International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 5, No. 10, p. 146-154, 2014

RESEARCH PAPER OPEN ACCESS

The effect of drought stress in dry farming conditions on grain yield and some morphologic traits in various bread wheat genotypes

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Key words: Beard Wheat, Coefficient of Correlation, Dry, Genotype.

http://dx.doi.org/10.12692/ijb/5.10.146-154 Article published on November 26, 2014

Abstract

In order to assess and classify the morphological traits of bread wheat in drought stress conditions (dry farming), 18 bread wheat cultivars were studied. This experiment was performed in the form of a randomized complete blocks design (RCBD) in Gachsaran Dryland Agricultural Research Station during the agricultural years of 2010-2011. Variance of genotypes was significant for the traits, so there was a high genetic diversity among the traits. The studied traits included; agronomic score, spikelets per spike, leaf length, spike weight, grain length, thousand kernel weight (TKW) and grain yield. The results obtained showed that the total weight of the spike had the highest correlation with grain yield in dry farming conditions. Based on the results obtained of tests of resistance to dry stress genotypes of 16, 8 and 6 are the most resistant genotypes to drought stress. Generally, one can conclude that the traits of agronomic score and Spikelets per spike are main traits for recognizing superior genotypes.

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Introduction

The increase in the world population means increased demand for food. Especially when most of the foods are supplied by plants, especially grains. Furthermore, drought is one of the major global threats for food production, in addition climate change and increase in global population expands the scale of this problem. One way to solve this problem is to use new varieties with greater tolerance to dry stress (Takeda and Matsuoka, 2008) (Passioura, 2006). Today, one third of the world's arable lands are facing water shortfall and it is expected to reach about two-thirds up to 2025 (Annan, 2001). Due to the shortage of water resources, efficient use of each unit of water volume in crop production seems necessary. The amount of rainfall and its poor distribution in tropical and subtropical areas caused drought and heat stresses to act as the main limiting factors of crop productions in these regions (Pospisilova, *et al.*, 2000) (Saranga, *et al*, 2001). About 50 percent of the agricultural products in Iran due to the lack of water and poor distribution of rainfall are conducted in the form of dry farming in semi-arid areas (Sabaghpour, *et al.*, 2006). Drought stress affects the content of leaf water, photosynthesis and water use efficiency (Egilla, *et al.*, 2005) (Cattivelli, *et al.*, 2008). According to some researchers, the selection for high yield under non-stress conditions improve plant yield (Fernandes, *et al*, 1996; Blum, 2001).Wheat is one of the most important crops in terms of cultivation area and amount of production in the world that plays an essential role in supplying the nutrient need of in human societies. One of the major factors limiting development of wheat in the world is environmental stresses such as drought stress which is one the major obstacles to attain the full yield potential of this plant. Therefore, identification of resistance varieties and studying the mechanisms which increase resistance to drought stress are among appropriate strategies for coping with the effects of drought stress (Rajaram *et al.*, 1996). This study was designed to identify drought stress resistant varieties of bread wheat and the effect of drought stress on morphological traits and correlations of traits with each other. The main objective of this study was to investigate the correlations of different traits and effect of morphological traits associated with the increase drought tolerance on bread wheat genotypes under dry farming conditions in Gachsaran country, Kohgiluyeh-va-Boyer-Ahmad Province, Iran.

Materials and methods

The location of project

The research was conducted during the agricultural years of 2010-2011 in Gachsaran Dryland Agricultural Research Station which is located at longitude 50 degrees 50 minutes and latitude 30 degrees and 17 minutes and altitude of 710 meters in Kohgiluyeh-va-Boyer-Ahmad Province at southwestern Iran. The area is classified as hot and dry climate areas. Mean annual rainfall in the long term (thirty-year mean) was calculated 479.3 mm and mean long-term evaporation (mean thirty-year during agricultural season) was calculated 1202.7 mm (Motamedi Pour, 2012).

Cultivation Steps

Preparing the ground was performed after the first effective rainfall in the form of till, disk, clearing and fertilizer application on the basis of 60 kg per hectare Urea and 80 kg of potassium sulfate per hectare. Before planting, the seeds were disinfected with an appropriate fungicide. Seeds of various wheat genotypes in the first week of January were planted in 6 lines, each 6 meters in length and 5.17 cm spacing by seed planting machine in dry farming. The amount of basic fertilizer consumption was 120 kg ammonium phosphate per hectare basis and 80 kg Urea per hectare in the dry farming conditions. Cares such as fight against weeds before stem elongation and Tillering was done on the right time through 2-4-D herbicide (Motamedi Pour, 2012).

Studied Traits

In this experiment, 18 bread wheat genotypes were plant in the form of a randomized complete blocks design (RCBD) with four replications in dry farming conditions. The studied traits included; agronomic score, spikelets per spike, leaf length, spike weight, grain length, thousand kernel weight (TKW) and grain yield.

Methods of measuring traits

To obtain the size of each of the traits individually after performing the genotype design in replications, the genotype mean of four replications was indicated and included as the final data for each genotype in desired trait.

Agronomic Score (AS)

Based on the observations of all important agronomic traits, each genotype in each plot was assigned an agronomic score and then the mean scores were determined.

Leaf Length

To this end, 5 samples of normal leaves were selected from each plot and the length measured using a ruler in cm.

The number of spikelets per spike (SS)

10 spikes were selected from each plot and the numbers of spikelets were counted, then the mean number of was calculated for each plot and from the mean of replications the mean number of spikelets per spike was calculated for each genotype.

Grain Yield (GYD)

To determine the grain yield of harvested seed, each plot was harvested by using a combine and weighted by a digital scale in grams. This figure was defined in terms of kilogram per hectare and extended.

Grain length (GL)

From among the seeds of 10 clusters, 20 seeds were selected and seed length of 20 seeds was calculated in centimeters and its mean was determined.

Thousand kernel weight (TKW)

First of all thousand seeds of each plot were calculated using the counting machine and then weighed using a precision balance to determine thousand kernel weight (TKW) per plot.

Spikes total weight (SW)

When the spikes ripened and clusters dried, 10 main normal spikes were selected from each plot and weighed then the mean total weight of spike was obtained.

Drought stress resistance indexes and their calculation

In 1992, Fernandez based on response to stress and or non-stressed conditions classified the genotypes of plants in four groups.

Group A: Genotypes with high yield in both environments (stress and favorable).

Group B: Genotypes with good seed yield only in non-stress environments.

Group C: Genotypes with good seed yield in stress environment.

Group D: Genotypes with poor seed yield in both environments.

He also stated that the most suitable selection criterion for stress is an index that is able to detect group A from other groups. Therefore to identify the varieties of group A, this researcher provided the stress tolerance index (STI). The high value of this index for genotype indicates the greater drought tolerance and higher yield potential of that genotype. This index is able to identify the genotypes of group A (Genotypes with high yield in both environments (stress and favorable) than other groups. Drought tolerance index was calculated by the following formula.

*STI= (YP*YS)/ (Mp) 2*

In this formula, YP and YS are respectively, the mean yield of each genotype in the favorable and stress environment. Genotypes with higher stress tolerance index will have high drought tolerance and yield. In a research conducted in 1978 SSI was identified as stress sensitive index which can be calculated by the following formulas:

SI=1-(Mys-Myp), SSI= ((1-(YS/YP))/SI

In this formula Myp is the mean of genotypes under non-stress conditions, Mys is the mean of genotypes under stress conditions, SI stress intensity (in less amount of tension, genotype will have greater drought resistance), YS is the yield of each genotype in stress conditions, YP yield of each genotype in non-stress conditions and SSI is drought stress sensitive index (Fischer and Maurer, 1978). Provided indicators, lead the selection toward low-yielding but drought resistant varieties. In another study that was conducted in 1981, drought tolerance indices were calculated through the following relationships: tolerance index (TOL) and Mean Productivity (MP) are obtained respectively by the relations of MP= (YP-YS)/2) and TOL=YP-Ys Where YP and YS, respectively are the yield of each genotype in stressed and non-stressed conditions. The smaller the drought tolerance index the less sensitive will be against drought (Rosielle and Hambelen, 1981).

Statistical Analysis

The results obtained were analyzed using the statistical software SAS, SPSS, EXCEL and the mean of data were compared by Duncan test.

Results and conclusion

Agronomic Score (AS)

The results of variance analysis indicated that water stress (dry farming) had a significant effect at the level of 1% on the trait of agronomic score in various genotypes of wheat (Table 1). Among various genotypes of wheat in mild stress conditions (dry farming) the highest agronomic score was 12.4 which related to the treatments of 16 and 18, which their difference was significant with most treatments. Also the among these genotypes lowest agronomic score was 3 and belonged to the treatment of genotype14 (Table 2).

Grain Yield (GYD)

Analysis of variance indicated that grain yield trait under water stress conditions had a significant effect at the level of five percent on the various genotypes of wheat (Table1). According to the mean comparison table in mild dry farming stress conditions the highest grain yield (2754.1 kg/ha) belonged to the treatment of genotype 3. Line number 3 had a significant difference with treatments 9 and 14 but the rest of the lines in terms of grain yield had no significant difference. The lowest yield among studied genotypes in moderate stress conditions (dry farming) (2066.2) was observed in treatment14 (Table 2). In a study on various genotypes of bread wheat under drought stress it was reported that grain yield, thousand kernel weight, harvest index and biomass yield were significantly affected by the drought. It also stated that increasing the severity of drought stress, especially at critical reproductive stages such as pollination and grain fill more reduces the grain yield (Dastfal *et al.*, 2009). Investigating the results of supplementary irrigation conditions indicates that among the studied genotypes the highest yield is equal to 4557 which belongs to treatment 2 and there was no significant difference between this treatment and 1, 3, 9 and 13 treatments. However, this treatment has a significant difference with most of the treatments. Among studied genotypes under supplementary irrigation conditions the lowest grain yield was 3274 which belonged to the treatment number 7 which its difference with most of the treatments is significant at the level of five percent (Table 8). The reason for the low grain yield in medium stress conditions (dry farming) in some genotypes is mainly due to the stress conditions and thereby reduction in the duration of developmental stages particularly pollination until ripening and above all grain filling period due to not having enough time of the next stage from pollination until ripening and also the interface of plant with very high temperatures of the first half of May reduced grain filling period and consequently severely wrinkled and emaciated seeds and ultimately reduced grain yield. Wheat varieties with high yield potential have key role in increasing the yield per hectare in the appropriate growth conditions (Qasim *et al.*, 2008). Grain yield has high positive correlation with the number of grains per spike, biological yield and harvest index; the number of grain alone from 35.2% to 78.1% justifies the yield variations (Ouda and Elmarsafawy, 2005). The grain yield in cereal is the result of the multiplication of three components, the number of spike per unit area, number of grains per spike and the mean weight of each seed (Y = Nr Ng Wg) (Kochaki and Sarmadnya, 2001).

Thousand Kernel Weight (TKW)

Analysis of variance indicated water stress (dry farming) had a significant effect at the level of one percent on TKW trait in various genotypes of wheat (Table 1). The results of the mean comparison indicated that in dry farming stress conditions the highest TKW (25.5 g) belonged to the treatment of line15 and the lowest TKW was (20.6 g) which belonged to the treatment 10 (Table 2). The high TKW weight in this treatment may be due to greater tolerance and efficient use of resources by this genotype than other genotypes in the dry conditions. Unfavorable environmental conditions that are mainly due to the lack of moisture and high temperature is a part of grain filling period which can reduce the remobilization of stored materials in vegetative organs to grain and metabolism of within grains faces with difficulty and therefore grain weight reduces (Askari *et al.*, 2002.) In these conditions, genotypes tolerate less damage, seed weight increases and ultimately produce more yield. Farshadfar and Mohammadi (2006) in the evaluation of drought tolerance in bread wheat genotypes expressed that from the view point of TKW, yield and most of the studied traits both stressed and non-stressed environments are significantly different which indicates the different reaction of wheat genotypes to drought treatments.

Table 1. Variance analysis of different traits of wheat genotypes under dry farming.

S.O.V	DF							
Sources of variation	Degrees of freedom	Agronomic Score	Grain yield	TKW	Spike weight	Number of spikelets per spike	Seed length	Leaf length
Repeat	3	1.59	4903212	484.2	427.4	8.63	1.73	40.13
Treatments	17	0.45**	152810*	9.38**	13.82**	2.82**	0.298*	7.06*
Error	51	0.16	109755	5.26	4.36	0.655	0.163	3.51
Coefficient of (%)Variation	-	11.38	13.78	9.98	7.91	4.21	6.19	9.11

*: Significantly different at P < 0.05 , **: Significantly different at P < 0.01.

The spike weight (SW)

Analysis of variance indicated water stress (dry farming) had a significant effect at the level of one percent on the spike weight trait in various genotypes of wheat (Table 1). The results of the mean comparison indicated that in dry farming stress conditions the highest spike weight (30.4 g) belonged to the treatment of line15 which had no significant difference with lines 4, 6, 12 and 13. The lowest spike weight was (22.3 g) which belonged to the line 14 (Table 2). Kobota in his experiment on different wheat varieties under moderate stress conditions of (dry farming) reported that the number of spikelets per spike, grains per spike, spike weight and peduncle length were affected by drought had a significant difference (Kobota, *et al.*, 1992).

The number of spikelets per spike (SS)

Analysis of variance indicated water stress (dry farming) had a significant effect at the level of one percent on the number of spikelets per spike in various genotypes of wheat (Table 1). The results of the mean comparison indicated that in dry farming stress conditions the highest number of spikelets per spike (20.5 cm) belonged to the treatment of line3 and the lowest number of spikelets per spike was (17.9 cm) which was observed in line 5 (Table 2). Khezri Afravi *et al.*, (2009) in their experiment on wheat stated that the stepwise regression analysis of traits showed that in normal conditions the number of spikelets per spike and days to flowering under stress conditions are more important than the traits such as spike weight, number of grains per spike, number of tillers and biological function.

Grain length (GL)

Analysis of variance indicated water stress (dry farming) had a significant effect at the level of five percent on the length of the grain in various genotypes of wheat (Table 1). The results of the mean comparison indicated that in dry farming stress conditions the highest grain length (12.7 cm) belonged to the treatment 4 (Table 2) which was significantly different with lines 2, 3, 6, 8, 10, 12 and 18. Minimum grain length (5.82 cm) was observed in the treatment 6 (Table 2.)

Table 2. Comparison of mean square of different traits of wheat genotypes under dry farming.

Dryland conditions	Agronomic Score	Grain Yield Kg / hec	TKW Gr	Number of spikelets per spike	Seed length Cm	Leaf length Cm	Spike weight Gr
1	3.5 abcd	2514.5ab	24.8abc	19.8ab	6.67ab	21.1abc	25.5cde
2	3.75 abc	2577.4ab	21.6bcd	20.1ab	6.35bc	19.3bcd	25.3cde
3	4 ab	2754.1a	21.9abcd	20.5a	6.27bc	20.4abcd	25.1cde
4	3.75 abc	2455ab	25.4ab	19.9ab	7.12a	19.9bcd	28.2abcd
5	3.25cd	2249.8ab	25.4ab	17.9e	6.82ab	20.2bcd	25.8bcd
6	3.12cd	2399.8ab	23.8abcd	19.7ab	5.28c	21.3abc	28abcd
7	3.62abcd	2124ab	22.2abcd	18.3de	6.45abc	21.1abc	25.8bcd
8	3.37abcd	2336ab	22.9abcd	20.2ab	6.32bc	23.5a	26.7bcd
9	3.75abc	2155b	21.5bcd	18.3de	66.57ab	20.1bcd	25.7bcde
10	3.62abcd	2489.5ab	20.6d	19bcde	6.4bc	19.7bcd	25.8bcd
11	3.25cd	2228ab	22.3abcd	19.1bcde	6.5abc	18.7cd	26.3bcd
12	3.62abcd	2394.2ab	22.5abcd	19.6abc	6.4bc	20.4bcd	29.2ab
13	3.12cd	2316.6ab	23.9abcd	20ab	6.47abc	21.7abc	28.6abc
14	3d	2066.2b	21.2cd	18.1de	6.67ab	20.2bcd	22.3e
15	3.62abcd	2541.6ab	25.5a	19.7ab	6.67ab	17.8d	30.4a
16	4.12a	2752.8a	22.2abcd	18.4cde	6.77ab	22.2ab	25.6cde
17	3.37bcd	2416.2ab	23.4abcd	19.3abcd	6.52ab	20.4bcd	26bcd
18	4.12a	2514.9ab	23.4abcd	18.2de	6.37bc	22.1ab	24.9de

Similar letters in each column indicate no significant difference at 5% level based Duncan's multiple range tests.

Leaf length (LL)

Analysis of variance indicated water stress (dry farming) had a significant effect at the level of five percent on the leaf length in various genotypes of wheat (Table 1). The results of the mean comparison indicated that in dry farming stress conditions the highest leaf length (23.5 cm) belonged to the treatment 8 (Table 2) which had no significant difference with lines 1, 3, 6, 13, 16 and 18 (Table 2). Minimum leaf length (17.8 cm) was observed in the treatment 15 (Table 2).

The correlation coefficients of studied parameters in various genotypes of wheat under water stress conditions (dry farming)

According to the table of correlation coefficients, it is observed that the trait of AS had a positive and significant correlation with grain yield, TWk, spike weight traits at the level of one percent and positive and significant correlation with leaf length at the level of five percent (Table 3). Table of correlation coefficients of traits showed that grain yield trait had a positive and significant correlation with AS, TKW, spike weight, number of spikelets per spike and leaf length at the level of one percent (Table 3). Based on the results of the correlation coefficient table of traits, TKW trait had a significant positive correlation with AS, grain yield and Spike weight traits at the level of one percent (Table 3). Based on the results obtained of the correlation coefficient table, spike weight trait had a positive and significant correlation with AS, grain yield, TKW and number of spikelets per spike at the level of one percent (Table 3). The results of correlation coefficient table of traits showed that number of spikelets per spike had a Positive and significant correlation with grain yield and spike weight at the level of one percent (Table 3). The results of correlation coefficient table of traits showed that grain length trait had a negative and significant correlation with leaf length. Based on the results of the correlation coefficient table of traits, leaf length trait had a positive and significant correlation with grain yield at the one percent level and had a positive and significant correlation with agronomic score traits and spike weight at five percent level (Table 3).

In an experiment on different wheat varieties under moderate stress conditions (dry farming) a significant positive correlation between TKW and grain yield was reported and it was also observed that the correlation between the number of seeds in spike and total weight of spike with grain yield was significant and positive (Leilah, 2005). Golparvar *et al.*, (2000) in an experiment on bread wheat reported that the trait of spike grain yield has negative indirect effect via the number of grains per spike on the grain yield of plant; but because of its large direct and indirect impacts that especially through the number of seeds influences this trait is positively and significantly correlated with it.

Table 3. correlation coefficients between different traits.

Dry farming	AS	GYD	TKW	SW	SS	GL	LL
AS	1	0.65**	0.28**	0.32**	0.13	0.04	0.23*
GYD		1	0.66**	0.72**	0.32**	0.01	0.35**
TKW			1	0.71**	0.08	0.17	0.07
SW				1	0.32**	0.1	0.22*
SS					1	0.1	0.11
GL						1	-0.01
LL							1

*: Significantly different at $P < 0.05$, **: Significantly different at $P < 0.01$.

Table 4. Indices of drought resistance in different genotypes.

Different wheat genotypes	Stress susceptibility index (SSI)	STI (STL)	Tolerance index (TOL)	Mean productivity (MP)
1	0.274	17.078	1546.5	773.25
2	0.4344	11.998	1979.6	989.8
3	0.3680	18.663	1603.9	801.95
4	0.3739	17.916	1466	733
5	0.3356	23.604	1136.2	568.1
6	0.2879	34.367	970.2	458.1
7	0.3512	21.033	1150	575
8	0.2887	34.144	948	474
9	0.4695	9.628	1907	953.5
10	0.3768	17.552	1505.5	752.75
11	0.4104	14.000	1551	775.5
12	0.3335	23.977	1197.8	598.9
13	0.4339	12.03	1775.4	887.7
14	0.4837	8.826	1935.8	967.9
15	0.3103	28.656	1143.4	571.7
16	0.2429	51.326	883.2	441.6
17	0.3443	22.123	1268.8	634.4
18	0.2295	31.245	1075.1	537.55

Drought stress resistance indexes

The results showed that some genotypes in non-stressed condition yield highly, while their yield in moisture stress conditions was not high. Within this an index which can detect first group genotypes from the rest of the group is of the utmost importance.

According to Table (4), it is observed that based on stress tolerance index (STI) and the stress sensitive index (SSI) genotypes 16, 8 and 6, respectively has the most STI ,that these genotypes in comparison with most genotypes are more resistant to drought and dehydrated conditions. Also it is observed that in these conditions genotypes of 14, 9, 2 and 13 between various genotypes of wheat are less resistant to drought .Genotypes 16, 8 and 6, which had the highest value of these indices, were identified and selected as most tolerant genotypes. Shafazadeh *et al.*, (?) reported the same conclusion for the mentioned indices and stated that STI, SSI, MP and TOL, due to having positive and significant correlation with grain yield under drought stressed and non-stressed can be used to identify high yielding and drought tolerant genotypes in both environmental conditions.

Conclusion

In this study, the correlation of six different agronomic traits with grain yield and together was studied. In the correlation of traits with grain yield which was the base of our measurements five traits of those traits had significant correlation with yield in dry farming conditions. The total traits of the spike weight (r_{sw} = 0.72), thousand kernal weight (r_{TKW} = 0.66), AS (r_{AS} =0.65), Leaf length (r_{LL}= -0.35) and number of spikelets per spike (r_{SS}=0.32) had positive and significant correlation at the level of one percent with grain yield. Based on these results, no significant correlation was observed between grain length trait (r_{GL}=0.01) and grain yield. Genotypes were compared using drought indices of Fernandez and it was observed that genotypes 16, 8 and 6 respectively, had the highest STI and compared with other genotypes were more resistant to drought and dehydrated conditions. It is suggested that other research stations conduct the same research in irrigated-fed conditions and compare the results with the results of this study.

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