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ASSESSMENT OF $G \times E$ INTERACTION AND HERITABILITY FOR SIMPLIFICATION OF SELECTION IN SPRING WHEAT GENOTYPES

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ABSTRACT

While evaluating genotypes for yield in multi environment tests, the variation can only be observed in the relative yield performance of genotypes across environments. Nineteen (19) wheat genotypes along with a standard farmer check variety were tested under normal and late sowing conditions for yield comparison, heritability and selection response to understand the causes of $G \times E$ interaction and identification of specific desirable traits and genotypes. Analysis of variance showed highly significant differences ($P < 0.01$) for spikes per m^2 , seed yield and harvest index, while significant differences ($P < 0.05$) were observed for spikelets spike⁻¹ and grains spike⁻¹. The environmental component revealed highly

significant differences ($P < 0.01$) for all traits except for grain weight spike⁻¹, which exhibited significant differences ($P < 0.05$). However, the $G \times E$ interaction showed highly significant differences ($P < 0.01$) only for harvest index. The better accessions may further be tested for performance under late sowing conditions. The accession also have potential for utilization in breeding programs for accumulating the genes of interest in genotypes which otherwise failed to perform better in late sowing environments. The selected accessions can be extremely useful for breeding cultivars to fill the gap between cultivars under conditions of very early or very late sowing.

Key words: $G \times E$ interaction, Genetic gain, heritability, selection differential, selection intensity, *Triticum aestivum*

Abbreviations: $G \times E$, Genotype by Environment; h^2 , Broad-sense heritability; **LSD**, Least Significance Difference; **RCBD**, Randomized Complete Block Design; **Re**, Response to selection; **(S)**, Selection differential; **SAS**, Statistical Analysis Software; **Vp**, Phenotypic Variance;

INTRODUCTION

Based on production and area harvested, wheat (*Triticum aestivum* L.) ranks first among cereals worldwide (Khan et al. 2015). Wheat being the primary cereal crop in the country was planted on 9.03 million hectares in Pakistan during 2013-14 with a total grain production of 2.53 million tonnes, averaging 3569 kg ha⁻¹ (Anonymous 2014).

Evaluation of wheat cultivars and advanced experimental lines across environments and years is of critical importance in wheat breeding programs for stable grain yield in a specific region (Allard and Bradshaw 1964; Eberhart and Russel 1966). Some wheat cultivars are adapted to a broader range of environments, while others have limited environmental adaptation. Cultivars with consistent performance across environments are

considered more stable in yield and related traits of economic importance (Ghaderi et al. 1980). Lack of significant interaction of cultivars with environment simplifies the selection process for development of stable and high yielding cultivars (Qari et al. 1990). In contrast, presence of relatively higher Genotype $\times$ Environment interaction necessitates the development of cultivars adapted to specific agro-ecological regions (Fehr 1993).

Wheat has been subjected to extensive research to maximize its productivity. However, a major breakthrough occurred in wheat production with the green revolution of 1960's (Stevenson et al. 2013). The grain yield almost doubled with cultivation of more fertilizer and moisture responsive, short statured wheat genotypes.

Due to low per unit area production of wheat in Pakistan, the country is confronted with possible wheat grain shortage. To forestall shortages and to insure food security for the ever-increasing population, it is imperative to increase wheat yield by developing high yielding and relatively stable wheat genotypes for diverse environments. Planting time plays a vital role in a country like Pakistan, where the climatic conditions vary throughout the country. Previous studies show that significantly higher yield of wheat was observed for November sown crops (Tunis et al. 1995; Choudhry et al. 1992). Similar reports are available which show that wheat sown in mid November produces more tillers plant⁻¹, maximum 1000-grain weight and more grain yield (Ansari 2002). However, yield components and grain yield declines when sowing is delayed till mid or late December. Since cultivars of wheat are grown under a wide range of environmental conditions in Pakistan, they are exposed to different soil types, soil fertility, moisture level, temperatures and cultural practices. All the variables encountered in producing a crop are described collectively as the environment. When cultivars are compared in different environments,

their relative performances may not be the same across environments. One cultivar may have the highest yield in some environments and a second cultivar may excel in others.

When assessing grain yield of a set of cultivars in multi environmental trials, variations are commonly observed in the relative yield performance of genotypes across environments. This differential response of genotypes to environmental conditions is called Genotype by Environment interaction ($G \times E$ interaction). Understanding of $G \times E$ interactions is important at all stages of plant breeding programs. Understanding its causes can be used to identify and target specific traits in desirable genotypes for achievement of breeding objectives in the form of a cultivar.

In the present experiment, 19 wheat genotypes along with two check cultivars were evaluated under normal and late sowing conditions for yield losses due to late sowing. Moreover, the study included estimation of on one hand, and for estimating the environmental influence on genetic parameters like heritability and selection response for important yield contributing traits.

2. Materials and Methods

2.1 Experimental Site

This study was conducted at Malakandher Research Farm (Lat. $34^{\circ} 01' 10.37''$ N", Long. $71^{\circ} 28' 01.69''$ E, Elevation 365.5m), the University of Agriculture, Peshawar during the crop season 2014-15. Nineteen wheat genotypes viz TW0170, 9244, 32862, 33010, DN38, PR88, PR89, V03079, V04188, V04189, V03138, CT99022, AUP4606, 2KC050, NR285, MSH14, Vmalir, VMPT7 and two check cultivars (Ghaznavi 98 and Sehar) were evaluated for yield and yield contributing traits under normal and late sowing conditions as independent experiments. Selection of the genotypes was based on their previous

recommendations for other regions of the world. The normal planting experiment was sown on November 30, 2014 and late on January 10, 2015.

A Randomized Complete Block Design (RCBD) with four replications was used for each experiment. Each genotype was planted in 6-rows plots of 5-meter length and row to row space of 30 cm. To minimize environmental influence, both experiments were adjacently planted in the same field. Both experiments received similar amount of fertilizer (120 kg N ha^{-1}) and other crop husbandry practices throughout the growing season.

Data were recorded on days to 50% heading, spikes m^{-2} , spikelets spike $^{-1}$, grains spike $^{-1}$, grain weight spike $^{-1}$, 1000-grain weight, biological yield, grain yield and harvest index

2.2 Statistical Analysis

The data across two planting dates were statistically analyzed using a mixed effects model in SAS statistical package (SAS, version 6.12) wherein sowing dates were considered as fixed effect, while genotype and Genotypes $\times$ Environment ($G \times E$) interaction as random effects (Gomez and Gomez 1984).

The mean squares pertaining to reps within environment served as an error term to test the significance of the main effect due to sowing date. Genotypic main effect was tested against the mean squares pertaining to $G \times E$ interaction, while the $G \times E$ effect was tested using pooled error term. Though $G \times E$ was significant for harvest index only, the data was also analyzed for each environment (sowing date) independently using appropriate model for RCBD and the means were separated using least significant difference (LSD) test. Genetic and environmental variances were computed from the expected mean squares to estimate broad-sense heritability under each environment

following the procedure already reported by Singh and Chaudhary (1985). Using 20% selection intensity, selection differential (S) for a trait was determined as

$$S = \bar{X}_s - \bar{X} \text{ under each environment,}$$

wherein $\bar{X}_s$ = mean of top 20% selected lines,

and $\bar{X}$ = mean of all 19 wheat genotypes.

Expected response to selection (Re) was estimated as $Re = i\sqrt{V_p} h^2$

Wherein $i = 1.40$ at 20% selection intensity,

V_p = phenotypic variance for a trait,

and h^2 = broad-sense heritability for a specific trait (Singh and Chaudhary 1985).

RESULTS AND DISCUSSION

Spikes m^{-2} , grain yield and harvest index was highly significant ($P < 0.01$) as revealed by the analysis of variance while spikelets $spike^{-1}$ and grains $spike^{-1}$ were found significant ($P < 0.05$). Rest of the traits showed non-significant differences. The environmental component revealed highly significant differences ($P < 0.01$) for all the traits except for grain weight $spike^{-1}$, which exhibited significant differences ($P < 0.05$). However, the $G \times E$ interaction showed highly significant differences ($P < 0.01$) only for harvest index (Table 1). Significant genetic variation among spring wheat cultivars for number of spikes m^{-2} as well as its differential production at test locations have also been previously reported by Lungo et al. (1990). Grains $spike^{-1}$ and harvest index were found significant in other studies conducted by Ansari et al. (1989) and Dimitrijevic et al. (2000).

The data of mean values, selection differential and harvest index are presented in table 2. The experimental lines produced more spikes m^{-2} under normal sowing as

compared to late sowing. It showed that normal sowing conditions are favorable for producing more spikes m^{-2} than late sowing. Identical results were also obtained by Tammam et al. (2000), who had concluded that spikes m^{-2} had positive effects on grain yield. In our experiment, generally all genotypes produced more spikelets spike^{-1} in normal sowing as compared to late sowing. Similar results were also reported by Khan et al. (1968) who concluded that early sown crop produced more number of spikelets spike^{-1} . The significant differences observed in present experiment for different genotypes for number of grains spike^{-1} were also supported by the findings of Ansari et al. (1989), who reported that grains spike^{-1} being an important yield component was significantly affected by time of sowing. However, Wariach et al. (1982) had concluded that the number of spikelets were least affected by late sowing conditions. This may have been due to high expressivity of the genetic parameters controlling the number of spikelets. However, even in this case significant differences among wheat genotypes were observed for grains spike^{-1} across two environments.

Normal sowing conditions leads to maximum grains spike^{-1} and delay in sowing suppresses the yield by reduction in grains spike^{-1} and grain weight. Similarly, Matsumura et al. (1988); Razzaq and Munir (1988) reported decreased grains spike^{-1} with delay in planting time. In general wheat genotypes produced more grain weight spike^{-1} under normal sowing as compared to late sowing conditions. It showed that normal sowing is favorable for producing more grain weight spike^{-1} as compared to late sowing conditions. Delay in sowing significantly reduces grain weight spike^{-1} (Dardic et al. 1988). 1000-grain weight is very important yield contributing character and is generally given more emphasis during cultivar selection. Average 1000-grain weight of 20% selected lines under normal

sowing was 41g, while it was 37g under late sowing conditions. Mean biological yield of 20% selected lines was 9968 kg ha⁻¹ and 5270 kg ha⁻¹ for normal and late sowing conditions respectively.

The data shows that normal sowing conditions are favorable for producing more grain yield than late sowing. Mean grain yield of 20% selected lines was 3906 kg ha⁻¹ and 1437 kg ha⁻¹ for normal and late sowing conditions respectively. Reduction in yield of genotypes has been given in Fig. 1. Therefore, for getting higher grain yield, sowing at normal dates is recommended. Present results are in agreement with the findings of Okuyama (2005) who had found that delayed sowing is directly associated with consistent reduction in grain yield. Harvest index is an important character because it represents the plant's efficiency of nutrient translocation from vegetative to reproductive tissue. Depending on two distinctively quantitative traits (total biomass and grain yield), this index is highly variable. Highly significant differences were observed among wheat genotypes for harvest index across two environments. Similarly, G × E interaction was also highly significant indicating that the wheat genotypes were not consistent in harvest index under normal as well as late sowing conditions.

Medium to high heritability was recorded for days to heading and spikelets spike⁻¹ under normal sowing time. High estimate of heritability for number of spikes m⁻² indicated that this trait is less affected by environment. However, under late sowing conditions, the characters showing good heritability estimates were spike m⁻², grains spike⁻¹, grain weight spike⁻¹, grain yield (kg ha⁻¹) and harvest index (%). The expected selection response of these traits was also greater in late sowing conditions. This was due to some of the genotypes, which performed well under late, sowing conditions. This means that the

potential of these genotypes can be utilized to obtain high yield in multiple cropping systems where late sowing of wheat is done.

CONCLUSIONS

Our results indicate that some bread wheat genotypes (2KC050, NR285, V04188) performed well under late sowing conditions. Therefore, these genotypes can be used for late sowing in multiple cropping systems. Development of improved varieties or utilization in breeding programs for transferring the genetic parameters of better performance under late sowing conditions to those varieties which may possess other traits but do not perform well under late sowing. Heritability estimates for all yield contributing traits were greater in magnitude under late sowing condition. This already shows that selection should be more focused under late sowing environment to reduce the existing gap between normal and late sown wheat crop and to have a control over $G \times E$ interaction.

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For Review Only

Table 1. Mean squares for agronomic and harvest traits of 19 wheat genotypes evaluated under normal and late sowing dates at the University of Agriculture, Peshawar during 2014-15.

Source	Environment (E)	Reps w/n E	Genotypes (G)	G × E	Error
Df	1	6	18	18	108
Days to heading	852.63**	4.2	4.16 ^{NS}	9.02 ^{NS}	6.67
Spikes m ⁻²	595876.90**	8279.58	3674.43**	1145.74 ^{NS}	997.12
Spikelets spike ⁻¹	210.79**	1.18	2.56*	1.01 ^{NS}	0.677
Grains spike ⁻¹	368.90**	65.36	70.47*	48.41 ^{NS}	39.75
Grain weight spike ⁻¹	0.66*	0.06	0.05 ^{NS}	0.11 ^{NS}	0.07
1000-grain weight	1679.45**	6.78	0.34 ^{NS}	12.37 ^{NS}	11.98
Biological yield	661459586.77**	3903068.04	2017598.97 ^{NS}	1843542.96 ^{NS}	1289705.58
Grain yield	169807684.5**	346602.96	944897.18**	210992.20 ^{NS}	216150.336
Harvest index	4155.69**	102.67	257.42**	167.75**	75.21

Table 2: Mean values of top 20% selected lines ($\bar{X}_s$), check cultivars mean ($\bar{X}_c$), mean of all lines ($\bar{X}$), selection differential (S), expected selection response, (R_e), genetic variance (V_G), environmental variance (V_e), and broad sense heritability (h^2) in wheat under normal and late sowing dates at the University of Agriculture, Peshawar during 2014-15.

Traits	Environment	$\bar{X}_s$	$\bar{X}_c$	$\bar{X}$	S	R_e	V_g	V_e	h^2
Heading (days)	Normal	113	115	114	-1	1.01	0.85	2.07	0.62
	Late	108	110	110	-2	1.54	2.54	11.04	0.48
Spike m ⁻² (No)	Normal	295	270	263	32	18.34	345.96	1352.08	0.50
	Late	168	157	136	32	31.1	637.92	693.19	0.78
Spikelets spike ⁻¹ (No)	Normal	19	17	18	1	0.60	0.30	0.68	0.63
	Late	17	15	15	2	1.42	0.22	0.81	0.52
Grains spike ⁻¹ (No.)	Normal	47	41	43	4	1.33	12.44	35.85	0.27
	Late	44	37	39	5	2.41	4.7	46.98	0.68
Grain weight spike ⁻¹ (g)	Normal	1.8	1.6	1.5	0.3	0.0002	0.000075	0.099	0.003
	Late	1.5	1.6	1.3	0.2	0.23	0.037	0.044	0.77
1000-grain weight (g)	Normal	41	40	38	3	0.60	1.0	16.52	0.19
	Late	37	33	33	4	0.05	0.05	6.53	0.029
Biological yield (kg ha ⁻¹)	Normal	9968	9234	8688	1280	342.16	1212051.45	90724212.5	0.05
	Late	5270	4875	4539	731	928.30	99768.57	469785.23	0.45
Grain yield (kg ha ⁻¹)	Normal	3906	4854	3435	471	195.23	49102.21	289791.48	0.40
	Late	1437	1270	1249	188	471.30	141451.6	142509.24	0.80
Harvest Index (%)	Normal	0.52	0.35	0.40	0.12	2.22	7.86	61.51	0.33
	Late	0.36	0.26	0.29	0.07	10.01	68.65	88.92	0.75

Fig. 1 Reduction (% of normal) in grain yield of wheat genotypes under late sowing at the University of Agriculture, Peshawar, 2014-15.