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Original scientific paper

DETERMINATION OF THE BEST INDIRECT SELECTION CRITERIA IN IRANIAN DURUM WHEAT (*Triticum aestivum* L.) GENOTYPES UNDER IRRIGATED AND DROUGHT STRESS CONDITIONS

Ahmad Reza GOLPARVAR[1*], Mohammad Mehdi GHEISARI[2], Davoud NADERI[3], Ali Mehras MEHRABI[4], Amin HADIPANAH[5], Saeed SALEHI[6]

[1]Department of Agronomy and Plant Breeding, College of Agriculture, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran
[2]Department of Chemistry, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran
[3]Department of Horticulture, College of Agriculture, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran
[4]Department of Plant Breeding, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran
[5]Department of Horticultural, Science and Research Branch, Islamic Azad University, Tehran, Iran
[6]Department of Agronomy, College of Agriculture, Sanandaj Branch, Islamic Azad University, Sanandaj, Iran

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In order to evaluate and classify morphological and morpho-physiological traits of durum wheat genotypes in drought and irrigated conditions 200 durum wheat genotypes were sown in modify augmented design with four replications during 2013-2014 farming season. Two replications were considered as drought condition and two as irrigated. Factor analysis based on principal component analysis method and varimax rotation indicated that four important factors accounted for about 87 and 92 percent of the total variation among traits in drought and irrigated conditions, respectively. In drought stress condition, the first factor assigned 37 percent of total variation between traits and was significantly related with spike yield and it's components. Therefore, this factor was regarded as spike seed yield factor. Other factors in drought stress condition

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Corresponding author: Ahmad Reza Golparvar,Department of Agronomy and Plant Breeding, College of Agriculture, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran, dragolparvar@gmail.com

accounted for 22, 16 and 12 percent of variation between traits and were entitled as plant seed yield, spike density and assimilate transmission factors, respectively. In irrigated condition, the first factor assigned 36 percent of total variation between traits and was significantly related with traits plant and spike seed yield, plant and spike harvest index, No. seed/spike and plant height. This factor was regarded as plant seed yield factor. Other factors in irrigated condition accounted for 24, 18 and 14 percent of variation between traits and were entitled as production, assimilate transmission and spike density factors, respectively. Overall, results revealed effect of different environments on extracted factors, percent of variation accounted for by factors and traits related with each factor.

Key words: Durum wheat, simple correlation, factor analysis, varimax rotation, drought stress, yield

INTRODUCTION

Besides common wheat (*Triticum aestivum* L.), durum wheat (*Triticum durum* Desf.) is of the largest economic importance of all the other species. Sowing area of durum wheat in the world is 13.7 million ha which constitutes 6% of the total wheat sowing area with production averaging about 30 million tons annually (DIXON *et al*., 2009). This substantial increase in wheat production could be environment interaction studies and evaluate their attributed to evolution of number high yielding wheat stability and adaptability over environments.

Morphological and agronomic characters of wheat have a special role in determining the importance of each trait in increasing yield, so these traits were used in breeding programs which at least led to improving yield and introducing commercial varieties (MOLLASADEGHI *et al*., 2011).

In determining the potential of genetically different lines and cultivars, breeders have to observe many different characters that influence yield. Accurate evaluation of these characters is made more difficult by the genotype by environment interaction (TADESSE and BEKELE, 2001). Drought usually is the most important abiotic stress that affects crop production. Hence, selection for drought resistance and production of tolerant cultivars with high yield potential is the main objective of breeding programs. Many researchers (SIDDIQUE *et al*., 2000; ARAUS *et al*., 2003; GOLPARVAR, 2013) believed that tolerance to drought stress must be done via genetic improvement of physiological traits. Harvest index and biological yield introduced as the most important traits for this aim. In small-grained cereals increase in harvest index may causes yield improvement, without increase in plant water use. Indirect selection in early generations through traits correlated with seed yield is one of the most important strategies in plant breeding (GOLPARVAR, 2013).

The knowledge of genetic association between grain yield and its components under water deficit conditions would improve the efficiencyof breeding programs byidentify ing appropriate indices for selecting wheat varieties (JAYNES *et al*., 2003). Simulating performance of wheat under soil moisture deficit presents special challenges for wheat modelers, because of wide variations in grain yield under normal and water stress conditions (GUPTA *et al*., 2001).

Correlation coefficient analyses helps researchers to distinguish significant relationship between traits. Factor analysis is a multivariate analysis method that aims to explain the correlation between a large set of variables in terms of a small number of underlying independent factors.

SIOSE MARDEH *et al*. (2006) introduced five factors by complementation of factor analysis via principal components analysis which they justified 67.7 percent of data variations as a whole. ZAKIZADEH *et al.* (2010) found three factors that explained 83% of variability between traits of bread wheat genotypes. First factor was named as yield, second as seed quality and third as biomass production. LEILAH and AL-KHATEEB (2005) studied bread wheat genotypes under drought stress condition using different multivariate techniques. In this study revealed that three factors accounted for 74.4% of total variation exist between traits. First factor related with number of spikes/plant, 100-seed weight, spike yield and biological yield. Therefore, this factor was regarded as a yield factor. Second factor was strongly associated with plant height, spike length and number of seed/spike. This factor entitled as a biomass factor. Third factor has significant loading factor for spike diameter and harvest index. This factor regarded as a harvest index factor.

MOHAMED (1999) determined two factors for explain relation of traits in bread wheat genotypes. These factors accounted for 80.8% of variation between traits and entitled as seed yield and spike density, respectively.

In the other study (JANMOHAMMADI *et al*., 2014) factor analysis divided the eighteen traits into five factors and the first factor included stem diameter, leaf width, tiller number, spike length, floret number, spikelet number, grain number and grain yield. The second factor was composed of some morphological traits and indicated the importance of the grain diameter, grain length, 1,000 seed weight and grain yield. The two PCA and factor analysis methods were found to give complementary information, and therefore such knowledge would assist the plant breeders in making their selection. In other words, this data reduction would let the plant breeder reduce field costs required to obtain the genetic parameter estimates necessary to construct selection indices.

Attempts to create an ideal model for durum wheat plants under arid and semi-arid drought conditions have rarely been made. This study was conducted as a practical trial to clarify the relationship between wheat grain yield and its components under drought and irrigated conditions. The aim was to provide theoretical foundations to guide wheat breeders who are researching the genetic correlation of the main agronomic characters and their influence in wheat plant productivity. To achieve this goal the relationship between grain yield and its components for wheat was studied using Pearson's correlation coefficient and factor analysis.

MATERIALS AND METHODS

In this study, 200 durum wheat genotypes randomly selected from Tehran university collection were planted at the beginning of November 2013 at the Research field of Islamic Azad University in a augmented design along with two controls namely, Sardari and Karadj1.

Experiment involve four replications viz., two drought as well as two irrigated modify augmented designs that were cultivated separately. The plots were 2m long and 0.1m apart. The trial in stress condition was not supplied with irrigation. In spring 2014 the trial in irrigated condition irrigated every 10 days. Amount of precipitation was 149 mm.

Measurements for 12 traits; Plant yield (g), spike weight (g), spike harvest index (%), plant harvest index (%), number of seed/plant, biological yield (g), number of seed/spike, spike yield (g), 1000-seed weight (g), spike length (cm), plant height (cm) and peduncle length (cm) were achieved on 10 normal plants randomly selected from each plot.

Relationships between traits investigated using simple correlation coefficients. Then it is assumed that each of the variables measured depends upon the underlying factors but is also subject to random errors. The principal factor analysis method was followed in the extraction of the factor loadings. Factors having eigen value higher than 1 selected for performing loading factors matrix.

The varimax rotation method (an orthogonal rotation) was used in order to make each factor uniquely defined as a distinct cluster of intercorrelated variables. The factor loadings of the rotated matrix, the percentage variability explained by each factor and the communalities for each variable were determined. In order to better interpretation, loadings higher than 0.5 were considered as significant coefficients (TADESSE and BEKELE, 2001; MANJIT, 2003; KHAYATNEZHAD *et al.*, 2010).

The array of communality, the amount of the variance of a variable accounted by the common factors together, was estimated by the highest correlation coefficient in each array. The number of factors was estimated using the maximum likelihood method. Correlation and Factor analysis were performed using SPSS software for all the traits of durum wheat genotypes.

RESULTS AND DISCUSSION

Correlation coefficients for all the traits have been showed in Tables 1 and 2. In drought stress condition plant yield positively correlated with all the other traits. On the other hand, in irrigated condition plant yield positively correlated with all the traits except spike weight.

Correlation of spike yield with another traits was positive and highly significant except with spike weight and peduncle length in irrigated condition.

Factor analysis in drought stress condition indicated that only 4 first factors, which account for 87% of the total variance are important (Table 3). Factor 1, which accounted for about 37% of the variation, was strongly associated with spike weight, number of seed/plant, biological yield, number of seed/spike, spike yield and 1000-seed weight (Table 4). This factor was regarded as a spike yield factor since it included several traits, which are components of spike yield. All variables had positive loadings in factor 1. The sign of the loading indicates the direction of the relationship between the factor and the variable.

Factor 2, which accounted for about 22% of the variation was named a plant yield factor because it consisted of plant yield, spike harvest index and plant harvest index which are associated with plant yield. The third factor was named negative factor for spike density since negative loadings for traits spike weight and spike length. This factor accounted for 16% of the variation.

Factor 4, accounted for 12% of the variation. In this factor, loading factors related to number of seed/plant and peduncle length were highly positive. Because of that this factor entitled as assimilate transmission factor. Factor analysis in irrigated condition also revealed that only 4 first factors, which accounted for 92% of the total variance are important (Table 3). Amongst, 36% of variance specified to factor 1 and other traits accounted for 24, 18 and 14% of the variation between traits, respectively.

Factor 1 had positive loading factors for plant yield, plant and spike harvest index, number of seed/spike, spike yield and plant heigth since regarded as a plant yield factor (Table 4).

Table 1. Pearson's correlation coefficients for traits studied in drought stress condition (n=200)

	Plant yield	Spike weight	Spike harvest index	Plant harvest index	Seed plant^{-1}	Biological yield	Seed spike^{-1}	Spike yield	1000-seed weight	Spike length	Plant height	Peduncle length
Plant yield	1											
Spike weight	0.865**	1										
Spike harvest index	0.523**	-0.325**	1									
Plant harvest index	0.685**	0.206**	0.281**	1								
Seed plant^{-1}	0.811**	0.442**	0.204**	0.280**	1							
Biological yield	0.856**	0.520**	0.182**	0.026	0.702**	1						
Seed spike^{-1}	0.530**	0.422**	0.431**	0.289**	0.802**	0.404**	1					
Spike yield	0.777**	0.569**	0.524**	0.461**	0.562**	0.590**	0.528**	1				
1000-seed weight	0.524**	0.314**	0.380**	0.421**	-0.029	0.360**	-0.093*	0.823**	1			
Spike length	0.194**	0.253**	0.007	0.029	0.282**	0.546**	0.223**	0.169**	0.004	1		
Plant height	0.278**	0.333**	0.052	-0.006	0.126**	0.353**	0.117**	0.291**	0.322**	0.196**	1	
Peduncle length	0.203**	0.252**	0.023	-0.005	0.073	0.278**	0.009	0.193**	0.358**	-0.037	0.802**	1

* and ** : Significant at 0.05 and 0.01 probability levels, respectively.

Table 2. Pearson's correlation coefficients for traits studied in irrigated condition (n=200)

	Plant yield	Spike weight	Spike harvest index	Plant harvest index	Seed plant^{-1}	Biological yield	Seed spike^{-1}	Spike yield	1000-seed weight	Spike length	Plant height	Peduncle length
Plant yield	1											
Spike weight	0.141	1										
Spike harvest index	0.524**	0.114	1									
Plant harvest index	0.475**	0.012	0.329**	1								
Seed plant^{-1}	0.409**	-0.024	0.048	0.010	1							
Biological yield	0.538**	-0.048	-0.006	-0.193**	0.450**	1						
Seed spike^{-1}	0.358**	-0.024	0.049	0.042	0.875**	0.371**	1					
Spike yield	0.877**	-0.025	0.411**	0.430**	0.303**	0.412**	0.503**	1				
1000-seed weight	0.721**	-0.009	0.489**	0.519**	-0.117	0.082	-0.087*	0.824**	1			
Spike length	0.139**	-0.032	-0.037	0.004	0.116*	0.203**	0.458**	0.212**	0.003	1		
Plant height	0.213**	-0.049	0.047	0.001	0.139**	0.303**	0.156**	0.203**	0.060	0.204**	1	
Peduncle length	0.104*	-0.021	0.018	-0.018	0.049	0.161**	0.023	0.071	0.056	0.091*	0.490**	1

* and ** : Significant at 0.05 and 0.01 probability levels, respectively.

Table 3. Eigen value, percent of variance and cumulative variance of extracted factors

	Irrigated condition			Drought stress condition		
Factors	Eigen value	Variance (%)	Cumulative variance (%)	Eigen value	Variance (%)	Cumulative variance (%)
1	4.68	36.00	36.00	4.99	37.00	37.00
2	3.02	24.00	60.00	2.18	22.00	59.00
3	2.12	18.00	78.00	1.98	16.00	75.00
4	1.18	14.00	92.00	1.12	12.00	87.00

Table 4. Principal factor matrix after varimax rotation for traits of 200 durum wheat genotypes in drought and irrigated conditions

	Irrigated condition					**Drought stress condition**				
	Factor 1	Factor 2	Factor 3	Factor 4	Community	Factor 1	Factor 2	Factor 3	Factor 4	Community
Plant yield	**0.712**	0.165	-0.490	0.005	0.912	0.455	**0.612**	0.110	-0.493	0.982
Spike weight	-0.018	-0.007	-0.019	**0.830**	0.999	**0.720**	0.327	**-0.720**	0.154	0.902
Spike harvest index	**0.963**	-0.182	-0.060	**0.725**	0.941	0.025	**0.903**	0.086	0.128	0.988
Plant harvest index	**0.951**	-0.182	-0.060	0.009	0.941	0.025	**0.842**	0.086	0.128	0.988
Seed plant^{-1}	0.227	0.293	**0.812**	-0.009	0.971	**0.612**	0.254	0.010	**0.703**	0.958
Biological yield	0.035	**0.902**	0.169	-0.013	0.925	**0.803**	-0.092	0.035	0.358	0.869
Seed spike^{-1}	**0.872**	0.333	0.253	-0.003	0.921	**0.625**	0.467	0.081	0.397	0.922
Spike yield	**0.809**	0.328	0.185	-0.001	0.867	**0.702**	0.455	0.027	0.063	0.899
1000-seed weight	0.070	**0.863**	0.140	-0.012	0.927	**0.912**	-0.162	0.350	-0.007	0.899
Spike length	-0.039	-0.016	-0.023	**0.842**	0.998	-0.127	-0.110	**-0.903**	0.103	0.939
Plant height	**0.612**	0.052	-0.194	-0.096	0.402	0.274	0.196	**0.852**	-0.007	0.779
Peduncle length	-0.200	0.166	**0.904**	-0.028	0.954	0.173	0.131	-0.141	**0.942**	0.878

Factor 2 was strongly associated with biological yield and 1000-seed weight. Because of that this factor entitled as a productivity factor. The third factor was named assimilate transmission factor since positive loadings for number of seed/plant and peduncle length. Finally, factor 4 was named as spike density factor. Loadings related to spike weight, spike harvest index and spike length were highly positive (Table 4).

Correlation analysis helps to determination effective traits in order to indirect selection superior genotypes. On the other hands, factor analysis is suitable multivariate technique in identify and determination of independent factors that are effective on plant traits separately.

Varimax rotation maximizes variance between factors since factors that accounted for higher variations between traits are more important that others. Because of that, traits effective in every factor were identified and factors also entitled based on traits having loading factor greater than 0.5.

Therefore, correlation and factor analysis helps breeders to genetic improvement traits such as yield that have low heritability specifically in early generations via indirect selection for traits effective on this (MOHAMED, 1999; TADESSE and BEKELE, 2001; GOLPARVAR *et al*., 2003 a,b; LEILAH and AL-KHATEEB, 2005; GOLPARVAR *et al.*, 2006).

In this study also revealed that in order to genetic improvement plant yield potential in irrigated condition plant and spike harvest index, number of seed/spike, spike yield and plant height must be increased. These results have been emphasized in many researchs (MOHAMED, 1999; GOLPARVAR *et al*., 2003 a,b; LEILAH and AL-KHATEEB, 2005; KHAYATNEZHAD *et al.*, 2010).

On the other hands, in drought stress condition spike and plant harvest indexes are suggested as the best indirect selection criteria for genetic improvement of yield in early generations. This result is inconsistent with reports given by GOLPARVAR *et al.* (2003 b) and GOLPARVAR *et al.* (2006) for breeding plant yield in drought stress condition.

In order to genetic improvement of spike yield selection via traits plant and spike harvest index and number of seed/spike in irrigated condition and traits spike weight, number of seed/plant, biological yield, number of seed/spike and 1000-seed weight in drought stress condition are proposed.

Increasing plant yield in drought and irrigated condition could enable breeders to better realize the desired increment in drought stress resistance of durum wheat genotypes.

In conclusion, indirect selection via traits harvest index, number of seed/spike, spike yield and biological yield which have higher heritability relative to plant yield especially in early generations and strongly associated with this trait is emphasized in this study for genetic improvement of plant yield and drought resistance. TOPAL *et al*. (2004) and GOLPARVAR (2013) have reported similar results for breeding these important traits in durum wheat genotypes. In drought and irrigated condition increasing in traits number of seed/plant and peduncle length can improve assimilate transmission in durum wheat genotypes. Surprisingly, reverse effect of spike weight and spike length that could decrease spike density in stress condition and increase this in irrigated condition. This probability because of competition between spikelets for receive assimilates that decrease seed weight as well as spike density in stress condition (LEILAH and AL-KHATEEB, 2005). Results of correlation analysis also emphasized on negative relation of spike length with 1000-seed weight in stress and its positive relation in irrigated condition.

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DETERMINACIJA NAJBOLJIH INDIREKTNIH SELEKCIONIH KRITERIJUMA KOD IRANSKI GENOTIPOVA TVRDE PŠEICE (*Triticum aestivum* L.) U USLOVIMA NAVODNJAVANJA I STRESA SUŠE

Ahmad Reza GOLPARVAR[1*], Mohammad Mehdi GHEISARI[2], Davoud NADERI[3], Ali Mehras MEHRABI[4], Amin HADIPANAH[5], Saeed SALEHI[6]

[1-] Odelenje za poljoprivredu i oplemenjivanje biljaka,Department za poljoprivredu i oplemenjivanje bilajka, Poljoprivredni fakultet, Isfahan (Khorasgan) Branch, Islamski Azad Univerzitet, Isfahan, Iran

[2-] Odelenje za hemiju, Isfahan (Khorasgan) odeljak, Islamski Azad Univerzitet, Isfahan, Iran

[3-] Odelenje za hortikulturu, Poljoprivredni fakultet, Isfahan (Khorasgan) odeljak, Islamski Azad Univerzitet, Isfahan, Iran

[4-] Odelenje za oplemenjivanje biljaka, Kermanshah ogranak, Islamski Azad Univerzitet, Kermanshah, Iran

[5-] Odelenje za hortikulturu, Odeljak za nauku i sitraživanja, Islamski Azad Univerzitet, Teheran, Iran

[6-] Odelenje za poljoprivredu, Poljoprivredni fakultet , Sanandaj odeljak, Islamski Azad Univerzitet, Sanandaj, Iran

Izvod

Izvršena je klasifikacija morfoloških i morfo-fizioloških osobina kod 200 genotipova tvrde pšenice u uslovima suše i navodnjavanja 200 genotipova durum pšenice u toku sezone gajenja 22014-2015. Rezultati su dobijeni u dva ponavljanja u uslovima suše i dva ponavljanja u uslovima navodnjavanja. Faktorijalna analiza bazirana na analizi osnovnih komponenata i varimaks rotaciji ukazuje da četiri značajna faktora određuju 87 odnosno 92 procenta ukupnog variranja između osobina u uslovima suše i navodnjavanja.U uslovima stresa prinos po klasu i njegove komponente učestvuju u ukupnom variranju sa 37 procenata i značjno su vezani za sa prinsom i njegovim komponentama. Prinos semena po biljci, gustina klasa i faktori transmisijee asimilata su odgovorni za 22, 16 i 12 procenata variranja. U uslovima navodnjavanja prvi faktor utiče na 36 procenata ukupnog variranja i značajno je vezan sa osobinama biljaka i prinosa semena po klasu, žetveni indeks biljke i klasa, broj zrna po klasu i visinu biljke. Ovaj faktor je vezan za prinod semena po biljci. Produkcija, transmisija asimilata i gustina klasa su odgovorni za 24, 18 i 14 procenata variranja.

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