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Original Research

Genotypic Performance of $F_{4:7}$ Wheat Lines under Irrigated and Rainfed Conditions

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Abstract

Wheat (*Triticum aestivum* L.) is an important crop also known as the king of cereals and consumed as a staple crop by one-third of the global population. However, wheat production under rainfed conditions is restrained by water scarcity. The experiment was conducted to evaluate wheat breeding lines for yield. Fifteen $F_{4:7}$ bread wheat lines along with two check cultivars Tatara and AUP-5008 were tested in RCB design in three replications under irrigated and rainfed conditions. Analysis of variance showed significant ($p \leq 0.01$) differences among the genotypes for days to heading, plant height, spike length, grains spike^{-1}, grain weight spike^{-1}, 1000-grains weight and grain yield while non-significant for rest of the traits. Genotype by environment (GE) interaction was significant ($P \leq 0.05$) for grain yield and non-significant for the remaining traits.1000-grains weight showed positive significant

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correlation with grain weight spike^{-1}. Grain weight spike^{-1} revealed positive significant correlation with grains spike^{-1}, harvest index and grain yield. Grains per spike exhibited positive significant correlation with harvest index and grain yield. Harvest index presented positive significant correlation with grain yield. Among wheat lines, maximum (4278 kg) grain yield was produced by Tatara/Margla-5 followed by Margala/Inqelab-5 (4056 kg) under irrigated and the lines Margala/Inqelab-5 (3833 kg) and Wefaq/Ghaznavi-2 (3500 kg) produced maximum grain yield under rainfed condition. According to the results of the study irrigated environment was recommended for wheat sowing. The lines Margala/Inqelab-5 and Tatara/Takbeer-1 relative performance was maximum and were recommended for sowing under both irrigated and rainfed conditions. Thus these lines could further be evaluated for future breeding programs.

Keywords: genotypic, bread wheat lines, rainfed, irrigated, GE interaction

Introduction

Global wheat (*Triticum aestivum* L.) production is raising continuously through conventional and advanced breeding techniques to meet the demands imposed by increasing population. Moreover, this must be achieved under reduced water availability, a scenario of global warming, stricter end-use quality characteristics, evolving pathogen and pest populations [1, 2]. Breeding wheat cultivars with increased grain yield potential, enhanced water use efficiency, heat tolerance, end-use quality, and durable resistance to important diseases and pests can contribute to least half of the desired production. While, the remaining half must come through better agronomic and soil management practices and incentive policies [3, 4].

Wheat, the main staple food, contributes 13.1 percent to the value added in agriculture and 2.7 percent to GDP. It is grown on an area of 8.805 M ha with an estimated production of 24.214 M tons with an average of 2.750 t ha^{-1} yield. However, average yield is very low compared to other wheat-growing countries of the world [5]. Drought is not merely a physical phenomenon that can be defined by the weather (a shortage of rainfall) rather than defined by the delicate balance between water supply and demand. However, it can be caused by too little precipitation (rain and snow) over an extended period. Due to global warming, the weather patterns are changing all over the world which generally affects not only the total amount of rainfall in a particular season but also the water stress in the plants at different stages [6, 7]. The irrigation has been shown to increase crop yield in arid and semi-arid climates. Soil moisture affects practically every aspect of plant growth, modifying their anatomy, morphology, physiology and biochemistry. Soil moisture not only affects physiochemical activities of a plant but also regulates the translocation of plant nutrients to various organs. Hence, adequate and timely irrigation is one of the most important cultural practices that should be considered necessary for successful crop husbandry [8]. The screening of elite and exotic wheat germplasm for drought tolerance is desirable to boost up grain yield [9]. Therefore, the present study was designed to ascertain yield potential and heritability estimates of advance breeding lines under irrigated and rainfed conditions to identify superior lines for future breeding program.

Materials and Methods

The experiment was conducted at the University of Agriculture Peshawar on fifteen $F_{4:7}$ bread wheat lines along with two check cultivars Tatara and AUP-5008 in Randomized Complete Blocked Design (RCBD) with three replications. Each plot comprised 4 rows having length of 5 meter with a row-to-row space of 30 cm. The experiment was conducted in irrigated and rainfed conditions and other than these two factors and all other cultural practices remained the same. All data were collected on the following given parameters:

Days to heading: Days to heading were taken from the date of sowing and to date when 50 percent of the spikes in the plot emerged from flag leaf.

Plant height (cm): Plant height was measured from the bottom of the plant that is from the surface of the soil where first emergence of plants to the uppermost spikelet excluding the awns in (cm).

Flag leaf Area (cm^2): The flag leaf area was measured lengthwise and width wise at the broadest point. Flag leaf area was taken as the product of length and width multiplied by 0.75.

Spike length (cm): Spike length was recorded from the base of the spike to the tip of the last spikelet excluding awns.

1000-grains weight (g): A sample of 1000 grains was counted with the seed counter and weighed to record thousand kernel weight from each plot and then it was weighed through electric balance.

Harvest index (%): The harvest index was determined as the ratio of grain yield to the Biological yield (kg ha^{-1}).

$$\text{Harvest index (\%)} = \frac{\text{Grain Yield (kg)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

Grain weight spike^{-1} (g): Grain weight spike^{-1} was estimated from grain yield of 50 randomly selected spikes following formula of [10]

$$\text{Grain weight spike}^{-1} = \frac{\text{Grain yield of 50 tillers}}{50}$$

Grains spike^{-1}: Grains spike^{-1} was computed from grain weight spike^{-1} and 1000-grains weight using the formula,

$$\text{Grains spike}^{-1} = \frac{1000 \text{ x grains weight spike}^{-1} \text{ (g)}}{\text{1000-grains weight (g)}}$$

Number of Spikes/m^2: Number of Spikes/m^2 were calculated by converting grain yield plot^{-1} into grams and then by grain weight spike^{-1} and plot area.

$$\text{Number of Spikes/m}^2 = \frac{\text{Grain yield plot}^{-1} \text{ (g)} \times 1000}{\text{Grain weight spike}^{-1} \text{ (g)} \times \text{plot area (m}^2\text{)}}$$

Spikes plot^{-1}: Spikes plot^{-1} were calculated by multiplying number of Spikes/m^2 and total plot area.

$$\text{Spikes plot}^{-1} = \text{number of Spikes/m}^2 \text{ x plot area (m}^2\text{)}$$

Spikes ha^{-1}: Spikes ha^{-1} were calculated by converting spikes m^{-2} to spikes ha^{-1} as,

$$\text{Spikes ha}^{-1} = \text{Spikes m}^{-2} \text{ x } 10{,}000$$

Grain yield ha^{-1} (kg): Total dry weight of grains harvested from all rows was taken as grain yield plot$^{-1.}$ Plot yield was converted to grain yield ha^{-1}.

Statistical Analysis: Data after compilation were analyzed using Pooled analysis of variance to quantify GE interaction effect and comparison of means was accomplished by LSD test at 5% level of probability.

Correlation Analysis

The phenotypic correlation co-efficient was calculated by using the statistical software IBM SPSS 20. The correlation coefficient was computed using formula,

$$r\ (p) = cov_p(XY) / \sqrt{V_p(X) \text{ x } V_p(Y)}$$

Whereas: r (p) = phenotypic correlation coefficient. cov_p (XY) = phenotypic covariance of traits x and y. $V_p(X)$ = phenotypic variance of trait x. $V_p(Y)$ = phenotypic variance of trait y.

Results and Discussion

Days to Heading

Analysis of variance for days to heading showed significant ($p \leq 0.01$) differences among genotypes and non-significant genotype-environment interaction (Table 1). Mean value for days to heading was 139 days under rainfed condition and 144 days under irrigated condition (Table 2). Days to heading under rainfed condition ranged from 134 to 145 days and 134 to 150 days under irrigated environment (Table 4). Minimum (134) days to heading were recorded for Wefaq/Margala-1under rainfed condition while under irrigated environment Tatara/Margla-3 acquired minimum (134) days. The maximum (145) days to heading under rainfed condition were recorded for Wefaq/Ghaznavi-1 and under irrigated condition, AUP-5008 received maximum (150) days (Table 2). Days to heading reported significant positive correlation with grains spike^{-1} (r = 0.52) while significant negative correlation with plant height (r = -0.63) and spike length (r = -0.54) (Table 5). The differences in days to heading among genotypes across environments were due to genetic variability and the environment has no influence on genotypes performance. Results of this study were supported by [9, 11] also reported significant differences for days to heading, while non-significant interaction results validated the findings of [9, 8]. The correlation results

Analysis of variance with degrees of freedom

Source of variation	Df	MS	F-Ratio	Probability
Environment	e-1	M1	M1/M2	….
Reps within E	e(r-1)	M2		
Genotypes (G)	g-1	M3	M3/M5	
G x E	(g-1)(e-1)	M4	M4/M5	
Error	erg-1	M5		

were supported by the finding of [12], who investigated a non-significant positive correlation between days to heading and grains spike^{-1}, a non-significant negative correlation between days to heading and plant height, while in contrast to the present results a positive and significant correlation between days to heading and spike length.

Plant Height

Analysis of variance showed significant ($p \leq 0.01$) differences for plant height among genotypes across environments and non-significant genotype-environment interaction (Table 1). Mean values of 88.7 cm under rainfed condition and 102 cm under irrigated condition was recorded for plant height (Table 2). Plant height ranged from 78.7 to 95.3 cm under rainfed condition and 93 to 109 cm under irrigated condition (Table 4). Wefaq/Ghaznavi-1 was described to have lowest plant height (78.7 cm) under rainfed condition and Wefaq/Ghaznavi-2 picked up minimum (93 cm) plant height under irrigated condition. Maximum (95.3 cm) plant height under rainfed condition was noted for Tatara/Margla-3 and under irrigated condition. However, Wefaq/Margala-1 received maximum (109 cm) plant height (Table 2). Plant height showed significant positive correlation ($r = 0.48$) with 1000-grain weight and significant negative correlation ($r = -0.63$) with days to heading and grains spike^{-1} ($r = -0.49$) (Table 5). The present study confirmed the similar results for plant height [9, 13, 14]. The interaction results validated the previous result [15]. According to the results, the genotypes with increased plant height were observed for maximum flag leaf area and 1000-grains weight. The correlation results were in close proximity with [16].

Flag Leaf Area

Mean squares for flag leaf area revealed non-significant ($p > 0.05$) differences and GE interaction among genotypes (Table 1). Mean value for flag leaf area was 18.8 cm^2 under rainfed condition and 27.8 cm^2 under irrigated environment (Table 2). Flag leaf area ranged from 16.3 to 21.8 cm^2 under rainfed condition and 23.9 to 32.0 cm^2 under irrigated condition (Table 4). Under rainfed condition, line Wefaq/Margala-8 was reported with a minimum (16.3 cm^2) leaf area and the line Wefaq/Ghaznavi-1 under irrigated conditions was reported with a minimum (23.9 cm^2) leaf area. Maximum (21.8 cm^2) leaf area was recorded for Wefaq/Margala-4under rainfed condition and under irrigated condition, Wefaq/Margala-7 was reported with a maximum (32cm^2) leaf area (Table 2). Leaf area had a significant positive correlation ($r = 0.48$) with 1000 grain weight (Table 5). The earlier reports confirmed significant GE interaction for flag leaf area [13]. Leaf area had significant positive correlation with 1000-grain weight indicates that increased leaf area

Table 1. Mean squares for days to heading, plant height, flag leaf area, spike length, 1000-grains weight, harvest index, spikes meter^{-2}, grain weight spike^{-1}, grains spike^{-1}, spikes plot^{-1}, spikes ha^{-1} and grain yield, Peshawar, 2011-2012.

SOV	Environment	Reps within E	Genotypes	G x E	Error	CV (%)
Days to heading	593.294**	35.706	60.940**	28.607^{ns}	16.435	2.87
Plant height	4480.157**	31.863	101.199**	21.032^{ns}	35.946	6.29
Flag leaf area	2051.125**	71.978	11.826ns	9.654ns	11.058	14.26
Spike length	2.235^{ns}	0.364	2.210**	0.481^{ns}	0.776	8.12
1000-grains weight	2490.353^{ns}	450.941	52.270**	12.936^{ns}	18.816	9.65
Harvest index	20.926^{ns}	54.834	31.210^{ns}	23.580^{ns}	28.454	19.01
Spikes meter^{-2}	2048.435^{ns}	15517.416	3165.179^{ns}	2344.006^{ns}	3825.380	27.51
Grain weight spike^{-1}	3.428*	0.314	0.146**	0.046^{ns}	0.056	16.48
Grains spike^{-1}	35.412^{ns}	173.043	54.273**	24.895^{ns}	25.095	15.55
Spikes plot^{-1}	73835.112^{ns}	558521.133	113940.518^{ns}	84379.238^{ns}	137711.503	27.51
Spikes ha^{-1}	205047582080.125^{ns}	1551506789381.437	253600035733.332^{ns}	499021787610.680^{ns}	332100477394.431	25.63
Grain yield	12916394.206^{ns}	2279452.647	893874.380**	660890.706*	376673.543	19.48

Table 2. Mean values for days to heading, plant height, leaf area, spike length, 1000-grains weight and harvest index.

Lines	Days to heading			Plant height			Leaf area			Spike length			1000-Grains Wt			Harvest index		
	Ir	Rd	Mean	Ir	Rd	Mean	Ir	Rd	Mean	Ir	Rd	Mean	Ir	Rd	Mean	Ir	Rd	Mean
Tatara/Margla-5	142	138	140	105	95.0	100	27.1	17.3	22.2	11.7	11.3	11.5	55.3	42.7	49.0	30.1	27.3	28.7
Tatara/Margla-4	147	139	143	105	93.3	99	28.1	17.3	22.7	11.3	11.3	11.3	52.7	40.0	46.4	26.9	31.4	29.2
Tatara/Margla-3	134	140	137	105	95.3	100	29.9	19.5	24.7	11.6	11.2	11.4	52.7	40.0	46.4	31.6	24.3	28.0
Wefaq/Margala-8	140	138	139	103	88.7	96	27.9	16.3	22.1	10.6	9.9	10.3	44.7	38.7	41.7	23.7	27.2	25.5
Wefaq/Margala-7	138	136	137	102	86.0	94	32.0	19.2	25.6	11.6	11.1	11.4	51.3	40.0	45.7	24.3	27.1	25.7
Wefaq/Margala-5	145	135	140	104	90.0	97	27.1	18.2	22.7	11.3	10.5	10.9	49.3	36.7	43.0	23.4	25.3	24.4
Wefaq/Margala-4	138	139	139	107	86.7	97	26.2	21.8	24.0	11.4	11.1	11.3	52.7	44.7	48.7	30.2	25.5	27.9
Wefaq/Margala-3	144	135	140	101	91.0	96	28.7	18.4	23.6	10.9	10.5	10.7	48.7	38.0	43.4	27.5	28.4	28.0
Wefaq/Margala-1	140	134	137	109	93.0	101	27.4	18.9	23.2	11.2	11.2	11.2	51.3	35.3	43.3	30.3	27.4	28.9
Margala/Inqelab-3	145	141	143	97	90.3	94	26.9	20.3	23.6	11.1	11.0	11.1	51.3	41.3	46.3	22.4	27.6	25.0
Margala/Inqelab-5	145	143	144	107	87.3	97	25.3	17.4	21.4	11.2	10.9	11.1	49.3	40.0	44.7	29.2	34.1	31.7
Wefaq/G-98-1	147	145	146	95	78.7	87	23.9	18.2	21.1	10.4	9.5	10.0	42.7	36.7	39.7	29.7	31.9	30.8
Wefaq/G-98-2	147	141	144	93	80.3	87	26.6	20.0	23.3	9.8	9.9	9.9	42.7	36.0	39.4	28.4	33.2	30.8
Tatara/Takbeer-1	147	137	142	104	91.3	98	25.6	19.8	22.7	10.3	11.7	11.0	52.0	40.7	46.4	28.2	26.3	27.3
Tatara/Takbeer-2	149	139	144	100	90.3	95	27.4	18.0	22.7	12.3	11.1	11.7	47.3	40.7	44.0	25.9	25	25.5
AUP-5008	150	143	147	101	85.0	93	31.1	21.5	26.3	10.0	9.9	10.0	52.0	44.0	48.0	25.9	32.5	29.2
Tatara	148	140	144	97	86.3	92	31.3	18.0	24.7	10.2	9.9	10.1	52.0	44.7	48.4	31.7	30.4	31.1
Mean	144	139		102	89		27.8	18.8		11.0	10.7		49.9	40.0		27.6	28.5	

Table 3. Mean values for spikes m^{-2}, grain weight $spike^{-1}$, grains $spike^{-1}$, spikes $plot^{-1}$, spikes ha^{-1} and grain yield ha^{-1}.

Lines	Spikes $Meter^{-2}$			Grain Wt $Spike^{-1}$			Grains $Spike^{-1}$			Spikes $plot^{-1}$			Spikes ha^{-1}			Grain yield ha^{-1}		
	Ir	Rd	Mean	Ir	Rd	Mean	Ir	Rd	Mean	Ir	Rd	Mean	Ir	Rd	Mean	Ir	Rd	Mean
Tatara/Margla-5	224	187	206	1.7	1.4	1.6	31	31	31	1341	1123	397	2235525	2011214	386392	4278	2722	3500
Tatara/Margla-4	186	234	210	1.4	1.2	1.3	28	30	29	1118	1403	405	1862840	2177771	367659	3111	3000	3056
Tatara/Margla-3	225	197	211	1.8	1.3	1.6	36	31	34	1350	1183	408	2250735	2589365	440343	3833	2833	3333
Wefaq/Margala-8	158	197	178	1.5	1.0	1.3	34	28	31	951	1185	345	1584240	2460865	368019	2778	2667	2723
Wefaq/Margala-7	231	221	226	1.4	1.0	1.2	29	27	28	1388	1326	435	2313024	2257317	415841	3333	2444	2889
Wefaq/Margala-5	243	258	251	1.3	1.0	1.2	27	29	28	1457	1550	480	2427611	2333907	433258	2889	2333	2611
Wefaq/Margala-4	297	216	257	1.6	1.3	1.5	31	29	30	1783	1298	493	2971509	1494704	406422	3833	1944	2889
Wefaq/Margala-3	241	209	225	1.4	1.1	1.3	30	32	31	1444	1253	433	2406778	2066095	406979	3111	2389	2750
Wefaq/Margala-1	213	252	233	1.7	1.0	1.4	33	33	33	1279	1513	449	2131944	2433357	415394	3778	2556	3167
Margala/Inqelab-3	209	272	241	1.8	1.2	1.5	34	30	32	1251	1631	462	2084848	3138614	475239	3000	3389	3195
Margala/Inqelab-5	241	285	263	1.7	1.4	1.6	36	33	35	1445	1708	506	2408551	2917269	484579	4056	3833	3945
Wefaq/G-98-1	236	232	234	1.5	1.4	1.5	35	35	35	1418	1390	452	2362746	2030401	399747	3389	2722	3056
Wefaq/G-98-2	224	247	236	1.5	1.5	1.5	35	41	38	1342	1479	455	2236099	2457826	427093	3444	3500	3472
Tatara/Takbeer-1	228	242	235	1.7	1.3	1.5	32	38	35	1366	1451	453	2276194	2358155	421675	3945	3222	3584
Tatara/Takbeer-2	226	227	227	1.6	1.3	1.5	34	30	32	1354	1362	436	2257172	2030708	390164	3167	2389	2778
AUP-5008	175	241	208	1.8	1.4	1.6	34	31	33	1050	1444	402	1748760	2407296	378152	3056	2833	2945
Tatara	191	183	187	2.1	1.5	1.8	42	33	38	1144	1095	364	1906161	1824298	339431	4000	2722	3361
Mean	220	229		1.6	1.3		33	32		1322	1376		2203808	2293480		3471	2794	

will enhance the rate of photosynthesis and accumulation of assimilates from source to sink for higher grains yield. A positive correlation between flag leaf area and grain yield was observed in wheat genotypes [17].

Spike Length

The analysis showed significant ($p \leq 0.01$) differences among genotypes while the genotype environment interaction was non-significant (Table 1). Spike length was recorded with mean value of 10.7 cm for rainfed and 11 cm for the irrigated environment (Table 2). Spike length ranged from 9.5 to 11.7 cm under rainfed condition and 9.8 to 12.3 cm under irrigated condition (Table 4). The genotype Wefaq/Ghaznavi-1 was reported to have minimum value of (9.5cm) under rainfed condition while, under irrigated condition Wefaq/Ghaznavi-2 reported minimum value of (9.8 cm) for spike length. For spike length maximum value (11.7cm) under rainfed condition was recorded for Tatara/Takbeer-1 while, under irrigated condition, genotype Tatara/Takbeer-2 revealed maximum value of (12.3 cm) (Table 2). Spike length revealed significant negative correlation with days to heading (r = 0.54) and grains spike^{-1} (r = -0.55) (Table 5). The results of this study were supported by the earlier findings of [20] for spike length while interaction results confirmed the findings of [18, 19]. The results of negative effect of spike length on grains spike^{-1} and days to heading corroborated the findings of [20]. The negative effect of spike length on grain yield may be due to different environmental conditions and genetic background of breeding materials investigated [21].

1000-Grains Weight

Significant ($p \leq 0.01$) differences were observed among the mean values for 1000-grain weight under irrigated and rainfed conditions and showed non-significant GE interaction (Table 1). Mean values of 40 gm under rainfed condition and 49.9 gm under irrigated condition were observed for 1000-grains weight (Table 2). 1000-grains weight ranged from 35.3 to 44.7 gm under rainfed condition and 42.7 to 55.3 gm under irrigated condition (Table 4). Wefaq/Margala-1 was reported minimum (35.3 gm) 1000-grains weight under rainfed condition and two lines Wefaq/Ghaznavi-1 and Wefaq/Ghaznavi-2 under irrigated environment were reported with minimum (42.7 gm)1000-grains weight. Maximum (44.7 gm) 1000-grains weight was recorded for Wefaq/Margala-4 under rainfed condition and under irrigated condition Tatara/Margla-5 was reported with maximum (55.3 gm) 1000-grains weight (Table 2). 1000-grain weight had significant effect on grain weight spike^{-1} (r = 0.47), leaf area (r = 0.48) and plant height (r = 0.48) (Table 5). [22, 23, 24] found significant differences in 1000-grain weight among wheat genotypes and interaction results were supported by previous findings of [25, 26]. An increase in grain weight spike^{-1}increased 1000-grain weight which ultimately resulted in increased grain yield. These results are in line with the previous finding of [21, 24, 25].

Harvest Index

Mean squares for harvest index revealed non-significant ($P>0.05$) differences and genotype-

Table 4. Range, Mean and LSD Values for days to heading, plant height, flag leaf area, spike length, 1000-grains weight, harvest index, grain weight spike^{-1}, grains spike^{-1}, spikes m^{-2}, spikes plot^{-1}, spikes ha^{-1}and grain yield ha^{-1} under irrigated and rainfed conditions.

	Irrigated		Rainfed		Lsd (5%)	
Parameters	Range	Mean	Range	Mean	Irrigated	Rainfed
Days to Heading	134-150	144	134-145	139	6.72	6.77
Plant height	93-109	102	78.7-95.3	88.7	10.06	9.88
Flag leaf Area	23.9-32.0	27.8	16.3-21.8	18.8	5.18	5.86
Spike length	9.8-12.3	11	9.5-11.7	10.7	1.53	1.40
1000 grains weight	42.7-55.3	49.9	35.3-44.7	40	7.68	6.71
Harvest index	22.4-31.7	27.6	24.3-34.1	28.5	7.71	9.90
Grain weight spike^{-1}	1.3-2.1	1.6	1.0-1.5	1.3	0.45	0.32
Grains spike $^{-1}$	26.2-41.7	32.8	26.5-41.0	31.6	7.73	8.89
Spikes m^{-2}	158.4-297.2	220.4	182.4-284.6	229.3	90.79	113.66
Spikes plot $^{-1}$	950.5-1782.9	1322.3	1094.6-1707.6	1376.1	544.77	681.96
Spikes ha^{-1}	1584240-2971509	2203808	1494704-3138614	2293480	907944.62	1006409.23
Grain yield ha^{-1}	2778-4278	3471	1944-3833	2794	927	998.3

Table 5. Phenotypic correlations for days to heading (DH), plant height (PH), leaf area (LA), spike length (SL), spikes plot^{-1} (SPP), spikes ha^{-1} (SPH),spikes $^{-2}$ (SPMS), grain weight spike^{-1} (GWPS), grains spike^{-1} (GPS), harvest index (HI), 1000-grains weight (TGW) and grain yield ha^{-1} (GYH).

	DH	GWPS	GPS	HI	LA	PH	SL	SPH	SPMS	SPP	GYH
TGW	-0.21	0.47*	-0.22	-0.03	0.48*	0.48*	0.41^{ns}	-0.17	-0.15	-0.15	0.18
DH	1	0.37	0.52*	0.42^{ns}	-0.13	-0.63**	-0.54*	0.005	0.23	0.23	0.17
GWPS		1	0.71**	0.59**	0.2	-0.16	-0.19	-0.11	-0.19	-0.19	0.65**
GPS			1	0.68**	-0.09	-0.49*	-0.55*	-0.002	-0.07	-0.07	0.63**
HI				1	-0.12	-0.28	-0.44^{ns}	-0.12	-0.009	-0.009	0.63**
LA					1	-0.04	-0.06	-0.18	-0.24	-0.24	-0.22
PH						1	0.75^{ns}	0.09	-0.01	-0.01	0.05
SL							1	0.27	0.26	0.26	0.00
SPH								1	0.75^{ns}	0.75^{ns}	0.37
SPMS									1	0.99	0.17
SPP										1	0.17

environment interaction (Table 1). Mean value for harvest index was 28.5% under rainfed condition and 27.6 % under irrigated condition (Table 2). Harvest index ranged from 24.3 to 34.1% under rainfed condition and 22.4 to 31.7% under irrigated condition (Table 4). Minimum (24.3%) harvest index was reported for Tatara/Margla-3 under rainfed condition while under irrigated condition minimum (22.4%) value was recorded for Margala/Inqelab-3. Maximum (34.1%) harvest index was recorded for Margala/Inqelab-5 under rainfed condition and under irrigated condition Tatara was reported with maximum (31.7%) (Table 2). Harvest index revealed highly significant correlation with grain weight spike^{-1} (r = 0.59), grains spike^{-1} (r = 0.68) and grain yield ha^{-1} (r = 0.63) (Table 5). The present results of non-significant differences for harvest index confirmed the findings of [19, 27]. The genotypes showed no response to the environment and confirmed that the studied genotypes were stable for harvest index and thus certified the earlier findings of [15]. Increase in grains spike^{-1}, grain weight spike^{-1} and grain yield eventually increased harvest index. Correlation studies certified the findings of [21].

Grain Weight Spike^{-1}

Genotypes showed significant (p≤0.01) differences for grain weight spike^{-1} across environments with non-significant GE interaction (Table 1). Mean value for grain weight spike^{-1} was 1.3 g under rainfed condition and 1.6 gm under irrigated condition (Table 3). Grain weight spike^{-1} ranged from 1.0 to 1.5 gm under rainfed condition and 1.3 to 2.1 g under irrigated condition (Table 4). Minimum (1.0 g) grain weight spike^{-1} under rainfed condition was observed for Wefaq/Margala-8, Wefaq/Margala-7, Wefaq/Margala-5 and Wefaq/Margala-1 and under irrigated condition Wefaq/Margala-5 was noticed with minimum (1.3 g) grain weight spike^{-1}. Maximum (1.5 g) grain weight spike^{-1} under rainfed condition was detected forWefaq/Ghaznavi-2 and Tatara and under irrigated condition Tatara was described with maximum (2.1 g) grain weight spike^{-1} (Table 3). Grain weight spike^{-1} showed highly significant positive correlation with 1000-grains weight (r = 0.47), grains spike^{-1} (r = 0.71), harvest index (r = 0.59) and grain yield (r = 0.65) (Table 5). The results of significant differences among genotypes and interaction were also in line with findings of [13, 14]. Grain weight per spike is one of the yield contributing trait which enhance the final grain yield. Correlation results were in close agreement with the results of [15, 21, 28, 29].

Grains Spike^{-1}

Genotypic performance of wheat lines for grains spike^{-1} was significantly (p≤0.01) different and showed non-significant GE interaction (Table 1). Mean value for grains spike^{-1} was 32 under rainfed condition and 33 under irrigated condition (Table 3). Grains spike^{-1} ranged from 27 to 41 under rainfed condition and 26 to 42 under irrigated condition (Table 4). Minimum (27) grains spike^{-1} under rainfed condition were observed for Wefaq/Margala-7and under irrigated environment Wefaq/Margala-5 was warranted with minimum (26) grains spike^{-1}. Maximum (41) grains spike^{-1} under rainfed condition was recorded for Wefaq/Ghaznavi-2 and under irrigated condition Tatara was reported with maximum (42) grains spike^{-1} (Table 3). Grains spike^{-1} had significant correlation with grain weight spike^{-1} (r = 0.71), harvest index (r = 0.68), grain yield ha^{-1} (r = 0.63) and days to heading (r = 0.52) while negative correlation with plant height (r = -0.49) and spike length (r = -0.55) (Table 5). Significant variances among wheat lines and non-significant genotype-environment interaction indicated stability of the wheat lines. Similar results were reported for grains spike^{-1} and interaction results were supported by [12, 13]. Among genotypes, higher grain yield was obtained by genotypes with maximum grains per spike. These results corroborated some of the previous results of [11, 8, 29, 30]. Decrease in plant height decreases vegetative growth which initiates earlier reproductive growth for increasing grain fill duration which increases grains per spike. Grains spike^{-1} has an adverse relationship with plant height and spike length which supported by the earlier results of [19].

Number of Spikes/meter^2

Studying wheat lines under irrigated and rainfed conditions, the genotypes exhibited non-significant ($P>0.05$) differences and genotype-environment interaction for spikes m^{-2} (Table 1). Mean value for spikes/m^2 was 229 under rainfed condition and 220 under irrigated condition (Table 3). Spikes/m^2 ranged from 182 to 285 under rainfed condition and 158 to 297 under irrigated condition (Table 4). Minimum (182) number of spikes/meter were observed for Tatar under rainfed condition and under irrigated condition Wefaq/Margala-8obtained minimum (158) spikes meter^2. Maximum (285) spikes m^{-2} under rainfed condition were recorded for Margala/Inqelab-5 and under irrigated condition Wefaq/Margala-4 was discovered with maximum (297) spikes per m^2 (Table 3). Spikes per m^2 were not correlated with other parameters (Table 5). [11, 8] found significant differences for spikes per m^2 which are contrary to the present results but interactive effects were found non-significant as found in the current study. Spikes per m^2 had not developed an apparent correlation with other important traits.

Spikes Plot^{-1}

Genotypes presented non-significant ($p>0.05$) differences and genotype-environment interaction for spikes plot^{-1} (Table 1). Mean value for spikes plot^{-1} was 1376 under rainfed condition and 1322 under irrigated condition (Table 3). Spikes plot^{-1} ranged from 1095 to 1708 under rainfed condition and 951 to 1783 under irrigated condition (Table 4). Minimum (1095) spikes plot^{-1} were observed for Tatar under rainfed condition and under irrigated condition Wefaq/Margala-8 got minimum (951) spikes plot^{-1}. Maximum (1708) spikes plot^{-1} under rainfed condition were recorded for Margala/Inqelab-5 while, under irrigated condition Wefaq/Margala-4 obtained maximum (1783) spikesplot^{-1} (Table 3). There was no obvious correlation of spikes plot^{-1} with other traits (Table 5). According to results, no genetic variability was observed among the genotypes and were stable under both environmental conditions. These findings are in line with the previous results of [19].

Spikes ha^{-1}: Genotypic performance of breeding wheat lines revealed non-significant ($p>0.05$) differences and GE interaction for spikes ha^{-1} (Table 1). Mean value for spikes ha^{-1} was 2293480 under rainfed condition and 2203808 under irrigated condition (Table 3). Spikes ha^{-1} ranged from 1494704 to 3138614 under rainfed condition and 1584240 to 2971509 under irrigated condition (Table 4). Minimum (1494704) spikes ha^{-1} were observed for Wefaq/Margala-4 under rainfed condition and under irrigated condition Wefaq/Margala-8 received minimum (1584240) spikes ha^{-1}. Maximum (3138614) spikes ha^{-1} under rainfed condition were recorded for Margala/Inqelab-3 while, under irrigated condition Wefaq/Margala-4 was reported with maximum (2971509) spikes ha^{-1} (Table 3). Spikes ha^{-1} revealed no prominent correlation with any trait (Table 5). The non-significant variances for spikes ha^{-1} reported similarities for performance among the genotypes. As there is no interaction effect between genotypes and environment which indicates that spikes ha^{-1} could be used selection criteria for improvement. Spikes ha^{-1} revealed no prominent correlation with any trait. These results are in agreement with the finding of [29, 30].

Grain yield ha^{-1}: The analysis for grain yield showed significant ($p\leq0.01$) differences across genotypes and genotype-environment interaction (Table 1). Mean value for grain yield was 2794 kg under rainfed condition and 3471 kg under irrigated condition (Table 3). Grain yield ranged from 1944 to 3833 kg under rainfed condition and 2778 to 4278 kg under irrigated condition (Table 4). Minimum (1944 kg) grain yield under rainfed condition was observed for Wefaq/Margala-4 and under irrigated environment Wefaq/Margala-8 offered minimum (2778 kg) grain yield. Maximum (3833 kg) grain yield under rainfed condition was recorded for Margala/Inqelab-5 and under irrigated condition Tatara/Margala-5 was reported with maximum (4278 kg) grain yield (Table 3). Grain yield presented significant correlation with grain weight spike^{-1} ($r = 0.65$), grains spike^{-1} ($r = 0.63$) and harvest index ($r = 0.63$) (Table 5). The present results were compatible with the results of [25, 31, 32] for grain yield. Interaction results proved the results of [33, 34] while in contrast non-significant GE interaction was observed by [13, 35, 36]. Grain yield is the final effect of different yielding traits. In the current study, grain yield was maximum at irrigated condition due to maximum 1000-grains weight, spike length and grains weight spike^{-1}. Correlation results are supported by the results of [23, 32, 37, 38, 39].

Conclusion

The current study concluded significant ($p\leq0.01$) differences among the genotypes for days to heading, plant height, spike length, grains per spike, grain weight per spike, 1000-grains weight, and grain yield while non-significant for rest of the traits. Genotype-environment interaction was significant ($p \leq 0.05$) for grain yield and non-significant for the remaining traits. Among the genotypes maximum days to heading (150), plant height (109 cm), flag leaf area (32 cm^2), spike length (12.3 cm), 1000-grains weight (55.3 g), harvest index (31.7%), grain weight $spike^{-1}$ (2.1 g), grains $spike^{-1}$ (42), no of spikes/m^2 (297), spikes $plot^{-1}$ (1783), spikes ha^{-1} (2971509) and grain yield (4278 kg) under irrigated conditions were observed for AUP-5008, Wefaq/Margala-1, Wefaq/Margala-7, Tatara/Takbeer-2, Tatara, Wefaq/Margala-4 and Tatara/Margla-5 respectively while, under rainfed condition the wheat lines Wefaq/Ghaznavi-1, Tatara/Margla-3, Wefaq/Margala-4, Tatara/Takbeer-1, Margala/Inqelab-5, Wefaq/Ghaznavi-2 and Margala/Inqelab-3 had maximum days to heading (145), plant height (95.3 cm), flag leaf area (21.8 cm), spike length (11.7 cm), 1000-grains weight (44.7 g), harvest index (34.1%), grain weight $spike^{-1}$ (1.5 g), grains $spike^{-1}$ (41), no of spikes/m^2 (285), spikes $plot^{-1}$ (1708), spikes ha^{-1} (3138614) and grain yield (3833 kg) respectively. 1000-grain weight showed positive significant correlation with grain weight $spike^{-1}$. Grain weight $spike^{-1}$ revealed positive significant correlation with grains $spike^{-1}$, harvest index and grain yield. Grains per spike exhibited positive significant correlation with harvest index and grain yield. Harvest index presented positive significant correlation with grain yield. It was further concluded from the current findings that irrigated environment is best for the genotype performance. The wheat lines Tatara/Margla-5 and Margala/Inqelab-5 performed best among the genotypes under irrigated condition while the linesMargala/Inqelab-5 and Wefaq/Ghaznavi-2 were best performing under rainfed conditions. The lines Margala/Inqelab-5 and Tatara/Takbeer-1 were recommended for plantation under both irrigated and rainfed conditions as their relative performance was maximum and thus can further be evaluated for future breeding programs.

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Conflict of Interest

All the authors declare having no conflict of interest.

Author's Contributions

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