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Estimation of Heritability and Genetic Parameters Associated with Agronomic Traits of Bread Wheat (Triticum aestivum L.) Under Two Constructing Water Regimes

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Abstract

A 2-years field investigation was carried out to estimate genetic parameters and relationship among morpho-agronomic traits studied on 24Iranian bread wheat cultivars under two constructing water regimes. There was a positive and significant correlation between harvest index, number of grains per spike and number of seeds per m2 with yield at both genotypic and phenotypic level in both environments. The highest environmental variances were found for plant height, number of seeds per m^2 and yield in both environments. Across the traits studied, in irrigated condition the PCV ranged from 0.359% for harvest index to 35.9% for number of seeds per spike and in drought stress condition this value ranged from 0.113% for harvest index to 21.57 for plant grain yield. The GCV values were the lowest (<2%) for harvest index and highest (12%) for plant height, number of seeds per spike and plant grain yield. 1000-seeds weight and plant biomass as well as number of seeds per m2, also showed relatively low GCV values (3.8-8.8%).Broad sense heritability estimates was very high under both control and water stress conditions, for plant height and number of seeds per spike, while broad sense heritability significantly decreased under water stress conditions for harvest index, 1000 grain weight and number of seeds per plant. In irrigated condition number of seeds per spike, 1000 grain weight and plant biomass showed more direct positive effects on yield, while, in drought stress condition number of seeds per spike showed negative direct effect on yield and harvest index and number of seeds per m2 showed more direct positive effects on yield. In conclusion, this study indicates that the improvement of the Iranian wheat cultivars may be possible either through indirect selection for yield components or direct selection for grain yield.

Key words: wheat, heritability, genetic variance, drought stress

INTRODUCTION

Wheat (Triticum sp), one of the largest cereal crops of the world, is the first most important source of staple food and income in Iran. It is the only crop to have produced more than 500 million tonnes in a single year and to contribute more calories and more protein to world's diet than any other food crop. Wheat production in Mediterranean region is often limited by sub-optimal moisture conditions. Most of the countries of the world are facing the problem of drought. The insufficiency of water is the principle environmental stress and to enter heavy damage in many part of the world for agricultural products [15, 22]. Hence, even at the same level of moisture stress condition different genotypes show characteristically different responses which in turn related to their genetic potential for expression of traits concerning to mechanism of adaptation. However, from the point of plant breeding, the adaptive traits of the plant for drought should also be combined with grain yield. Achieving a genetic increase in yield under these environments has been recognized to be a difficult challenge for plant breeders while progress in yield grain has been much higher in favourable environments [21]. Meeting this challenge will require efforts in multiple areas, one of which will be the development of high yielding varieties that are better adapted to wide range of environment. Both genotype and the environment affect grain yield and yield components of wheat. For that purpose, effective plant selection characters that are associated with yield are obligatory. Thus, study of correlation and direct and indirect effects of yield components provides the basis for successful breeding plan. Drought stress can reduce grain yield, have estimated the average yield loss of 17 to 70% in grain yield due to drought stress [20]. On the other hand, selection for yield under drought stress conditions is complicated by low heritability and large genotype-environment interactions [11]. Various morphological and physiological characters contribute to grain yield. Each of these component characters has its own genetic systems. Further, these yield components are influenced by environmental fluctuations. Therefore, it is necessary to separate the total variation into heritable and non-heritable components with the help of genetic parameters, that is, genotypic and phenotypic coefficient of variation, heritability and genetic gain [3, 14, 18]. Morphological characters such as grain per spike number, 1000 grain weight, plant height, spike length, kernel number per spike, grain weight per spike and etc. affect the wheat tolerance to the moisture shortage in the soil [2, 4, 20]. For that purpose, effective plant selection traits that are associated with yield are obligatory. Thus, study of correlation and direct and indirect effects of yield components in different moisture regimes is one of the main tasks of plant breeders for exploiting the genetic variations and interrelationship of yield component traits to improve the stress-tolerant cultivars [8, 22]. The objective of this study was to determine the correlation and path analysis of yield and yield contributing characters in Iranian bread wheat cultivars and to assess their suitability in a breeding plan under moisture stress conditions. .

MATERIALS AND METHODS

Twenty four winter wheat cultivars (Table 1) kindly provided by the Agricultural Research Institutes in karaj-Iran and were cultivated in the research field of Agricultural Research Institute of Gerizeh, Sanandaj, Iran in 2008-2009 and 2009-2010.The cultivars were grown in three replicated randomized complete blocks and in 2-m rows with 0.3 m intra-block and 1-m inter-block distances. Irrigated plots were watered at tillering, joining, flowering and grain filing stage. Non-irrigated plots were grown under rain-fed conditions. Sowing was done in November in all experiments. The fertilizer was applied before sowing (50 kg N ha^{-1} and 30 kg P ha^{-1}) and at stem elongation (50 kg N ha^{-1}).Data were collected for the following seven different agromorphological and phenological traits: plant height, grain yield (g/ $plant^{-1}$), biological yield (g /$plant^{-1}$),1000-grain weight, number of grain/m^2, number of seeds per spike and harvest index. Heritability in broad sense was estimated from the result of variance analysis according to the formula used by Burton and DeVane (1953) [5]. Genotypic and phenotypic correlations were worked out according to the method given by Kwon and Torrie (1964) [17]. The direct and indirect effects of each trait were assessed by path analysis using the method of Dewey and Lu (1959) [10].

RESULTS AND DISCUSSION

Genetic parameters of yield and their components are computed using the variance components based on the combined analyses over the two years for irrigated and stress conditions are shown in Table 2. In irrigated condition, the highest genotypic variances were found for yield (1226.9), PH (117.29), SM^2 (50.56) and SPK (80.22) while the lowest genotypic variations were found for HI (0.019), BIO (5.13) and TSW (13.39). The results for phenotypic variation also were the same that found for genotypic variation. The highest environmental variances were found for PH, SM^2 and yield in both environments. Across the traits studied, in irrigated condition the PCV ranged from 0.359% for harvest index to 35.9% for number of seeds per spike and in drought stress condition this value ranged from 0.113% for harvest index to 21.57 for plant grain yield. The GCV values were the lowest (<2%) for harvest index and highest (12%) for plant height, number of seeds per spike and plant grain yield. 1000-seeds weight and plant biomass as well as number of seeds per m^2, also showed relatively low GCV values (3.8-8.8%). In contrast, h^2 estimates were comparatively low (15.16% and 25.8% in stress and irrigated condition, respectively) for grain yield $plant^{-1}$ and biomass. We can declare that among the agronomic and morphologic traits, selecting genotypes through 1000-grain weight, grain per spike number and harvest index affected in improvement yield in stress condition. Broad sense heritability estimates was very high under both control and water stress conditions, for plant height and number of seeds per spike, while broad sense heritability significantly decreased under water stress conditions for harvest index, 1000 grain weight and number of seeds per plant. Due to higher heritability estimates, great benefits from selection might be expected for all the traits studied [19]. The present results are in accordance with those previously reported by Ahmadizade et al. (2011) and Maniee et al. (2009) [2, 18]. The higher value of heritability for number of seeds per plant, harvest index and 1000 grain weight indicates that these characters can be used as the genetic parameters for the improvement and selection of high yielding genotypes in both environments. These results were in accordance with the findings of Kahrizi et al. (2010) and Khayatnejad et al. (2010) [13, 16]. Genotypic and phenotypic correlations for all possible combinations for traits under non-stress and drought stress conditions are presented in Table 3 and Table 4, respectively. In almost all the cases genotypic correlations were higher as compared to phenotypic ones. The correlation between plant height and yield was negative and significant ($P \leq 0.05$) at both genotypic levels in both environment. Also, negative and significant association with harvest index, number of seeds per spike and number of seeds per m^2 were observed at genotypic and phenotypic levels (Table 4 and 5). There was a positive and significant correlation between harvest index, number of grains per spike and number of seeds per m^2 with yield at both genotypic and phenotypic level in both environments. Whereas harvest index was positively and highly significantly associated with plant biomass, number of grains per spike and number of seeds per m^2 at phenotypic and genotypic level. Similar results have also been reported by Golabadi et al. (2005) and Kahrizi et al. (2010) [11, 13]. The results of the path-coefficient analysis corresponding to the irrigated and drought stress conditions are shown in Table 5 and 6, respectively. This path analysis demonstrate the influence of grain yield components on grain yield as well as the process that determined the magnitude of these grain yield components, thereby providing a more complete view of how rainfed and irrigated conditions affect grain yield formation in wheat. In irrigated condition number of seeds per spike, 1000 grain weight and plant biomass showed more direct positive effects on yield (Table 5), while, in drought stress condition number of seeds per spike showed negative direct effect on yield and harvest index and number of seeds per m^2 showed more direct positive effects on yield (Table 6). In irrigated condition, number of seeds per m^2 and harvest index showed more indirect positive effect via number of seeds per spike on grain yield and 1000 grain weight showed more negative indirect effect number of seeds per spike on grain yield (Table 5). In drought stress condition, plant biomass showed more positive indirect effect via harvest index on grain yield (Table 6). This was in agreement with previous reports

Table 1. Name of 24 Iranian bread wheat cultivars used in this study.

Number	*Cultivar name*	*Number*	*Cultivar name*
1	*Marvdasht*	*13*	*Alamot*
2	*Kavir*	*14*	*Ghods*
3	*Golestan*	*15*	*Chamran*
4	*Azar2*	*16*	*Alvand*
5	*Roshan/BC/S*	*17*	*Omid*
6	*Rashid*	*18*	*Tajan*
7	*Sholeh*	*19*	*Shiraz*
8	*Roshan/BC/W*	*20*	*Bezostaya*
9	*Zarin*	*21*	*Gasiard*
10	*Mahdavi*	*22*	*Roshan*
11	*Falat*	*23*	*Olaf*
12	*Shirodi*	*24*	*Sardari*

Table 2. Estimates of genetic variation (GV), phenotypic variation (PV), environmental variance (EV), genotypic and phenotypic coefficient of variation (GCV and PCV), genetic advance (GA) and broad-sense heritability (h^2_{bs}) components in wheat cultivars under irrigated condition (N) and drought stress condition (S).

Variables	*EV*		*GV*		*PV*		*PCV%*		*GCV%*		*GA*		*h^2_{bs}%*	
	S	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*
PH	*44.54*	*147.25*	*102.13*	*117.29*	*146.67*	*264.54*	*15.15*	*19.68*	*12.64*	*13.1*	*17.37*	*14.85*	*69.6*	*44.3*
HI	*0.0014*	*0.002*	*0.0005*	*0.019*	*0.0019*	*0.02*	*0.113*	*0.359*	*0.06*	*0.337*	*0.025*	*0.267*	*27.5*	*88*
BIO	*8.81*	*28.62*	*2.13*	*5.13*	*10.94*	*33.75*	*9.84*	*9.718*	*4.341*	*3.8*	*1.32*	*1.819*	*19.47*	*15.2*
TSW	*9.82*	*20.31*	*4.39*	*13.39*	*14.21*	*33.7*	*12.11*	*14.9*	*6.73*	*9.4*	*2.4*	*4.751*	*31*	*40*
SM^2	*70.73*	*94.57*	*17.96*	*50.56*	*88.69*	*145.14*	*12.01*	*14.91*	*5.4*	*8.8*	*3.93*	*8.64*	*20.25*	*34.8*
SPK	*12.34*	*46.4*	*16.52*	*80.22*	*28.86*	*126.62*	*19.81*	*35.9*	*14.98*	*28.57*	*6.33*	*14.68*	*57.24*	*63.3*
Yield (g/m^2)	*1416.6*	*3518.06*	*253.23*	*1226.9*	*1669.83*	*4744.9*	*21.27*	*26.9*	*8.29*	*13.71*	*12.76*	*36.69*	*15.16*	*25.8*

PH= plant height, BIO= plant biomass, TSW= 1000-seeds weight, SM^2= number of seeds per m2, SPK= number of seeds per spike, HI=harvest index.

Table 3. Genotypic and phenotypic correlation of various quantitative traits under irrigated condition.

Variable		*PH*	*BIO*	*TSW*	*SM^2*	*SPK*	*HI*	*Yield (g/m2)*
PH	r_p	*1*						
	r_g	*1*						
BIO	r_p	*0.22*	*1*					
	r_g	*-0.09*	*1*					
TSW	r_p	*0.16*	*0.023*	*1*				
	r_g	*0.35***	*-0.18*	*1*				
SM^2	r_p	*-0.13*	*0.73***	*-0.42***	*1*			
	r_g	*-0.63***	*0.63***	*-0.61***	*1*			
SPK	r_p	*-0.25**	*0.16*	*-0.51***	*0.53***	*1*		
	r_g	*-0.32***	*0.26**	*-0.96***	*0.73***	*1*		
HI	r_p	*-0.46***	*0.06*	*0.045*	*0.44***	*0.60***	*1*	
	r_g	*-0.32***	*0.26**	*-0.35***	*0.77***	*0.52***	*1*	
Yield (g/m^2)	r_p	*-0.05*	*0.84***	*0.09*	*0.85***	*0.26**	*0.51***	*1*
	r_g	*-0.63***	*0.74***	*-0.03*	*0.75***	*0.23*	*0.77***	*1*

* = Significant at 5% probability level, ** = highly significant at 1% probability level, PH= plant height, BIO= plant biomass, TSW= 1000-seeds weight, SM^2= number of seeds per m^2, SPK= number of seeds per spike, HI=harvest index.

by other researchers [9, 23]. The existence in the bread wheat cultivars of large variability for each of seven traits assessed offers ample chances for the genetic improvement of the crop through selection and recombination of cultivars with desired expression. The most effective way to improve the productivity of wheat is to perform selection under targeted environments. Ceccarelli (1994) [6] reported that high grain yield in high-yielding conditions and high grain yield in low yielding conditions are under the control of different sets of alleles at most of the several loci that presumably controlled the grain yield. In contrast to our results, other studies have concluded that selection under favourable conditions could produce lines suitable in both stress and non-stress environments [1, 24]. Grain yield $plant^{-1}$, harvest index, number of seeds per spikes and 1000 grain weight showed relatively higher h^2 at irrigated condition than water stress environment. Our results support the findings of Ceccarelli (1996) [7] in barley and Abdel-Ghani (2008) [1] in durum wheat who reported that heritability is higher in high-yielding than in low yielding environments. According to Ceccarelli (1994) [6], the most common justification for conducting selection in optimum environments, regardless of the nature of the target environment, is the lower heritability found in low yielding ones. Generally, higher h^2 values indicated that relative ease with which selection can be made based on phenotype, but their practical utility in plant breeding is further enhanced if accompanied by concomitantly high genetic advance estimates [12]. In this study, grain yield, harvest index and number of seeds per spike showed higher values of h^2 and GA in both environments. Thus, the selection of superior cultivars based on these traits for improving the grain yield would be effective.

Table 4. Genotypic and phenotypic correlation of various quantitative traits under drought stress condition.

Variable		PH	BIO	TSW	SM²	SPK	HI	Yield (g/m2)
PH	r_p	1						
	r_g	1						
BIO	r_p	-0.03	1					
	r_g	-0.61**	1					
TSW	r_p	0.17	0.21	1				
	r_g	0.23	-0.07	1				
SM²	r_p	-0.09	0.81**	-0.32**	1			
	r_g	-0.54**	0.83**	-0.61**	1			
SPK	r_p	-0.25*	0.47**	-0.36**	0.58**	1		
	r_g	0.51**	0.78**	-0.56**	0.89**	1		
HI	r_p	-0.27*	0.46**	0.41**	0.23*	0.43**	1	
	r_g	-0.68**	0.76**	-0.05	0.76**	0.73**	1	
Yield (g/m²)	r_p	-0.007	0.76**	0.23*	0.83**	0.38**	0.48**	1
	r_g	-0.52**	0.98**	0.04	0.76*	0.65**	0.63**	1

* = Significant at 5% probability level, ** = highly significant at 1% probability level, PH= plant height, BIO= plant biomass, TSW= 1000-seeds weight, SM²= number of seeds per m², SPK= number of seeds per spike, HI=harvest index.

Table 5. Direct (diagonal) and indirect effects of various traits on grain yield in wheat under irrigated condition.

variables	PH	BIO	TSW	SM²	SPK	HI	Correlation coefficient (r_g)
PH	(0.08)	-0.036	0.163	-0.136	-0.31	-0.08	-0.63**
BIO	-0.007	(0.38)	-0.082	0.14	0.244	0.066	0.74**
TSW	0.028	-0.088	(0.462)	-0.131	-0.913	-0.088	-0.03
SM²	-0.051	0.24	-0.281	(0.216)	0.694	0.192	0.75**
SPK	-0.03	0.098	-0.445	0.16	(0.941)	0.131	0.23
HI	-0.02	0.1	-0.164	0.166	0.497	(0.25)	0.77**

PH= plant height, BIO= plant biomass, TSW= 1000-seeds weight, SM²= number of seeds per m², SPK= number of seeds per spike, HI=harvest index.

Table 6. Direct (diagonal) and indirect effects of various traits on grain yield in wheat under drought stress condition.

variables	PH	BIO	TSW	SM²	SPK	HI	Correlation coefficient (r_g)
PH	(0.041)	-0.143	0.056	-0.23	-0.007	-0.243	-0.52**
BIO	-0.61	(0.243)	0.016	0.36	-0.011	0.76	0.98**
TSW	0.009	-0.016	(0.238)	-0.26	0.008	-0.017	0.04
SM²	-0.027	0.19	-0.147	(0.43)	-0.013	0.25	0.76**
SPK	0.002	0.18	-0.14	0.38	(-0.015)	0.26	0.65**
HI	-0.03	0.18	-0.012	0.31	-0.01	(0.35)	0.63**

PH= plant height, BIO= plant biomass, TSW= 1000-seeds weight, SM²= number of seeds per m², SPK= number of seeds per spike, HI=harvest index.

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