.3bcd	305cd	40.3cd	36bc	38bc	11732.6bc	12.6a
I_2C_2	3486.6ef	280.3d	46.3bc	30defg	35c	9866.6bc	12.3a
I_2C_3	4350bcd	313.3bcd	43.3cd	33cde	37.3bc	11466.6bc	12.1a
I_3C_1	4403.3bcd	340bc	37.3d	34.3bcd	37.6bc	11600bc	12.4a
I_3C_2	3716.6def	323.3bcd	42.3cd	29efg	35.3c	10133.3bc	12.2a
I_3C_3	4300cde	333.3bc	39.3d	33.6cd	37.3bc	11216.6bc	12.1a
I_4C_1	4120de	328.6bcd	41.3cd	27.3fg	36.c	11383.3bc	12.8a
I_4C_2	3350f	322bcd	46.3bc	26.6g	34c	9533.3c	12.7a
I_4C_3	4600bc	306.6b	43.3cd	31.6cdef	41.6b	11050bc	12.5a

Mean which have at least once common letter are nit significant different at the 5%level using (DMRT)

I_1, I_2, I_3 and I_4 =Full irrigation, Stress in stem elongation, flowering and grain filling stages, respectively

C_1, C_2 and C_3= Chamran, Dez and Verinak respectively.

filling stages wouldn't effect on increasing number of spikes/m^2. Researches of Jones *et al* showed that deficit water during flowering stage affected grain number, while water deficiency after anthesis reduces grain size [20]. A significant difference was observed in number of spikes/m^2 among tested cultivars. As shown in table 3, Chamran cultivar had maximum and Dez cultivar had minimum of spikes/m^2, respectively. These results indicated that there are genetic differences in tested cultivars. Interactive effect of irrigation treatment and cultivars on number of spikes/m^2 was significant at P<0.01 (Table 2). The most and least number of spikes/m^2 were observed in full irrigation and Chamran cultivar and in stress at stem elongation stage and Dez cultivar, respectively (Table 4). In comparison with results of grain yield, we can imply that the number of spikes/m^2 is the most important factor for grain yield stability under deficit water stress. In this experiment, Verinak cultivar in stress levels could produce more spikes/m^2 than other cultivars. It seems that number of spikes/m^2 was the most important characteristic affected on grain yield among other characteristics and had most correlation with grain yield.

Also we can related the less number of spikes/m^2 of Dez cultivar under stress treatment at stem elongation stage to reducing grain yield of this cultivar in compared with full irrigation treatment.

Number of Grains per of Spike: Results obtain from data analysis of variance indicated that there is significant differences ($p<0.01$) under drought stress treatments on number of grains per spike (Table 2). Full irrigation treatment had most grain number and stress treatment at flowering stage had the least number of grains per spike (Table 3). It is obvious that deficit moisture at flowering stage induced imperfect inoculation resulted in florets abortion. Reduction of grain yield in deficit water conditions are related to reducing number of flowers and ability of flowers to transform to grain. In other hand, transferring materials from phloem is depended on photosynthesis which supplying main materials and sink metabolism. Deficiet water stress reduces photosynthesis materials in growing leaves. So, drought decreases amount of photosynthesis materials produced by leaves. Because rate of transferred extract from phloem is depending on pressure potential, water potential of phloem decreasing during deficit water stress and reducing turgor potential. Also, reduction of grain forming under deficit water affected by decrease of transforming photosynthesis materials and amount of reserved assimilation resulted in enhancing damage. Stress in grain filling stage induced the reduction of the anthesis and consequently reduction of number of grains per spike in compared with other treatments. Stress at grain filling stage had low effect on survival of spikelet in spike. Under stress conditions at flowering stage, deficit water had significant effect on florets fertility and number of grains per spike. Among cultivars, number of grains per spike had a significant difference. So, Dez cultivar had the most number of grains per spike and the least number of grains per spike was observed in Chamran cultivar. Overall, an negative relation was observed between number of spikes per m^2 and number of grains per spike. This indicated interactive effects among yield components. Interaction of irrigation and cultivars on number of grains per spike was significant ($p<0.01$). Moisture stress is known to reduce grains per spike and grain size at any stage when it occurs. So, the over all effect of the moisture stress depends on its intensity and length of stress [21]. Song *et al.* in corn showed that water stress led to slower pollen and filament development decreased filament fertility and resulted in a reduction in grain number and weight per ear [22]. Maximum number of grains per spike was obtained in treatments of full irrigation and Dez cultivar and minimum number of grains per spike obtained under stress conditions at flowering stage and Verinak cultivar. Number of grains per spike had not significant effect on enhancing grain yield. It is obvious that number of spikes/m^2 and 1000-grain weight had a more effective role in wheat grain yield.

1000-grain Weight: Results obtained from data analysis of variance indicated that there is a significant difference ($p<0.01$) using drought stress treatment to 1000-grain weight (Table 2). Full irrigation and stress treatment at grain filling stage had the most and least 1000-grain weight, respectively (Table 3). Stress at grain filling stage is caused to reducing grain yield due to decreasing 1000-grain weight. In grain filling stage, photosynthesis materials transferred to grain. Therefore, any deficit water stress in this stage induced thinning and small size of grain. Also, it is suggested that drought stress at grain filling stage decreases 1000-grain weight [23]. In general, 1000-grain weight is a function of their filling period and rate. Environmental stress including deficit stress water especially at grain filling stage reduces the speed and period of grain filling that due to decreasing current photosynthesis rate. In the study of pandy *et al* under water stress conditions at flowering stage, grain yield was decreased due to reducing 1000-grain weight [24]. A significant difference was observed between tested cultivars in 1000-grainweight. Among cultivars, the most and least 1000-grain weight was observed in Chamran, Verinak and Dez cultivars, respectively. Interaction of irrigation treatments and cultivars effect was significant ($p<0.05$). The most and least 1000-grain weight was observed in full irrigation and in stress conditions at grain filling stage and Dez cultivar, respectively. Westgate suggested that grain water status is affected directly by drought and may be an important determinant of grain development and that a water deficit after anthesis shortens the duration of grain filling by causing premature desiccation of the endosperm and by limiting embryo volume [25].

Grain Yield: Results obtained from data analysis of variance showed that there had a significant difference ($p<0.01$) under drought stress treatment for grain yield (Table 2). Drought stress at any growth stages induced decreasing grain yield. In comparison with control (full irrigation), the most grain yield was observed at control treatment (full irrigation), by grain yield of 5450 kg.ha^{-1} at this treatment. Stress at stem elongation, flowering and grain filling stages caused to decreasing 32%, 32% and 35% grain yield. Solomon *et al*. and Ozturk and Aydin also found yield reductions of 79.7 and 65.5% when water stress was imposed either at earlier stages or at grain formation. Significant reducing grain yield under deficit water stress was due to variability of yield components [26, 27]. The results obtained from data analysis of variance indicated a significant difference between cultivars in grain yield (Table 2). Among tested cultivars, Chamran cultivar had the most grain yield by 4897 kg/ha and Dez cultivar had least grain yield by 3813 kg/ha (Table 3). In this study, it is specified that Chamran cultivar was better than the other cultivars both in number of spikes/m^2 and 1000-grain weight. Although, Dez cultivar had more number of grains per spike than the other cultivars, it had less number of spikes/m^2 and 1000-grain weight than the other cultivars. Interaction of irrigation treatments and cultivars effect on grain yield was significant ($p<0.05$). Chamran cultivar had more yield at full irrigation and Dez cultivar had least yield under stress at flowering stage (Table 4). But under stress treatment at grain filling stage, Verinak cultivar had the highest grain yield. High yield of this cultivar could attribute to high number of spikes and 1000-grain weight. In respect to these results and existing positive correlation of grain yield with number of spikes/m^2 and 1000-grain weight, it is conducted that vegetable growth caused to producing fertile stem and optimum grain weight per spike, it could result in high grain yield in wheat cultivars. Guttieri *et al*. and Zhang *et al*. found that drought reduced grain yield due to a reduction in kernel growth rate, whereas Altenbach *et al.* demonstrated that kernel size and thus yield reduction, was due to the shortening of the duration of grain filling [28-30].

Biological Yield: Results obtained from data analysis of variance indicating a significant difference ($p<0.01$) under stress conditions (Table2). Full irrigation and stress treatment at all stages had the highest and lowest 1000-grain weight, respectively. This difference could due to decreasing cultivars ability to adsorption nutrients and transforming material as a result of deficit water which caused biological yield [31]. Increasing biological yield at full irrigation treatment was due to more expanded leaf area and its durability which caused to increasing biological yield by generating physiological source to consuming received light. On the basis of data analysis of variance, there had significant differences among cultivars. Chamran cultivar had the highest and Dez cultivar had the lowest biological yield (Table 3). Long growth period induced more biological yield [32]. As Chamran cultivar has a long growth period (150 days), its high biological yield is result of its long growth period which providing more time to producing and accumulating materials for plant parts.

Harvest Index: Harvest index, an indicator to how photosynthesis material distributed among plant parts, had significant differences among treatments ($p<0.01$). Full irrigation treatment and stress at grain filling stage had the highest and stress at stem elongation and flowering stages had the lowest harvest index. Decrease of transforming materials to grain induced reducing harvest index. Harvest index had a significant difference at various cultivars. The highest harvest index was belonging to Chamran and Verinak cultivars and the lowest was belonging to Dez cultivar. This is due to less 1000-grain weight at Dez cultivar and high number of spikes/m^2 in Chamran and Verinak cultivars. Interaction of full irrigation treatments and cultivar on harvest index was significant. Verinak cultivar could produce the highest harvest index at stress, specially stress at grain filling stage. There are some reports indicated that lower soil moisture might inhibit photosynthesis and decrease translocation of assimilates to the grain which lowered grain weight. Usually, water stress at grain filling period but increases remobilization of assimilates from the straw to the grains [33, 34].

Protein Percent: Significant differences in Protein percent was observed among different irrigation levels ($p<0.05$). In overall, full irrigation and stress at grain filling stage had the lowest and the highest protein percent, respectively. Variability of protein percent at grain filling stage could attributed to changes in grain weight and concentration of other materials in grain.

CONCLUSION

Finally, it is indicated that stress at any growth stages decreased grain yield of wheat cultivars in compared with control. Any growth stage had much sensitivity in response to water and could affect on grain yield and its components. Stress at stem elongation, flowering and grain filling stages induced decreasing number of spikes/m^2, fertility of florets and 1000-grain weight. It is seem that among cultivars, Verinak cultivar could produce high grain yield by transforming materials because of it's high harvest index under stress conditions. As a result, we can use this cultivar under conditions which irrigation is not possible or water deficit occurs.

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