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YIELD STABILITY IN BREAD WHEAT GENOTYPES

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Abstract

Stability for grain yield performance and genotype x environment (GxE) interaction was studied in twelve (nine advance genotypes and 3 checks) wheat genotypes evaluated at various locations having different agro-climatic conditions in Sindh province of Pakistan over two years. The combined and individual analysis of variance for locations and years was conducted. Pooled analysis of variance revealed highly significant ($p \leq 0.01$) difference for genotypes, environments and genotype x environment (GxE) interaction. A joint regression analysis was applied to grain yield data to estimate the stability parameters viz., regression coefficient (b), s.e. (b) and deviation from regression coefficients (S^2d) for each genotype. Genotype MSH-14 produced the highest mean yield (5090 kg/ha) in all environments averaged for two years, and had regression coefficient (b) close to unity (0.86) and S^2d close to zero (0.7923). This indicated wide adaptation and stability of performance of MSH-14 in all environments. Other high yielding genotypes MSH-03 and MSH-05 ranked 2nd and 3rd showing regression coefficient (b=0.78 and 0.69 respectively) and deviation from regression (S^2d= 1.076 and 1.29 respectively) indicating specific adaptability of these genotypes to harsh (un favorable) environments. These findings suggested that both the genotypes could be used as stress tolerant genotypes under stressed environments (such as drought, heat and salinity stress).

Introduction

Wheat (*Triticum aestivum* L.) is the major cereal crop in Pakistan on which the food security rests. It covers an area around 9.13 million hectares with the annual production near 23.31 million tones in Pakistan (Anon., 2010). Environmental factors such as abiotic (soil, fertility, moisture, temperature, sowing time, day length) and biotic (diseases and pests) are not consistent across years and locations which ultimately affect the yield stability of wheat genotypes. Grain yield is the function of genotype, environment and genotype x environment interaction (Arain *et al*., 2001; Hamam *et al*., 2009; Sial *et al*., 2007). Stability in yield of genotypes over a wide range of environments is of great concern to plant breeders. Genotype x environment interaction studies thus provide a basis for selection of genotypes that suit for general cultivation and others for the specific area and under defined environments (Nachit *et al.,* 1992; Ahmed *et al.,* 1996; Peterson *et al*., 1997; Yan & Rajcan, 2002; Khan *et al*., 2007). Yang & Baker (1991) suggested that the inconsistency for yield among genotypes from one environment to another may arise due to the expression of different sets of genes in different environments or difference in responses of the same set of genes to different environments. Stability in grain yield among genotypes can be described as the linear response to environmental yield and the deviation from that response (Ahmed *et al.,* 1996; Sial *et al.,* 2000; 2003). An ideal genotype generally show low GxE interaction variance, above average response to environmental yield potential and lower deviations from the expected response within a target environment.

Stability for yield can be described by pooled analysis of variance using regression coefficients (b) according to method as suggested by Finlay & Wilkinson (1963) for barley genotypes. They proposed that a genotype with high mean grain yield and regression coefficient (b) close to 1.0 as being average stability are desirable and considered as widely adapted or stable over all environments. Accordingly, the genotypes having b<1.0 were considered to be specifically adapted to harsh (unfavorable) environments; whereas genotypes with b>1.0 were having specific adaptation to favorable or high yielding environments. Similarly, Eberhart & Russell (1966) used regression coefficient as a parameter of stability and regressed the mean yield of each genotype on the mean of all genotypes for each environment (environmental index). The method suggests that a genotype is regarded stable or widely adaptable over environments, if it possesses high mean yield, a unit regression coefficient (b) close to 1.0 and the lowest or close to zero S^2d. Although many new methods of stability analysis have been practiced (Gauch, 1988; Yau, 1995; Yan and Rajcan, 2002; Romagosa *et al.,* 1996), yet methods stated earlier are still more commonly practiced. Stability studies (Genotype x environment interaction) are therefore of great importance to identify superior genotypes that perform well across a wide range of environments and to detect specific adaptability of genotypes over favorable or unfavorable environments. The aim of present study was to evaluate the performance of newly developed wheat advance genotypes and to investigate their yield stability across a range of environments over two consecutive years. The information generated by such studies will be helpful for breeders to develop wheat genotypes which could produce higher and stable yields over diversified environments.

Materials and Methods

Nine candidate high yielding strains viz., MSH-28, MSH-30, MSH-05, MSH-14, MSH-34, MSH-03, NIA-4/7, NIA-1/2, NIA-21/7 along with three check varieties Sarsabz, Kiran-95 and T.J-83 were evaluated at different locations of Sindh province having different agro-climatic conditions during 2004-05 and 2005-06. During 2004-05, the trials were conducted at six locations (Tandojam, Moro, Sukkur, Jhudo, Sanghar and Thatta), while in 2005-06 the experiments were conducted at seven sites (Tando Jam, Moro, Sukkur, Jhudo, Sanghar, Sindhri and Khairpur). At each site, the experiments were conducted in randomized complete block design (RCBD) with 4 replications. Each genotype was sown with four rows 4m long and 30 cm apart, being plot size of 4.8m^2. Four rows (3m each) were harvested and the net harvested plot was 3.6m^2 (3m x 1.2m). Data on grain yield were recorded from each location and statistically analyzed using analysis of variance method for individual years and the means were compared using Duncan's multiple range test (Steel & Torrie, 1981). Pooled ANOVA for 5 common sites of two years viz., Tandojam, Moro, Sukkur, Jhudo and Sanghar were also conducted.

Stability analysis (genotype x environment interaction) for grain yield based on 5 common sites over two years was performed according to joint regression analysis method as suggested by Finlay & Wilkinson (1963), Eberhart & Russell (1966) and Arain & Siddiqui, 1977. Stability parameters calculated were regression coefficient (b) and deviation from regression coefficient (S^2d). Genotypes were considered as fixed effects and the locations were considered as random effects. 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

Pooled analysis of variance for 5 common sites over two years revealed highly significant difference for grain yield among genotypes and environments (Table 1). 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, suggesting the differential response of genotypes during each year over environments. 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). The results indicated that there is a significance of genotype x environment interaction in this region as genotypes responded differently at different locations over years. Some genotypes showed wide adaptation and stability over a range of environments, while others exhibited specific adaptation to specific environments.

Table 1. Pooled analysis of variance for grain yield (kg/ha) of wheat genotypes evaluated at 5 common sites and two years in Sindh.

Source of variation	DF	Mean square	F-value	Probability
Genotypes	11	0.792	22.8242	0.000
Environments (locations)	4	16.086	463.3404	0.000
Years	1	1.863	53.6486	0.000
Genotype x environment (Gx E interaction)	44	0.31	8.9374	0.000
Year x locations x genotypes	44	0.262	7.5572	0.000
Year x location	4	5.822	167.7047	0.000
Year x genotypes	11	0.416	11.9716	0.000
Error	330	0.035	--	--
Total	**449**	**--**	**--**	**--**

Coefficient of variation: 11.84%

During first cropping season 2004-05, the trials were conducted at 6 different locations. The overall genotypic mean yield on environmental index ranged from 3976 to 5061 kg/ha (Table 2). An advance line MSH-14 produced significantly the highest overall mean grain yield (5061 kg/ha) among all genotypes over all environments; whereas NIA-1/2 produced the lowest mean yield (3976 kg/ha). Other high yielding genotype was MSH-03 with mean yield of 4741 kg/ha. The increase in grain yield was non significant with check varieties Sarsabz and Kiran-95. The over all site mean yield ranged from 3695 kg/ha at Sukkur to 4983 kg/ha at Moro (Table 2). Other high yielding sites were Jhudo (4812 kg/ha) and Sanghar (4722 kg/ha). Mutant line MSH-14 produced the highest potential yield 5938 kg/ha at Moro site.

In the second year (2005-06), variation in grain yield of genotypes was more pronounced over 7 sites reflecting the significant role of changing climate in 2005-06 in the yield of genotypes. In this year, the overall site mean yield ranged from 1806 to 6088 kg/ha at Sukkur and Moro respectively (Table 3). Moro location showed significantly higher mean yield in both the years while Sukkur remained at the bottom; the possible reason could be the fertile soil and favourable temperatures at Moro and poor soil and water scarcity at Sukkur site. Other high yielding sites were Jhudo and Sindhri where 5872 kg/ha and 4629 kg/ha respectively yields were recorded. Overall genotypic mean grain yield during 2005-06 ranged from 3437 kg/ha in NIA-1/2 to 4861 kg/ha in genotype MSH-03. Genotypes MSH-28 and MSH-14 ranked 2nd and 3rd in yield (4737 and 4630 kg/ha) respectively. Five genotypes produced significantly high mean grain yield than all 3 check varieties. Among local checks, Sarsabz produced higher grain yield (4192 kg/ha). The highest potential yield ($\geq$7300 kg/ha) was recorded from three advance lines MSH-5, MSH-3, and MSH-28 at Moro while Sarsabz produced high potential yield among checks (7292 kg/ha) during 2005-06 (Table 3).

Pooled analysis of variance was conducted on 5 common sites (Tando Jam, Moro, Sukkur, Jhudo and Sanghar) over two years (2004-05 to 2005-06). The combined analysis of variance indicated that the year effects were significant for grain yield, as grain yield was higher in year 2004-05 than in 2005-06. Combined results showed that MSH-14 produced significantly high mean combined over grain yield (5090 kg/ha) than other genotypes and ranked first over all sites both years. Other high yielding genotypes were MSH-03, MSH-05 and MSH-28 which produced 4855, 4705 and 4571 kg/ha respectively grain yield and ranked as second, third and fourth. Genotype NIA-1/2 remained poor in performance (3691 kg/ha) in both the years. The highest site mean yield (5536 kg/ha) was recorded at Moro followed by Jhudo (5342 kg/ha) and Sanghar (4363 kg/ha); while the lowest site mean yield (2750 kg/ha) was recorded from Sukkur over both the years (Table 4).

Table 2. Grain yield (kg/ha) performance of wheat genotypes evaluated at 6 different locations in Sindh during 2004-05.

Genotypes	Locations						Genotypic mean yield
	Tando jam	Moro	Sukkur	Jhudo	Sanghar	Thatta	
MSH-28	4417 abcd	4201d	3750 ab	5139 ab	4028 b	5486 a	4503 bc
MSH-30	3875 de	4792 bcd	3681 ab	5035 ab	4410 ab	4202 b	4332 bcd
MSH-05	4695 abcd	5834 ab	3820 ab	4340 ab	4583 ab	4167 b	4573 bc
MSH-14	5229 ab	5938 a	4514 a	5312 a	4861 ab	4514 ab	5061 a
MSH-34	3972 cde	4236 d	3472 abc	4583 ab	4479 ab	4688 ab	4238 cd
MSH-03	5042 abc	5590 abc	3264 bc	4653 ab	5278 a	4618 ab	4741 ab
NIA-4/7	4313 bcd	4521 d	3820 ab	4688 ab	5104 ab	4375 b	4470 bc
NIA-1/2	3125 e	4966 abcd	2500 c	4826 ab	4688 ab	3750 b	3976 d
NIA-21/7	4618 abcd	5069 abcd	3611 ab	5417 a	4340 ab	3750 b	4468 bc
Sarssabz	4840 abcd	5035 abcd	4167 ab	5035 ab	4792 ab	4653 ab	4753 ab
Kiran-95	5452 a	4618 cd	3646 ab	4688 ab	5243 a	4792 ab	4740 ab
T.J-83	4646 abcd	5000 abcd	4097 ab	4028 b	4861 ab	4375 b	4501 bc
Site mean yield	4519 b	4983 a	3695 c	4812 a	4722 ab	4447 b	---

Table 3. Grain yield (kg/ha) performance of wheat genotypes evaluated at 7 different locations in Sindh during 2005-06.

Genotypes	Locations							Genotypic mean yield
	Tando Jam	Moro	Sukkur	Jhudo	Sanghar	Khairpur	Sindhri	
MSH-28	3026 cd	7361 b	1701 b	7326 abc	4757 b	4097 a	4889 ab	4737 ab
MSH-30	2366 f	4792 d	1770 b	6909 c	3264 ef	2916 cd	4514 bc	3790 f
MSH-05	3606 ab	7916 a	1909 b	6875 c	3472 def	3681 ab	3993 d	4493 c
MSH-14	3627 ab	7015 b	2708 a	7465 ab	4236 c	4097 a	3264 e	4630 bc
MSH-34	3160 bc	7187 b	1458 b	7708 a	3993 cd	3056 cd	4653 ab	4459 c
MSH-03	3922 a	7500 ab	2431a	7118 bc	3750 cde	4236 a	5069 ab	4861 a
NIA-4/7	3451 ab	5347 c	1805 b	5486 d	3160 f	2952 cd	4166 cd	3767 f
NIA-1/2	3295 bc	4098 e	1423 b	5000 d	2986 f	2396 e	4861 ab	3437 g
NIA-21/7	2970 de	4063 e	1666 b	5144 d	3750 cde	2500 de	5069 ab	3595 fg
Sarsabz	2990 de	7292 b	1492 b	3159	5173 ab	4028 a	5208 a	4192 d
Kiran-95	3569 ab	4722 d	1840 b	4340	5486 a	3195 bc	4791 ab	3992 e
T.J-83	2770 ef	5764 c	1458 b	3923	4027 cd	2674 cd	5069 ab	3670 f
Site mean yield	3229 e	6088 a	1806 f	5872 b	4005 d	3319 e	4629 c	--

Table 4. Overall grain yield (kg/ha) performance of wheat genotypes evaluated at 5 common sites in Sindh during two years (2004-05 to 2005-06).

Genotypes	Locations					Genotypic mean yield
	Tando Jam	Sukkur	Moro	Sanghar	Jhudo	
MSH-28	3722 cd	2726 b	5781 cd	4392 cd	6233 a	4571 cd
MSH-30	3121 e	2726 b	4792 f	3837 d	5972 ab	4089 f
MSH-05	4150 abc	2865 b	6875 a	4028 cd	5608 bc	4705 bc
MSH-14	4428 ab	3611 a	6476 ab	4549 bc	6389 a	5090 a
MSH-34	3566 cde	2465 bc	5712 cd	4236 cd	6146 ab	4425 d
MSH-03	4482 a	2847 b	6545 ab	4514 bc	5885 ab	4855 b
NIA-4/7	3882 bc	2813 b	4934 ef	4132 cd	5087 cd	4169 ef
NIA-1/2	3216 de	1962 c	4532 f	3837 d	4913 de	3691 g
NIA-21/7	3794 c	2639 b	4566 f	4045 cd	5281 cd	4065 f
Sarsabz	3915 bc	2830 b	61643bc	4983 ab	4097 f	4398 de
Kiran-95	4510 a	2743 b	4670 f	5365 a	4514 ef	4360 de
T.J-83	3708 cd	2778 b	5382 de	4445 bc	3976 f	4058 f
Site mean yield	3874 d	2750 e	5536 a	4363 c	5342 b	--

Stability analysis: Stability analysis showed a wide variation among genotypes; some genotypes exhibited wide adaptation while other showed specific adaptation either to favorable or un-favorable environments. The high yielding genotype MSH-14 produced the highest mean yield (5090 kg/ha) over all environments and years had regression coefficient (b) close to unity (0.86) and deviation from regression (S^2d) close to zero (0.7923). Preferred genotypes generally show low GxE interaction variances, high mean yield potential over environments and below deviations from the expected response within a target environment (Lillimo *et al.,* 2004; Lin & Binns, 1988). This indicated its high yielding performance based on wide adaptation and stability of performance over all environments. Genotypes MSH-03 and MSH-05 also produced high grain yield over range of environments showed below regression coefficient (b=0.78 and 0.69 respectively) and higher deviation from regression (S^2d= 1.076 and 1.29 respectively), indicated specific adaptability of these genotypes to harsh (unfavorable) environments. It is evident that both of these genotypes could be used as stress tolerant genotypes under stressed environments (such as drought, heat and salinity stress). Similarly, MSH-28 and MSH-34 produced high grain yield had shown below regression coefficient less than 1.0 (0.77 and 0.73 respectively) and higher S^2d (1.08 and 1.23 respectively) are specifically adapted to poor yielding or unfavorable environments. According to Finlay & Wilkinson (1963) and Eberhart & Russell (1966), genotypes with 'b' value less than 1.0 and higher S^2d than 0.00 are said to be specifically adapted to poor or unfavorable environments while genotypes having high 'b' value are specifically adapted to favorable or high yielding environments. Some researchers have also opinion that the cultivar must have the genetic potential for superior performance under ideal growing conditions, and yet must also produce acceptable yields under less favourable environments (Koemel *et al.,* 2004). Genotype NIA-4/7 with above average regression coefficient (b=1.23) it indicated that this genotype could produce higher yield at favorable environments with fertile soil, adequate water and other inputs. The check varieties Kiran-95 and T. J-83 proved to be widely adapted cultivars whereas Sarsabz showed suitability to stress environments.

Table 5. Stability parameters of wheat genotypes evaluated at 5 sites common in two years in Sindh.

Genotypes	Overall grain yield (kg/ha)	Regression coefficient (b) ± s.e (b)	Deviation from regression (S^2d)
MSH-28	4571 cd	0.77 ± 0.096	1.0812
MSH-30	4089 f	0.77 ± 0.224	0.8807
MSH-05	4705 bc	0.69 ± 0.141	1.2974
MSH-14	5090 a	0.86 ± 0.135	0.7923
MSH-34	4425 d	0.73 ± 0.086	1.2309
MSH-03	4855 b	0.78 ± 0.082	1.0767
NIA-4/7	4169 ef	1.23 ± 0.099	0.2835
NIA-1/2	3691 g	0.96 ± 0.109	0.6291
NIA-21/7	4065 f	1.10 ± 0.219	0.3440
Sarsabz	4398 de	0.73 ± 0.316	0.8180
Kiran-95	4360 de	0.81 ± 0.490	0.4650
T.J-83	4058 f	1.01 ± 0.360	0.3978

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