Asian J. Med. Biol. Res. 2017, 3 (1), 38-43; doi: 10.3329/ajmbr.v3i1.32034

Asian Journal of
Medical and Biological Research
ISSN 2411-4472 (Print) 2412-5571 (Online)
www.ebupress.com/journal/ajmbr

Article

Genotype x environment interaction of wheat genotypes under salinity environments

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Received: 12 January 2017/Accepted: 13 March 2017/ Published: 30 March 2017

Abstract: Genotypes x environment interaction as well as stability of performance were determined for grain yield and yield contributes of 12 wheat genotypes under four salinity levels of environments (control, 8, 12, 16 dS/m). Significant genotype-environment interaction (linear) for days to heading, plant height, number of spikes per plant and grains per spikes, 1000-grain weight and grain yield per plant at 1% level of probability when tested against pooled deviation. Both the environment (linear) and genotype x environment (linear) components of variation for stability were also significant indicating that prediction of the genotypes on the environment appeared feasible for all the characters. The variance due to pooled deviation was significant for only days to heading. Considering all the three stability parameter, genotype G11 was found most stable among all the genotypes for grain weight of wheat. Among the genotypes G11, G22, G24, G33 and G40 were most desirable for yield per plant. The genotype G32 showed more responsiveness to changing environment and was suited only for highly favorable environments. Based on three stability parameters, G11, G22 and G37 were the most stable and desirable genotypes with reasonable good yield among the all.

Keywords: genotype; environment; stability; wheat genotype; salinity

1. Introduction

Yield and its component being quantitative in nature, it would be useful to gain knowledge about the nature and magnitude of the genetic variability and its interaction with environment. The grain yield which is the ultimate expression to various yield contributions characters is a polygenic character and influenced by many genetic factors as well as environmental fluctuations. Combined effects of grain set per spike, ear bearing tillers per plant, spikes per plant, as well as per unit area and 1000 grain wt. and also other morphelogical characters, especially plant height, spike area, days to physiological maturity influence directly in yield (Barma *et al*., 1990). Yield is also a complex character, which is dependent on a number of a agronomic characters and is highly influenced by many genetic factors as well as many environmental fluctuations (Joarder *et al.*, 1978). Genotypes which can adjust its phenotypic state in response to environmental fluctuations in such a way that it give maximum stable economic return can be termed as well buffered or stable (Allard and Bardshow, 1964). In a plant Breeding program potential genotypes are usually evaluated in different environments selecting desirable ones. For stabilizing yield, it is necessary to identify the stable genotypes suitable for wide range of environments. To identify such genotypes, genotype environment interactions are of major concern for a breeder because such interactions confound the selection of superior cultivars by altering their relative productiveness in different environments (Eagles and Frey, 1977). Varietal stability in yield with respect to wide range of environments is one of the most desired properly of a genotypes to fit the crop under available cropping pattern. So under adaptability and stability are prime considerations in formulating efficient breading programme. Stability analysis is a good technique for meaning the adaptability of different crop varieties to varying environments (Morale *et al*., 1991). Therefore, the experiment was conducted to estimate the nature of genotype and environment interaction in wheat under artificially induced saline environment.

2. Materials and Methods

2.1. Treatment

In this experiment, 12 genotypes were evaluated under four artificially induced saline environment (control, 8, 12, 16 dS/m). List of wheat genotypes are shown in Table 1.

Table 1. List of wheat entries with pedigree used in the experiment.

Sl. No.	Genotype code #	Variety/Line/Pedigree	Source
1	G1	Akber	Wheat Research Centre, BARI, Joydebpur, Gazipur
2	G11	Shatabdi	
3	G15	JUN/PRL	
4	G18	Barkat/Bulbul	
5	G22	Chirya-3	
6	G24	PVN/BL1022	
7	G26	RAWAL-87	
8	G32	YIE86-60774	
9	G33	AKR/BALAKA//FAN/PVN	
10	G37	G162/BL1316//NL-297	
11	G40	KRL 1-4	
12	G45	RAWAL87//BUC/BJY	

The experiment was conducted in pot culture under semi-controlled environment (inside plastic greenhouse) and natural light during the season of 2009-10. This was two factor experiment following randomized complete block design with three replications.

2.2. Pot preparation and plant raising

Pots were prepared with the dried soil and evenly mixed well rotten cow dung at the ratio of 3:1 (by volume). Clean and dry plastic pots of 12 liter size were used for each hybrid. Each pot was then filled with 10 kg previously prepared growth media (soil and cow dung mixture). Fertilizations were done following BARC fertilizer recommendation guide-2005. After pot preparation ten seeds per pot were sown by making holes and keeping more or less equal distances. Ten days after germination five seedlings of each genotypes in each pot and after seedling establishment two uniform healthy plants were allowed to grow in each pot.

2.3. Salinity development

Salt solution was prepared artificially by dissolving calculated amount of commercially available NaCl with tap water to make 80, 120 and 160 mM NaCl solution. The electric conductivity (EC) of the respective salt solutions was equivalent to 8, 12, 16 dS/m, respectively and 0.8 dS/m for tap water (control). The salt solution was applied with an increment of 30 mM at every alternate day till the respective concentrations were attained. Plants in control group were irrigated with tap water. Treatment solution was applied in excess so that extra solution dripped out from the bottoms of the pots (Ashraf and McNeilly, 1988; Aziz *et al.*, 2005, 06).

2.4. Data collection and analysis

Days to heading, days to maturity, plant height (cm), number of spikes per plant, number of grains per spike, 1000-grain weight (g), grain yield/plant were recorded with standard procedure. Genotype and environmental interactions were estimated according to Eberhart and Russell (1966).

3. Results and Discussion

3.1. Pooled analysis of variance

The results of the pooled analysis of variance for relevant characters after Eberhart and Russell's model is presented in Table 2. Luthra *et al*. (1974) recommended Eberhart and Russell model for stability analysis considering its simplicity. Mean sum of square due to genotypes were significant ($P < 0.01$) for all the characters when tested against pooled deviation. ANOVA shows the significant genotype environment interaction (linear) for days to heading, plant height, number of spikes per plant and grains per spikes, 1000-grain weight and grain yield per plant at 1% level of probability when tested against pooled deviation. Mahak *et* *al.* (2002) reported significant genotype-environment interaction (linear) for plant height, while Madariya *et al.* (2001) also observed significant genotype-environment interactions (linear) for grain number per spike, 1000 grain weight and yield. This indicates that the genotypes differed considerably with respect to their stability in different environments (salinity levels). Both the environment (linear) and genotype x environment (linear) components of variation for stability were also significant indicating that prediction of the genotypes on the environment appeared feasible for all the characters. The variance due to pooled deviation was significant for only days to heading. This suggest that the genotypes fluctuated significantly from their respective linear path of response to environments as well as considerable genetic diversity among the materials for days to heading. Mean square due to pooled deviation was not significant for all characters except days to heading which indicated that the major components of differences in stability for these characters was due to the linear regression and not the deviation from linear function (Ghose and Das, 1981; Ahmed and Khatum, 1996; Hossain *et al.*, 2004).

3.2. Stability and response parameter

The mean performance of individual genotypes along with their estimated stability parameters for yield and its contributing characters are presented in Table 3 and Table 4. The results were discussed character wise as follows:

3.2.1. Days to heading

For days to heading, early to medium flowering type are generally preferred i.e. negative phenotypic index (Pi) is desirable. Seven genotypes such as G1, G15, G18, G24, G26, G33 and G40 to be desirable for this character. A genotype with larger bi value indicates its highest degree of response to environmental changes. In the study genotyped G22, G26, G32, and G45 was very sensitive to changes of environments. The genotypes G1, G15, G18, G22, G24, G26, G40 and G45 showed significant S^2di values which indicate that they were more affected by the environmental fluctuations i.e. performance of these genotypes were unpredictable. Genotype G45 had both bi and S^2di significant, indicating high genotype x environment interaction for this trait. Genotypes G11, G33, G37 and G40 however, exhibited non-significant S^2di values which suggest that the performance among the genotypes were predictable in nature. Among the genotypes, G33 showed bi value of nearly unity (0.771) with non-significant S^2di and also had the higher negative indices, indicating that the genotype was fairly stable and less sensitive to environmental changes.

3.2.2. Days to maturity

The genotype environment interaction (linear) was non-significant for days to maturity. Genotypes G18, G24, G26, and G32 had the negative phenotypic indices, therefore, they are desirable genotypes with early maturity. Genotypes G11, G22, G24, G33, G37 and G45 showed bi value higher than the unity, indicating their suitability only for favorable environmental condition Genotype G15, G33, G37, and G40 exhibited significant S^2di, thus prediction of their performance over environments would be not authentic. The rest of the genotypes showed non-significant S^2di values, therefore, their performance was predictable in nature. Genotype G1 possessed the regression coefficient (bi) value were close to unity with non-significant S^2di and genotypes G32 and G18 had the higher negative phenotypic indices with non-significant S^2di values, indicating that they were to be more or less stable for this trait. Based on all the three estimates of stability parameters (negative phenotypic index, bi value close to unity and non-significant S^2di value) into consideration, it appeared that G32 might be regard as suitable genotype among the all.

3.2.3. Plant height

Genotype G33 had the highest phenotypic index (Pi = 8.56) and G45 the lowest (-8.36). Genotypes G11, G15, G24, G37, and G40 exhibited positive Pi values (p>0) which might be expected to be able to exploit the most favourable environments. The genotype (G45) showed combined response to bi and S^2di values suggesting that both linear and non-linear components were responsible for significant G X E interaction. Due to significant S^2di, genotypes G11 G22, and G45 are unstable and as such prediction across the environment would not be possible. Considering all the three stability parameter it is observed that G1 and G26 were the most stable as they fulfilled the requirement, i.e. bi ≈ 1 and S^2di ≈ 0.

Table 2. Pooled analysis of variance (MS) for genotype X environment interaction for seven economic characters in twelve wheat genotypes.

Items	df	Days to heading	Days to maturity	Plant height (cm)	Spikes/ plant (no.)	Grains/ plant (no.)	1000-grain weight (g)	Grain yield (g/plant)
Genotypes	11	65.51**	17.71**	117.49**	3.12**	73.86**	138.47**	8.83**
Env. + (Gen.X Env.)	36	3.62**	9.68**	55.43**	0.74**	42.32**	41.69**	3.88**
Env. (linear)	1	24.35**	193.45**	1571.32**	16.22**	1184.92**	1079.96**	109.76**
Gen.X Env. (linear)	11	3.58**	3.52	29.56**	0.74**	26.99**	31.74**	2.59**
Pooled deviation	24	2.78**	4.85	5.72	0.09	1.74	2.99	0.06
Pooled error	96	1.20	3.96	8.02	0.12	4.07	4.32	0.44

and ** indicate significant at 5% and 1% level of probability, respectively

Table 3. Mean performance, phenotypic index (Pi), regression coefficient (bi), deviation from regression (S^2di) of twelve genotypes of wheat for yield and its components.

Genotype	Days to heading				Days to maturity				Plant height				Number of spikes/plant			
	Mean	Pi	bi	S^2di	Mean	Pi	bi	S^2di	Mean	Pi	bi	S^2di	Mean	Pi	bi	S^2di
G1	55.33	-2.61	0.388	3.87**	102.0	0.72	0.85	-2.68	74.75	0.89	1.02	-4.96	4.58	0.03	1.93**	-0.12
G11	58.83	0.89	0.160	-0.72	102.8	1.55	1.23	-3.93	75.33	1.47	0.93	4.83**	4.83	0.28	1.03	-0.11
G15	56.67	-1.28	0.192	0.99**	102.0	0.72	0.93	17.03**	75.08	1.22	1.38	-7.01	3.38	-1.18	1.54	0.01*
G18	51.67	-6.28	-0.064	2.24**	97.75	-3.54	-0.01	-1.48	69.33	-4.53	1.33	-3.36	3.58	-0.97	1.63*	0.04*
G22	63.00	5.06	1.643	4.07**	102.9	1.63	1.32	-0.82	70.83	-3.03	0.98	6.35**	4.29	-0.26	1.30	-0.03
G24	53.08	-4.86	0.648	0.64**	99.83	-1.45	1.60	-2.85	78.17	4.31	0.51	-7.99	5.92	1.37	-0.35**	0.03*
G26	57.17	-0.78	2.053	0.36**	100.6	-0.70	0.66	-3.22	69.08	-4.78	1.00	-6.77	3.92	-0.64	1.17	-0.04
G32	64.25	6.31	2.888	-0.62	97.17	-4.12	0.55	-1.42	67.25	-6.61	1.39	-5.71	3.96	-0.60	1.60**	-0.08
G33	56.00	-1.94	0.771	-0.80	102.0	0.72	1.41	5.43**	82.42	8.56	-0.02	-0.94	5.86	1.32	-0.10**	-0.04
G37	64.08	6.14	0.443	-0.24	102.9	1.63	1.43	4.11**	78.33	4.47	1.16	-1.29	4.33	-0.22	0.80**	0.17**
G40	57.25	-0.69	-0.858	7.54**	101.4	0.13	0.73	1.41**	80.25	6.39	0.14	-6.76	5.79	1.24	0.10	-0.12
G45	58.00	0.06	3.737*	1.63**	104.0	2.72	1.31	-0.97	65.50	-8.36	2.19**	5.30**	4.17	-0.39	1.36	-0.12
Mean	57.94				101.29				73.86				4.55			
SE of mean and bi	1.18		1.17		1.56		0.55		1.70		0.22		0.21		0.25	

* and ** indicate significant at 5% and 1% level of probability, respectively

Table 4. Mean performance, phenotypic index (Pi), regression coefficient (bi), deviation from regression (S^2di) of twelve Genotypes of wheat for number of grains per spike, 1000-grain weight and grain yield per plant.

Genotype	Number of grains/spike				1000-grain weight				Grain yield (g/plant)			
	Mean	Pi	bi	S^2di	Mean	Pi	bi	S^2di	Mean	Pi	bi	S^2di
G1	28.458	-8.628	0.913	-3.280	34.958	-5.226	0.997	-3.297	5.518	-0.228	1.407**	-0.397
G11	36.633	-0.453	0.961	1.623**	44.717	4.533	0.874	-3.311	6.345	0.600	0.914**	-0.387
G15	33.733	-3.353	1.820**	0.093*	35.317	-4.867	1.387*	-4.282	5.019	-0.726	1.342**	-0.393
G18	36.617	-0.469	1.683**	-3.950	34.183	-6.001	1.496*	-3.745	3.671	-2.075	1.096	-0.429
G22	35.025	-2.061	0.987	-3.048	36.750	-3.434	0.759	8.380**	6.166	0.420	0.968**	-0.357
G24	42.700	5.614	0.274	-3.002	48.625	8.441	0.283	-0.159	7.458	1.713	-0.061	-0.396
G26	36.325	-0.761	0.982	-2.793	39.958	-0.226	1.679**	-1.121	3.727	-2.019	1.382**	-0.334
G32	34.775	-2.311	1.671**	-2.484	31.792	-8.392	1.747**	-3.789	4.589	-1.156	1.598**	-0.256
G33	42.558	5.472	0.310	-4.063	50.108	9.924	0.499	2.812**	7.708	1.962	0.567**	-0.408
G37	39.092	2.006	0.888	-1.566	41.525	1.341	1.088**	-3.953	5.318	-0.427	1.127**	-0.400
G40	43.375	6.289	0.387	-3.676	44.567	4.383	-0.208	-1.238	8.232	2.486	0.151	-0.354
G45	35.742	-1.344	1.124	-1.800	39.708	-0.476	1.400**	-2.275	5.195	-0.550	1.508**	-0.429
Mean	37.07				40.19				5.75			
SE of mean and bi	0.93		0.13		1.22		0.18		0.17		0.08	

* and ** indicate significant at 5% and 1% level of probability, respectively

3.2.4. Number of spikes per plant

Genotypes G1, G11, G24, G33 and G40 had positive phenotypic indices, therefore they were desirable for this character G1, G32, and G33 showed significant linear component (bi significant and S^2di non-significant) for spikes/plant. Such a linear response is predictable. Both the regression coefficient (bi) and deviation from regression (S^2di) were non-significant for G11, G22, G26, G40 and G45. So these genotypes are stable for both favorable and unfavorable environments. Genotype G40 had the lowest bi value (0.01) with non-significant S^2di values indicates the genotype was suited only for poor environmental condition. Talking all the three stability parameter genotype G11 considered as stable and desirable for number of spikes per plant.

3.2.5. Number of grains per spike

This trait is considered to have higher variation due to variable size of spikes for most of the varieties/genotypes of wheat. The genotypes G24, G33, G37 and G40 exhibited positive phenotypic indices, so these genotypes were desirable for this character. G15, G18, G32 and G45 tended to be responsive to change in environments as affirmed by their high bi values (1.82, 1.68, 1.67 and 1.12, respectively). These genotypes could be exploited favorable environment. The genotypes G33 and G40 with lower bi values (0.3 and 0.39, respectively) can be considered less responsive than that of the previous four genotypes. The genotypes G11 and G15 had the significant S^2di values, therefore, performance of these genotypes were somewhat unpredictable. Again the genotypes G15 showed combined linear and non-linear sensitivity indicating that both linear and non-linear components were responsible for significant G X E interactions. While the genotypes G18 and G32 had significant bi values with non- significant S^2di values indicating that genotypes are responsive and stable to favorable environment (bi >1). Considering all the three stability parameters, G37 having bi ≈ 1 an S^2di ≈ 0 was most stable and desirable genotypes.

3.2.6. 1000-grain weight

This character is important as to indicate the size of the seed. The phenotypic indices of G11, G24, G33, G37 and G40 were positive. This indicates that these genotypes had 1000-grain weight higher than the average and are desirable. The genotype G15, G18, G26, G32, G37 and G45 exhibited higher bi values (bi >1) and were suitable only for highly favorable environments. All the others genotypes gave low bi values and thus indicated better performance to average environmental condition. The regression coefficient of genotypes G15, G18, G26, G32, G37 and G45 were also significantly different from unity with non-significant S^2di values demonstrating their responsiveness to changing environments, which suggested that the performances of these genotypes were predictable in nature. All the other genotypes had the bi values, which were not significantly differed from unity. The genotypes G22 and G33 showed significant S^2di values with non-significant bi values which indicate that they are more affected by the environmental fluctuations i.e. performance of these genotypes over environments (salinity level) were unpredictable. Considering all the three parameters (Pi, bi and S^2di), the genotype G11 was found most stable among all the genotypes having bi value near to unity with non-significant S^2di value.

3.2.7. Grain yield per plant

The most predictive parameter was the phenotypic index (Pi) of the individual genotypes. The genotypes G11, G22, G24, G33 and G40 exhibited positive Pi value. So these were desirable for this trait while the same for others were negative and therefore, are not desirable. However, it was the highest in G40 (Pi=2.49) while the lowest in G18 (Pi=-2.08). The genotype G32 showed the highest bi value (bi=1.6**) with non-significant S^2di value, demonstrating their responsiveness to changing environments, which suggested that, the performance of the genotype was predictable in nature and was suited only for highly favorable environments. But the genotype G33 exhibited lower bi value (bi=0.57**) with non-significant S^2di value indicating that this genotype was less responsive to environmental changes and were suited only for poor environments. All the genotypes possessed non-significant S^2di values, indicating that their performance was predictable. Based on all the three stability parameters into consideration, it was observed that G11, G22 and G37 having bi ≈1 and S2di≈0 were most stable and desirable genotypes with reasonable good yield among the all.

4. Conclusions

Considering all the three stability parameter, genotype G11 was found most stable among all the genotypes for grain weight of wheat. The genotypes G11, G22, G24, G33 and G40 were most desirable for yield per plant. The genotype G32 showed more responsiveness to changing environment and was suited only for highly favorable environments. Based on three stability parameters, G11, G22 and G37 were the most stable and desirable genotypes with reasonable good yield among the all.

Conflict of interest

None to declare.

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