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Effect of genotype × environment interaction on grain yield factors in durum wheat

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Abstract

Identifying environment-specific and widely adapted genotypes is necessary through understanding of environmental interaction (GEI). To estimate the enormousness of genotype (G), environment (E) and GEI results on yield and yield components and it is necessary to conduct multi-locations trials of durum wheat. During the year 2019/20 cropping season eleven (11) durum wheat genotypes were appraised under three locations within Balochistan, Pakistan. Almost all traits exhibit significant results for combined analyses of variance for genotypes (G) and Genotype X Environmental Interaction (GEI), the results of the genotypes were not uniform transversely the locations shows strong effect of environments. Commonly, out of total variation, GEI explicated chief share of deviation and thus had greater effect than genotypes (G) and environment (E) on the countenance of makeup for all characters. Mean value of three environments indicates that the genotype/line (G-9) produced supreme value for grain yield (4682.4 Kg ha^{-1}) and harvest index (34.66%), signifying it as reputable their exact malleability in corresponding environments. Among environments, E-02 was acknowledged as exceedingly fruitful environments in relations of grain yield. High yielding and widely adaptable genotype thus seemed as principal genotype/line for supreme of the production traits. Likewise, in all three environments G-9 had produced higher grain yield excluding E-03. Analysis of correlation exposed momentous positive link of grain yield with plant density m^{-2} (rg = 0.40*), biological yield (rg = 0.39*) and harvest index (rg = 0.82*). The genotype/line G-9 was originated as extraordinary yielding genotype/line and consequently could be suggested for commercialization in Balochistan.

Keywords: *Triticum durum*; Genotypic environmental interaction (GEI); Correlation; Yield components.

1. Introduction

The people of Pakistan use wheat as primary source of food. In our country wheat was cultivated on 9.1 million hectares and the production was 27.4 M tons with mean yield of 3.01-ton ha^{-1} (Pakistan Bureau of Statistics 2021-22), whereas in Balochistan, it was planted on 0.427 million hectares and production was 0.867 million tons with a mean yield 2.03-ton ha^{-1} (Agriculture Statistics Balochistan 2019-20).

The Pakistan country wide mean yield is extremely beneath than world agro technologically advanced countries. The situation in Balochistan is more poorest where the durum wheat production is lower than the country wide mean yield. The causes of lesser grain yield are shortage of irrigation water, erratic rainfall, heat/could stress, unobtainability of high yielding varieties and quality seed. With increase in world population the demand of durum wheat crop is also increase due to staple food crop. The production of durum wheat can be increased by introduction of high yielding cultivars and brings more area under durum wheat cultivation. The cultivation of durum wheat on large area is restricted; though introduction of high yielding with broader adaptability to environment play significant part for their high production. The act of varieties/cultivars mostly base on their genetic makeup (G), environment (E) and their interactions (GEI). Akcura et al., 2009; Karimizadeh et al., 2012 and Mohammad et al., 2012 reported that mutable retort

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of genotypes diagonally in assessment environments are common phenomenon, identified as GEI. The yield potential of varieties/cultivars depends on the act ended environment/location and year. Therefore, to identify high yielding and comparatively stable genotypes/lines are prerequisite for GEI. Annicchiarico, 2002 reported that the trials in numerous locations, the GEI rules the identification of the utmost unwavering genotypes/lines that are appropriate for explicit environment/location. The genetic homeostasis is necessary to boost up mean yield of durum wheat. The cultivars with broader genetic makeups and healthier presentation under different agro-climatic conditions can increase the durum wheat production. The genetic improvement of durum wheat course is naturally slow but it can be speed up by using selective process of man via proper supervision of environmental aspects. Mohammad, 2011 reported that the genetic progress is more complex due to traits are governed by environment. With reference to identifying widely adopted genotypes/lines, keeping in the prominence of GEI, the present experiment was designed using eleven (11) durum wheat genotypes including one check wheat variety Shalkot-14. The research trials were sown transversely in three (3) environments to examine GEI effects on durum wheat production and its other traits, classify high yielding, more suitable genotypes/lines with constant yield, assess genetic correlation coefficients among yield and yield components in durum wheat.

2. Materials and methods

To explain genotype with reference to environmental interaction (GEI) for grain yield and related traits, ten (10) durum wheat genotypes with one check wheat variety Shalkot-14 were tested over 3 environments of Balochistan, Pakistan during 2019/20, the experimental material was planted in Balochistan Agricultural Research & Development center Quetta (E-01), farmer field Sibi (E-02) and farmer field Khuzdar (E-03).

Table 1 Genotypes/cultivars Pedigree

Sr. #	Genotypes/cultivars	Name/Pedigree	Selection History
1.	G-1	Stj3//Bcr/Lks4/3/Ter3	ICD99-0091-T-3AP-AP-10AP-AP
2.	G-2	Azeghar1/4/IcamorTA0462/3/Maamouri3 //Vitron/Bidra1/5/Mgnl3/Ainzen1	ICD06-0230-BLMSD-0AP-12AP-0Tr- 3AP-0Tr-11AP-0THT-0AP -0TR
3.	G-3	Ossl1/Stj5/5/Bicrederaa1/4/BezaizSHF// SD19539/Waha/3/Stj/Mrb3/6/Icajihan12	ICD07-094-BLMSD-0AP-6AP-0Tr-1AP-0THT-0AP -0TR
4.	G-4	Mrb3/Mna1//Ter1/3/ICAMORTA0459/ Ammar7/4/Beltagy2	ICD06-0279-0AP-2AP-0AP-1AP-0THTD
5.	G-5	Ossl1/Stj5/5/Bicrederaa1/4/BEZAIZSHF// SD19539/Waha/3/Stj/Mrb3/6/Mgnl3/Aghrass2	ICD06-1525-0AP-1AP-0AP-5AP-0THTD
6.	G-6	Terbol975/Geruftel2	ICD06-1790-0AP-4AP-0AP-4AP-0THTD -0TR
7.	G-7	ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/7/SRN_3/AJAIA_15	CDSS04B00764D-11Y-0M-3Y-0M-4Y-0B
8.	G-8	Icasyr1/3/Gcn//Stj/Mrb3	ICD02-1016-C-6AP-0TR-1AP-0AP-7AP-0AP-3AP-0AP-0TR-0AUB
9.	G-9	20048Traikia(Mor)/Mrb5//Stj3	ICD92-0511-MABL-0AP-16AP-0TR-12AP-0AP
10.	G-10	Terbol975/Geruftel2	ICD06-1790-0AP-4AP-0AP-4AP-0THTD -0TR-0AUB
11.	G-11	Shalkot-14	

The experimental material was planted in plot size of 5m^{-2} with RCBD in factorial strategy with three repeats at each location. Each plot size had 4x5-meter long x 0.25 m apart. Recommended rate of nitrogen 120 Kg ha^{-1} and phosphorous 80 Kg ha^{-1} was used. Throughout the growing period standard culture practices were used. At physiological maturity plant height was dignified from bottom to the top of selective plants. Plant density m^{-2} was measured by using quadrate succeeding the technique defined by Sayre et al., (1997). At maturity the plot size of 5m^{-2} (4 rows) were harvested and measured to record the biological yield and then calculate in Kg ha^{-1}. The harvested crop was sun drying for the period of a week, then threshed for record grain yield/plot and then tuned into Kilo gram per hectare. The harvest Index was measured by dividing economical yield with biological yield and multiplied by 100 (tuned in to percentage). Adopted the procedure of Singh and Chaudhry (1997) computed genetic correlations of morphological and yield traits.

The observed data of numerous yield and yield traits were statistically examined transversely in three locations suitable for RCBD factorial design using SAS computer program, averages were disjointed using LSD test at 5% level of likelihood for substantial differences.

3. Results

Significant differences were observed amid genotypes, locations and interaction between genotype by environment (GEI.) in all characters for Combined analysis of variance (Tab.5). Across different environments the GEI. reveled significant difference, it means that the performance of genotypes was not uniform and hereafter right to ensued for further analysis of genotypes in specific environments.

The semi-dwarf durum wheat cultivars are resistance to lodging and nitrogen reactive. Environment effects plant height and it is may different in varying environmental circumstances (Petrovi et al., 1997). Combined analysis of variance for plant height discovered substantial differences ($P \leq 0.05$) amid genotypes, locations, and their GEI. Significant effect was noted for environment and genotypes but had seized least sum of squares. The variation clarified by environments was 14.30% and genotypes 24.84% of variation, while GEI effects was 20.43% (Tab.5). Averaged main effect of genotypes over three environments/locations, plant height between 92.33 to 81.55 cm with mean value of 87.57 cm (Tab.2).

Table 2 Main effect of genotypes in three environments

Genotype	Plant height (cm)	Plant Density m^{-2}	Biological Yield (Kg ha^{-1})	Grain Yield (Kg ha^{-1})	Harvest Index (%)
G-1	88.55abc	473.78c	14760a	4258.6d	30 d
G-2	85.77 c	490.56ab	14351b	4055.6e	28.55 ef
G-3	90.77ab	470.00c	14272b	4481.9b	31.33 c
G-4	87.88 bc	485.22ab	14214bc	4239.2d	29.89 d
G-5	87.11 bc	487.11ab	14155bc	4246.9d	32.55 b
G-6	86.44 c	491.67ab	14111bc	4334.9c	29.44 de
G-7	85.88 c	484.67b	13958bc	3794.8f	27.33 g
G-8	81.55 d	492.11ab	13840cd	4339.0c	31.44 c
G-9	89.11abc	487.67ab	13545 d	4682.4a	34.66a
G-10	92.33a	493.11a	13019e	4457.3b	31.55bc
G-11	87.88 bc	473.33c	13015e	3630.0g	27.88fg
LSD Value (0.05)	4.004	8.3238	397.08	65.45	1.018

Values within the same column followed by the same letters are not significantly different, using LSD Range Test at 5% level.

Recorded maximum plant height for G-10 (92.33 cm), which was at par with G-3 (90.77 cm), G-9 (89.11 cm) and G-1 (88.55 cm) followed by G-4 (87.88 cm), G-11 (87.88 cm) and G-5 (87.11 cm) while least plant height was documented for G-8 (81.55 cm). Among environments, higher plant height was 90.30 in E-02 followed by E-03 (87.06 cm) and E-01 (85.36 cm) table-3. Extreme plant height was perceived for G-3 in E-02 (95.66 cm); G-10 in E-01 (93.66 cm); G-11 in E-02 (93.66 cm); G-9 (92.66 cm) in E-02; G-10 in E-02 (91.66 cm); G-10 in E-03 (91.66 cm); G-9 in E-03 (91.33 cm); G-1 in E-02 (90.33 cm); G-7 in E02 (89.33 cm) and G-6 in E-02 (89.00 cm) and minimum was recorded in G-8 in E-01 (Tab.4).

Table 3 Mean value of genotypes in three environments

Environment/Location	**Plant height (cm)**	**Plant Density m^{-2}**	**Biological Yield (Kg ha^{-1})**	**Grain Yield (Kg ha^{-1})**	**Harvest Index (%)**
1 (Quetta)	85.36 b	481.30b	1403a	4221.2ab	30.24a
2 (Sibi)	90.30a	487.76a	13967ab	4254a	30.45a
3 (Khuzdar)	87.06 b	484.36ab	13795b	4211.6b	30.57a
LSD Value (0.05)	2.091	4.3469	207.37	34.180	0.5316

Values within the same column followed by the same letters are not significantly different, using LSD Range Test at 5% level.

Table 4 Mean effect of Genotype*Environment interaction in three environment

Sr .#	Geno type	Plant height (cm)			Plant Density m^{-2}			Biological Yield (Kg ha^{-1})			Grain Yield (Kg ha^{-1})			Harvest Index (%)		
		Quetta (E-01)	**Sibi (E-02)**	**Khuzdar (E-03)**	**Quetta (E-01)**	**Sibi (E-02)**	**Khuzdar (E-03)**	**Quetta (E-01)**	**Sibi (E-02)**	**Khuzdar (E-03)**	**Quetta (E-01)**	**Sibi (E-02)**	**Khuzdar (E-03)**	**Quetta (E-01)**	**Sibi (E-02)**	**Khuzdar (E-03)**
1	G-1	87.66 bcdefg h	90.33a bcde	87.66 bcdehg h	449.00 j	488.33a bcdefg	484.00b cdefgh	14109b cdefghi	14455a bcdef	14253b cdefgh	4054. 3lmn	4363. 7fgh	4357. 7fgh	29.00 hijkl	30.33 efghi	30.66 defgh
2	G-2	83.00g h	88.66b cdefgh	85.66 defgh	496.67a b	487.33a bcdefg	487.67a bcdefg	14380a bcdefg	14347a bcdefgh	13914d efghij	3958. 3no	4117. 3kl	4091. 0klm	27.66 klmn	28.66 ijklm	29.33 ghijk
3	G-3	86.66 cdefgh	95.66 a	86.66 cdefgh	474.00g hi	464.33i	471.67hi	14662a bc	14338a bcdefgh	14052d efghi	4504. 7cd	4540. 3c	4400. 7defg	31.00 cdefg	31.66 cdef	31.33 cdef
4	G-4	90.33a bcde	87.66b cdefgh	85.66d efgh	479.00e fgh	495.33a bcd	481.33d efgh	13832ef ghijk	14149bc defghi	14484a bcde	4000. 7mn	4419. 0def	4298. 0ghi	29.00 hijkl	31.33 cdef	29.33 ghijk
5	G-5	84.66ef gh	88.00b cdefgh	88.66b cdefgh	487.67a bcdefg	484.00b cdefgh	489.67a bcdef	12998n o	12963n o	13095 lmno	4236. 3ij	4232. 3ij	4272. 0hij	32.66 bc	32.33 bcd	32.66 bc
6	G-6	85.00d efgh	89.00a bcdefg	85.33d efgh	489.00a bcdef	495.33a bcd	490.67a bcdef	14791a b	15011a	14478a bcdef	4304. 7ghi	4365. 7fgh	4334. 3fghi	29.33 ghijk	29.00 ijkl	30.00f ghij
7	G-7	83.33fg h	89.33a bcdefg	85.00d efgh	484.67b cdefgh	481.67c defgh	487.67a bcdefg	13741g hijkl	14059cd efghi	14073c defghi	3870. 3op	3678. 3q	3835. 7p	28.33 jklm	26.33 n	27.33l mn
8	G-8	73.33i	86.66c defgh	84.66ef gh	495.33a bcd	500.00a	481.00d efgh	14539a bcd	13496ij klmn	13485 ijklmn	4574. 0bc	4267. 7hij	4175. 3jk	31.66 cdef	31.33 cdef	31.33 cdef
9	G-9	83.33fg h	92.66a bc	91.33a bcde	482.33b cdefgh	494.67a bcd	486.00a bcdefgh	13795fg hijk	13691hi jklm	13148k lmno	4837. 0a	4672. 0b	4538. 3c	35.33 a	34.00 ab	34.66 a
10	G-10	93.66a b	91.66a bcde	91.66a bcde	492.67a bcde	496.00a bc	490.67a bcdef	14186b cdefgh	14094cd efghi	14053c defghi	4487. 7cde	4509. 0cd	4375. 3efgh	31.66 cdef	32.00 cde	31.00 cdefg

11	G-11	88.00bcdefgh	93.66ab	82.00h	464.00i	478.33efghi	477.67fghi	13303jklmno	13027mno	12716 o	3605.3q	3635.7q	3649.0q	27.00mn	28.00klmn	28.66ijklm
LSD Value (0.05)		6.93			14.41			687.76			113.36			1.763		

Values within the same column followed by the same letters are not significantly different, using LSD Range Test at 5% level.

Table 5 Pooled SS and MS for various traits of durum wheat genotypes across three environments/Locations

Traits	Environment (df=2)			Genotypes (df=10)			GXE (df=20)			Replication (df=2)			Error (df=64)		
	SS	**MS**	**SS %**	**SS**	**MS**	**SS %**	**SS**	**MS**	**SS %**	**SS**	**MS**	**SS %**	**SS**	**MS**	**SS %**
Plant height	415.70	207.848*	14.30	721.96	72.196*	24.84	593.86	29.693*	20.43	17.64	8.818	0.61	1157.03	18.079	39.81
Plant density	688.00	344.010*	3.86	6166.7	618.669*	34.74	4325.3	216.266*	24.29	1608.8	804.404	9.03	4999.9	78.123	28.08
Biological yield	975393	487697*	4.54	3773326	2674498*	17.58	4949627	247481*	23.06	386777	193389	1.80	11378303	177786	53.01
Grain yield	33707	16853*	0.35	8313696	831370*	85.97	1008052	50403*	10.42	5995	2997	0.06	309127	4830	3.20
Harvest index	1.879	0.9394*	0.35	419.293	41.9293*	79.08	33.677	1.6838*	6.35	0.545	0.2727	0.10	74.788	1.1686	14.11

*: Significant relation at 5% level of probability, whereas ns= non-significant

Table 6 Estimate of simple correlation coefficients (Pearson) between different characters (Weighting Variable) in durum wheat cultivars at (P < 0.05)

	Plant height	Plant density	Biological Yield	Grain Yield
Plant density	0.0206			
P-Value	0.8398			
Biological Yield	-0.1158	0.2532		
	0.2535	0.0115		
Grain Yield	0.0575	0.4033	0.3942	
	0.5717	0.00	0.0001	
Harvest Index	0.1305	0.2790	-0.1809	0.8251
	0.1979	0.0052	0.0731	0.0000

In durum wheat production plant density are measured as key trait. It has been apprised that round about main stem produced 30% to 50% of the grain yield in durum wheat and 50% to 70% produced from lateral tillers under ordinary circumstances (Elhani et al., 2007). Substantial variances ($P \leq 0.05$) was observed between genotypes, locations and GEI for plant density m^{-2} for combined study of difference. The results accessible in tab.5 exhibiting that 1.22 times more variation due to GEI which was 34.74% then combined effect of environments/locations (3.86%) and genotypes (24.29%) so it can be concluded that average presentation and position of genotypes were primarily due to their interaction with locations. The main effect of genotypes averaged over three environments, plant density m^{-2} extended from 493 to 470 tillers m^{-2} with the average value of 484.47 tillers m^{-2} (Tab.2). Higher number of tillers was fashioned by G-10 (493.11 tillers m^{-2}), followed by G-8 (492.11 tillers m^{-2}), G-6 (491.67 tillers m^{-2}), G-9 (487.67 tillers m^{-2}), G-5 (487.11 tillers m^{-2}) and G-4 (485.22 tillers m^{-2}), however least number of tillers were observed for G-3 (470.00 tillers m^{-2}). Among locations, plant density m^{-2} in between from 481.30 to 487.76 tillers m^{-2}. No anyone of genotype was utterly dominated on rest of genotypes in all environments/locations, observing site exact performance for plant density m^{-2}. Environment E-02 (487.76 tillers m^{-2}) and E-03 (484.36 tillers m^{-2}) were acknowledged as exceedingly fruitful and less fruitful locations, correspondingly for of tillers m^{-2} (Tab.3). Genotype G-8 produced maximum tillers m^{-2} in E-02 (500 tillers m^{-2}) and minimum was observed in G-1 in E-01 (449.00 tillers m^{-2}) Table- 4.

Collective analysis of variance exposed substantial variances ($P \leq 0.05$) among genotypes, locations and genotypes/lines and GEI for biological yield. In the total sum of squares, 23.06% of dissimilarity was supplementary by GEI (Tab.5). The main effect of biological yield mean over three environments/locations, ranged from 14760 to 13015 Kg ha^{-1} with an average value of 13940 Kg ha^{-1} (Tab.2). Higher biological yield was renowned for G-6 (14760 Kg ha^{-1}), followed by G-3 (14351 Kg ha^{-1}) and G-1 (14272 Kg ha^{-1}), however lower assessment was verified for genotype G-11 (13015 Kg ha^{-1}). Average of three environments/locations, biological yield extended from 14031 to 13795 Kg ha^{-1}. Higher biological yield was observed for G-1 (14031 Kg ha^{-1}), followed by G-2 (13967 Kg ha^{-1}), however lower value was recorded for genotype G-3 (13795 Kg ha^{-1}) (Tab.3). Indoors, biological yield (GxE) fluctuated from 15011Kg ha^{-1} to 12716 Kg ha^{-1} higher biological yield was logged for G-6 in E-02 (15011Kg ha^{-1}) followed by G-6 in E-01 (14791 Kg ha^{-1}) whereas lower biological yield was noted in G-11 in E-03 (12716 Kg ha^{-1}) tab.4.

Among genotypes significant differences was observed for combined analysis of variance of environments/locations and GEI for grain yield. Least sum of squares was significant for environments/locations and GxE and captured 0.35% and 10.42%, individually. Similarly, genotype apprehended 85.97% of the total dissimilarity, displaying its part in average performance and position of genotypes diagonally environments (Tab.5). Mean value of three environments/locations, grain yield in between from 4211.6 to 4254.6 Kg ha^{-1} with average value of 4229.13 Kg ha^{-1} (Tab.3).

Generally, 8 genotypes had higher yielding than average yield, while all 10 genotypes had maximum yield than check variety (Fig.1). Genotype G-9 meaningfully produced higher grain yield (4682.4 Kg ha^{-1}), followed by G-3 (4481.9 Kg ha^{-1}) and G-10 (4457.3 Kg ha^{-1}), however lower value for grain yield was perceived for G-11 (3630 Kg ha^{-1}) table 2. The GEI ranged from 4837 Kg ha^{-1} in G-9 E-01 to 3605.3 Kg ha^{-1} in G-11 E-01. higher grain yield was noted for G-9 in E-01 (4837 Kg ha-1), followed by G-9 in E-02 (4672 Kg ha^{-1}), however lower value was recorded for genotype G-11 in E-01 (3605.3 Kg ha^{-1}) table 4.

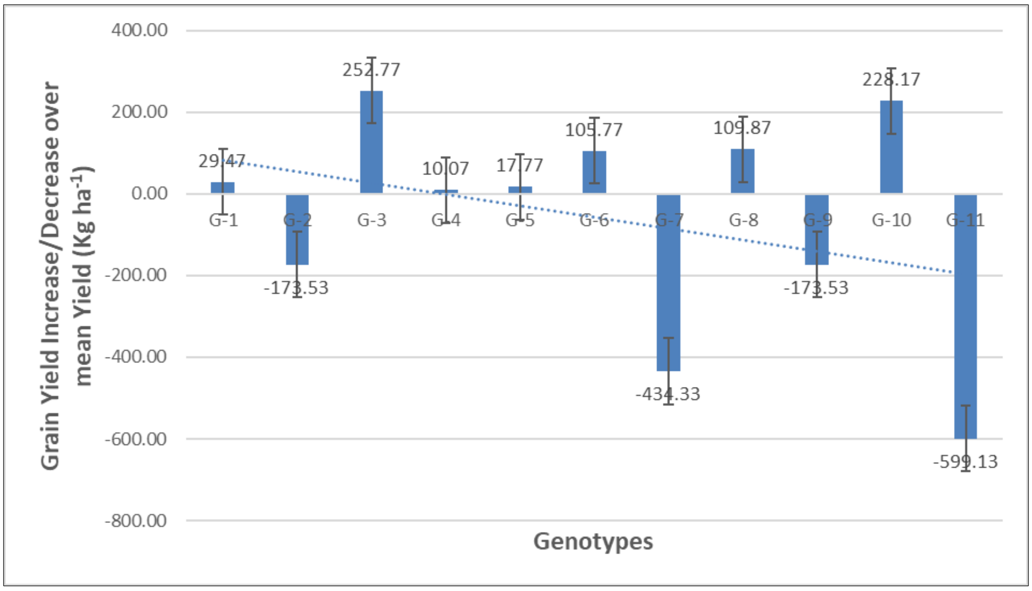

Figure 1 Grain yield increase/Decrease over mean yield (Kg ha^{-1})

Combined analysis of difference represented significant variances (P≤0.05) among genotypes, environments and GEI for harvest index. While, variances for GEI was significant, but they apprehended fewer sum of squares. GEI explicated only 6.35% total difference, whereas maximum variation was captured (79.08%) by genotype and minimum was found in environment which was 0.35% (Tab.5). Mean value of three environments/locations, harvest index ranged from 30.57 to 30.24% with average value of 30.42% (Tab.3). The main effect of Genotype in three environments G-9 (34.66 %) exhibited maximum value for harvest index which was at par with G-5 (32.55%) and G-10 (31.55%) whereas, minimum value was noted in G-7 (Tab.2). The GxI, higher value for harvest index was documented for G-9 in E-01 (35.33%) which was at par with G-9 in E-03 (34.66%) and G-9 in E-02 (34%). Minimum harvest index was recorded in G-7 in E-02 (26.33%) table 4.

The correlation coefficients were measured on average values of yield and yield components of 11 genotypes in three environments. The correlation investigation represented that grain yield had positive association with plant density m^{-2} (rg = 0.40*), biological yield (rg = 0.39*) and harvest index (rg = 0.82*). Progressive affiliation of these aforesaid traits with grain yield designated that these traits had foremost impact towards grain yield however, plant density showed positive connotation with harvest index (rg = 0.27*), whereas negative correlations with biological yield (rg = -0.18*) table 6.

4. Discussion

Collective analysis of variance exposed significant differences among genotypes, environment and their interaction for plant height, plant density, biological yield and grain yield. Previously, Mohammad et al. (2012), Mehari et al. (2015) and Ebrahimnejad and Rameeh (2016) also described analogous results in wheat. Contrarily Khan et al. (2010) and Motamedi et al. (2013) conveyed non-significant variances among genotypes, environments and their interaction for tillers m^{-2}. The findings were not similar may be due to alteration in genetic makeup of genotypes and tested environmental conditions or both. The biological yield is a multiplicative yield integral with harvest index (Kozak et al., 2007). In durum wheat harvest index is an important trait and have direct impact on grain yield. However, harvest index has substantial genetic progress for higher grain yield was mostly attained, which increase plant size to dispense biomass into the reproductive parts (Sayre et al., 1997).

To develop high yielding lines/cultivars is the fundamental part of every plant breeding program which governs forthcoming of crop and its cultivators (Muflin, 2000). There are many challenges for plant breeder to get besides, to identify best potential lines for series of diverse environmental circumstances with stable yielding genotypes and maintained their productivity (Roozeboom et al., 2004; Loffler et al., 2005). Genotype G-9 displayed higher grain yield and harvest index and hereafter may be painstaking as most constant high yielding genotype for commercialization. Correlation analysis exposed that grain yield had positive connotations with plants m^{-2}, and harvest index. Mohsen et al. (2011) also described that grain yield had positive correlations with above cited traits and recommended that plant breeders should deliberate these traits in durum wheat breeding for grain yield upgrading.

5. Conclusion

Presence of sufficient variability needs significant genetic variance for all traits to make effective selection among genotypes. Like wisely the recital of genotypes transversely locations for virtually all characters was not uniformed, directed that significant relationship between genotypes by environment interactions (GEI). The superior properties in the phenotypic countenance of all characters due to GEI apprehended major share of sum of squares. Significant positive associations of grain yield with plants m^{-2} and harvest index signifying that these traits had major impact towards grain yield in durum wheat in correlation analysis. Higher grain yield and harvest index transversely all locations were produced by the genotype G-9, recognized as high yielding cultivar and recommended for commercialization in Balochistan.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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