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Research Article

Interrelationships Between Characteristics of F_4 Wheat Families Under Rain-Fed Conditions

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ABSTRACT

In order to study associations between traits in F_4wheatfamiliesunder rain-fed conditions, diverse wheat genotypes including80 F_4lines as well as their parents (Sardari and Azar 2) were evaluated in a randomized complete blocks design with three replications in experimental field of University of Mahabad, Iran during 2013-2015 cropping seasons. According to the results, significant differences between genotypes for all understudy traits were obtained. In this research significant and positive correlations between grain yield and number of tillers, spike length, grain per spike numbers, plant height, awn length, and fertile tillers per plant, 1000 kernel weight, harvest index and biological yield were measured. In addition, in regression analysis (stepwise method), biological yield, harvest index, number of grains per spike and 1000 kernel weight remained in the final model (R^2 = 0.83). Path analysis revealed that, biological yield, harvest index, number of grains per spike and 1000 kernel weight showed significant direct positive effects on grain yield, while number of grains per spike had the highest indirect effect on yield through biological yield. Also factor analyses showed three main factors (groups) which justified for 67.3% of the total data variations. It was finally concluded that selection of F_4genotypes on the basis of the grain yield, biological yield, harvest index, number of grains per spike and 1000 grain weight as election criteria seems to be more useful than the others to achieve more grain yield in breeding programs under rainfed conditions.

Key words: Correlation, Drought, Genetic diversity, Path analysis, Yield

INTRODUCTION

Water shortage is assigned as one of the most imperative environmental stress, leading to hazardous effects on a wide range of crops including wheat (*Triticumaestivum* L.) worldwide(Khan *et al.*, 2010).In Iran, with the average annual rain fall of nearly 220 mm, wheat plants commonly exposed to serious drought stress during growing season, especially oncean thesis phase begins (Nouri-Ganbalani *et al.*, 2009).However, introducing drought tolerant plants followed by producing significant grain yield must be accordingly considered as an inevitable case.

With the exception of molecular works, however, plant breeders believe that morphological and physiological features are still applicable to select the best lines as regard to releasing new tolerant wheat cultivars, consequently higher levels of yield. Hence, a wide range of morpho-logical characters such as number of tillers, grain per spike number, fertile tillers number per plant, 1000grain weight, peduncle length, awn length, plant height, spike length, kernel number per spike, grain weight per spike have been recommended and are still employed to make moisture shortage tolerant wheat genotypes (Blum, 2005; Nouri-Ganbalani *et al.*, 2009; Aminzadeh, 2010).

Unfortunately, development of tolerant cultivars is hampered by low heritability for drought tolerance and a lack of effective selection strategies (Kirigwi *et al.*, 2004). Indeed, plant-drought-stress-responses are significantly affected by the plant genetic background, low heritability of traits as well as large genotype-by-environment interactions (Richards, 1996). Needless to say, grain yield is a complex trait made up of the interaction between different yield components and environmental effects. In addition, because of some limitations (e.g., project management, interpreting data, negative interaction among different breeding traits, cost, climatic changes, etc.), breeders often prefer to design a breeding scheme according to the most important traits previously reported as well as target environment.

Wheat production can be enhanced through development of improved genotypes capable of producing

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better yield under various agro-climatic conditions and stresses (Inamullah *et al*., 2006). By now, a large number of studies have been performed in order to evaluate genetic relationships and genetic diversity among wheat lines on the basis of different morphological and physiological traits. For instance, at the study of Heydari *et al*., (2006), in which 157 double haploid lines of bread wheat were employed to address genetic diversity of different traits, number of fertile spike per area unit, plant height, number of grain and grain yield per spike as compared with other traits such as grain 1000 kernel weight, days to heading, days to anthesis and days to maturity exhibited significant genetic diversity. Evaluation of 20 bread wheat genotypes was later reported by Garavandi and Kahrizi (2010), traits including grain yield, spike number per square meter, number of seed per spike, spike density and awn length as compared with other traits had higher levels of genetic diversity.

To increase grain yield improvement, however, the study of yield contributing components according to their genetic mechanisms plays a pivotal role. Information regarding interrelationships between quantitatively inherited plant traits and their direct and indirect effects on grain yield is more fundamental in achieving success in a selection program (Khan *et al*., 2010). In this regards, the correlation coefficients have been proved as one method to estimate interrelationships between traits, but it cannot demonstrate reason of associations. Alternatively, path coefficient analysis is simply a standardized partial regression coefficient and as such measures the direct and indirect effect for one variable upon another and permits the separation of the correlation coefficient into components of direct and indirect effect (Dewey and Lu, 1959).In wheat, it has been reported a significant correlation between grain yield and grain weight, fertile tillers or spikes per plant, spikelet's per spike as well as spike(Saleem *et al.* (2006); Mohsin *et al*., (2009); Ganbalani *et al.* (2009) and Habibpor *et al.* (2011). In addition, these traits had significant direct and indirect effect on grain yield. Dawari and Luthra (1991), in bread wheat cultivars, showed that the harvest index, kernels per plant and spike length were important components of performance and selection. Subhani and Chowdhry (2000), Attarbashi *et al.* (2002) and Talebi (2011) reported positive correlation between plant yield (g/m2) with biomass and grain yield. Talebi*et al*., (2011) and Destro *et al*., (2001) showed Biomass had the most direct positive effect on grain yield in drought environment while at the study of Simane *et al*. (1993) and Monral *et al*. (1997) the number of seeds and number of fertile tillers had a great positive effect on grain yield according to path analyses.

This study, however, was conducted to address the following objectives: 1) assessment of the variation study of the important agronomic traits and identify the most important ones which may be useful as selection criteria in a wheat breeding program, 2) to determine the direct and indirect contributions of important yield components on the yield of wheat genotypes.

MATERIALS AND METHODS

This study was carried out in the experimental field of University of Mahabad, Iran during 2013-2015 under no irrigation or rain fed conditions. The experimental material consisted of two wheat genotypes Sardari and Azar 2(as parents) and80 F_4lines obtained from crossing between them. All 82 wheat genotypes were planted in a randomized complete block design with three replications. Spacing between plants and rows were kept as 15 and 30 cm, respectively. Ten plants per pot of each wheat genotype were selected for recording nine vital traits including tiller number, awn length, grain number, 1000-kerenal weight, spike length, biomass (biological yield), plant height, harvest index and grain yield.

To compute yield components, the plants contained in 1 m long rows were pulled out in 2 central rows of each plot at ripening, tillers number of each sample were carefully recorded. Harvest index was calculated by dividing the grain weight by the total plant weight of the 1 m long row sample. A sub-sample of 10 randomly selected plants was used to calculate spike length and plant height also measured from the soil to the top of the spike excluding the awns. 1000-grain weight was determined by weighting the weight of number 1000 grains drawn randomly from harvested grains of each plot. Biomass at ripening was calculated from the yield and harvest index of each plot. Lastly, awn lengths, grain yield followed by grain number were measured for further analyses.

With the aim of determining the significance of data, the analysis of variance (ANOVA) for all nine characters was determined using SAS software (Version. 9.1). In addition, the associations between traits were computed via SPSS software in order to determine the simple linear relations between the all traits. According to Dewey & Lu (1959), path analysis was finally carried out on the traits considered as the yield components. In this context, seed yield was taken into account as dependent variable in the method, while biological yield, Harvest index, number of seeds and 1000 grain weight which were thought to be effective on seed yield were consequently considered as independent variables. Correlation coefficients were found initially in order to determine the simple linear relations between the traits. The factor analysis method consisted of the reduction of a large number of correlated variables to a much smaller number of clusters of variables called factors was done by SAS 9.2 software.

RESULTS AND DISCUSSION

The results of analysis of variance (ANOVA) for all nine used traits are presented in Table 1. In this research effect of year and interaction between year× genotype not statistically significant on all understudy treats. Thus it can be stated that the response of genotypes was similar in terms of understudy traits from one year to the other. In general, there was significant difference among all genotypes in terms of all understudy traits, that it demonstrating the presence of genetic diversity in the mentioned traits. According to these results, apparently, direct selection on the basis of grain yield and indirect selection on the basis of biological yield and harvest index can help us to increase grain yield due to the genetic diversity governing on understudy genotypes. At the study of Heydari *et al*. (2006), in assessing of genetic diversity of different traits in a collection consisted of 157 double haploid lines of bread wheat, the traits including last internodes length, number of grain and grain yield per spike in comparison to other traits like grain volume weight, days to maturity, and days to heading had the highest values of genetic diversity. At the study of Garavandi and Kahrizi (2010), in which 20 bread wheat genotypes were evaluated, grain yield, spike number per square meter, number of seed per spike, spike density and awn length had the heights genetic diversity in compare with other traits.

Relationships between traits

The simple correlation between investigated traits is shown in Table 2. The correlation coefficient of grain yield with number of tillers, spike length, grains per spike, plant height, awn length, fertile tillers per plant, 1000 grain weight, harvest index and Biological yield were positive and significant. Golparvar *et al*. (2003), Amini *et al*. (2005) and Habippor *et al*. (2011) showed similar correlations in their experiments. Akram *et al*. (2008) and Abinasa *et al*., (2011) reported a significant positive correlation between number of kernels per spike, number of spikelets per spike and grain yield in wheat. In addition, this finding correspond to the results of Sinebo (2002), Khoda Rahmi *et al*., (2006), and Abinasa *et al*., (2011) who reported that biological yield had positive and significant correlation with grain yield and also is one of the most effective traits which affect the grain yield. By increasing biological yield, not only the amount of green area that can have photosynthesis and produce photo assimilate (sink) are extended, but also at the same time the number of sources that can store the photo assimilate will increase. Positive and significant correlation between biomass and the number of seed sand the number of fertile tillers confirm this concept. In addition, biomass showed a negative and significant correlation with harvest index. A positive and significant correlation was computed finally between the grain yields and spike length. In this research, the fact can be interpreted that increased spike length may lead to enlarge the number of seed and subsequently decrease in grain yield. Furthermore, between the number of seeds and spike length, positive and significant correlation was observed. These results were in agreement with the results of Yildirim *et al*., (1993), Khan *et al*., (2010), Habibpor *et al*., (2011) and Naghavi *et al*., (2015) who reported appositive and significant correlation between grain yields and spike length. Number of seeds, in this study, experienced a negative and significant correlation with 1000 grain weight. Khan *et al*., (2010) reported a negative and significant correlation between the number of seed and 1000 grain weight.

Path coefficients

In regression analysis using stepwise method under stress (Table 3), biomass, harvest index, the number of grains per spike and 1000 kernel weight remained in the final model, and explaining 83.4% of grain yield variation (R^2 = 0.834). A general linear model regression of grain yield under drought stress was computed through the following formula:

$$Y= - 1.09+ 0.27x + 2.496z + 0.08p + 0.01r$$

Where x, z, p and r, represent the biological yield, harvest index, number of grains per spike and 1000 grain weight, respectively.

Direct and indirect effects of these components determined on grain yield are presented in Table 4. The results of path coefficient analysis of important yield components with yield, revealed that biological yield exerted the highest positive and significant direct effect (+0.69) on grain yield followed by harvest index (+0.31), number of grains per spike (+0.25) and 1000 kernel weight (+0.05). These findings confirm the results of Izzat *et al*. (2000), Talebi *et al*., (2011) Abinasa *et al*., (2011) and Ahmadzade *et al*., (2011), in which the traits including biomass, harvest index and the number of seed had significant direct effect on yield. Khan *et al*. (2010), showed positives direct effect among the number of seed and grain yield but they announced 1000 kernel weight

Table 1: Analysis of variance of studied traits under different stress conditions

S. O. V.	df	mean of squares								
		No. of tillers	Plant height	Spike length	No. of seeds	Awn length	1000kernel weight	Grain yield	Biological yield	Harvest index
Year (Y)	1	3.89**	1976.79^{ns}	176.79^{ns}	68.04^{ns}	13.58^{ns}	92.33^{ns}	125.15^{ns}	7441.95^{ns}	0.031^{ns}
$Error_1$	4	0.22	175.8	93.2^{ns}	17.30	32.45	75.32	4747.14	7003.28	0.01
Genotype (G)	81	1.21^{**}	550.70^{**}	929.52^{*}	89.89**	7938.4**	15.50^{**}	1105.2**	3212.23**	0.02**
G×Y	81	0.49^{ns}	57.03^{ns}	228.49^{ns}	25.52^{ns}	1037.7^{ns}	4.17^{ns}	156.21^{ns}	649.95^{ns}	0.001^{ns}
$Error_2$	162	0.67	44.60	278.5	21.71	2100.07	3.73	309.43	644.13	0.01
CV	-	38.69%	20.5%	47.5%	18.34%	99/13%	4.89%	17.5%	11.73%	13.28%

**,* and ^{ns}, significant at P<0.01, 0.05 level of probability and non-significant, respectively

Table 2: Simple correlation between studied traits in average of conditions

Trait	Grain yield	Spike Length	Plant height	Biological yield	No. of seeds	Awn length	1000 grain weight	Harvest index
Spike Length	0.14^{*}							
Plant height	0.16^{*}	0.04^{ns}						
Biological yield	0.77^{**}	0.21^{**}	0.16^{*}					
No. of seeds	0.72^{**}	0.16^{*}	0.04^{ns}	0.75^{**}				
Awn length	0.26^{**}	0.14^{*}	0.02^{ns}	0.16^{*}	0.16^{**}			
1000 kernel weight	0.20^{**}	-0.006	0.01	0.05	-0.11^{*}	0.04^{ns}		
Harvest index	0.25^{**}	0.03^{ns}	0.01	-0.18^{*}	0.16^{*}	0.05	0.26^{**}	
No. of tillers	0.58^{**}	0.28^{**}	0.03^{ns}	0.69^{**}	0.62^{**}	0.05	0.04	-0.03^{ns}

**,* and ns, significant at P <0.01, 0.05 level of probability and non-significant, respectively.

Table 3: Step by step regression

Variant add to model	regression coefficient					
	Intercept	b_1	b_2	b_3	b_4	R^2
Biological yield	0.23	0.32				67.5%
Harvest index	-1.08.	0.28	2.6			81.3%
No. of seeds	-1.08	0.28	2.6	0.007		83.1%
1000 grain weight	-1.09	0.27	2.49	0.008	0.01	83.4%

Table 4: Direct and indirect biological yield, No. of seeds, Harvest index and 1000 grain weight on grain yield

Trait		Indirect effect on yield			
	Direct effect	Biological yield	Harvest index	No. of seeds	1000 grain weight
Biological yield	0.69**	-	-0.05	0.18	0.0
Harvest index	0.31**	-0.12	-	0.01	0.009
No. of seeds	0.24**	0.51	0.21	-	-0.009
1000 grain weight	0.05**	0.00	0.04	-0.04	-

Table 5: Direct and indirect effects of number of seeds, harvest index and 1000 grain weight on biological yield

Trait	Indirect effect on biological yield			
	Direct effect	No. of seeds	Harvest index	1000 grain weight
No. of seeds	0.78**	-	-0.015	0.014
Harvest index	-0.25**	0.052	-	0.020
1000 grain weight	0.13**	-0.095	0.04	-

Table 6: Direct and indirect effects of harvest index and 1000 grain weight on number of seeds

Trait	Indirect effect on No. of seeds		
	Direct effect	Harvest index	1000 grain weight
Harvest index	0.084*	-	0.013
1000 grain weight	-0. 13*	0.020	-

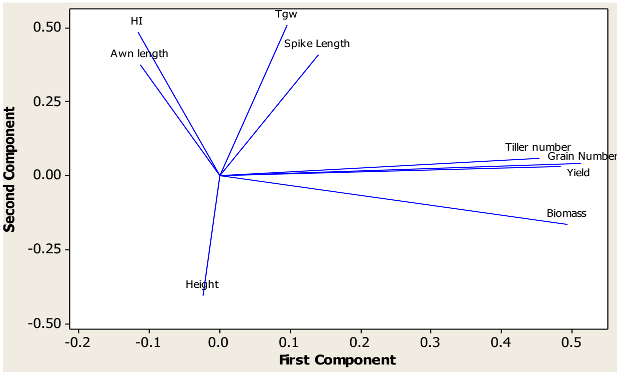

Fig. 1: Biplot display based on first and second component for 9 wheat genotype traits.

had negative indirect effect on the yield, which do not confirm the present results. On the other hand, increase in biological yield cause to increase the number of grains per spike and in this way indirectly effected the grain yield (increase direct effect between biological yield and grain yield 18%) however increase amount of biological yield indirectly diminished grain yield in way of reduced rate of harvest index. Also number of grains per spike had negative indirect effect on grain yield through reduce1000 kernel weight. Abinasa (2011) also reported a negative indirect effect among biological yield and harvest index. According to Table 5, number of grains per spike and 1000 kernel weight had significant and positive direct effect on biological yield. Furthermore, harvest index showed significant and negative direct effect on biological yield. Harvest index although had negative indirect effect on biological yield, through increase the number of seed and 1000 kernel weight had positive effect indirectly. Lastly, Table 6 showed harvest index and1000 kernel weight had significant and positive and negative direct effect on number of grains per spike.

Factor analysis

Data in Table 6 and Figure 1 showed that three main factors (groups) were justified for 67.3% of the total variability in the dependent structure. The first factor (group) included number of tillers, number of seeds, biological yield and grain yield which justified for 40.1% of the total variability in the dependent structure. The suggested name for this factor is yield potential component. The second factor included, spike length, awn length, 1000 kernel weight and harvest index which accounted for 14.3% of the total data variation, and it was named the grain characters component. The third factor included only plant height which justified for 12.8% of the total data variation. Therefore, three factors could justify major variations and could regard only these factors and summarize all variation in three factors. Leilah and Al-Khateeb (2005) by using factor analysis in wheat under drought conditions reported only three factor could justify 74.4% of the total variation and who named frets, second and third factor as biological yield, spike length and harvest index respectively.

Conclusion

Finally, according to the study results, grain yield had significant genetic variation, therefore selecting of F_4 lines on the basis of the yield criteria can be helpful in wheat breeding program. In addition, biological yield, harvest index, number of grains per spike and 1000 kernel weight showed remarkable genetic diversity and significant and positive directs effect on grain yield. Such traits could be accordingly considered as the main components for selection in a breeding program to improve grain yield. This implies the fact that these traits are the major contributors for the improvement of grain yield.

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Table 7: Special amounts and vectors of eight indices for 9 studied traits in wheat genotypes

Component	Initial Eigen values											
	Total	% of Variance	% Cumulative	No. of tillers	Plant height	Spike length	No. of seeds	Awn length	1000 kernel weight	Grain yield	Biological yield	Harvest index
1	3.21	40.15	40.15	0.82	0.03	0.14	0.88	-0.02	0.01	0.90	0.91	
2	1.15	14.37	54.53	-0.35	0.08	0.74	0.12	0.74	-0.53	0.11		
3	1.02	12.84	67.37	0.07	0.97	0.18	-0.14	0.18	-0.42	0.10	0.01	

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