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Full Length Research Paper

Correlated response of morpho-physiological traits of grain yield in durum wheat under normal irrigation and drought stress conditions in greenhouse

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In order to evaluate the relationship between different traits of grain yield in durum wheat, 20 durum wheat (*Triticum durum* Desf.) landraces selected from the northwest of Iran together with five controls were evaluated under normal and drought stress conditions. Environmental mean squares were significant for all the traits studied except for harvest index which showed that drought stress has significant effect on all the traits. In normal condition, fertile tillers, peduncle length, spike length, number of grain spike and harvest index had the most positive direct effect on yield, while under drought stress condition, biological yield and harvest index had the most positive direct effect on yield. In regression analysis (stepwise method) in normal condition, infertile tillers and 1000 grain weight remained in the final model (R^2 = 0.485), while under stress condition, Fv/Fm, Fm and biological yield remained in the final model (R^2 = 0.667). Factor analysis of the total five factors was used to determine 76.708 and 77.128% of the data changes and adjustments in normal irrigated and drought stress conditions, respectively. The multiple statistical procedures used in this study showed that harvest index and biological yield were the most important yield variables to be considered under drought conditions. So, these traits could be used as selection criteria for increasing yield.

Key words: Durum wheat, drought stress, chlorophyll fluorescence, chlorophyll content, multivariate analysis.

INTRODUCTION

Producing superior varieties that have helped in the increase of wheat production has not been possible without identifying genetic variation. Botany scientists have concluded that natural variation is much more valuable than artificial variation since it possesses stable forms and ideal genes and is economical. The success of plant breeding experts in the future depends on the genetic resources protection at present. The success chance of plant breeding depends on suitable selection probability and variation existence (Ali et al., 2009). In plant breeding, the kinds of traits which have more heritability have more importance. This assessment and usage of these results had a significant role in the agricultural sciences (Borojevic, 1990).

For thousands of years, durum wheat (*Triticum turgidum*, L. var. *Durum* Defs.) has been cultivated both in irrigated and rain-fed fields in the west of Iran. Also, tetraploid durum wheat (T. *durum*) or hard wheat is mainly used to produce semolina flour used in the food industries, especially pasta spaghetti. Considering that performance is a polygenic adjective and its heritability is high, to achieve high yield, the selection used is by performance components (Khayatnezhad et al., 2010a). Drought is the most common environmental stress affecting about 32% of 99 million hectares under wheat cultivation in developing countries and at least 60 million hectares under wheat cultivation in developed countries (Shamsi et al., 2011). Therefore, most of the countries of

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the world are facing the problem of drought. The insufficiency of water is the principal environmental stress that causes heavy damage of agricultural products in many parts of the world. Drought stress can reduce grain yield, therefore, it has been estimated that average yield loss of 17 to 70% in grain yield is due to drought stress (Ahmadizadeh et al., 2011). Morphological and agronomic traits 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 that can withstand seasonal drought stress condition (Mollasadeghi et al., 2011a).

A logical attitude for categorizing the traits in the sample which contains the above variation as what is seen in the germplasm necessitates the use of multivariable methods like factor analysis. This method is a strong method that has been used to estimate the components of yield, to extract a subset of identical variables, to identify the basic concepts of multivariable data, to recognize applied and biological connections among the traits, to reduce a large number of correlative traits to a few number of factors and to explain the correlation among the variables (Bramel et al., 1984; Zakizadeh et al., 2010). In other words, multivariable analysis like stepwise regression and factor analysis are used to explain existing relations between traits and to group them on the basis of these relations. In this way, the most important traits influencing yield as well as the unknown factors are identified. This results in bringing a particular structure of covariance matrix among traits and variables which had the most intergroup correlation and showed a minimum correlation to other groups. Consequently, it can improve simultaneously different traits which are influenced by different factors. In order to achieve ideal yield, we could strengthen or weaken one or more unknown factors with the hope that these traits can be influenced by each one of the unknown factors (Mollasadeghi et al., 2011b).

Khayatnezhad et al. (2010a) using factor analysis in his studies on durum wheat cultivars, showed that the importance of factor coefficients characteristics of total and fertile tillers, main spike length, 1000-seed weight and yield selected genotypes is desirable for dry conditions. Also, Gholamin et al. (2010) showed that the importance of factor coefficients characteristics of fertile tillers, grain weight original lavender, seed weight and harvest index selected genotypes is desirable for dry conditions.

Regression analysis is a method that is used to estimate the value of a quantitative variable regarding its relation with one or some other quantitative variables. This relation is such that it is possible to predict other changes using one variable. Stage regression method is used to determine the role of yield components in increasing the yield and selection efficiency by means of few traits as the effective indicator to obtain breeding aims (Farshadfar, 2004). With the aid of stepwise regression analysis, ineffective or low-effective traits on yield can be omitted in the regression model, and traits which had significantly accounted for yield alterations can be evaluated. Genetic diversity can also be analyzed on the basis of morphological and biochemical data by multivariable statistical methods while considering several measurements simultaneously (Mollasadeghi et al., 2011a). Shamsi et al. (2011) stated that stepwise regression analysis showed that the most important yield component was the number of grains per spike followed by number of spikes per unit area, then, by 1000 grain weight, while path analysis showed that in the overall given direct and indirect effects of yield components on grain yields, the number of grains per spike had the largest effect on grain yield. Mollasadeghi and Shahryari (2011) showed that stepwise regression and path analysis revealed that biological yield, main spike weight, number of spike per square meter and grain weight per spike can be a criterion to select high-yielding genotypes in wheat breeding programs.

Path analysis showed direct and indirect effects of cause variables on effect variables. In this method, the correlation coefficient between two traits is separated into the components which measure the direct and indirect effects (Farshadfar, 2004; Zakizadeh et al., 2010).

Naserian et al. (2007) showed that irrigated condition biomass and harvest index had positive and direct effect on yield, while plant height had a direct negative effect except in rain fed condition biomass. Harvest index and grain weight per plant had a direct positive effect and plant height and number of grain per plant had a direct negative effect on yield of 1 m row. Ahmadizadeh et al. (2011) reported that in regression analysis (stepwise method) under drought stress, the number of grains per spike and plant height remained in the final model (R^2 = 0.634). In well-watered condition biological yield, awn length and harvest index showed more direct and positive effects on yield. In drought stress condition, biological yield, spike length, number of grains per spike and harvest index showed more direct and positive effects on yield. Harvest index showed the highest indirect effect on yield in the two conditions. Zarei et al. (2010) in a similar research which was done on Iranian wheat landraces revealed that the effectiveness of traits is due to the indirect effect of harvest index and biological yield, while these two traits had a high, direct and positive effect on grain yield. This investigation was done to determine the cause and effect relationships between yield and some of its related traits in wheat genotypes that can withstand seasonal drought stress.

The aims of the present study were to evaluate genetic diversity in durum wheat genotypes in normal irrigation and drought stress conditions, to identify traits that the most variation of yield, to study the relationship between traits, and to determine the direct and indirect effects of effective traits on grain yield.

MATERIALS AND METHODS

The experiments were undertaken on 20 durum wheat (*T. durum* Desf.) landraces which were selected from the northwest of Iran along with five controls (Korifla, Chakmak, Zardak, Haurani-1 and Omrabi-5), and then they were evaluated under irrigated and drought stress conditions. Based on randomized complete block design with three replications, the experiment was carried in the greenhouse agricultural research station of Islamic Azad University, Ardabil branch, Iran (Northwest of Iran), during the 2010 and 2011 cropping year. All the pots were watered within three days to reach the irrigation capacity. In the flowering phase, drought stress was exerted through watering control pots every day while stress pots were not watered until they reached 80% soil moist evacuation via weight. The characters studied were morphological: Leaf chlorophyll content and chlorophyll fluorescence. Analysis of variance was done and stepwise regression was calculated using mean values of characters from the two conditions. The direct and indirect effects of component characters on yield were studied using path coefficient analysis. Statistical analysis was obtained through the use of SPSS version 16 and Path analysis software.

RESULTS AND DISCUSSION

The analysis of the variance of data showed that environment mean squares were significant ($P < 0.001$) for all the traits studied except for harvest index showing that the drought stress had significant effect on all traits. G x E interaction was significant for all the traits, except for biological yield showing variation of genotypes over environments.

Path analysis

Although the correlation coefficient important to determine traits that directly affected grain yield could not determine the indirect effects of these traits on grain yield. These situations were more common in cereals, because yield traits that occurred at a different growing stage could affect each other and were explicitly studied using path coefficient analysis (Asadi and Naserian-Khiabani, 2007). The results of these studies were used in studies related to the yield characteristics of methods for causality effects on yield traits and interface between the traits. With the help of this method, the correlation between yield and its components could be analyzed and the direct and indirect effects of these traits could also be identified (Manifesto et al., 2001; Kirigwi et al., 2004; Ali et al., 2009; Anwar et al., 2009; Khayatnezhad et al., 2010b). The yield components had either a direct or an indirect effect on grain yield (Dofing and Knight, 1992; Asadi and Naserian-Khiabani, 2007) therefore, it was essential to determine the effects of yield components. In this study, path coefficient analysis for morphological and some physiological traits under normal condition revealed that fertile tillers, peduncle length, spike length, number of grain spike and harvest index had the most positive and direct effect, while awn length had the most negative effect on yield. Under drought stress condition, biological yield and harvest index had the most positive and direct effect on yield. Under normal condition, plant height had the most indirect effect through peduncle length on yield, while under stress condition the number of grain spike had the most indirect effect through harvest index on yield (Table 1).

Wallace et al. (1993) claimed that the trend of achieving higher grain yield by increasing harvest index is not sustainable, and so recommended total biomass could be considered in breeding programs to ensure long-term yield improvement. Soghi et al. (2006) by examining the relationship between yield and yield components of 19 advanced wheat lines in Gorgan showed that the direct effect of a thousand grain weight was little, but the direct effect of the number of grain per spike was high. Also, indirect effects of the number of grain per spike increased by 1000 grain weight and grain weight per spike.

Golabadi et al. (2005) through path analysis revealed that biological yield and number of spike had the greatest direct positive and negative effects on yield. Okuyama et al. (2004) through path coefficient analysis indicated that under irrigated condition, yield per spike had a positive and direct effect and a positive correlation with spike length and stem diameter, while under non-irrigated condition, yield per spike showed a positive and direct effect and a positive correlation with stem diameter, spike length and plant height. Okuyama and Federizzi (2005) reported that under irrigated condition, flag leaf length, peduncle length and sheath length had high and direct positive effect on yield per spike, but due to the negative effects of other plant traits, the total correlation was very low. Path analysis for yield components revealed that under both conditions, harvest index had a direct positive effect on yield.

Regression analysis

In regression analyses using stepwise method in normal condition, infertile tillers and 1000 grain weight remained in the final model, explaining 48.5% of variation in the yield ($R^2 = 0.485$) (Tables 2 and 3).

Considering the positive and significant regression coefficient of 1000 grain weight, it could be stated that increasing the amount of this trait would increase the yield. Also, regarding the negative and significant regression coefficient of infertile tillers, it could be said that increasing the amount of this trait would decrease the yield.

Under stress condition, Fv/Fm, Fm and biological yield remained in the final model, explaining 66.7% of variation in the yield ($R^2 = 0.667$) (Table 3). With respect to the positive and significant regression coefficient of biological yield, it could be stated that increasing the amount of this trait will cause an increase in the yield, while regarding the negative and significant regression coefficient of Fm, Fv/Fm it could be declared that an increase in the amount

Table 1. The direct and indirect contribution of various characters to yield in durum wheat genotypes under normal and stress conditions.

Traits	Condition	Direct effect	Indirect effect														Total effect
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Infertile tillers (1)	Normal	0.044		-0.082	-0.209	0.082	-0.087	0.047	-0.059	-0.039	0.083	-0.48	0.005	0.042	-0.01	0.047	-0.616
	Stress	-0.024		-0.009	-0.012	0.00	-0.003	-0.013	0.003	0.016	0.106	-0.325	-0.005	-0.014	0.019	-0.013	-0.269
Fertile Tillers (2)	Normal	0.268	-0.014		0.019	-0.008	-0.067	-0.001	0.041	-0.014	-0.025	0.192	-0.001	-0.008	0.008	-0.001	0.397
	Stress	0.03	0.006		0.012	0.004	-0.005	-0.001	-0.005	0.002	0.00	0.059	-0.021	0.021	-0.002	0.00	0.107
peduncle length (3)	Normal	0.391	-0.024	0.013		-0.093	0.141	-0.075	0.07	0.004	-0.049	0.055	-0.005	-0.062	0.024	-0.048	0.349
	Stress	0.037	0.007	0.01		-0.008	0.00	0.027	0.023	-0.027	0.15	0.328	-0.047	0.069	-0.024	-0.034	0.515
Awn length (4)	Normal	-0.175	-0.022	0.012	0.206		0.17	-0.056	0.009	0.028	0.023	0.142	-0.004	-0.044	0.006	-0.039	0.263
	Stress	-0.024	0.00	-0.007	0.012		0.008	0.029	0.012	-0.045	0.206	0.033	-0.003	0.022	-0.017	-0.005	0.226
Spike length (5)	Normal	0.248	-0.016	-0.073	0.222	-0.12		-0.056	0.06	0.034	-0.013	-0.101	-0.008	-0.056	0.004	-0.018	0.114
	Stress	0.014	0.004	-0.01	0.00	-0.014		0.006	-0.013	-0.019	0.073	0.046	0.01	-0.001	0.002	0.009	0.115
Plant height (6)	Normal	-0.088	-0.025	0.00	0.335	-0.112	0.157		0.061	0.029	-0.036	0.151	-0.004	-0.044	0.018	-0.042	0.405
	Stress	0.043	0.006	-0.001	0.023	-0.016	0.002		0.016	-0.013	0.183	0.101	-0.007	0.038	-0.034	-0.027	0.319
No. of Grain Spike (7)	Normal	0.217	-0.013	0.051	0.127	-0.008	0.069	-0.025		0.023	-0.091	0.143	-0.005	-0.029	-0.001	-0.021	0.444
	Stress	0.085	-0.001	-0.002	0.01	-0.004	-0.003	0.008		-0.069	0.06	0.367	-0.011	0.02	-0.02	-0.006	0.439
1000 Grain weight (8)	Normal	0.164	-0.011	-0.022	0.01	-0.03	0.052	-0.016	0.031		0.09	0.208	-0.004	-0.002	-0.014	0.002	0.463
	Stress	-0.129	0.003	-0.001	0.007	-0.009	0.002	0.004	0.045		0.06	0.41	-0.031	0.029	-0.008	0.021	0.409
Biological yield(9)	Normal	0.262	0.014	-0.026	-0.073	-0.016	-0.012	0.011	-0.075	0.056		-0.27	-0.002	0.014	-0.012	0.027	-0.095
	Stress	0.549	-0.005	0.00	0.01	-0.009	0.001	0.014	0.009	-0.015		-0.08	0.005	0.016	-0.011	-0.03	0.46
Harvest index (10)	Normal	0.83	-0.026	0.062	0.026	-0.03	-0.031	-0.016	0.037	0.041	-0.086		0.00	0.001	0.008	-0.042	0.779
	Stress	0.896	0.008	0.002	0.013	-0.001	0.00	0.004	0.034	-0.059	-0.049		-0.022	0.055	-0.04	-0.019	0.828
F0 (11)	Normal	0.023	0.01	-0.009	-0.083	0.026	-0.086	0.014	-0.043	-0.028	-0.018	0.032		0.061	0.01	0.009	-0.076
	Stress	0.084	0.001	-0.008	-0.021	0.00	0.001	-0.004	-0.011	0.046	0.036	-0.233		-0.07	-0.004	-0.001	-0.176
Fm (12)	Normal	0.103	0.018	-0.02	-0.232	0.072	-0.135	0.036	-0.06	-0.003	0.037	0.01	0.013		-0.016	0.046	-0.124
	Stress	-0.092	-0.004	-0.008	-0.029	0.005	0.00	-0.019	-0.019	0.041	-0.102	-0.541	0.064		0.031	0.021	-0.645
Fv/Fm (13)	Normal	-0.049	0.012	-0.049	-0.199	0.022	-0.022	0.032	0.002	0.044	0.061	-0.153	-0.006	0.033		0.052	-0.213
	Stress	0.064	-0.008	-0.001	-0.014	0.006	0.00	-0.023	-0.026	0.015	-0.087	-0.555	-0.004	-0.046		0.018	-0.654
CCI (14)	Normal	0.107	0.019	-0.001	-0.173	0.061	-0.041	0.033	-0.042	0.003	0.065	-0.322	0.002	0.044	-0.024		-0.262
	Stress	0.085	0.003	0.00	-0.015	0.001	0.001	-0.014	-0.006	-0.032	-0.193	-0.191	-0.001	-0.023	0.013		-0.368

of these traits will cause a reduction in the yield. Naderi et al. (2000), Hosseinpur et al. (2003) and Mollasadeghi et al. (2011a) in their researches also found out that through biological yield we could have some yield changes.Maas et al. (1996) through stepwise regression analysis in bread wheat showed that grain yield depends on the number of fertile tillers that are produced by each plant. Efyoni and Mahloji (2005) used stepwise regression analysis in 42 lines and for bread wheat, and showed that the grain yield period, the number of grains per spike, the number of spikes per m^2 and plant height entered into regression model sooner than other traits and were the most effective traits on grain yield.Results of multiple regressions confirmed that through path analysis of traits can be appraised in drought stress condition. Vishwakarma et al. (2002) reported that multiple regression analysis serves an effective solution for the improvement of wheat yield through some adequate models. Comparing the results obtained in step by step regression and path analysis, it can be inferred that in step by step regression, the effective factors were used

Table 2. Stepwise regression on the yield (dependent variables) and other traits (independent variables) under normal and stress conditions.

Model	Parameter	Sum of squares	D.F.	Mean square	F	Significance
Normal	Regression	21.172	2	10.586	10.380	0.001
	Residual	22.437	22	1.020		
	Total	43.609	24			
Stress	Regression	4.589	3	1.530	14.044	0.000
	Residual	2.288	21	0.109		
	Total	6.877	24			

Table 3. Result of stepwise regression analysis for grain yield in durum wheat genotypes under normal and stress conditions.

Model		Unstandardized coefficient		Standardized coefficient	t	Significance	R^2	R^2_{Adj}
		B	Standard error	Beta			Model	Model
Normal	Constant	2.303	1.158		1.988	0.059	0.485	0.439
	Infertile tillers (X_1)	-0.505	0.149	-0.535	-3.401	0.003		
	1000 grain weight (X_2)	0.032	0.015	0.337	2.138	0.044		
	Final model	$Y = 2.303 – 0.505(X_1) + 0.032(X_2)$						
Stress	Constant	18.094	4.839		3.739	0.001	0.667	0.620
	Fv/Fm (X_1)	-0.019	0.007	-0.416	-2.869	0.009		
	Fm (X_2)	-0.007	0.003	-0.380	-2.610	0.016		
	Biological yield (X_3)	0.242	0.095	0.325	2.532	0.019		
	Final model	$Y = 18.094 – 0.019 (X_1) – 0.007 (X_2) + 0.242 (X_3)$						

directly on grain yield, while in path analysis, the effective factors were identified and introduced directly or by means of other factors on the grain yield. Thus, in this study, two traits, biological yield and harvest index had the most effect on the grain performance in drought stress condition.

Factor analysis

With respect to the complex relations of the traits with each other, the final judgment cannot be done on the basis of simple correlation coefficients and as such, it is necessary to use multivariable statistical methods in order to intensely identify the reactions among the traits. In the meantime, factor analysis is an effective statistical method in decreasing the volume of the data and getting the results of the data which showed a high correlation among the primary variables (Cooper, 1983). Selecting factor numbers was done on the basis of root numbers larger than 1 and the number of the primary variables used in the factor analysis was equal to 15. According to the formula $F < (P+1)/2$ (in which P and F refer to the number of variables and number of factors, respectively), selection of five factors was compatible with the presented principles (Tousi Mojarrad et al., 2005). This method was used effectively for identifying the relationships and structure of yield components and some traits of cultivated plants (Bramel et al., 1984; Walton, 1971).

As seen in Table 4, with the total five factors, 76.708 and 77.128% of the data changes were accounted for in normal irrigated and drought stress conditions, respectively.

The importance of every factor is observed in Figures 1 and 2. It should be mentioned that due to the more suitable formation of factor structures, factorial coefficients turned over through varimax method, and factorial coefficient was considered to be larger than 0.5,

Table 4. Factor analysis by principal components using varimax rotation under normal and stress conditions.

Parameter	Normal					Stress				
	1	2	3	4	5	1	2	3	4	5
Infertile Tillers	-0.464	-0.650	0.140	0.201	0.172	-0.042	-0.109	0.174	-0.147	0.880
Fertile Tillers	-0.307	0.560	-0.373	-0.415	0.118	-0.179	0.542	0.010	-0.353	-0.320
Plant height (cm)	0.851	0.229	-0.105	-0.038	-0.097	0.041	0.274	0.512	0.572	-0.292
Spike length (cm)	0.844	-0.146	0.221	-0.210	-0.137	-0.020	-0.159	-0.157	0.778	-0.149
Peduncle length (cm)	0.794	0.142	-0.298	-0.192	-0.153	0.180	0.744	0.417	0.203	-0.240
Awn length (cm)	0.784	0.186	-0.004	-0.094	0.221	0.118	0.106	0.198	0.896	0.032
No. of grain spike	0.150	0.275	0.184	-0.281	-0.700	0.765	0.056	0.070	0.012	0.166
Biological yield	-0.002	-0.100	0.348	-0.076	0.826	0.103	0.044	0.636	0.344	0.280
Grain yield	0.215	0.908	0.096	-0.037	-0.119	0.734	0.194	0.433	0.096	-0.306
1000 Grain weight (g)	0.231	0.448	0.691	-0.007	0.203	0.707	0.269	-0.349	0.326	0.125
Harvest index	0.038	0.852	-0.046	0.191	-0.201	0.797	0.175	0.074	-0.094	-0.449
F0	-0.181	0.019	-0.231	0.843	0.060	-0.183	-0.896	0.159	0.038	-0.189
Fm	-0.538	0.012	0.236	0.677	0.132	-0.411	-0.771	-0.254	-0.098	0.170
Fv/Fm	-0.331	-0.174	0.786	-0.120	-0.002	-0.508	0.001	-0.441	-0.083	0.529
CCI	-0.448	-0.285	0.436	0.001	0.177	-0.045	-0.069	-0.832	0.128	-0.027
Variance (%)	24.981	18.760	12.458	10.737	9.772	18.759	16.798	14.880	14.662	12.029
Cumulative (%)	24.981	43.741	56.199	66.936	76.708	18.759	35.557	50.437	65.099	77.128
Total	3.747	2.814	1.869	1.611	1.466	2.814	2.520	2.232	2.199	1.804

ignoring the related sign as significant coefficients (Tousi Mojarrad et al., 2005).

In this study, under normal condition, the first major factor that accounted for 24.981% of the total variation had a positive correlation with plant height, spike length, peduncle length and awn length. Accordingly, the positive coefficients indicate that when this factor is introduced, it is effective in increasing the grain yield (Table 4). Under stress condition, the first major factor that accounted for 18.759% of the total variations had a positive relationship with the number of grain spike, grain yield, grain weight 1000 and harvest index. Accordingly, the positive coefficients indicate that this is introduced as an effective factor in increasing the grain yield (Table 4).

In stress condition, the second factor that accounted for 16.798% of the total data changes had a positive relationship with fertile tillers and peduncle length traits, but had a negative coefficient with F0 and Fm. In selecting the genotypes by means of the second major factor, the mentioned fluorescence parameters had less importance (Table 4). The third factor that accounted for 12.458% of the total changes had a positive relationship with 1000 grain weight and Fv/Fm (Table 4). The fourth factor which accounted for 10.737% of the total data changes had a positive relationship with F0 and Fm. The fourth factor could be taken as an effective factor on fluorescence parameters. The fifth factor accounted for 9.772% of the total changes. It had a positive relationship with the number of grain spike and biological yield (Table 4). Finally, it is concluded that the second factor and the first factor were introduced as the superior factor respectively in normal and stress conditions.

They can have more usage in selecting genotypes for yield improvement. Peduncle length and plant height were mentioned as the fourth factor by Golparvar et al. (2002), as the fifth one by Mohammadi et al. (2002) and as the third factor by Damania and Jackson (1986). Xiao and Pei (1991) and Yildrim et al. (1993) mentioned the length of spike as the second factor.Sio-Se Mardeh et al. (2006) noted tall varieties as an optimal trait under drought condition. The fourth factor, the most factor coefficients related to the number of fertile tillers, spike length and peduncle length and can be regarded as plant growth factor.

Walton (1971) used factor analysis to identify growth and morphological traits relevant to yield in spring wheat and introduced four factors which included yield components, morphological traits, spike length and the number of grain per plant, as well as the relationship between large grains and grain filling duration with high yield. Tousi Mojarrad et al. (2005) introduced five factors by complementing factor analysis with principal

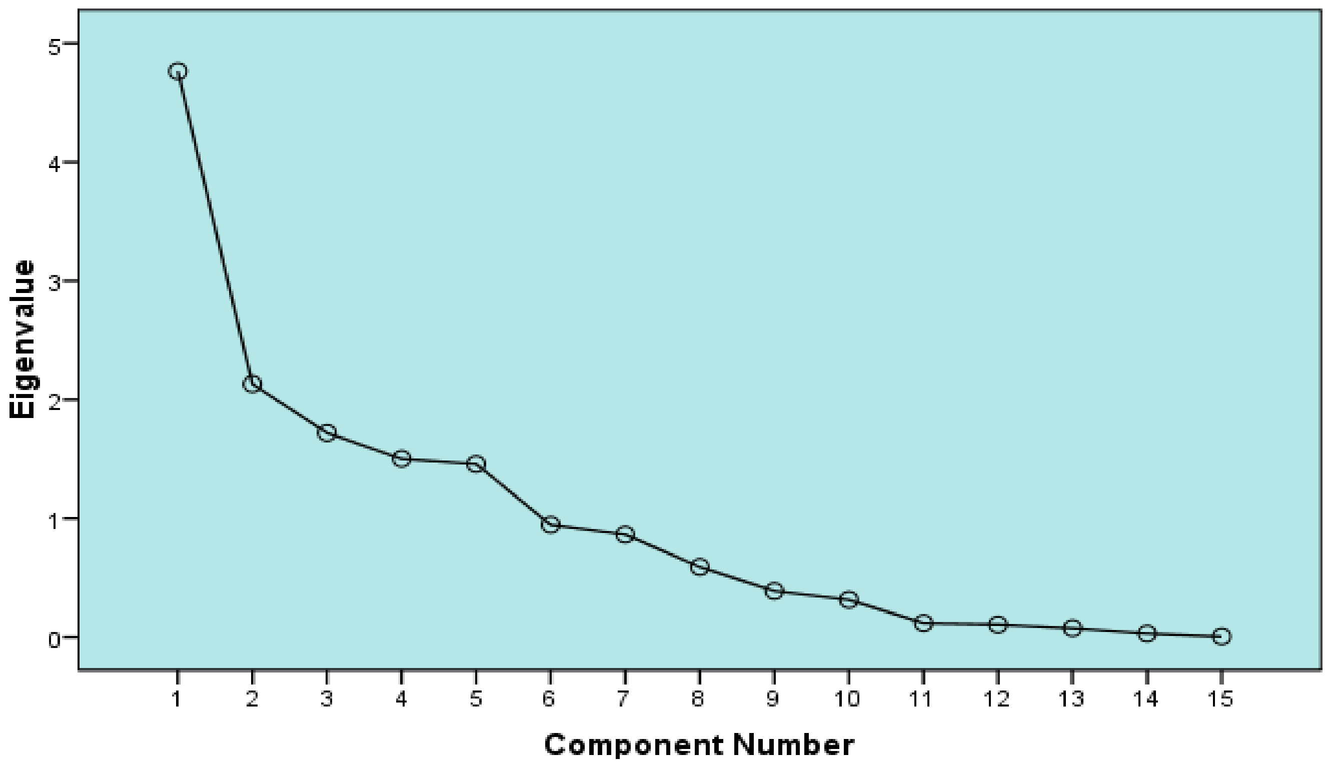

Figure 1. Screen plot showing Eigen values in response to number of components for the estimated variables of durum wheat genotypes in stress condition.

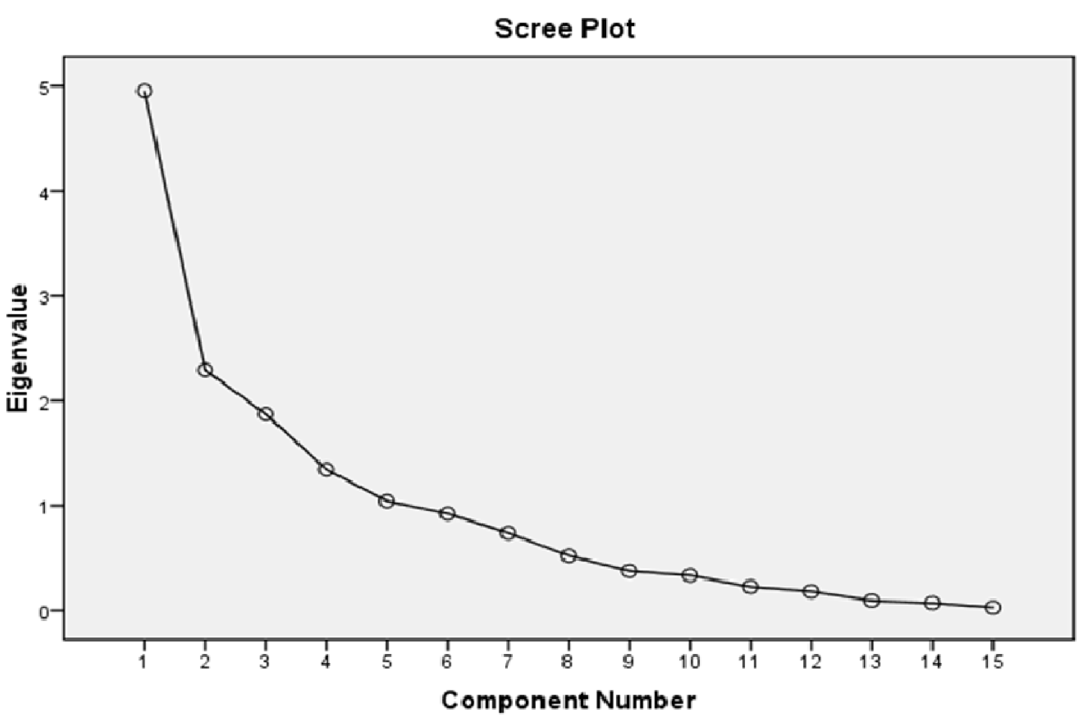

Figure 2- Scree plot showing eigen values in response to number of components for the estimated variables of durum wheat genotypes in normal condition.

components analysis which accounted for 67.7% of the data variations as a whole.

Conclusion

In general, the results of the inferences are that the traits related to grain yield index can be important for the evaluation and improvement of durum wheat varieties in future. The multiple statistical procedures which were used in this study showed that harvest index and biological yield were the most important yield variables to be considered under drought conditions, so these traits could be used for increasing yield. With respect to the results of factor analysis in stress condition, the first factor could be introduced as an effective factor in increasing yield. It accounted for 18.75% of the total changes. In the first factor, the number of grains, spike, grain yield, 1000 grain weight and harvest index had significant importance. Under normal condition, the second factor which accounted for 18.76% of the total changes could be introduced as an effective factor in increasing yield. In this factor, fertile tillers, harvest index and grain yield had remarkable importance. In general, it could be concluded that yield is a complex feature and in order to get more production and genetic improvement, the important factor which is the amount of hereditary traits must not also be ignored; moreover, the relation cognition should be done through regression and path analysis. In other words, the less the common aspects of the traits, the more successful the performance reform by means of the components will be.

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