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Full Length Research Paper

Differential agronomic responses of bread wheat cultivars to drought stress in the west of Iran

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Two similar and concurrent experiments were carried out in 2007- 2008 on dry land agriculture research sub- institute Sararood and Mahidasht agricultural research center to study the effects of drought stress on yield and yield components of wheat cultivars under field conditions. The experimental design was split plot based on randomized complete block design with three replications. Main plots consisted of four drought stress treatments which was imposed by irrigation stoppage at different growth stages, that is, at initiation of stem elongation stage (31 of the Zadoks) (I_1), at booting stage (43 of the Zadoks) (I_2), at initiation of grain – filling stage (70 of the Zadoks) (I_3), and full irrigation (I_4). Subplots included three cultivars, that is, Chamran (C_1), Marvdasht (C_2), and Shahriar (C_3). Compared to control treatment (I_4), treatments (I_1), (I_2) and (I_3) exhibited 85, 57 and 43% yield decreases, respectively. In response to moisture stress during different growth stages, Shahriar CV (C_3) was damaged more severely than Chamran CV (C_1), the latter enjoyed more yield stability under such conditions. The result of stepwise regression analysis showed that the most important yield component was number of grains per spike followed by number of spikes per unit area, then, by 1000 grain weight. Analysis of simple correlation and path analysis showed that, in overall, given direct and indirect effects of yield components on grain yields, number of grain per spike had the largest effect on grain yield.

Key words: Bread wheat, cultivar, drought stress, path analysis, grain yield, yield components.

INTRODUCTION

Drought is the most common environmental stress affect-ting about 32% of 99 million hectares under wheat cultivation in developing countries and at least 60 million hectares under wheat cultivation in developed countries (Rajaram, 2000). Iran is one of countries where such abiotic stresses such as drought, salinity, heat and cold result in yield decrease, soil fertility destruction, and in some cases, impossibility of continuing farming. In Iran, about 67% of wheat – cultured area is devoted to dry-farming lands, which are exposed to drought stress during growth season (Galeshi and Oskuei, 2001). Such limiting factors as low temperature in winter (absolute minimum of temperature;-30°C), high temperature during the terminal grain filling period (+35°C), and post anthesis water deficit condition in irrigated wheat, influence crop growth and yield (Sanjari, 2001).

Stage of plant growth is important, under stress conditions, to the degree of the impact of drought stress on wheat growth and final yield in addition to intensity and duration of drought stress period (Palta et al., 1994). Many reports relate to drought stress on yield and yield components of grain wheat. On the whole, the drought stress entailed a significant decrease in grain yield, number of fertile spikes per unit area, number of grains per spike, 1000 grain weight, biological yield, harvest index and plant height (Fischer, 1979; Debaek et al.,1996; Moustafa et al., 1996; Reynolds et al., 2001).

In a study on wheat, Day and Intalop (1970) declared grain yield reduction because of drought stress at stem

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elongation stage due to decrease in number of spikes per unit area and grain yield per spike. Flowering and grain-filling stages were identified among the most critical stages of wheat growth and development to drought stress, during which wheat exhibits the highest sensitivity to water deficit. Also, it has been reported that wheat is sensitive to drought 2 weeks prior to anthesis (Rajaram et al., 1995; Machado et al., 1993; Richards et al., 2001).

Entz and Fowler (1990) declared that environmental stresses between 21 (tillering) and 65 (flowering) Zadoks stages had maximum effect on grain quantity, shoot dry matter production, harvest index, grain protein yield , number of spike per square meter, number of grain per spike and number of grain per square meter. Sieling et al. (1994) stated that post flowering drought stress reduces the numbers of spike and of grain per spike and in terminal growth stages, it even reduces grain weight. Saleem (2003) reported that at stem elongation stage, moisture stress reduces yield due to less number of spikes per unit area and grains per spike.

Royo et al. (2000) reported that flowering-to-maturity drought stress, is usually accompanied by high temperature, shortened grain filling period for Triticale, reducing 1000 grain weight. Debake et al. (1996) demonstrated that imposing stress, especially after anthesis stage, entailed a significant decrease in harvest index. Gupta et al. (2001) declared that there was a direct positive relation between biological yield and grain yield. Harvest index is so extremely affected by environmental changes that its value increases under desirable climatic conditions and decreases under drought stress condition at final period of plant growth (Siddique and Whan, 1994). The objective of this experiment is to determine the sensitivity of wheat growth stages to drought stress and to study correlations between yield, yield components and different traits related to yield under moisture stress conditions.

MATERIALS AND METHODS

This research was conducted in 2007- 2008 in Sararood station of dryland agriculture research sub- institute, Kermanshah, Iran (47°, 20'E; 34°,20'N), 1351 m elevated from sea level and also in Mahidasht research station of Kermanshah agricultural research center, Iran (46°,50'E; 34°,16'N), 1380 m elevated from sea level. Based on Dumarten's climate classification method, climate of both stations is cold semi-arid. Soil type of Sararood station at test site was silty- clay – loam with EC= 1.3 ds.m^{-2} and pH=7.3, Mahidasht test site had loamy – clay texture with EC=1.4 ds.m^{-2} and pH=7.5. Main plots included four drought stress treatments, that is , (I_1): drought imposed from onset of stem elongation stage (31 of the Zadoks) until maturity; (I_2) : drought imposed from onset of boot stage (43 of the Zadoks), (I_3) : drought imposed from onset of grain-filling stage (70 of the Zadoks); and (I_4): full irrigation (test plots were fully irrigated during growth period and irrigation applied at 40% depletion of soil moisture until maturity). For I_1, I_2 and I_3, irrigation was applied after 40% depletion of soil moisture up to targeted growth stage and thereafter irrigated at 80% depletion of soil moisture, until full maturity. Subplots were three commercial cultivars, that is, Chamran (C_1), Marvdasht (C_2) and Shahriar (C_3).

Planting date was 23th November, 2007. Based on soil analysis, required fertilizers were used as follows: 100 kg P_2O5/ha and 60 kg N/ha prior to planting and 30 kg N/ha were used as top dressing at tillering stage. Each plot consisted of 8 rows 20 cm apart, and 4 m long, 1 and 2 m distances were kept between test plots and blocks, respectively. Density was taken at 400 seeds per square meter. The first irrigation was applied immediately after seed sowing. For each cycle of irrigation, water quantity was determined with respect to test plots areas and based on continuous measurement of test plots moisture with wet HH_2 device. For targeted growth stages, drought stress treatments were imposed through stopping irrigation and preventing rainfall from penetrating into the plots by covering them with rain-shelter. At the maturity stage, plants from 4th and 5th rows, 3 m long, were harvested from each plot center; grain yield, biological yield, and harvest index were measured.

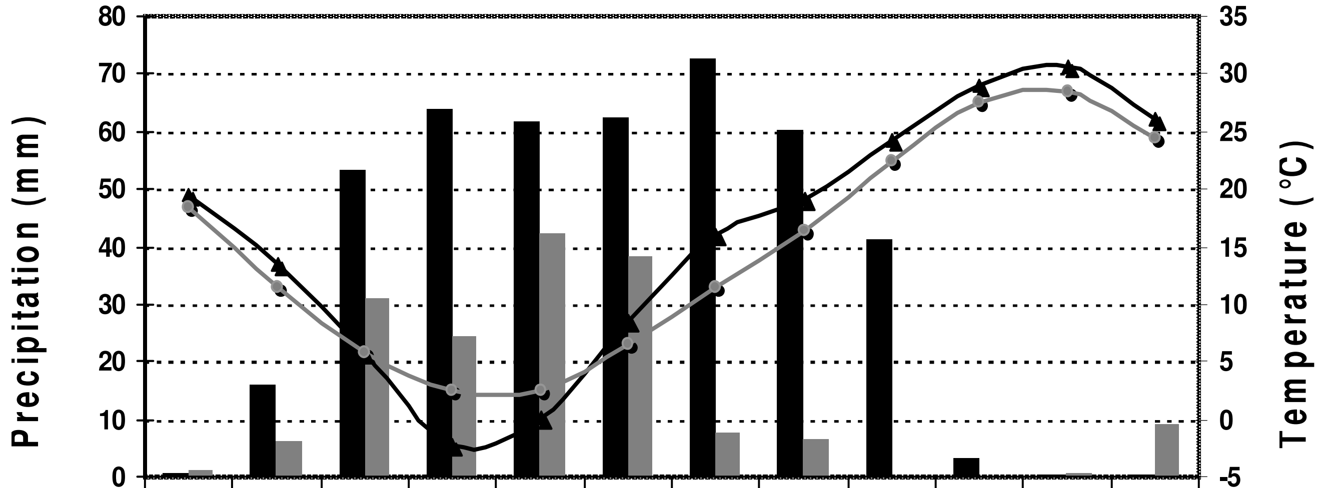
Figure 1 shows the mean temperature and precipitation in Sararood region, during the (2007 to 2008) farming year and long time (1976 to 2006). Figure 2 shows the mean temperature and precipitation in Mahidasht region, during the (2007 - 2008) farming year and long time (1976 to 2006). Thousand grain weight was determined by selecting 10 random samples from grains harvested from each plot. Number of grains per spike, plant height, and peduncle length were determined by selecting 20 plants from each plot. To determine number of spikes per unit area, spikes of harvested area of each plot were counted.

MSTATC and the Statistical Package for the Social Sciences (SPSS) software were used for statistical analysis. Combined variance analysis was performed after Bartlet test for checking uniformity of data variance (p=0.05) on targeted traits. Error MS of each source of variation were determined with McIntosh (1983) and Carmer et al. (1989) methods. Duncan's multirange test was used to compare meansand finally, Excel software was used to construct diagrams.

RESULTS AND DISCUSSION

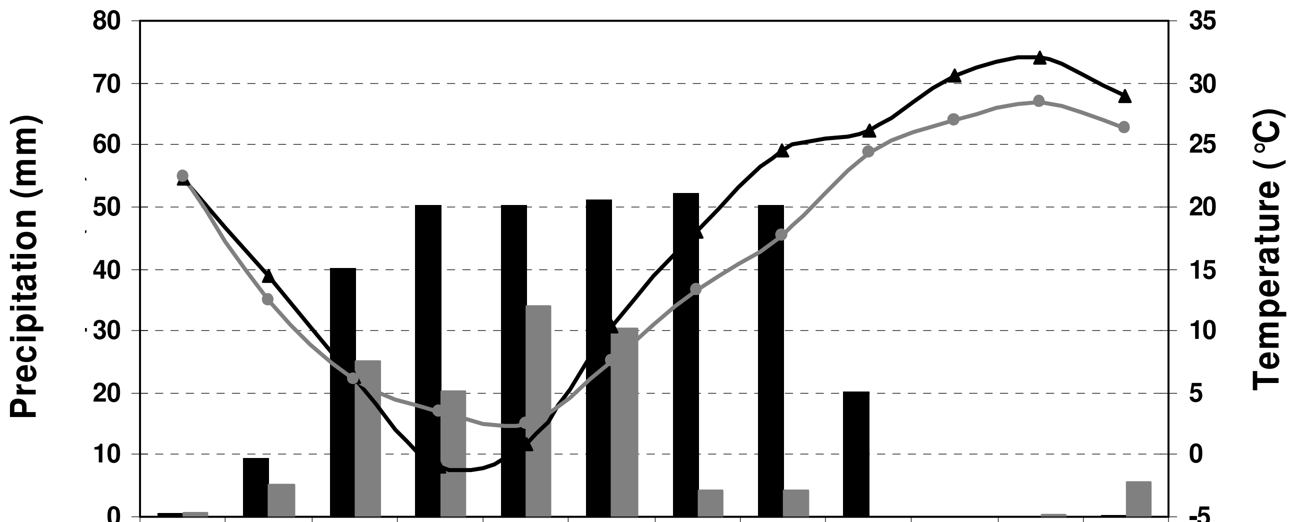
Combined analysis of variance, showed that there were significant differences between the testing sites for grain yield (p=0.05), peduncle length, plant height and grain yield, while there were highly significant (p=0.01) differences for number of grains per spike and harvest index (Table 1). For all experimental treatments, grain yield mean in Sararood station were higher than Mahidasht station (Table 2), because of distribution of precipitation in winter and spring on Mahidasht and Sararood region which were lower by 60 and 50% than mean of long time; also mean temperature in Mahidasht region (March and April) when compared to Sararood region was higher than mean of long time, within the experiment year. On the other side, mean temperature was higher in Mahidasht region during terminate months of wheat growth period (May and June) compared to Sararood region, which resulted in shortening the reproductive period, hence in reducing wheat yield in this region (Figures 1 and 2).

Within most wheat- bearing regions, especially those with Mediterranean climatic conditions, cultivating conventional wheat (*Triticum aestivum.L.*) face drought and heat stresses during grain filling period and this terminal drought reduces grain yield (Ehdaie et al., 1988; Ehdaie and Waines, 1989). Higher yield in Sararood region in comparison with Mahidasht region is associated with



	October	November	December	Januery	February	March	April	May	June	July	August	September
Precipitation(long time)	0.6	15.95	53.42	63.94	61.71	62.46	72.81	60.14	41.32	3.3	0.51	0.51
Precipitation(2007 - 08)	1.2	6.3	31.1	24.3	42.5	38.2	7.5	6.6	0	0	0.8	9.3
Temperature(2007 - 08)	19.5	13.5	5.7	-2.3	0.2	8.6	16	19.1	24.2	29	30.7	26
Temperature(long time)	18.43	11.45	5.8	2.48	2.53	6.5	11.44	16.45	22.47	27.52	28.39	24.36

Figure 1. Mean of temperature and precipitation in Sarorood region during the (2007 to 2008) farming year and long time (1976 to 2006).



	October	November	December	Januery	February	March	April	May	June	July	August	September
Precipitation(long time)	0.5	9.35	40.24	50.27	50.14	51.32	52.34	50.35	20.3	0	0	0.2
Precipitation(2007-08)	0.8	5.2	25.3	20.2	33.9	30.5	4.2	4.3	0	0	0.4	5.4
Temperature(2007-08)	22.2	14.5	6.3	-0.9	0.8	10.4	18	24.5	26.2	30.6	32	29
Temperature(long time)	22.41	12.45	6.11	3.56	2.53	7.5	13.24	17.75	24.42	27.08	28.42	26.3

Figure 2. Mean of temperature and precipitation in Mahidasht region during the (2007 to 2008) farming year and long time (1976 to 2006).

Table 1. Combined analysis of variance of grain yield, yield components and some morphological traits of wheat.

Source of variation	d.f	Mean squares (MS)							
		PL (cm)	PH (cm)	SPSM	GPS	TGW (g)	GY (kgh^{-1})	BY (kgh^{-1})	HI (%)
Location	1	49.336 *	599.580 *	399.974 ^{ns}	16.820**	30.811 ^{ns}	987370.643*	1887934.866 ^{ns}	44.510**
Replication and location	4	9.521	32.580	115.014	0.053	179.327	1168831.752	1324272.606	7.031
Irrigation	3	255.518 **	3572.732**	1144.901**	430.032**	251.788 **	3138210.826 **	29835385.922 **	989.841 **
Location and irrigation	3	0.301	2.174	136.804	0.119	0.101	18685.335	1536726.276	0.351
Error	12	8.821	119.794	128.574	0.224	39.649	183443.239	2066227.483	3.711
Cultivar	2	359.723 **	1375322**	1053.064**	37.102**	61.402 **	2064905.977 **	7285832.858 *	76.379 **
Location and cultivar	2	0.233	0.013	136.914	0.008	0.032	1910.657	1426407.285	0.035
Irrigation and cultivar	6	3.234 ^{ns}	89.249 ^{ns}	356.354**	2.887**	2.854 **	189356.852 ^{ns}	2330378.219 ^{ns}	9.355 **
Location, irrigation and cultivar	6	0.014	0.397	143.382	0.026	0.003	269.903	1360073.350	0.016
Error	32	29.449	108.121	102.449	0.539	0.385	133952.775	2252129.477	2.087
Coefficient variation (%)	-	18.77	13.60	4.42	4.22	4.80	7.69	12.38	3.68

*, **Significant at p<0.05 and 0.01, respectively ; NS, non-significant ; PL, peduncle length; PH, plant height; SPSM, spike per square meter; GPS, grain per spike; TGW, thousand kernel weight; GY, grain yield; BY, biological yield; HI, harvest index.

higher 1000 grain weight and more numbers of spikes per unit area (Table 2).

Biological yield was higher in Sararood due to higher plant height and longer peduncles. Considering high cor-relation between grain yield and number of grain per spike ($r=0.89^{**}$), 1000 grain weight ($r=0.63^{**}$), biological yield ($r= 0.60^{**}$), harvest index ($r=0.93^{**}$) and these components being higher in Sararood region, it was predictable that yield would be higher there (Table 4). Giunta et al. (1993) showed that drought stress reduced all yield components so that numbers of fertile spikes as well as number of grains per spike were decreased by 60 and 48%, respectively.

In a research done on three wheat cultivars in four regions under drought stress, Shanahan et al. (1984) reported that grain yield, number of spike per unit area, number of grain per spike, and 1000 grain weight were different for each cultivar in different regions. Also Gupta et al. (2001) reported that during wheat anthesis period, drought stress reduced stem dry weight, number of grains, 1000 grain weight, grain yield, harvest index and biological yield.

In our study, drought stress had highly significant effect (p=0.01) on grain yield and all yield components so that control treatment (I_4) had the highest yield equal to 6632 kg/ha and treatment (I_1) had the lowest yield, equal to 3576 kg/ha (Tables 1 and 2). Day and Intalop (1970) reported that drought stress during stem elongation stage reduced the number of days from planting to flowering, plant height, grain yield, grain volumetric weight, number of spike per unit area, number of grain per spike and increased lodging with reduction of number of spike, grain yield also was decreased. Therefore, yield depends on number of grains per spike under such conditions, as a result, a significant correlation was observed between number of grain per spike and grain yield (Table 4).

Comparison of grain yield and yield components means shows that numbers of spikes per unit area(709.35 spikes) and number of grain per spike (17.7 grains) were reduced by treatment (I_1) (Tables 1 and 2). Saleem (2003) reported that during stem elongation stage, mois-ture stress reduced grain yield due to fewer number of spikes per unit area and fewer number of grains per spike. Due to I_1 treatment, grain yield showed significant correlation with number of spikes per unit area ($r=0.80^{**}$), biological yield ($r=47^{**}$), number of grain per spike ($r=0.68^{**}$), plant height ($r=0.47^{*}$), 100 grain weight (0.85^{**}) and harvest index ($r=0.59^{**}$) (Table, 4). Because of I_2 treatment, between grain yield and number of spike per unit area ($r=0.80^{**}$), biological yield ($r=57^{**}$) number of grain per spike ($r=0.56^{**}$) and plant height ($r=0.47^{*}$) were significantly correlated (Table 4). Richards et al. (2001) declared that during flowering stage, drought stress disrupted photosynthesis and transfer of stored sub-stances into grains, which can cause reduction in the number and weight of grains. Under I_3 treatment, grain yield had high correlation with harvest index ($r= 0.69^{**}$) and spike number per square meter (r=

Table 2. Effect of cultivar and irrigation on grain yield, yield components and some morphological traits.

Irrigation	PL (cm)	PH (cm)	SPSM	GPS	TGW (g)	GY (kgh^{-1})	BY (kgh^{-1})	HI(%)
I1	24.72C	58.44C	709.3B	17.79B	31.04B	3576D	10600C	32.90D
I2	27.02B	68.14B	705.3B	20.12C	32.19B	4210C	12440B	34.71C
I3	28.84B	82.54A	723.8A	24.32B	34.89AB	4607B	11780B	40.20B
I4	33.43A	89.46A	712.4B	28.89A	39.46A	6632A	13690A	49.41A
Cultivar								
C1	32.88A	83.62A	717.6A	23.72A	35.55A	4999A	12610A	40.87A
C2	26.86B	71.83B	715.3A	23.25B	35.06B	4849A	12230AB	39.68B
C3	25.77B	69.23B	705.2B	21.37C	32.57C	4428B	11520B	37.36C
Experimental location								
Mahidasht Sararood	28.08b	73.58b	710.34a	22.26a	33.74b	4639b	11956a	38.51b
	29.74a	79.34a	715.05a	22.29a	35.05a	4873a	12280a	40.08a

Within treatment means followed by the same letter are not significantly at $p < 0.05$ according to Duncan's multiple range test. PL, Peduncle length; PH, plant height; SPSM, spike per square meter; GPS, grains per spike; TGW, thousand grain weight; GY, grain yield; BY, biological yield; HI, harvest index: I1,I2,I3 and I4 ; 80% moisture depletion from stem elongation to end season; 80% moisture depletion from boot stage to end season; 80% moisture depletion from grain filling to end season and 40% moisture depletion during growing season(Control);C1,C2 and C3: Chamran, Marvdasht and Shahriar cultivars.

Table 3. Interaction effect between cultivar and irrigation on grain yield, yield components and some morphological traits.

Treatment	PL (m)	PH (cm)	SPSM	GPS	TGW (g)	GY (kgh^{-1})	BY (kgh^{-1})	HI(%)
I1C1	2877 BCDEF	71.70 CDE	714.7BCD	19.0 I	32.25 GH	3921 FG	11780 BC	35.83F
I2C2	22.58 F	51.68 F	709.7COE	18.05J	31.53H	3669 B	11000 C	32.77 K
I3C3	22.82 EF	51.93 F	703.7DE	16.32K	29.33J	3139 H	9023 D	30.09 I
I2C1	30.80 BCD	77.10 BCD	713.8BCD	21.45G	33.62F	4510 CD	12980 ABC	36.00 F
I2C2	25.60 CDEF	66.25 DE	703.8DE	20.53H	32.25 GH	4146 DEF	12190 ABC	34.74 FG
I3C3	24.65 DEF	63.47 EF	698.2E	18.38IJ	30.72 I	3975 EFG	12040 ABC	33.39GH
I3C1	33.75 AB	25.28 B	735.8A	25.67 D	36.60 D	4336 C	11800 BC	42.29 D
I3C2	27.08 BCDEF	81.99 BC	721.9BE	24.18 E	35.33 E	4595 CD	11840 BC	39.28 E
I3C3	25.70 CDEF	79.67 BCD	713.8 BCD	23.12 F	32.75 G	4391 CDE	11690 BC	38.42 E
I4C1	38.22 A	99.70 A	706.2 DE	28.77 B	59.75 B	6702 A	13860 A	49.33 B
I4C2	32.18 ABC	86.82 B	725.9 AB	30.23A	41.13 A	6986 A	13890 A	51.34 A
I4C3	29.90 BCDE	81.85 BC	705.0 DE	27.67 C	37.48 C	6207 B	13330 AB	47.55 C

Within treatment means followed by the same letter are not significantly at $p < 0.05$ according to Duncan's multiple range test. PL, Peduncle length; PH, plant height; SPSM, spike per square meter; GPS, grains per spike; TGW, thousand grain weight; GY, grain yield; BY, biological yield; HI, harvest index: I1,I2,I3 and I4 ; 80% moisture depletion from stem elongation to end season; 80% moisture depletion from boot stage to end season; 80% moisture depletion from grain filling to end season and 40% moisture depletion during growing season(Control); C1,C2 and C3: Chamran, Marvdasht and Shahriar cultivars.

0.73^{**}) (Table 4).Day and Intalop (1970) reported that considerable decrease in grain yield for stress during stem elongation stage was because of reduction of number of spike per unit area and of grain yield per spike. I_2 with grain yield equal to 4210 kg/ha shows 57% yield reduction com-pared to control treatment (I_4). Moustafa et al. (1996) declared that imposing drought stress at time of wheat spike initiation sharply decreased the yield.

I_3 with yield equal to 4607 kg/ha shows 43% reduction of yield compared to control treatment (I_4). Sieling et al. (1994) reported that post flowering drought stress reduces the number of spikes and grains per spike; it can even reduce grain weight during final growth stages.

Raynolds et al. (2000), Svihra et al.(1996) and Donaldson (1996) reported that post anthesis drought stress reduces grain filling rate, resulting in reduction of

Table4. Correlation coefficients of grain yield with yield components and some morphological traits in wheat.

Character		PL (cm)	PH (cm)	GPS	SPSM	TGW (g)	BY (kgh^{-1})	HI(%)
Grain yield (all of data)		0.564**	0.698 **	0.897 **	0.158 ns	0.633 **	0.606 **	0.930 **
	Irrigation							
	I1	0.45 ns	0.473 *	0.677 **	0.804 **	0.859 **	0.474 *	0.594 **
Grain yield	I2	0.013 ns	0.472*	0.565 *	0.804 **	0.429 ns	0.579 *	0.030 ns
	I3	0.248 ns	0.310 ns	0.186 ns	0.724 **	-0.380 ns	0.341 ns	0.689 **
	I4	0.125 ns	0.279 ns	0.281 ns	-0.62 ns	0.436 ns	0.223 ns	0.697 **
	Cultivars							
Grain yield	C1	0.609 **	0.708 **	0.884 **	-0.236 ns	0.505 **	0.65 **	0.862 **
	C2	0.527 **	0.700 **	0.879 **	0.537 ns	0.716 **	0.780 **	0.929 **
	C3	0.630 **	0.724 **	0.920 **	-0.189 ns	0.588 **	0.570 **	0.980 **

P^{*}<0.05; ** p<0.01; NS: Non-significant.; PL, peduncle length; PH, plant height; GPS , grain per spike; SPSM, spike per square meter; TGW, thousand grain weight; BY, biological yield; HI, harvest index; I1,I2,I3 and I4; 80% moisture depletion from stem elongation to end season; 80% moisture depletion from boot stage to end season; 80% moisture depletion from grain filling to end season and 40% moisture depletion during growing season(Control); C_1,C_2 and C_3: Chamran, Marvdasht and Shahriar cultivars.

1000 grain weight which is in agreement with the results of this experiment. Since availability of water for this treatment was limited at flowing time, fewer grains were produced and the plants were able to avoid terminal season stress condition and prevented high decrease in yield, by increasing grain weight through flowing photo-synthesis, available water and through remobilization of substances due to higher biological yield caused by higher plant's height and longer length of peduncles. Plaut et al. (2004) declared that weight of 1000 grains and of grains per spike were sharply reduced by occurring drought stress in the post anthesis stage.

The result of inter- trait correlation analysis in experiments done under drought and normal stress conditions indicated that traits of grains per spike,1000 grain weight, number of spikes per plant, peduncle length , biological yield and harvest index had significant positive correlations with grain yield under irrigated and normal conditions (Merah et al., 2001).

The results of variance analysis for gain yield and all yield components shows a significant difference among the testing cultivars. So that Chamran CV (C_1) with a yield equal to 4992 kg/ha produced the highest yield and was at par with Marvdasht CV (C_2) with a yield equal to 4849 kg/ha within a statistical group, but of Shahriar CV (C_3) with a yield equal to 4428 kg/ha shows a significant difference with Chamran (C_1) and Marvdasht CV (C_2). The values of all testing traits were highest for Chamran CV (C_1). Higher 1000 grain weight in C1 and C2 indicates the inability of Shahriar CV (C_3) to transfer substances into grain in comparison with Chamran (C_1) and Marvdasht CV (C_2) (Table 2). The results of grain yield and yield components correlations shows that, for all the cultivars, number of grain per spike had the highest correlation with grain yield (Table 4), indicating the importance of number of grains per spike in determining grain yield of testing cultivars; harvest index, biological yield, 1000 grain weight were of subsequent importance. Also, plant height and peduncle length had significant effects on grain yield, having high correlation with it.

Dejan et al. (2002) also reported high significant positive correlation between grain yield and the number of grains per spike. The results of experiments shows that, under moisture stress conditions, number of spikes per square meter, number of grains per spike, number of days prior to flowering had significant positive correlations with grain yield of plants (Garcia et al., 2003). They also concluded that under favorable conditions, properties of number of days prior to flowering, duration of grain filling period and grain weight per square meter had significant positive correlations with grain yield. Also, the results of path analysis indicated that number of grains per spike had the highest direct positive effect on grain yield (Table 5).

Calderini et al. (1999) believe that the increase in grain yield is largely dependent on the increase in grain number, in that this yield component is of more importance than 1000 grain weight. The best linear equation obtained from stepwise forward regression for yield components is as follows:

$$Y = 229.855\ NGPS - 2.058\ NSPM + 28.603 TGW$$

$$R^2 = 0.98^{**}$$

Where, NGPS = Number of grains per spike; NSPM = number of spikes per square meter; TGW=1000 grain weight, from which the first component entering model and having the most important is the number of grains per spike (NGPS) followed by number of grains per square meter (NGPM) and 1000-grain weight(TGW).

Generally, the difference between grain yields of

Table 5. Path coefficient analysis for wheat grain yield components.

Character	Direct effect	SPSM	Indirect effect (GPS)	TGW
SPSM	- 0.142	-	0.271	0.029
GPS	0.864 **	0.271	-	0.077
TGW	0.124 **	0.029	0.077	-

Residual = 0.41. *' * Significant at the 0.01 and 0.05 probability level. Spike; Respectively. SPSM, spike per square meter; GPS, grain per TGW, thousand grain weight.

cultivars can be attributed to differences in these traits, among which the share of numbers of grains per spike is the highest among all. Leilah and Khateeb (2005) demonstrated that five traits of grain weight per spike, harvest index, biological yield, number of spike per square meter and spike length were introduced into stepwise regression model, accounting for 98.1% of grain yield variance. The results of this analysis are in agreement with Moragues et al. (2006) findings. In the present experiment, results of variance analysis showed that cultivar and drought stress interaction effects on traits of harvest index, 1000 grain weight, number of grain per spike, and number of spike per unit area are significant (Table3). The highest and lowest 1000 grain weights related to Marvdasht CV (C_2) and control treatment (I_4), and Shahriar CV (C_3) and treatment (I_1), respectively. Also, the highest and lowest number of grain per spike related to Marvdasht cultivar (C_2) and treatment (I_4) and Shahriar CV (C_3) and treatment (I_1), respectively. And the highest number of grain per unit area related to Chamran CV (C_1) and treatment (I_3), and after it, related with treatment (I_4) and Marvdasht CV (C_2). Marvdasht CV (C_2) had the highest grain yield under full irrigation condition (I_4) and the lowest grain yield under stress treatment (I_1) related with Shahriar CV (C_3).

Review of results shows that, under moisture stress conditions, Chamran (C_1) and Shahriar CV (C_3) had the highest and lowest yield, respectively. Fischer (1979) believes that there was genotypic variance between wheat cultivars in terms of drought tolerance and, usually cultivars having high yields under normal conditions better tolerate stress conditions and produce acceptable yields.

Conclusion

Analysis of simple correlation, stepwise regression and path analysis shows that in total, the given direct and indirect effects of yield components on grain yield, number of grains per spike had the highest effect on grain yield. Number of grains per spike, which accounts for a high degree of variation in grain yield, can be considered to improve wheat grain yield. High yield of Chamran CV (C_1) is associated with number of grains per spike since this cultivar has retained superiority of its number of grains per spike in all drought stress treatments (Table 3). In general, these results confirm that Chamran CV (C_1) is one of the cultivars with high yield potential in moisture stress conditions, especially in terminal season drought stress conditions and enjoys high stability of yield and Marvdasht CV (C_2) is one of the cultivars with high yield in full irrigation condition.

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