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Seasonal Effects and Genotypic Responses for Grain Yield in Semi-dwarf Wheat

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Abstract: To assess the genotypic response and seasonal (environmental) effects for grain yield in bread wheat, multi-locational trials of newly developed genotypes were conducted during two wheat-growing seasons in Sindh. Grain yield is a complex character, attributed to genotype (G), environment (E) and GxE interactions. The highly significant and visible seasonal effects and their interactions to genotypes were observed as for as the grain yields are concerned. Environments, genotypes, GxE interactions and genotype x year interactions were also highly significant, which suggests perceptible seasonal effects. Two high yielding advanced genotypes SD-1200/14 and SI91195 confirmed superiority in yield and wide stability and adaptation over environments during both seasons, thus, less responsive to seasonal variations. Tando Jam, Sanghar and N. Feroze were identified as the high yielding sites, consequently, had favourable environments for wheat crop during both seasons.

Key words: Seasonal effects, stability, adaptation, grain yield, GxE interactions

INTRODUCTION

Wheat (*Triticum aestivum* L.) occupies around 0.87 million hectares with annual production of 2.1 million tones in Province of Sindh, whereas, in Pakistan, it is being cultivated over 8 million hectares with annual production of 18 million tonnes (Anonymous, 2002). Due to shortage of irrigation water throughout the country, the area and production of wheat has been significantly reduced during last couple of years. In year 1999-00, it was cultivated around 1.14 million hectares with annual production of 3.0 million tonnes in Province of Sindh (Anonymous, 2000). The yield limiting agro-climatic factors such as temperature, humidity, biotic and abiotic stresses (drought and high temperatures), soil types, precipitation, crop management, crop rotations etc highly effects the wheat yields (Sial *et al.,* 2001). The large significant genotype x environment (GxE) interactions for grain yield have been observed in this region (Sial *et al.,*1999; 2000), which suggests that breeding wheat for wide adaptation for this region would be difficult.

Superior cultivars/genotypes must be evaluated on the basis of multi-environmental trials (MET) and multiple traits to ensure that the selected genotypes have acceptable performance in variable environments within the target region (Yan and Rajcan, 2002). However, effective interpretation and utilization of the MET data in making selection decision remain a major challenge to plant breeders. These trials are very helpful to determine whether the target region is homogeneous or should be divided into different mega-environments and to select the superior (high yielding) cultivars/advanced lines for a given mega-environment (Yan and Hunt, 1998; Yan, 1999).

Cornelius *et al.* (1993), emphasized that GxE interaction can be result of genotype rank changes from one environment to another, difference in scale among environments or a combination of these both. Although, cultivar rank-changes, i.e crossover interactions (COIs) are more important than scale-change interactions in varietal trials conducted over a range of environments (Baker, 1988). Superior genotypes generally show low GxE interaction variances, above average response to environmental yield potential and lower deviations from the expected response within a target environment (Kang, 1993; Peterson *et al.,* 1997; Sial *et al.,* 1999). Growers need cultivars that are dependable and consistent in yield potential across a wide range of the environments (Peterson *et al.,* 1997).

However, there are well-recognized statistical limitations in the regression approach used by the plant breeders, which provides useful parameter estimates. The joint regression analysis of genotype yield on an environmental index derived from the mean of all or subset of genotypes is the most widely used stability analysis (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Perkins and Jinks, 1968). The other methods for explaining GxE interactions have also been extensively used by plant breeders such as cluster analysis (multivariate techniques), AMMI (Additive main effects and multiplicative interaction) analysis (Nachit *et al.,* 1992; Romagosa *et al.,* 1996; Voltas *et al.,* 1999; Yau, 1995; Chapman *et al.,* 2000).

Recently, Yan, (1999); Yan and Rajcan, (2002), proposed a GGE (genotype main effect plus genotype by environment interaction effect) biplots method, which shown to effectively identify the GxE interaction pattern of the data graphically and clearly shows the combined effects of G, E, GxE and which cultivar won in which environment. The objectives of this study were to determine I) the magnitude and nature of the GxE interaction for grain yield in bread wheat ii) to determine the yield stability among genotypes and response of genotypes to different environments.

MATERIALS AND METHODS

To determine the seasonal effects and genotypic responses in semi-dwarf wheat, two years (1997-98 to 1998-99) study was conducted over different sites viz. NIA, Tando Jam, Thatta, Mirpur Khas, Sanghar 1(Shoro Farm), Sanghar 2 (Wassan Farm), Nawabshah, N. Feroze, Khairpur and Sukkur in Province of Sindh. Nine high yielding advanced lines of bread wheat viz., SD-A1/15, SD-1200/14, SD-4088, SD-4, SI91195, RWM 9205, PN9005, 15-10, 7-03 and three local check varieties, Abadgar 93, Kiran 95 and Sarsabz were evaluated in multi-locational trials during two years. Of these seven advanced genotypes (SD-A1/15, SD-1200/14, SD-4088, SD-4, SI91195, RWM 9205, PN9005) along with two cultivars (Abadgar 93 and Kiran 95) were evaluated over 8 sites {NIA, Tando Jam, Thatta, Mirpur khas, Sanghar 2 (Wassan Farm), Nawabshah, N. Feroze, Khairpur, Sukkur} during season 1997-98. Genotypes RWM 9205 and PN9005, showed poor performance (had below mean yield than the grand mean) during 1997-98, therefore, replaced by two newly developed genotypes 15-10 and 7-03 and check variety Sarsabz during second season (1998-99) at nine locations (all the sites were similar except Shoro Farm, Sanghar). The trials were conducted in Randomized Complete Blocks Design (RCBD) with four replicates. Each one plot contained six 5m long rows and 0.3 m apart, with a space of 0.6 m between adjacent plots. The drilling was performed at 125 kg ha^{-1} for all genotypes and locations. Grain yield (kg/plot) data was recorded from central four rows (a net plot size of $6m^2$) at each location was statistically analysed individually and combined over sites and years (2 years, 8 common locations, 7 common genotypes.

The joint regression analysis (JRA), proposed by Finlay and Wilkinson, (1963); Eberhart and Russell, (1966); Perkins and Jinks, (1968), was used to estimate the stability for yield among genotypes. The stability parameters; regression coefficient (b), s.e.(b) and deviations from regression (S^2d) were calculated for each genotype. The genotypes were considered as fixed effects and the locations were considered as random effects in the linear model. Mean square deviations from linear regression response were used to compare magnitude of S.E (b). as a method in which average yield of each genotype at each location was used as an environmental index for subsequent regression analysis.

RESULTS AND DISCUSSION

The combined analysis of variance indicated that year effects were significant for grain yield (Table 1), as grain yields were lower in year 1998-99 than 1997-98. In 97-98, overall grain yield of genotypes ranged from 2.67 kg in SD-4 to 3.08 kg in SD1200/14 and 3.01 kg in SI91195 (Table 8). While, during year 98-99, yield range was 2.50 kg in SD4088 to 2.73 kg in SD1200/14 and 2.68 kg in SI91195 (Table 8). Genotypes x year interactions were also highly significant ($P \leq 0.01$), suggesting the differential response of genotypes during each year over environments. All main effects viz. genotypes, environments, year x locations and genotype x year x location differed significantly ($P \leq 0.01$) for mean grain yield. Genotype x environment (GxE) interaction was also highly significant indicating the impact of environments in the expression of grain yield in wheat genotypes (Table 1).

Significant GxE interaction suggests the evaluation of candidate lines over multiple sites over time for accurate inference (Sial *et al.,* 2001). Three genotypes viz. SD-4, RWM-9205 and PN9005 had the lowest yield than all the entries including check varieties Abadgar 93 and Kiran 95 in 1997-98 (Table 2). Tando Jam and Wassan Farm Sanghar, were the highest yielding sites (3.74 and 3.62 kg, respectively) followed by N.Feroze (2.83k g) and Thatta (2.82 kg).

The yield pattern of genotypes remained almost similar during 1998-99. Same genotypes i.e. SD1200/14 and SI91195 confirmed their superiority in yield (2.88 and 2.83 kg) overall the environments (Table 3). Although, their yield was not significantly different from check Sarsabz (2.86 kg). All other genotypes, except SD A1/15 had low yield which was non significant to local checks Abadgar 93 and Kiran 95. The Shoro Farm, Sanghar had significantly the highest site mean yield. The other high yielding sites were Khairpur, N. Feroze, Sukkur and Tando Jam. Mirpur khas had unfavourable environments for wheat yield. Highly significant differences were observed among overall site mean yield of common locations,

Table 1: Combined analysis of variance for grain yield (kg/plot) of wheat genotypes evaluated in multi-locational trials during 1997-98 to 1998-99

Source of variation	DF	Mean square	F value	Probability
Year (Y)	1	6.988	98.37	0.00
Locations (L)	7	7.689	108.24	0.00
Y x L	7	7.213	101.54	0.00
R (L x Y)	48	0.145	2.04	0.00
Genotypes (G)	6	0.676	9.52	0.00
G xY	6	0.220	3.10	0.05
Genotype x locations (G x L)	42	0.280	3.94	0.00
G x Y x L	42	0.270	3.80	0.00
Error	288	0.071	---	---

C.V. 9.72%

Table 2: Performance of 9 wheat genotypes tested in multi-locational trials over 8 locations in Sindh during season 97-98

Geno types	NIA T. Jam	Thatta	Mur khas	Sanghar	Nawabshah	N. Feroze	Khairpur	Sukkur	Mean
SD-A1/15	3.84	2.98	2.70	3.73	1.67	3.02	1.90	2.90	2.84 bcd
SD-1200/14	4.12	3.25	3.02	3.66	2.58	3.15	2.18	2.70	3.08 a
SD-4088	4.13	2.68	2.63	3.85	2.38	3.00	1.85	2.83	2.92 abc
SD-4	3.33	2.24	2.75	3.14	2.83	2.60	2.00	2.50	2.67 d
SI91195	3.98	2.95	2.63	3.90	2.55	2.97	2.25	2.83	3.01 ab
RWM 9205	3.22	2.63	2.48	3.53	2.58	2.53	2.18	2.70	2.73 d
PN 9005	3.47	3.00	2.45	3.75	1.80	2.43	2.13	2.58	2.70 d
Abadgar 93	3.56	2.90	2.45	3.69	2.05	2.90	1.98	2.60	2.77 cd
Kiran 95	3.99	2.73	2.43	3.34	2.22	2.83	2.03	2.75	2.79 cd
Mean	3.74a	2.82b	2.61c	3.62a	2.29d	2.83b	2.05e	2.71bc	----
Rank	1	2	4	1	5	2	6	3	

Table 3: Performance of 10 wheat genotypes tested in multi-locational trials over 9 locations in Sindh during season 98-99

Geno types	NIA	Thatta	M. khas	Sanghar 1	Sanghar 2	Nawabshah	N. Feroze	Khairpur	Sukkur	Mean
SD-A1/15	2.61	3.25	2.40	3.25	2.58	2.62	2.50	3.09	2.58	2.76bc
SD-1200/14	2.55	3.02	2.20	4.03	2.50	2.22	3.67	2.87	2.83	2.88a
SD-4088	3.07	2.25	1.75	3.92	2.20	2.05	2.84	3.04	2.83	2.66d
SD-4	2.67	2.22	1.73	3.59	2.43	1.85	3.33	3.47	2.92	2.69cd
SI91195	3.05	2.92	1.93	4.00	2.68	2.28	3.35	2.75	2.50	2.83ab
7-03	2.75	2.85	1.80	3.17	2.33	1.89	2.72	3.33	2.75	2.62d
15-10	2.64	3.05	2.38	3.58	2.53	2.08	2.87	2.50	2.59	2.69cd
Abadgar	2.80	2.47	1.75	3.50	2.58	2.30	2.87	3.43	2.50	2.69cd
Kiran 95	2.92	2.33	1.83	3.75	2.33	2.07	2.85	2.97	3.08	2.68cd
Sarsabz	2.43	3.02	2.18	3.83	2.63	2.33	2.93	3.42	3.00	2.86a
Mean	2.75d	2.74d	1.99g	3.66a	2.48e	2.17f	2.99c	3.09b	2.76d	--
Rank	4	4	7	1	5	6	3	2	4	

Table 4: Overall performance of 7 common wheat genotypes tested over 8 common locations in Sindh during two cropping seasons (1997-98 to 1998-99)

Geno types	Tando Jam	Thatta	MirpurKhas	San-ghar	Nawabshah	N. Feroze	Khair-pur	Sukkur	Mean
SD-A1/15	3.225	3.115	2.550	3.155	2.145	2.760	2.495	2.740	2.77BC
SD-1200/14	3.335	3.135	2.61	3.080	2.400	3.410	2.525	2.765	2.91A
SD-4088	3.600	2.465	2.19	3.025	2.215	2.920	2.445	2.830	2.71CD
SD-4	3.000	2.230	2.24	2.785	2.340	2.965	2.735	2.710	2.63D
SI91195	3.515	2.935	2.28	3.290	2.415	3.160	2.500	2.665	2.8 4AB
Abadgar 93	3.180	2.685	2.100	3.135	2.175	2.885	2.705	2.550	2.68CD
Kiran 95	3.455	2.530	2.130	2.835	2.145	2.840	2.500	2.915	2.67D
Mean	3.33A	2.73C	2.30E	3.04B	2.26E	2.99B	2.56D	2.74C	-----
Rank	1	3	5	2	6	2	4	3	---

Table 5: Stability analysis of 9 wheat genotypes evaluated in multi-locational trials over 8 sites in Sindh(1997-98)

Genotypes	Mean yield kg/plot	Regression coefficient b + S. E (b)	Variance due to deviation from regression (S^2d)
SD-A1/15	2.84	1.242 ± 0.165	0.075
SD-1200/14	3.08	1.008 ± 0.120	0.037
SD-4088	2.92	1.258 ± 0.082	0.025
SD-4	2.67	0.586 ± 0.191	0.098
SI91195	3.01	1.049 ± 0.057	0.017
RWM 9205	2.73	0.682 ± 0.116	0.036
PN 9005	2.70	1.046 ± 0.171	0.085
Abadgar 93	2.77	1.052 ± 0.085	0.029
Kiran 95	2.79	1.040 ± 0.108	0.034

Table 6: Stability analysis of 10 wheat genotypes evaluated in multi-locational trials over 9 sites in Sindh (1998- 99)

Genotypes	Mean yield kg/plot	Regression coefficient b + S. E (b)	Variance due to deviation from regression (S^2d)
SD-A1/15	2.76	0.449 ± 0.188	0.078
SD-1200/14	2.88	1.124 ± 0.210	0.097
SD-4088	2.66	1.256 ± 0.172	0.066
SD-4	2.69	1.274 ± 0.203	0.081
SI91195	2.83	1.108 ± 0.191	0.077
7-03	2.62	0.951 ± 0.169	0.054
15-10	2.69	0.713 ± 0.187	0.080
Abadgar 93	2.69	1.008 ± 0.161	0.062
Kiran 95	2.68	1.115 ± 0.158	0.049
Sarsabz	2.86	0.995 ± 0.152	0.054

Table 7: Overall stability analysis of 7 common wheat genotypes and 8 common sites over two cropping seasons (1997-98 to 1998-99)

Genotypes	Mean yield kg/plot	Regression coefficient b + S. E (b)	Variance due to deviation from regression (S^2d)
SD-A1/15	2.77	0.854 ± 0.224	0.051
SD-1200/14	2.91	0.905 ± 0.205	0.055
SD-4088	2.71	1.240 ± 0.143	0.026
SD-4	2.62	0.679 ± 0.206	0.052
SI91195	2.84	1.169 ± 0.130	0.018
Abadgar 93	2.68	1.019 ± 0.139	0.023
Kiran 95	2.67	1.125 ± 0.152	0.028

Table 8: Overall genotypic mean yield (kg/plot) of wheat genotypes tested over two cropping seasons

Genotypes	1997-98	1998-99	Mean	Rank
SD-A1/15	2.84CD	2.70AB	2.77BC	3
SD-1200/14	3.08A	2.73A	2.91A	1
SD-4088	2.92BC	2.50D	2.71CD	4
SD-4	2.67E	2.57BCD	2.62D	7
SI91195	3.01AB	2.68ABC	2.84AB	2
Abadgar 93	2.77DE	2.59BCD	2.68CD	5
Kiran 95	2.79CDE	2.55CD	2.67D	6
Mean				

Table 9: Overall site mean yield (kg/plot) of wheat genotypes tested over two cropping seasons

Genotypes	1997-98	1998-99	Mean	Rank
NIA T. Jam	3.85A	2.81B	3.33A	1
Thatta	2.82CD	2.64 C	2.73C	5
MirpurKhas	2.66E	1.94F	2.30E	7
Sanghar	3.62B	2.47D	3.04B	2
Nawabshah	2.33F	2.20E	2.26E	8
N. Feroze	2.93C	3.06A	2.99B	3
Khairpur	2.03G	3.09A	2.56D	6
Sukkur	2.73DE	2.75BC	2.74C	4
Mean				

ranging from 2.26 kg at Nawabshah to 3.3 kg at Tando Jam when averaged over two years (Table 4 and 9). The other higher yielding locations followed by Tando Jam were Wassan Farm, Sanghar (3.044 kg) and N.Feroze (3.0 kg); whereas, Sukkur, Thatta and Khairpur had favourable environments over both the years. Overall genotypic mean yields are presented in Table 4 and 8. The genotype SD1200/14 and SI91195 confirmed their superiority in yield (2.91 and 2.84 kg, respectively), when averaged over both years (Table 4 and 8). Non significant difference for yield was observed between SD4088 and check variety Kiran 95, while SD-4 was non significantly different from Abadgar 93 in yield during both the years.

Matus *et al.* (1997) suggested that a significant GxE interaction may be either I) a crossover GxE interaction, in which a significant change in rank occurs from one environment to another ii) a non-crossover GxE interaction, in which the ranking of genotypes remains constant across environments and the interaction is significant because of changes in the magnitude of the response. Usually, plant breeders look for a non-crossover GxE interaction or preferably the absence of GxE interaction when selecting the genotypes for wide adaptation (Baker, 1988).

Stability parameters b and S^2d calculated for each genotype for individual and over years are shown in Table 5, 6 and 7. The average yield of individual genotype was regressed on the mean of all genotypes at each location. Regression coefficient (b) ranged from 0.586 in SD-4 to 1.258 in SD4088 during year 1997-98 (Table 5). SI91195 produced the highest mean yield (3.01 kg) with unit regression coefficient (b=1.049) and the lowest value of S.E.(b) (0.057) and deviation from regression coefficient (S^2d = 0.017). The other highest yielding genotype SD1200/14 also showed b value close to unity (1.008) and lower S^2d value (0.037). These findings suggested that these both genotypes had the highest yield as well as wide stability and adaptation in year 1997-98 (Table 5). SD-4 and RWM 9205 had low yield with above average stability i.e. 0.586 and 0.682, might be adapted to poor or unfavourable environments. Two genotypes SDA1/15 and SD4088 had better yield, with higher b value (1.242 and 1.258, respectively), indicating specific adaptation to good environments.

Regression coefficient (b) of ten wheat genotypes in 1998-99, ranged from 0.449 in SDA1/15 to 1.274 in SD-4 (Table 6). Three genotypes viz. Sarsabz, SI91195 and SD1200/14 had high mean yield, with b value close to unity (0.99, 1.10, 1.12, respectively) and the lowest deviation from regression coefficient S^2d (0.054, 0.077, 0.097, respectively) indicating wide stability over environments. SDA1/15 and 15-10 had the lowest b values (0.449 and 0.713, respectively), suggesting above average stability, thus, specifically adapted to poor environments according to stability definitions suggested by Finlay and Wilkinson, (1963); Eberhart and Russell, (1966). SD4088 and SD-4 had highest b values (1.256 and 1.274, respectively), showing specific adaptations to favourable environments. The local check variety Kiran 95 had the lowest S^2d value than all the genotypes included in this group of comparison and b value close 1.0 having better stability.

Stability analysis of seven common genotypes tested over both the years over eight common sites are presented in Table 7. The results showed that SD1200/14 and SI91195 have continuously confirmed their superiority in the grain yield overall years, showing general stability. SI91195 had regression coefficient value close to unit regression (1.16), the lowest S.E(b) value and deviation from regression (S^2d = 0.018) than rest of the entries, suggesting wide stability and adaptability over years and locations. The low yielding genotype SD-4 had the lowest b value, indicating above average stability. Where as, SD4088 had highest b value having below average stability. Abadgar 93 and Kiran 95 had also better stability due to lowest S^2d values. The present study shows the combined effects of the genetic and environmental factors that influenced grain yield over years.

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