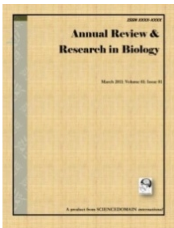

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Genotypic and Phenotypic Correlations among Yield and Yield Components in Durum Wheat (*Triticum durum* Desf.) under Different Water Treatments in Eastern Algeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AG, MH and MD designed the study, performed the statistical analysis. Authors AH and ZF wrote the protocol, and wrote the first draft of the manuscript. Authors SG and KM managed the analyses of the study. All authors managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The present study was conducted on the experimental site of ITGC (Technical Institute of Field Crops) station of Setif, Algeria; during 2010/2011 cropping season. The study was carried out to study the performance of durum wheat genotypes in relation to yield and yield component and evaluate genotypic and phenotypic correlations between yield and yield components under different water deficit conditions. Three irrigation treatments were obtained by irrigation at specified stages and no irrigation. These treatments were: no irrigation during all growth stages (I0); 20 mm irrigation during vegetative plant growth (Tillering stage) (I1) and 40 mm irrigation during reproductive plant growth (heading stage) (I2). Analysis of variance revealed that number of spike per m-2 (NS m-2) and grain yield (GY) were very significant (P < 0.001) affected under irrigation regime treatment whilst

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number of grain per spike (NG S-2) was shown highly significant (P <0.01). Grain yield reductions were 6 %, 12.4 % under the I1 and I0 treatments respectively, when compared with the optimum irrigation treatment (I2). Water limitation decreased NS m^{-2} by 14.11% and 9.67 % in the I0 and I1 treatments compared to the I2. Water limitation decreased NS m^{-2} by 14.11% and 9.67 % in the I0 and I1 treatments compared to the I2. Grain yield showed significant and positive genetic and phenotypic correlation with number of spikes per meter square (NS/m^2) under all conditions of growth. Harvest index and number of grains per meter square showed significant genetic and phenotypic correlations with grain yield under rainfed and irrigated conditions. The differential response of cultivars to imposed water stress condition indicates the drought tolerance ability of wheat cultivars. The significant genetic and phenotypic correlations among grain yield and yield components suggest that grain yield could be effectively increased by maximum genetic expression of grains spike-1, number of spikes per meter square, number of grains per meter square and harvest index.

Keywords: Durum wheat; genotypic and phenotypic correlations; irrigation; yield traits.

1. INTRODUCTION

Wheat production in Mediterranean region is often limited by sub-optimal moisture conditions. Visible syndromes of plant exposure to drought in the vegetative phase are leaf wilting, a decrease in plant height, number and area of leaves, and delay in accuracy of buds and flowers [1,2]. Drought stress at the grain filling period dramatically reduces grain yield [3]. Breeding for drought resistance is complicated by the lack of fast, reproducible screening techniques and the inability to routinely create defined and repeatable water stress conditions when a large amount of genotypes can be evaluated efficiently [4]. 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 favorable environments [5]. Sharif Alhosainy [6] and Saleem [7] observed that water deficit affected the number of spike m-2 and grains spike-1 in bread and durum wheat genotypes, furthermore terminal drought stress significantly reduced grain weight and plant dry mass in their study. Styk and Dziamba [8] showed that irrigation generally increased thousand-grain weight. The responses of crops or stages of plant growth, make a different water stress effects. Under different drought treatments, Giunta et al. [9] and Zhong-hu and Rajaram [10] found that the most sensitive wheat stage to drought was the grain filling period. The grain weight remains fixed at pre anthesis stage. Grain yield of durum wheat under hot and dry conditions is frequently limited by both high temperature and drought during grain growth. Halt irrigation induces a series of morphological and physiological changes in durum wheat such as a reduction in yield, grain weight and leaf area duration. Correlation between different traits is generally due to the presence of linkage disequilibrium, pleiotropic gene actions and epistatic effect of different genes [11]. The know-how regarding the nature and magnitude of association among plant traits is essential to improve crops yields. Singh et al. [12] observed that wheat grain yield was positively correlated with productive tillers and flag leaf area. Akram et al. [13] who reported significant positive correlation between number of grain per spike, number of spikelet per spike and grain yield in wheat. The objectives of present study were to investigate the effects of irrigation regimes during different growth and developmental phases on yield and yield components and test the genetic and phenotypic correlations of grain yield with the different yield components in durum wheat genotypes under stressed and irrigated conditions.

2. MATERIAL AND METHODS

Field experiment was done during the 2010-2011 growing season at the experimental field of ITGC Setif, Algeria. The statistical design employed was split plot based on a complete randomized block design (CRBD) with four replications. The three irrigation treatments were obtained by irrigation at specified stages and no irrigation. These treatments were: no irrigation during all growth stages (I0); 20 mm irrigation during vegetative plant growth (Tillering stage) (I1) and 40 mm irrigation during reproductive plant growth (heading stage) (I2). Total precipitation was recorded as 360.1 mm in 2010-2011 growing season. These cultivars were planted on November 30, 2010 on a clay-silt. The seeds were sown using an experimental drill in 1.2 m x 2.5 m plots consisting of 6 rows with a 20 cm row space and the seeding rates for experiments were about 300 seeds per m-2. The plots 1.2 m x 1.5 m size were harvested by a combined harvester. The plots were fertilized with SULFAZOT (26% N, 12% S, 120 Kg/ha) applied at tillage. Weeds were removed chemically by TOPIC (0.75 L/ha) and GRANSTAR (15 g/ha). At harvest, data were recorded on 1000-grain weight (TKW), grain yield (GY), and harvest index (HI). Also, some parameters such as number of spike m-2 (NS/m²) and grains per spike (NG/S were determined.

Analysis of variance (ANOVA) was performed to determine cultivar and treatment effects. Differences between treatments and genotypes means were tested using Fisher's LSD Test at the 0.05 level of probability. The genetic (rg) and phenotypic correlations (rp) between two characters, x1 and x2, were estimated according to Kwon and Torrie [14].

$$r_g = \frac{COV_g \ (X_1X_2)}{\sqrt{\sigma^2{}_g\,(x_1) \ \ \sigma^2{}_g\,(x_2)}}$$

Where,

COV g (x1x2) = Genetic covariance among trait x1 and x2.
$\sigma^2 g$ (x1) and $\sigma^2 g$ (x2) = Genetic variance for trait x1 and x2, respectively.

$$r_p = \frac{COV_p \ (X_1X_2)}{\sqrt{\sigma^2{}_p\,(x_1) \ \ \sigma^2{}_p\,(x_2)}}$$

Where,

COV g (x1x2) = Phenotypic covariance among trait x1 and x2.
$\sigma^2 g$ (x1) and $\sigma^2 g$ (x2) = Phenotypic variance for trait x1 and x2, respectively.

3. RESULTS AND DISCUSSION

A shown in Table 1, analysis of variance revealed that number of spike per m-2 (NS m-2) and grain yield (GY) were very significant (P < 0.001) affected under irrigation regime treatment whilst number of grain per spike (NG S-2) was shown highly significant (P <0.01). In addition, the genotypic effect was shown highly significant for number of spike per m-2 (NS m-2); grain yield (GY); number of grain per spike (NG S-2); number of grain per m-2 (NG m-2); 1000-grain weight (TKW) and harvest index (HI).

Table 1. Analysis of variance for grain yield (GY), harvest index (HI), no. spike m^{-2} (NS/m²), no. grains per spike (NG/S) and 1000-grain weight (TKW) of the durum wheat genotypes under different water deficit conditions

		Agronomic traits				
Source		**Mean Square (MS)**				
of variation	DF	GY	HI	NS/m²	NG/S	TKW
Bloc	3	106,21ns	49,99ns	4790,61**	3,15ns	2,209ns
Irrigation (I)	2	693,97***	84,84ns	23329,93***	69,17**	5,92ns
Genotype (G)	9	255,92***	725,49***	12873,41***	132,77***	207,16***
I X G	18	50,70ns	31,47ns	1392,04ns	10,8ns	16,15ns
CV %	/	11,46	11,28	10,39	7,72	6,5

***Significant difference at P < 0.01, *** Significant difference at P < 0.001 and ns: no significant*

3.1 Grain Yield (GY)

The results of the present study indicated that different irrigation regimes during growth and developmental stages had different considerable effects on grain yield. The highest grain yield (6.6 t ha-1) was produced under optimum irrigation treatment (I2) whilst the lowest (5.8 t ha-1) was observed in the (I0) treatment. Water deficit decreased grain yield at the different growth and developmental stages although the highest negative effect was observed in the I0 treatment. These grain yield reductions were 6%, 12.4 % under the I1 and I0 treatments respectively, when compared with the optimum irrigation treatment (I2) (Fig. 1 and Table 2). The negative effects of water deficit at Tillering decreased the number of spike per m-2 (NS m-2) and number of grain per spike (NG S-1) in the durum wheat genotypes. Tillering is also very sensitive to water stress being almost halved if conditions are dry enough [15,16]. These deleterious effects caused reduction in grain yield in the genotypes studied which are concurrent with the findings of Donaldson [17] and Nazeri [18]. Therefore, it is reasonable to suggest that a severe reduction in grain yield under the I0 treatment is associated with a decrease in number of spike per m-2 (NS m-2). Table 3 shows the different values for grain yield (GY) in the various durum wheat genotypes. The cultivar Sooty produced the highest GY (68 Qha-1) compared to the durum wheat genotypes under the irrigation treatments, although there was no significant difference between cultivar Sooty and Altar, Waha, Dukem, Mexicali and Kucuk genotypes. The genotype Oued Zenati which registered the lowest value (53.27 Qha-1), did not show a significant difference with the genotype Polonicum. According to Blum [19], identification of high potential varieties under optimum moisture and water deficit conditions (slow stressing) has been a principal breeding approach for durum and bread wheat genotypes.

Table 2. Response of grain yield (GY), harvest index (HI), no. spike m-2 (NS/m²), no. grains per spike (NG/S) and 1000-grain weight (TKW) under different irrigation regimes

Irrigation regime	**Agronomic traits**				
	GY	**HI**	**NS/m²**	**NG/S**	**TKW**
I0 (00 mm)	58,5 (c)	57,6 (a)	287,39 (c)	38,51 (b)	51,25 (a)
I1 (20 mm)	62,1 (b)	55,08 (a)	302,26 (b)	39,09 (b)	51,42 (a)
I2 (40 mm)	66,8 (a)	55,08 (a)	334,62 (a)	41,02 (a)	51,98 (a)
LSD 0,05	3,18	2,8	14,22	1,35	1,48

Column sharing the same letters indicates no significant differences.

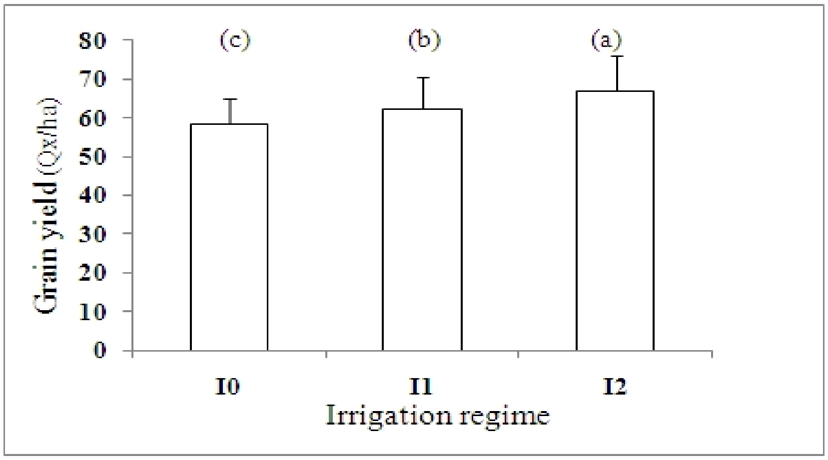

Fig. 1. The effect of different water deficit conditions on grain yield. Bars indicated standard deviations. Different letters indicated significant differences at <0.05 level

3.2 Harvest Index (HI)

The harvest index is the proportion of grain yield to biological yield and it shows the ability of the plants to translocate physiological matters to grains. Table 2 shows that there was no significant difference among all the treatments, but there is a highly significant difference between genotypes. The increase of the HI in the I0 treatment was related to the decreasing biological yield (Biomass) under water deficit conditions. This result is concurrent with the findings of Dakheel et al. [20] on durum wheat and Guinta et al. [9] on both durum wheat and triticale. The genotypic effects on the HI values indicated that the genotype Sooty gave the highest harvest index of 64 %, although there was no significant difference with the genotypes Altar, Dukem, Kucuk and Hoggar. Ehdaee [21] suggested that yield increasing in short varieties in recent years is due to increasing harvest index by selection in suitable agricultural conditions.

3.3 Number of Spike m-2 (NS/m²)

Fig. 2 shows that water deficit conditions during the different growth and developmental stages decreased the Number of Spike m-2. Water limitation decreased NS m^{-2} by 14.11% and 9.67% in the I0 and I1 treatments compared to the I2. El-Murshedy [22] summarized the effect of irrigation treatments on wheat yield attributes it could be concluded that skipping the irrigation at tiller stage produced the shortest plants with shortest spikes and lowest number of spikes m-2. Water limitation can cause severe competition between the different plant organs for photosynthesis assimilates during the stem elongation. Therefore, spike per unit area as the effective factor due to drought stress [23,5] has reduced under reproductive phase. With regard to genotype effects, Dukem cultivar produced the highest Number of Spike m-2 (343.06) compared to the other durum wheat genotypes (Table 3).

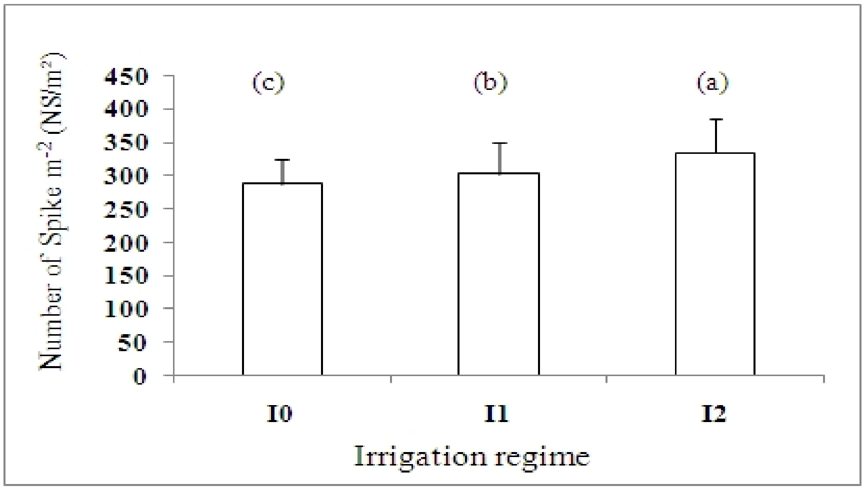

Fig. 2. The effect of different water deficit conditions on Number of spikes per meter square. Bars indicated standard deviations. Different letters indicated significant differences at <0.05 level

Table 3. Response of grain yield (GY), harvest index (HI), no. spike m^{-2} (NS/m²), no. grains per spike (NG/S) and 1000-grain weight (TKW) in different durum wheat genotypes

Genotype	Agronomic traits				
	GY	HI	NS/m²	NG/S	TKW
Oued Zenati	53,27(d)	40,32(e)	256,2(e)	37,3(c)	53,09(bc)
Altar	63,46(abc)	61,26(abc)	311,56(cd)	38,2(c)	54,15(b)
Sooty	68,00(a)	64,26(a)	327,5(ad)	44,3(ab)	47,10(d)
Polonicum	58,25(cd)	44,94(e)	253,8(e)	42,03(b)	51,19(c)
Waha	65,72(ab)	58,25(bc)	338,6(a)	38,82(c)	51,11(c)
Dukem	67,93(a)	61,56(ab)	343,06(a)	45,00(a)	43,19(e)
Mexicali	62,79(abc)	56,27(cd)	320,9(abc)	39,09(c)	51,77(bc)
Kucuk	65,00(ab)	59,68(abc)	338,61(a)	38,31(c)	51,59(bc)
Hoggar	60,37(bc)	60,23(abc)	300,56(cd)	38,14(c)	53,55(bc)
Bousselem	59,92(bc)	52,44(d)	290,00(d)	34,08(d)	58,77(a)
Mean	62,471	55,921	308,079	39,527	51,551
Min	53,27	40,32	253,8	34,08	43,19
Max	68	64,26	343,06	45	58,77
LSD **0,05**	5,8	5,12	25,9	2,47	2,71

Column sharing the same letters indicates no significant differences

3.4 Number of Grains per Spike (NG/S)

The number of the grains per spike is an important grain yield component. It has been reported that high yield in the new bread and durum wheat varieties are associated with the increasing number of grains per spike or unit area [24]. The results of the present study shows that there was no significant difference between I0 and I1 irrigation treatments for grains number, the exception being the I2 treatment, which yielded the biggish number for this important yield component (Table 2). With regard to genotype effects, Table 3 shows that the maximum and minimum grains number was produced by Dukem and Bousselem respectively. In addition to this, there were no significant differences among Dukem and Sooty.

3.5 1000-grain Weight (TKW)

Although the number of grain per spike has a predominant importance over grain weight with regard to grain yield, grain weight is well documented to be a major yield component determining final yield in Mediterranean environments [25,26]. The effects of cultivars treatment on thousand-grain weight were highly significant, but there is not significant effect of irrigation treatment on thousand-grain weight (Table 2). The absence of significant effect of irrigation treatment on thousand-grain weight probably due to halt of irrigation at anthesis stage. The effect of different genotypes on the TKW showed that the highest and lowest weight was shown by Bousselem and Dukem genotypes. In addition to this, there was no significant difference between Oued Zenati, Mexicali, Kucuk and Hoggar. The severe reduction in the NG S^{-1} in the genotype Bousselem is compensated with an increase in the TKW. Slafer et al. [27] argue that the lower grain weight observed with increased NG m^{-2} is not only due to a lower amount of assimilates per grain but it is the result of an increased number of grains with a lower weight potential coming from more distal florets.

3.6 Genotypic and Phenotypic Correlations

Genetic and environmental causes of correlation combine together and give phenotypic correlation. The dual nature of phenotypic correlation makes it clear that the magnitude of genetic correlation cannot be determined from phenotypic correlation. Therefore, estimation of degree of genotypic and phenotypic correlation of grain yield with yield components is very important to utilize the available genetic variability through selection [28]. As shown in Table 4, grain yield showed significant and positive genetic and phenotypic correlation with number of spikes per meter square (NS/m^2) under all conditions of growth. The above findings conform with earlier reports [29,13]. Yield, as a function of various components, is a complex character. It was suggested that yield depends on the number of spikes per unit area, the number of grains per spike and the average grain weight [30]. In addition, grain yield register significant genetic correlation with number of grains per spike (NG/S) ($r = 0.63^*$) under irrigated conditions, similar results were registered by Khan and Naqvi [31] and Burio et al. [32] under irrigated conditions. Harvest index and number of grains per meter square showed significant genetic and phenotypic correlations with grain yield under rainfed and irrigated conditions (Table 4). Majumder et al. [33] reported that grain yield per plant was positively and significantly correlated with grains per spike and harvest index both at genotypic and phenotypic levels in spring wheat. Khan et al. [34] registered significant genetic and phenotypic correlation between grain yield and harvest index in wheat. In the study of Leilah and Al-Khateeb [35] results proved that 1000-grain weight, weight of grains/spike, harvest index and the biological yield were the variables most closely related to the grain yield. Aslani et al. [36] reported in their study significant and positive correlation between grain yield and number of grains per meter square. Increases the number of grains per square meter is an important yield component that influences the grain yield [24]. Grain yield (GY) showed significant and negative genetic and phenotypic correlations with thousand grain weight (TKW) under irrigated and rainfed conditions. Abinasa et al. [37] reported significant genetic correlation between GY and TKW. Many researchers observed positive or negative correlations of grain yield with plant height, thousand grain weight, spike length and protein for wheat [38,39,40].

Table 4. Genotypic (r_g) and phenotypic (r_p) correlations among grain yield and yield components under rainfed and irrigated conditions

Dependent		Exploratory traits									
		NS/m²		NG/S		HI		NG/m²		TKW	
Trait		r_g	r_p	r_g	r_p	r_g	r_p	r_g	r_p	r_g	r_p
GY	Rainfed	0,95**	0,95**	0,55	0,38	0,99**	0,80**	0,95**	0,90**	-0,80**	-0,60
	Regime 1	0,95**	0,93**	0,24	0,37	0,92**	0,69*	0,64*	0,64*	0,02	-0,54
	Regime 2	0,96**	0,95**	0,63*	0,59	0,96**	0,95**	0,77**	0,66*	-0,86**	-0,69*

** Significant at 5% [r $_{(5\%)}$ = 0,632], ** Significant at 1% [r $_{(1\%)}$ = 0,765], r_g = genetic correlation, r_p = Phenotypic correlation*

4. CONCLUSIONS

It is concluded from the results of this study that water stress reduced durum wheat yield and some yield components in all cultivars. The differential response of cultivars to imposed water stress condition indicates the drought tolerance ability of wheat cultivars. The significant genetic and phenotypic correlations among grain yield and yield components suggest that grain yield could be effectively increased by maximum genetic expression of grains spike-1, number of spikes per meter square, number of grains per meter square and harvest index. Indirect selection of these yield contributing traits in early generations will enhance genetic potential of newly durum wheat genotypes for grain yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Boyer JS. Plant productivity and environment. Science. 1982;218:443-448.
2. Passioura JB, Condon AG, Richards RA. Water deficits, the development of leaf area and crop productivity. In: Smith J.A.C., Griffiths H. (eds). Water deficits plant responses from cell to community. BIOS Scientific Publishers limited, Oxford; 1993.
3. Ehdaee B, Shakiba MR. relationship of internode-specific weight and water soluble carbohydrates in wheat. Cereal Res Commun. 1996; 24: 61-67.
4. Ramirez P, Kelly JD. Traits related to drought resistance in common bean. Euphytica. 1998;99:127-136.
5. Richards RA, Rebetzke GJ, Condon AG, Herwaarden AF. Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. Crop Sci. 2002;42:111-121.
6. Sharif Alhosainy M. The effect of water stress on agronomical traits of durum and bread wheat. Tabriz University. Iran; 1998.
7. Saleem M. Response of durum and bread wheat genotypes to drought stress: Biomass and yield components. Asian journal of plant science. 2003;2:290-293.
8. Styk B, Dziamba S. Effect of some agronomic practices and irrigation on yield variability, 1000-grain weight, hectolitre weight and protein content in two spring wheat cultivars. Field Crop Abstr. 1984;37:82–83.
9. Guinta, F, Motzo R, Deidda M. Effect of drought on yield and yield components of durum wheat and triticale in a Mediterranean environment. Field Crops Res. 1993;33:399-409.
10. Zhong-hu H, Rajaram S. Differential responses of bread wheat characters to high temperature. Euphytica. 1994;72:197-203.
11. Falconer DS. A note on Fisher's 'average effect' and 'average excess'. Genet. Res. 1985;46:337–347.
12. Singh KN, Singh SP, Singh GS. Relationship of physiological attributes with yield components in bread wheat under rainfed condition. Agric. Sci. Digest. 1995;15:11-14.
13. Akram Z, Ajmal SU, Munir M. Estimation of correlation coefficient among some yield parameters of wheat under rainfed conditions. Pakistan J. Bot. 2008;40:1777-1781.
14. Kwon SH, Torrie JH. Heritability and inter-relationship among traits of two Soybean Populations. Crop Sci. 1964;4:196-198.
15. Peterson, CM, Klepper B, Pumphrey FB, Rickman RW. Restricted rooting decreases tillering and growth of winter wheat. Agron. J. 1984;76:861-863.

16. Rickman RW, Klepper BL, Peterson CM. Time distribution for describing appearance of specific culms of winter wheat. Agron. J. 1983;75:551-556.
17. Donaldson E. Crop traits for water stress tolerance .American Journal of Alternative Agriculture. 1996;11:89-94.
18. Nazeri M. Study on response of triticale genotypes at water limited conditions at different developmental stages. PhD thesis, University of Tehran, Iran; 2005.
19. Blum A. Plant Breeding for Stress Environments. CRC. Press Inc. Florida, USA; 1988.
20. Dakheel AL, Naji I, Mahalakshmi V, Peacock JM. Morphophysiolo-gical traits associated with adaptation of durum wheat to hars Mediterranean environments. Aspects of Applied Biology. 1993;34:297-306.
21. Ehdaee B. Common experimental statistic. Publisher Mashhad Barsava; 1994.
22. El-Murshedy WA. Effect of skipping one irrigation at different developmental stages of five bread wheat cultivars. J. Agric. res. Kafer ElSheikh Univ. 2008;34:25-41.
23. Simane B, Peacock JM, Struik PC. Differences in development and growth rate among drought resistant and susceptible cultivars of durum wheat (Triticum turgidum L. var. durum). Plant and Soil. 1993;157:155-166.
24. Calderini DF, Reynolds MP, Slafer GA. Genetic gains in wheat yield and main physiological changes associated with them during the 20 th century. In Satorre, E.H. and Slafer, G.A (Eds) wheat: Ecology and Physiology of determination New York: Food Products Press; 1999.
25. Peltonen-Sainio PA, Kangas Y, Salo A, Jauhiainen L. Grain number dominates grain weight in temperate cereal yield determination: Evidence based on 30 years of multiocation trials. Field Crops Research. 2007;100:179-188.
26. García Del Moral LF, Rharrabti Y, Villegas D, Royo C. Evaluation of grain yield and its components in durum wheat under Mediterranean conditions: An ontogeny approach. Agronomy Journal. 2003;95:266-274.
27. Slafer GA, Calderini DF, Miralles DJ. Yield components and compensation in wheat: opportunities for further increasing yield potential. In M.P. Reynolds, S. Rajaram and A. McNab, eds. Increasing Yield Potential in Wheat: Breaking the Barriers, México, D.F: CIMMYT. 1996;101-133
28. Singh AK, Singh SB, Yasave SH. Correlation and path analysis in early generation. Indian J. Genet. 1998;58:260-264.
29. Kashif M, Khaliq I. Heritability, correlation and path coefficient analysis for some metric traits in wheat. Int'l. J. Agric. Biol. 2004;6:138-142.
30. Aycicek M, Yildirim T. Path coefficient analysis of yield and yield components in bread wheat (*Triticum aestivum* L.) genotypes. Pak. J. Bot. 2006;38:417-424.
31. Khan N, Naqvi FN. Correlation and Path Coefficient Analysis in Wheat Genotypes under Irrigated and Non-Irrigated Conditions. Asian Journal of Agricultural Sciences. 2012;4:346-351.
32. Burio UA, Oad FC, Agha SK. Correlation coefficient (r) values of growth and yield components of wheat under different nitrogen levels and placements. Asian J. Plant Sci. 2004;3:372-374.
33. Majumder DAN, Shamsuddin AKM, Kabirand MA, Hassan L. Genetic variability, correlated response and path analysis of yield and yield contributing traits of spring wheat. J. Bangladesh Agril. Univ. 2008;6:227–234.
34. Khan HA, Shaik M, Mohammad S. Character association and path coefficient analysis of grain yield and yield components in wheat. Crop Research, Hisar. 1999;17:229-233.
35. Leilah AA, Al-Khateeb SA. Statistical analysis of wheat yield under drought conditions. Journal of Arid Environments. 2005;61:483-496.

36. Aslani F, Mehrvar MR, Juraimi AS. Evaluation of some morphological traits associated with wheat yield under terminal drought stress. African Journal of Agricultural Research. 2012;7:4104-4109.
37. Abinasa M, Ayana A, Bultosa G. Genetic variability, heritability and trait associations in durum wheat (*Triticum turgidum* L. var. durum) genotypes. African Journal of Agricultural Research. 2011;6:3972-3979.
38. Depauw RM, Clark JM, McCaig T, Townley TF. Opportunities for the improvement of western Canadian wheat protein concentration, grain yield and quality through plant breeding. In: Wheat Protein Production and Marketing: Prceedings of the Wheat Protein Symposium, 255-258, March, Saskatoon, Canada. 1998;9-10.
39. Chowdhry MA, Ali M, Subhani GM, Khaliq I. Path coefficient analysis for water use efficiency, evapotranspiration efficiency and some yield related traits in wheat. Pakistan Journal of Biological Sciences. 2000;3:313-317.
40. Tamman AM, Ali SA, El-Sayed EAM. Phenotypic, genotypic correlation and path coefficient analysis in some bread wheat crosses. Asian Journal of Agricultural Science. 2000;31:73-85.

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