Genotype environment interaction and yield stability in bread wheat (*Triticum aestivum* L.)

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Abstract: The objective of this study was estimate Genotype x Environment (GE) interaction effects and determine the stable bread wheat (*Triticum aestivum* L.) genotypes for grain yield and its components under different environments. Fifteen bread wheat genotypes including thirteen advanced lines and two wheat cultivars, Shandweel-1 and Giza-168 were evaluated during two winter seasons (2014/2015 and 2015/2016) with two sowing dates. The combined analysis of variance showed that the differences between genotypes as well as GE interactions were highly significant for all studied traits. The genotype No. 1, 3, 5 and 7 gave high mean grain yield, regression coefficient "b" not significantly from unit and considered more stable. On the other hand, genotypes No. 4, 8 and 10 showed below mean of grain yield. Also, genotypes No. 1, 3, 4, 5, 6 and 7 were relatively heat resistance (HSI values < 1), while, the remaining genotypes were relatively susceptible to heat stress. In general, in drought environments, grain yield of genotypes No. 1, 5 and 7 were the highest.
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Key words: Bread wheat, Stability analysis, genotype x environment interaction, grain yield, heat stress

1. Introduction

In wheat growing areas such as that of Egypt, temperature starts to rise while the plant reaches the full flowering stage and anthers. Delay of wheat sowing date up to the end of December reduced wheat yield as a result of exposure to high temperature, which reduces season length. Yield genotype x environment (GE) interactions result in genotype rank changes from one environment to another. genotype x environment interactions was of major importance because they provide information about the effects of different environment on cultivar performance and play a key role for assessment of performance stability yield in difference environments. genotype X environment (GE) interactions indicate the ranking of genotype depends on the particular environmental condition where they grown (Becker and Leon, 1988). Plant breeders aim to develop new wheat cultivars that consistently have high yield in a variety environment. The adaptability of a variety is usually tested by the degree of genotype x environment interactions. The combined analysis of variance indicated that genotype x environment interactions were significant for grain yield (Mohammadi *et al.,* 2014). Kurt Polat *et al.,* 2016 studied the stability performance of bread wheat lines. Their results indicated that three lines which were characterized by higher-adaptation capabilities and stability them those of the other genotypes. Yield stability of spring wheat (*Triticum aestivum* L.) in the North West Frontier Province, Pakistan was investigated by Amin *et al.,* 2005 who found that the interaction between genotypes and environments (G x E) was significant in this study. Many researchers have reported genetic progress in yield and yield stability of different crop species in different regions (Mohamed *et al.,* 2013, Arain *et al.,* 2011 and Hamlabad, 2012). Mevlut *et al.,* 2005 evaluated thirteen durum wheat genotypes under rainfed condition for two years and at three different locations around Central Amatolia. GE interaction was analyzed using linear regression techniques. There was considerable variation for grain yield among genotypes and environments. Fahri, (2012) evaluated eight varieties of bread wheat at 10 locations between 2007 and 2011 seasons. Their results indicated that the genotype x environment interactions were significant and were further investigated by the regression. Al-Otayk, (2010) investigated the heat tolerance of twelve wheat genotypes under four environment conditions (two sowing dates and two years). The combined analysis of variance showed that grain yield, spike length and number of kernel per spike were significantly influenced by years, sowing dates and genotypes. Also significant differences were found among the genotypes of Durum wheat for seed yield on individual years and combined over years in all locations. Genotype x Environment interactions showed significant (*P*>0.001) for seed yield. According to the coefficients of linear regression and deviations from the regression model, genotypes G2, G7 and G8 proved to be more stable (Mohammadi *et al.,* 2012). The study was conducted for two sowing dates and three different locations. The results showed different response among cultivars for environments and no cultivar had superior performance in all environments. The stability parameters showed wide range of variation between cultivars for grain yield (Aziz *et al.,* 2015). The objectively of this research were to study genotype x environment interactions (GE) and to determine stability of wheat genotypes for grain yield and its components under different environment condations.

2. Material and Methods

Materials used in this study consisted of 13 advanced breeding lines of bread wheat (*Triticum aestivum* L.) (Labeled from 1 to 13) with highest yield were selected at F5 generation of cross between long-spike-35 × Sakha-94 and two wheat cultivars, Shandweel-1 and Giza-168. Field experiments were conducted at the experimental farm of South Valley University, Egypt during 2014/2015 and 2015/2016 winter seasons. The 15 genotypes were sown in two sowing dates in both seasons, namely the normal sowing dates 30 November, where the sowing condition are favorable and the late sowing 2 January which allow the plants to be subjected to the heat stress resulting from the rise of temperature late in the growing season. Each genotype was sown in three rows within each environment in randomized block design with three replications. The row length was 3 m, the row spacing was 20 cm and spaced 10 cm apart. At harvesting time, grain yield, 1000 grain weight, number of spike and spike length were studied for individual plant.

Yield of different environments:

Four environments were used as follows: E1 is the first sowing date in the first season; E2 is the second sowing date in the first season; E3 is the first sowing date in the second season and E4 is the second sowing date in the second season.

Statistical procedures:

I- A combined analysis of variance was carried and for each trait with fixed genotype and random effect of each replicate and environmental effects following Gomes and Gomez (1984).

II- Stability analysis: Stability parameters for grain yield and its components of the 15 genotypes were calculated according to the model of Eberhart and Russel (1966).

Heat suscability index (HSI): HSI was calculates for each genotype with following formula of Fisher and Muarer (1978).

$$HSI = 1 - \frac{\bar{y}h}{yp}$$

Were $\bar{y}h$ = mean yield of all genotypes under heat, yp mean of all genotypes under normal sowing date.

$$HSI = \frac{YP - Yh}{Yp.HSI}$$

Were YP = mean yield of individual genotype under favorable, Yh mean yield of individual genotype under heat stress.

Genotype with average susceptibility or resistance to heat will have HIS value of 1.0. values less than 1.0 indicate greater resistance to draught. Meanwhile, a values of HIS = 0 indicate maximum possible heat tolerance (no effect of heat stress on yield).

Daily temperatures

The recorded temperatures during March 2015 and 2016 indicated that heat waves have occurred with temperature rising above 34ºC for several days which coincided with the post flowering stages of plant development (Fig. 1).

3. Results and Discussion

I-Genotype – environment interaction and stability.

a)-Grain yield: The means of grain yield of 15 genotypes over the four environments are tabulated in Table 2. The difference between genotypes and as well as G x E were highly significant (Table 1). Averaged over the 15 genotypes, the environmental means ranged from 0.95 – 2.52 indicating the wide range of environment. Meanwhile, the genotypes means ranged from 1.13 g for genotype number (4) to 2.41 g for genotype number (7). The environments in which sowing date was delayed (E1 and E3) showed a substantial reduction in grain yield. In this context, grain yield was reduced by 61.9% in E2 relative E1 and by 63% in E4 relative E3. The analysis of variance in Table (1) revealed that the genotype – environment interaction was highly significant confirming different response of the different genotypes to environmental changes. Mohammadi *et al.* (2012) who reported that the combined analysis of variance indicated genotype X environment interactions were highly significant for grain yield. According to the Eberhart and Russel (1966), a stable genotype is one with a high mean yield, unit regression coefficient (b = 1) and deviation from regression as small as possible $s^2d = 0$. In this text, the genotypes No. (5) and Giza-168 gave high mean grain yield and regression coefficient (b) not significantly different from unity. In contrast, the cultivar Shandweel 1 showed below average stability (b = 1.54) and significant s^2d. Also, the genotype number (4) gave lowest grain yield and b = 1.13 and significant s^2d indicating that these genotypes perform well under favorable conditions whereas their grain yield is reduce markedly under stressed conditions.

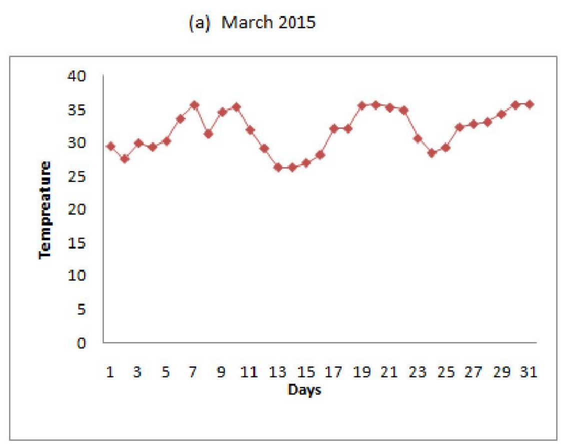
b)-Number of Kernel/spike: The data in Table 3 revealed the means of 15 genotypes for number of kernel/spike. The mean of 15 genotypes ranged from 40 to 61 for genotype number 4 and 5 respectively. The combined analysis of variance showed highly significant differences between genotypes and genotype environment interaction. These results are in harmony with that obtained by El-Morshidy *et al.* (2001), El-Ameen (2012) and Menshawy (2007). The genotypes number 1, 6. 11. And shandweel 1 had high mean number of kernel and regression coefficient not significant from unit. In the reverse, genotypes number 8 and number 10 displayed below average stability (1.24 and 1.34) confirmed that these genotypes performed under optimum sowing date.

C)-1000 grain weight: Means of 1000 grain weight of 15 genotypes bread wheat and their response regression are given in table 4. Table 1 revealed highly significant between genotypes and G x E interactions. The environmental mean ranged from 25.38 (g) to 41.74, while the genotypes mean ranged from 25.63 for genotype number 4 to 45.12 for genotype number 3. Highly significant-environment interaction. Ms was operating reflecting different response of the different genotypesto environmental changes. Similar results were obtained by Fahri (2012) and Aziz *et al.* (2015). Genotypes number 3 and 13 exhibited high 1000 grain weight and non significant liner regression while, genotypes namely Shandweel 1 Giza 168, genotype number 4, 8, 9, 10, 11 and 12 showed below average stability (b=1.28, 1.01, 1.01, 1.50 and 1.21 respectively) indicating that these genotypes performed well under favorable conditions.

d)-Spike length: The differences between environment, genotypes and G x E interaction were highly significant. The environmental mean ranged from 6.32 (cm) for E2 to 10.89 for E1 suggested the wide range of mean (Table 5). Regard to the mean of genotypes, the best mean performance was displayed by shandweel-1, Giza-168 followed by genotypes number 7, while the lowest mean performance was obtained by genotype number 9. Moreover, shandweel 1 cultivar and genotypes number 2 and 4 hat long spike length and regression coefficient not significant from unit. Motawea (2015) and Mohamed et al., (2013) showed that the differences between genotypes and genotype- environment interaction for grain yield component and spike length.

II- Heat susceptibility index.

The means of grain yield and 1000 grain weight of the 15 genotypes simultaneously grown in favorable and heat stress environments are shown in (Table 6). The analysis revealed highly significant differences between genotypes, environments as well as highly significant GE interaction which indicate differential response of the different genotypes to heat stress. Also, highly significant G x E interaction have been performed before by Mevlut *et al.*, 2005, Amin *et al.*, 2005, Hamam and Abdel-Sabour, 2009 and Kurt polat *et al.*, 2016. Accordingly, heat susceptibility index (HSI) was calculated for each of the 17 genotypes tested. Heat susceptibility index ranged from 0.49 for genotype number 1 to 1.18 for genotype number 2 for grain yield. Genotypes number 1, 3, 4, 5,6 and 7 were relatively heat resistance when they had HSI values < 1, while, the remaining genotypes were relatively heat susceptible (HSI > 1). As to 1000 grain weight, heat susceptibility index ranged from 0.68 for genotype number 3 to 1.39 for genotype number 10. HIS is measure yield stability and was 0.87, 0.68, 0.89, 0.86, 0.97 and 0.81 for genotypes number 1, 3, 6, 7, 12 and Giza-168 respectively, were relative heat resistance to heat. Heat susceptibility index is a measure of yield stability (Ahmed *et al.*, 2003). Blum (1989) stated that the stability in grain yield for each genotype can be estimated by the drought susceptibility index, derived from the yield differences between stress and non stress environments.



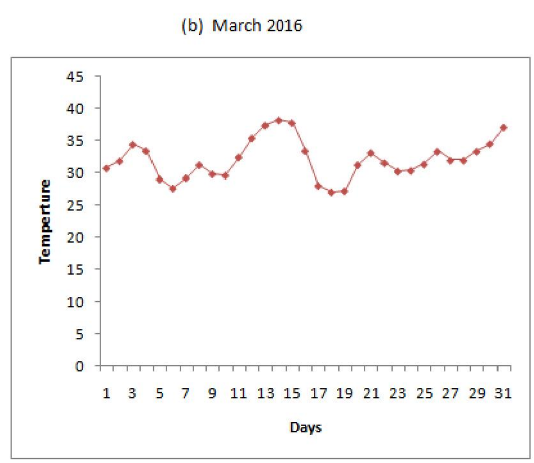


Fig. 1: Maximum daily temperatures during March 2015(a) and March 2016(b) at the experimental site.

Table (1): Analysis of variance for grain yield, number of kernel, 1000 grain weight and spike length among 15 bread wheat genotypes.

S. o. v	d.f	Grain yield	Number of kernel	1000 grain weigh	Spike length
Environments	3	38.12**	10630.08**	3402.19**	272.86**
Errer (a)	8	0.028	15.26	3.96	0.31
Genotype	14	1.68**	493.50**	325.90**	4.03**
G X E	42	0.19**	59.86**	81.61**	0.71*
Errer (b)	112	0.02	12.13	5.54	0.35

*, ** Significant at 5% and 1% respectively.

Table (2): Means of grain yield of 15 genotypes in the four environments with the stability parameters.

Genotypes	E1	E2	E3	E4	Mean	Stability parameters		
						b	Bi	S^2d
1	2.38	1.58	2.46	1.76	2.05	0.47	-0.53	0.03
2	2.21	0.55	2.45	0.70	1.48	1.07	0.07	0.04
3	2.76	1.42	2.72	1.35	2.07	0.85	-0.15**	0.01
4	1.99	0.49	1.61	0.43	1.13	0.83	- 0.17	0.14**
5	3.04	1.47	3.35	1.45	2.33	1.09	0.09	0.05
6	2.52	1.24	2.61	1.20	1.89	0.84	- 0.16	0.0
7	3.17	1.69	3.24	1.51	2.41	1.01	0.01	0.02
8	2.53	0.69	2.11	0.64	1.49	1.03	0.03	0.18
9	2.55	0.93	2.55	0.83	1.72	1.05	0.05	0.01
10	2.46	0.68	2.13	0.47	1.43	1.07	0.07	0.14
11	2.33	0.51	2.57	0.61	1.51	1.02	0.02**	0.03
12	2.26	0.83	2.58	0.74	1.60	1.03	0.03	0.06
13	2.29	0.93	2.07	0.67	1.49	0.88	- 012**	0.10**
Shandweel 1	3.09	0.76	3.72	1.15	2.18	1.54	0.54**	0.35**
Giza-168	2.28	0.74	2.57	0.82	1.61	1.03	0.03	0.05
Average	2.52	0.96	2.58	0.95				

Table (3): Means of number of kernel/spike of the 15 genotypes in the four environments with the stability parameters.

Genotypes	E1	E2	E3	E4	Mean	Stability parameters		
						b	Bi	S^2d
1	72	42	73	50	59	1.01	0.01	16.89
2	52	24	56	30	41	1.01	0.01	14.95
3	50	36	51	36	43	0.55	- 0.45	3.44
4	53	27	49	31	40	0.82	- 0.18	19.62
5	75	46	79	42	61	1.23	0.23**	58.33**
6	62	39	63	39	51	0.88	- 0.12	8.01
7	68	45	70	43	56	0.94	- 0.6	17.03*
8	58	24	66	34	45	1.24	0.24**	63.22**
9	55	26	68	33	45	1.21	0.21**	99.00**
10	65	22	57	28	43	1.34	0.34**	72.11**
11	60	28	59	34	45	1.07	0.07	7.53
12	65	34	57	37	48	0.94	- 0.06**	66.44**
13	64	37	58	33	48	0.97	- 0.03**	69.65**
Shandweel 1	60	31	67	38	49	1.08	0.08	34.45
Giza-168	50	34	53	35	43	0.65**	- 0.35	5.40
Average	60.60	33	61.73	36.20				

Table 4): Means of 1000 grain weight of the 15 genotypes in the four environments with the stability parameters.

Genotypes	E1	E2	E3	E4	Mean	Stability parameters		
						b	Bi	S^2d
1	33.59	36.48	33.62	35.19	34.72	-0.13**	- 1.13	2.16
2	42.33	22.49	43.23	22.94	32.75	1.31	0.31	13.86
3	51.50	39.10	52.70	37.17	45.12	0.93	- 0.07	1.40
4	37.66	18.28	32.67	13.93	25.63	1.28	0.28**	19.48*
5	40.43	31.56	42.11	34.44	37.13	0.52	- 0.48	16.68
6	40.26	31.08	41.55	30.88	35.94	0.65**	-0.35	3.28
7	40.26	36.80	46.17	34.91	41.03	0.69**	- 0.31	0.01
8	43.68	27.89	31.83	18.52	30.48	1.01	0.01**	138.26**
9	46.32	35.43	37.60	24.73	36.02	0.84	- 0.16**	109.98**
10	37.83	31.05	37.54	16.47	30.72	1.01	0.01**	105.29**
11	38.93	17.83	42.41	17.88	29.26	1.50	0.50**	22.81*
12	34.63	24.03	45.49	19.99	31.03	1.21	0.21**	87.80**
13	35.52	25.34	35.42	20.17	29.11	0.86	- 0.14	5.62
Shandweel 1	51.65	24.04	55.61	29.91	40.30	1.71	0.71**	99.25**
Giza-168	44.98	21.78	48.25	23.63	34.66	1.56	0.56**	37.56**
Average	41.30	28.21	41.74	25.32				

Table (5): Means of spike length of the 15 genotypes in the four environments with the stability parameters.

Genotypes	E1	E2	E3	E4	Mean	Stability parameters		
						b	Bi	S^2d
1	10	6.0	10.33	6.00	8.08	0.97	- 0.03	0.36
2	11	6.5	10.33	6.16	8.50	1.01	0.01	0.57
3	10.16	5.33	10.66	7.66	8.45	0.94	- 0.06**	3.21**
4	10.33	5.66	10.16	6.33	8.12	1.00	0.0	0.05
5	11.66	6.66	10.83	7.66	8.20	0.97	- 0.03	0.54
6	10.83	6.33	11.00	5.83	8.50	1.12	0.12	0.86
7	11.50	7.66	11.16	7.66	8.50	0.85	- 0.15	0.11
8	11.16	5.83	11.66	6.66	8.83	1.21*	0.21	0.54
9	9.83	5.16	10.16	6.00	7.79	1.04	0.04	0.37
10	9.66	5.83	10.33	5.66	7.87	0.98	- 0.02	0.86
11	10.83	6.50	10.33	7.00	8.66	0.90	- 0.10	0.07
12	11.83	7.16	11.00	6.83	8.20	1.03	0.03	0.71
13	10.66	5.66	10.50	6.33	8.29	1.08	0.08	0.04
Shandweel 1	12.00	7.33	10.16	8.16	9.41	0.80	- 0.20**	2.22**
Giza-168	12.00	7.16	11.33	7.06	9.41	1.05	0.05	0.28
Average	10.89	6.32	10.66	6.73				

Table (6): The mean of 15 genptypes in favorable and stress environments for grain yield and 1000 grain weight with HIS.

Genotypes	Grain yield				1000 grain weight			
	1st	2nd	Mean	HSI	1st	2nd	Mean	HSI
1	2.42	1.67	2.04	0.49	72.5	46.0	59.25	0.87
2	2.36	0.62	1.49	1.18	54.0	27.66	40.83	1.16
3	2.74	1.38	2.08	0.80	51.16	36.49	43.82	0.68
4	1.80	0.46	1.13	1.20	51.0	29.0	40.0	1.02
5	3.20	1.64	2.42	0.78	77.49	44.49	60.99	1.01
6	2.57	1.22	1.89	0.84	62.89	39.16	50.99	0.89
7	3.21	1.60	2.40	0.80	69.49	44.16	56.82	0.86
8	2.32	0.66	1.49	1.15	62.16	29.66	45.91	1.24
9	2.55	0.88	1.71	1.05	61.83	29.99	45.91	1.22
10	2.29	0.57	1.43	1.21	61.0	25.33	43.16	1.39
11	2.45	0.55	1.50	1.25	59.66	31.33	45.49	1.13
12	2.42	0.78	1.60	1.09	61.16	35.99	48.57	0.97
13	2.18	0.80	1.49	1.02	61.66	35.16	48.41	1.02
Shandweel 1	3.40	0.95	2.17	1.16	63.50	35.16	49.33	1.06
Giza-168	2.42	0.78	1.60	1.09	52.16	34.66	43.41	0.81
Average	2.55	0.97			61.44	35.62		

1st: First sowing date which represent favorable
2nd: Second sowing date which represent stress

Conclusion.

The results were obtained from this study revealed that the genotypes number 1, 5, and 7 which studied to late sown date had resistance to heat stress. It can to concluded that genotypes useful in developing new wheat varieties with resistance to drought stress conditions.

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