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Yield and yield components in bread wheat (*Triticum aestivum* L.) under non-stress and drought stress conditions

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Abstract

The experiment was conducted at the Agricultural Research Center of East Azarbaijan province during the cropping seasons of 2012 -2013 in order to evaluate effect of water stress on morphological traits, yield and yield components. In this research, five genotypes of winter wheat cultivars were used which were certified for Azerbaijan (cold and arid climate). Cultivars were included: Alvand, Azar 2, MV17, Sardari and Omid. The experimental design was implemented in form of factorial based on completely randomized design with three replications and two irrigation combination (normal irrigation and drought stress after heading). The results demonstrated that in non-stress condition, grain yield had positive and significant correlation with all traits except for flag leaf area, number of fertile tiller and 1000-grains weight. In drought stress condition, grain yield had positive and significant correlation just with straw yield and harvest index and also had negative and significant correlation with number of fertile tiller and plant height. Path analysis in each experimental condition revealed that under non-stress condition, direct effect of biological yield on grain yield was higher than other traits. Number of fertile tiller with low relative intensity had positive direct effect and plant height had negative direct effect on grain yield.

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Introduction

Wheat is one of the important and strategically crop because not only its cultivation is easy but also is essential and primary food for majority of world populations (Hassani *et al*, 1384). Wheat is an important cereal and main food for people all over the world (Rauf *et al*, 2007). Nowadays, increase wheat production due to encountering more demand as a consequence of population growth in many countries is still a challenge (Hamam *et al.*, 2008). On the other hand, production of agricultural crops encounters various biotic and abiotic stresses (Mahajan and Tutjan, 2005). Drought is a meteorological phenomenon that is associated with lack of precipitation over a period of time. This period is long enough to cause depletion of soil moisture which leads to drought stress with decrease in water potential of plant tissues (Syayz *et al.*, 2005). From an agricultural perspective, drought is the inadequacy of amount and distribution of usable water during plant growth which caused to reduction in incidence of complete genetic power in plant (Shao *et al.*, 2008).

Water is one of the major factors which preserved dynamic of species and population in soil (Bahrndvrf *et al.*, 2009). It is quite clear that plant survival and its growth are strongly influenced by water availability (Stiller, 2009). Insufficiency of water and drought restrict growth and development of plants, especially in arid and semi-arid regions of the world (Kohler *et al.*, 2009). The importance of this subject is clear when we know more than 25% of world lands are in arid and semi-arid areas (Komeili *et al.*, 2006). So that, 45% of the world's agriculture fields are exposed to frequent or severe drought that 38% of the world's population live in these fields (Ashraf and of folad, 2008). Water stress is effective on all aspects of plant growth and cause to intensive alterations in anatomy, physiology, morphology and its biochemically (Alizadeh, 2004). According to Rodriguez (2006), growth reduction due to drought stress is much higher than other environmental stresses. Deficiency of water is the most important responsible factor for decrease of cereal yield in global level (Rajala *et al.*, 2009). So that Abdolshahy *et al* (2009) reported about 47% reduction in yield of bread wheat due to water deficit.

Stress in agriculture is any external limiter factor that causes to failure of reaching plant production power to its genetic potential (Ahmadi *et al.*, 2006). Environmental stresses can be divided into two categories biotic and abiotic (Alksandrvvna, 2007). Due to considerable damage from environmental stresses (abiotic) to crops including cereals, investigation of plants response to environmental stresses has received much attention in recent years (Pasyvra, 2007). Among abiotic stresses, drought is serious threat for successful production of crops in worldwide (ober and Lvtrbachr, 2002, Chavs, 2002; Ashraf and Harrys, 2005). Among stressors, drought stress has the largest share. So that, about 26 % of cultivated lands in worldwide are faced with drought stress (Tas and Tas, 2007) and also deficit of available water in majority of agricultural areas, is the main reason of reduction in grain yield (Wesley *et al.*, 2002). Drought resistance is an important factor in sustainability of cereals in arid and semi-arid environments that already is evaluated by breeders and molecular biologists as valuable breeding target (Zhang *et al.*, 2005). Due to Iran location and existence of water crisis in the country, using better agronomic methods and also identify drought tolerant plants have great importance (Kuchaki and Khajeh-Hosseini, 2008). This study was performed with purpose of drought stress evaluation in wheat cultivars for selection of superior cultivars and also determines amount of drought stress effect on morphological traits, yield and yield components.

Materials and methods

Site description and experimental design

This experiment was conducted at the Agricultural Research Center of East Azarbaijan province during the cropping seasons of 2012 -2013. In this research, five genotypes of winter wheat cultivars were used which were certified for Azerbaijan (cold and arid climate). Studied cultivars have been shown in Table 1.

The used experimental design was implemented in form of factorial based on completely randomized design with three replications in two irrigation combination (normal irrigation and drought stress after heading). Before the experiment, soil samples were taken for soil test. NPK fertilizers were applied based on soil test results. Irrigation was conducted in all the plots normally with consideration to growth and phenology of plant and climate conditions but irrigation was interrupted after heading stage up to maturity for treatments under water stress.

Measurement of traits

Sampling was done with respect to margins and 10 plants as samples were tagged randomly in each plot. These samples were used for measurement of some traits but 1000-grains weight, biological yield and grain yield were measured from total experimental plot with removing their margins. Evaluated traits were included: flag leaf area, plant height at flowering stage, number of subsidiary stems, number of spike, spike length, biological yield, number of grains in main spike, grain yield and 1000- grains weight. Flag leaf area (for determination of flag leaf area, the largest length and width of main spike leaf were measured in 10 plants basis on centimeter and 0.1cm accurately). Using equation of $A= 0.7(W×L)$, flag leaf area was calculated which L and W are length and width of the leaf blade, respectively (Muller, 1991).

Statistical analysis

In order to better perception of relationship between traits, correlation coefficients between all the traits were computed and their significances were assessed at 5% and 1% probability level. Regression analysis based on backward method and path analyses were used to evaluate direct and indirect effects of impressive traits on grain yield. SPSS and EXCEL softwares were used for statistical analyses.

Results and discussion

Correlation between the traits under stress and non-stress conditions

Correlation coefficients among studied traits based on the data averages for drought stress and non-stress conditions have been presented in Tables 2 and 3. In non-stress condition, grain yield had significant and positive correlation with all traits except for flag leaf area, number of fertile tiller and 1000-grains weight. While in drought stress condition, grain yield had positive and significant correlation just with straw yield and harvest index and had negative and significant correlation with number of fertile tiller and plant height. Overall, in both experimental conditions, the highest correlation coefficient was belonged to biological yield with grain yield (in stress $r =0.84$, in non-stress $r= 0.98$) which is in conformity with results of Imam *et al* (2007). Thus it seems that this trait could be a factor in yield augmentation, so that Taiz and Ziger (2006) believed that measurement of biomass (biological yield) is the best factor for determination of plant actual tolerance to drought stress.

Table 1. Number and name of studied cultivars.

Cultivar name	Number
Alvand	1
Azar 2	2
MV17	3
Sardari	4
Omid	5

Golabadi *et al* (2008) in evaluation of late season drought stress effect on wheat, reported positive and significant correlation between grain yield with plant height, peduncle length, awn length, number of grains per spike and biological yield in terms of non-stress also they stated that in water stress condition, grain yield had positive and significant correlation with peduncle length, spike weight, biological yield and harvest index. Kyryjvy *et al* (2004) and Paknejad *et al* (2009) also reported significant positive correlation between grain yield with biological yield and harvest index under different regimes of water stress.

Also in both experimental conditions, biological yield demonstrated the highest positive correlation with straw yield (in stress $r =0.8$, in non-stress $r= 0.94$). This positive and significant correlation could be because biological yield is contained grain yield and straw yield. In non-stress conditions, biological yield had weak positive correlation with plant height, peduncle length, number of grains per spike, spike length and harvest index and also under drought stress biological yield had weak positive correlation just with 1000- grains weight. Golparvar *et al* (2006) investigated some bread wheat in both non-stress and drought stress conditions and reported positive and significant correlation between biological yield with grain yield, number of grain per spike, spike length, plant height and peduncle length at both experimental conditions and in drought stress condition in addition to these traits, biological yield had positive and significant correlation with 1000-grains weight and ear weight. They also stated that in terms of non-stress biological yield had negative and significant correlation with harvest index.

Table 2. Correlation coefficients among studied traits in wheat cultivars under normal condition.

	Biological yield	Grain yield	Straw yield	Harvest index	1000- grains weight	Number of grains in spike	Number of fertile tiller	Spike length	Peduncle length	Plant height
grain yield	0.988**									
Straw yield	0.991**	0.958**								
Harvest index	0.830**	0.895**	0.757**							
1000- grains weight	0.877**	0.842**	0.890**	0.746**						
number of grains in spike	0.700**	0.703**	0.684**	0.541**	0.374*					
number of fertile tiller	0.746**	0.707**	0.766**	0.494**	0.698**	0.582**				
spike length	0.562**	0.556**	0.557**	0.336	0.335	0.653**	0.681**			
peduncle length	0.694**	0.660**	0.711**	0.392*	0.547**	0.599**	0.680**	0.831**		
plant height	0.808**	0.757**	0.837**	0.457**	0.704**	0.579**	0.758**	0.553**	0.825**	
flag leaf area	-0.227	-0.233	-0.310	-.050	-0.189	-0.223	-0.486**	-0.520**	-0.287	0.125

* And **: significant at 5% and 1% probability level, respectively.

In stress condition, with consideration to harvest index which had positive and significant correlation with grain yield, ear components (ear length, number of grains per spike) had significant positive correlation with harvest index too. Also harvest index had correlation although weak but positive with number of fertile tiller. At stress condition, harvest index had weak negative correlation with straw yield. Mohammadi *et al* (2006) in evaluation of drought stress in some wheat cultivars observed significant negative correlation between harvest index and straw yield. With consideration to negative correlation between harvest index and straw yield in drought stress condition, existence of significant negative correlation between harvest index with plant height and peduncle length as components of straw yield seems to be natural. At drought stress condition in addition to biological yield, straw yield represented positive correlation with harvest index, 1000-grains weight, spike length and peduncle length.

Plant height in normal condition, demonstrated the highest correlation (r= 0.902) with peduncle length which this form of correlation was observed in results of Aziziniya *et al* (2005). In terms of non-stress, peduncle length had positive correlation with spike length. Behdad *et al* (2009) investigated wheat cultivars under drought stress and observed positive and significant correlation between peduncle length with plant height, number of grains per spike.

In drought stress and non-stress conditions, spike length had positive and significant correlation with number of grains per spike. Also Azadi *et al* (2009) reported positive and significant correlation between spike length with number of spikelet per spike, spike weight and number of grains per spike in wheat under drought stress condition. Golparvar *et al* (2006) investigated some bread wheat cultivars in two conditions of drought stress and non-stress and they observed positive and significant correlation between spike length with number of grains per spike and spike length, in both experimental conditions.

Under drought stress condition, 1000-grains weight had negative correlation at 5% probability level with number of grains per spike. Bahari *et al* (2006) in the study on wheat under water stress condition expressed that there was significant negative correlation between 1000-grains weight and number of grains per spike. Under low humidity condition, augmentation in 1000-grains weight is due to decrement in numbers of spikelets and grains in main spike because it reduce competition and compensates growth and grain filling (Azadi *et al*, 2009).

Table 3. Correlation coefficients among studied traits in wheat cultivars under drought stress condition.

	biological yield	grain yield	Straw yield	Harvest index	1000- grains weight	number of grains in spike	number of fertile tiller	spike length	peduncle length	plant height
grain yield	0.848**									
Straw yield	0.814**	-0.129								
Harvest index	-0.146	0.843**	-0.639**							
1000- grains weight	0.806**	0.429	0.676**	-0.040						
number of grains in spike	0.117	-0.062	0.163	-0.085	-0.367*					
number of fertile tiller	-0.024	-0.404	0.432	-0.834**	-0.262	0.478				
spike length	0.310	-0.324	0.521*	-0.495	-0.118	0.722**	0.762**			
peduncle length	0.293	-0.449	0.574*	-0.658**	-0.082	0.285	0.647**	0.727**		
plant height	0.009	-0.734**	0.428	-0.835**	-0.004	-0.360	0.540*	0.122	0.487	
flag leaf area	-0.375	0.385	-0.627*	-0.615*	0.066	-0.492	-0.727**	-0.887**	-0.820**	-0.327

* And **: significant at 5% and 1% probability level, respectively.

Although 1000-grains weight and number of fertile tiller are main components of yield but showed no correlation with grain yield in both experimental conditions. Siyadat and Hosseini (2001) in evaluation of bread wheat genotypes under different regimes of moisture and temperature; reported meaningless correlation between grain yield and number of tiller but Abhari *et al* (2007) in assessment of some growth parameters effect on grain yield in drought stress condition, observed positive significant correlation between grain yield and number of fertile tiller. Emam *et al* (2007) in both conditions of favorable moisture and drought stress and also Amer (2000) under limited rainfall condition reported lack of correlation between grain yield and 1000-grains weight in wheat. While, studies conducted by Mogaddasi *et al* (2009) displayed significant positive correlation between 1000-grains weight and grain yield in both conditions of optimum moisture and drought stress. According to same and antithetic reports about correlations, it is clear that determination of grain yield components role may be depends on studied cultivar or line and environmental condition (Golabadi and cheapness, 2003). On the other hand, because of complex relationships between majority of traits with each other and with yield, simple correlation coefficients may not provide complete information about relationship between different traits. Thus, for completion of information and elimination of ineffective or less effective impacts in relationships between impressive traits on yield, path analysis was used based on regression analysis.

Table 4. Regression coefficients of related traits to grain yield in wheat cultivars under normal condition. * and **: significant at 5% and 1% probability level, respectively. $R^2 = 0.98$.

Residual traits in model	Regression coefficients
Biological yield	0.989**
Number of fertile tiller	0.177**
Plant height	-0.103*

* And **: significant at 5% and 1% probability level, respectively.

Regression

Multiple regression analysis with stepwise method was used separately for each of stress and non-stress conditions to determinate cumulative effect proportion for effective traits on grain yield. So that, grain yield was evaluated as dependent variable and other traits were examined as independent variables to identify traits with important role in justification of grain yield. Based on regression analysis, in terms of non-stress (Tables 5 and 6); biological yield, number of fertile tiller and plant height were remained in the regression final model and under drought stress (Tables 7 and 8), number of fertile tiller, biological yield and number of grains per spike were remained in the regression final model. These traits were considered as effective characteristic on grain yield. In terms of non-stress, R-square (R^2= 0.98) showed that almost 98% of grain yield variation were justified through mentioned traits. Also according to R-square (R^2= 0.86) on drought stress condition, nearly 90% of grain yield variances were justified through traits which were entered in the regression final model. Hosseinzadeh *et al* (2009) used regression analysis to identify effective traits on grain yield of wheat under well watered and water stress and traits such as plant height, peduncle length, number of spike per square meter and 1000-grains weight in moisture conditions and characteristics of spike length, peduncle length, number of spikelets per spike, number of grains per spike and 1000-grains weight in stress conditions were reported as impressive characters on grain yield. The results of regression analysis under less irrigation condition; traits of 1000-grains weight, peduncle length and number of grains per spike were identified as justifier traits for grain yield of wheat (Hoseinpour *et al*., 2003).

Table 5. Regression coefficients of related traits to grain yield in wheat varieties under drought condition. * and **: significant at 5% and 1% probability level, respectively. R^2= 0.86.

Residual traits in model	Regression coefficients
Number of fertile tiller	-0.969**
Biological yield	0.340**
Number of grains in main spike	0.361**

* And **: significant at 5% and 1% probability level, respectively.

Path Analysis

In order to better interpret for results of regression analysis and separation of affecting amount of remain traits in regression to direct and indirect effects, path analysis was done for each experimental conditions. Tables of 9 and 10 show results of path analysis for grain yield in both stress and non-stress conditions.

According to Table 9 in non-stress condition, direct effect of biological yield on grain yield was higher than other traits. Number of fertile tiller with low relative intensity had positive effect and plant height had negative direct effect on grain yield. Plant height had the highest positive indirect effect via biological yield on grain yield. Also, this trait had positive indirect effect via number of fertile tiller on grain yield. Biological yield had low positive indirect effect through number of fertile tiller but via plant height had low negative indirect effect on grain yield. Indirect effect of fertile tiller number via biological yield and plant height was positive but these effects were not significant.

Overall, in terms of non-stress, biological yield with the highest direct effect and plant height with maximum positive indirect effect via biological yield caused to augmentation in grain yield. It should be noted that these traits were positively correlated with grain yield. Low amount of residual effects (0.09) demonstrated fewer roles of other factors in grain yield variation.

Results of path analysis for drought stress condition (Table 10) represented that positive and direct effect of number of grains per main spike on grain yield was higher than other traits. After number of grains per main spike, biological yield with less intensity had positive direct effect on grain yield. However, number of fertile tiller caused to reduction in grain yield. Number of fertile tiller had the highest positive indirect effect on grain yield via number of grains per main spike. Also, number of fertile tiller had indirect negative effect on grain yield through biological yield. Biological yield via both number of fertile tiller and number of grains per main spike had positive effect on grain yield. Number of grains per main spikes caused to the highest negative effect on grain yield via number of fertile tiller.

Table 6. Path analysis of grain yield with related traits in wheat cultivars under normal condition. E = 0.09.

Residual traits in model	Direct effect	Indirect effect via			Correlation with grain yield
		Biological yield	Number of fertile tiller	Plant height	
Biological yield	0.989	---	0.057	-0.071	0.980
Number of fertile tiller	0.177	0.332	---	0.033	0.446
Plant height	-0.103	0.686	0.058	---	0.597

Table 7. Path analysis of grain yield with related traits in wheat varieties under drought condition. E = 0.32.

Residual traits in model	Direct effect	Indirect effect via			Correlation with grain yield
		Number of fertile tiller	Biological yield	Number of grains in main spike	
Number of fertile tiller	-0.969	---	-0.008	0.172	-0.804
Biological yield	0.340	0.023	---	0.042	0.406
Number of grains in main spike	0.361	-0.463	0.039	---	-0.062

In conclusion it can be stated that in drought stress condition, the highest direct effect was related to number of grains per main spike and number of fertile tiller via number of grains per main spike had maximum indirect effect in augmentation of grain yield.

Different results of path analysis have been reported in several studies. In a study by Maleki *et al* (2008) on 12 wheat cultivars in two irrigated and non-irrigated conditions, biological yield had the highest positive direct effect on grain yield; also, in this research has been mentioned that desirable yield is impossible without certain support of total dry matter. Hosseinzadeh *et al* (2009), in an experiment on wheat under both drought stress and favorable moisture conditions stated that peduncle length and plant height had the highest direct effect on grain yield. Kashif and Khalig (2004) with conducting path analysis in bread wheat declared that maximum direct effect on grain yield was belonged to number of spikelet per spike. Path analysis of grain yield in Helalisoltanahmadi *et al* (2009) showed that plant height and number of spikelet per plant had positive direct and positive indirect effect on grain yield, respectively. Talei and Bahramnejad (2003) in a study of 467 wheat genotypes native to the west of country through path analysis reported that traits such as plant height, number of grains per spike, 1000-grains weight, spike length and flag leaf width had significant direct effect on grain yield. Mobser *et al* (2006) studied 25 cultivars and advanced breeding lines of six-rowed barley and distinguished that number of grains per spike was most effective trait on grain yield. Neyestani *et al* (2005) with evaluation of 10 barley varieties observed that number of grains per spike had the highest direct effect on grain yield, indirect effect of plant height via number of grains per spike was higher than other traits. Mondal *et al* (1997) stated in the study of wheat genotypes, number of grains per spike, 1000-grains weight and number of tillers had direct positive effect on yield, they suggested that selection based on 1000-grains weight and number of tillers is better to be done. Moghaddam *et al* (1997) in their study on wheat, demonstrated that number of grains per spike and

1000-grains weight had high direct effect on grain yield. Many researchers also reported direct and positive effect of grains number per spike on grain yield (Dogan, 2009; Khan *et al.*, 2010; Ashfaq *et al.*, 2003).

With consideration to results of correlation analysis, regression and path analyses can be seen that there were significant correlations between traits; therefore, factor analysis was used in order to reduce number of correlated traits to derive few numbers of factors and extract collection of similar variables. Thus, diversity among evaluated cultivars can be explained easily from the view point of these factors which had no correlation with each other.

Conclusion

Based on correlation analysis in both experimental conditions, biological yield demonstrated the highest correlation with grain yield. In regression analysis with stepwise method in terms of non-stress; biological yield, number of fertile tiller and plant height were remained in the regression final model which path analysis displayed direct effect of biological yield on grain yield was higher than other traits. Results of regression analysis for drought stress condition showed; number of fertile tiller, biological yield and number of grains per main spike were remained in the regression final model and in path analysis the highest direct effect was related to number of grains per main spike and number of fertile tiller via number of grains per main spike had maximum indirect effect in augmentation of grain yield.

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