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GENOTYPE-ENVIRONMENT INTERACTION, YIELD, PERFORMANCE AND STABILITY OF WHEAT VARIETIES GROWN IN DIVERSE ENVIRONMENTS

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ABSTRACT

A field experiment, through a split-plot arrangement, was carried out in two locations (old land "OL" and new a reclaimed land "NL") during 1998/99 (Y_1) and 1999/2000 (Y_2) seasons, using eight wheat varieties planted on two sowing dates (D_1 & D_2). So, the varieties evaluated under the conditions of eight diverse environments, i.e., 4 old-land environments and 4 newly reclaimed-land. Separate analysis of variance for each environment was performed. Bartlett's test indicated homogeneity of error terms allowing combined analysis of variance over environments. The stability variance analysis was computed. Six stability statistics were used to detect the phenotypic stability of each variety across a set of environments for grain yield and some of its attributes.

Combined split-plot analysis of variance revealed considerable effects of sowing dates, on all characters except harvest index due to locations, and on all characters in most cases due to 1st, 2nd, and 3rd order interactions. Yield performance of the tested varieties showed different rankings across the eight environments due to VE interaction and therefore, discussed on the basis of Y_1 vs. Y_2 and D_1 vs. D_2 in each location (OL & NL). V_1, V_4 and V_8 in old land as well as V_1, V_8 and V_7 in new reclaimed land were well adapted and highly yielding varieties, whereas V_3 was the worst in both lands. Great similarity was detected between CV_i % and each of r_i^2. S^2d_i and / or b_i, as well as between r_i^2 and S^2d_i as measures for variety stability. The results showed that V_1 (Sids$_7$), V_8 (Gemmiza 5) and V_4 (Sakha 69) followed by V_2 (Sids$_1$) are the most high yielding potential and stable varieties and could be recommended for growing across all of these different environments.

Key words: ***Bread wheat, Genotype-environment interaction, Performance, Diverse environments, and stability parameters.***

INTRODUCTION

Although actual improvement in local wheat production have been achieved in the last decade, the gap between the total consumption and production is still wide because of the continuos growth of the Egyptian population. To bridge gap, great efforts are needed to increase the national production of bread wheat. This could be attained by horizontal and/or vertical crop expanding. Both ways should depend on planting high yielding and stable varieties well adapted to different environments especially in new reclaimed land.

Till recently, establishing the contribution of plant breeding to crop improvement was difficult due to genotype-environment (GE) interaction.

This occurred because of different rankings of performance of genotypes,

according to their genotypic values and GE interactions, when evaluated across a range of diverse environments. Moreover, the GE interaction effect may be small or large depending on both the set of genotypes and the set of environments. Changes in rankings make it difficult for plant breeder to decide which genotype (s) should be selected. Therefore, several studies have been made to employ the GE interaction in selecting precise, refine and well adapted genotypes. The early attempt focused on the importance of GE interaction in plant breeding, based on regression analysis (Yates and Cochran, 1938) to measure the adaptation of barley varieties. They proposed that when genotypes were tested in several environments, the yield of each genotype should be regressed on the mean yield of all genotypes in each environment.

Recently, clear and fruitful exploitation of GE interaction effect has been adopted by many authors as a tool for developing successful high yielding and stable varieties. Plaisted and Peterson (1959) estimated mean variance components for pair wise GE interactions and calculated the individual contribution of each genotype to the total variance. They stated that the average of the estimates for all contributions including a variety, in common, was considered as a measure of the adaptability (stability) of that variety. Comstock and Moll (1963) indicated that the variance of the main effects across a set of environments tended to be smaller if the environments are more diverse. They reported that progress of selection is reduced in the presence of large GE interaction, and the breeder may be compelled to test in several environments. Finlay and Wilkinson (1963) proposed average yield of all varieties for each site and season, as a measure of that environment 'environmental value'. They considered the regression coefficient 'b' of mean individual genotype yield performance on the mean yield of all genotypes for each site and season, as a measure of adaptability for each of the tested varieties. Eberhart and Russell (1966) suggested the use of 'environmental index' for each of environments used for a series of trials, as the mean of all varieties at one environment minus the grand mean of all environments of the trials. They pointed that both the regression coefficient 'b' and the deviation from regression of a variety on the environmental indices 'S^2d' should be considered as parameters for measuring the stability of a variety. The stability variance 'σ_i^2' (the variance of a genotype across environments) proposed by Shukla (1972) to measure the contribution of each genotype to the GE interaction, the coefficient of determination 'r^2' proposed by Pinthus (1973) to measure the percentage of total variation due to linear regression, and coefficient of variability (CV%)

for each variety across a set of environments (Francis and Kannenberg 1978) and (Becker and Léon 1988) were used as stability statistics. Lately, a yield-stability statistics (YS_i,) was developed by Kang (1993) for simultaneous selection for yield and stability.

Phenotypic and genotypic stability studies for wheat yield and its contributing characters have been reported by many authors (Joppa *et al* 1971, Rabie *et al* 1988, Hindi *et al* 1990, El-Dafrawy *et al* 1994, El-Ashry, *et al* 1996, Hassan 1997 and Salem *et al* 2000).

The present work was undertaken to study the genotypic variability, and performance of eight wheat varieties grown in different environments (old- and new reclaimed- land at two sowing dates over two seasons). Other objectives of the study were, to detect the nature and magnitude of GE interaction, and to obtain information regarding varietal stability across-diverse environments using different stability statistics.

MATERIAL AND METHODS

A field experiment was carried out in two locations, i.e. Dar- Ramad (old and clay-loamy land 'OL') and Demo (newly reclaimed and sand-loamy land 'NL') at the two Experimental Farms, Fac. Agric. at Fayoum during 1998/99 and 1999/2000 seasons, using eight wheat varieties planted on two sowing dates. The tested varieties were; Sids 7 (V_1), Sids 1 (V_2), Sakha 8 (V_3), Sakha 69 (V_4), Giza 164 (V_5), Giza 167 (V_6), Gemmiza 3 (V_7), and Gemmiza 5 (V_8). Sowing dates were; Nov. 20 (D_1) and Dec. 20 (D_2) in the first season (Y_1) and Nov. 18 (D_1) and Dec. 18 (D_2) in the second season (Y_2). In each site and season, arranged complete block design in split - plot arrangements with three replications was used, where sowing dates were allocated in the main plots and the varieties were arranged in sub-plots. The preceding crop in both seasons was maize in the first location and sesame in the second one. The plot area was 3.0 x 3.5 m. Seeds were sown in rows, 30 cm apart. The other agricultural practices recommended for growing wheat were followed.

Each sowing date in a particular season at each location was considered as an environment, leading to 4 environments in old land, 4 environments in new reclaimed land, and 8 ones in both. So, the varieties were evaluated under the conditions of eight diverse environments, viz. E_1(OL Y1 D_1), E_2 (OL Y_1 D_2), E_3 (OL Y_2 D_1), E_4(OL Y_2 D_2), E_5(NL Y_1 D_1), E_6 (NL Y_1 D_2), E_7 (NL Y_2 D_1) and E_8 (NL Y_2 D_2). At harvest, ten guarded plants were randomly taken from each plot to record the average of grains weight/spike. Average of spikes/m^2 was determined by counting spikes per square meter in each plot. Seed index (g), harvest index (%) and grain yield (ardab/faddan) were computed on the plot basis.

Separate analysis of variance for each environment was performed. Following the detection of significant V x E interactions, homogeneity test of variances (Bartlett's test) was used according to procedures reported by Snedecor and Cochran (1988). Thus, if the eight error terms of a trait are homogeneous, the combined analysis of variance was computed; however, if they are heterogeneous the combined analysis was not computed. Combine analysis of variance over environments (either in old-, new reclaimed-land or both) for the characters exhibited homogeneity among error terms was computed. Seasons (Y), locations (L) and environments (E) were considered random variables, whereas varieties (V) were considered as fixed variables. Least significant difference (LSD) was used to compare the means. The stability variance analysis was followed after Shukla (1972).

Six stability statistics were used to detect the phenotypic stability of performance of each of the tested varieties across a set environments, as follow:

1-The linear regression coefficient (b_i) and the mean square of deviation from regression for each variety (S^2d_i) of the model described by Eberhart and Russell (1966).

2-The coefficient of determination (r^2_i) between the performance of individual genotypes and the environmental index, which determine the percentage of total variation in a character due to linear regression (Pinthus, 1973).

3-Coefficient of variability (CV_i%) (Francis and Kannenberg 1978).

4-The variance stability statistic σ_i^2 as a measure for the contribution of a variety to GE interaction (Shukla, 1972) was computed using STABLE program (Kang and Magarie 1995)

6-Yield-stability statistic (Ys_i) developed by Kang (1993) was calculated by STABLE computer program after Kang and Magari (1995).

RESULTS AND DISCUSSION

1- Genotype-environment interaction:

Combined split plot analysis of variance for number of spikes/ m^2, grains weight/ spike, seed index, harvest index and grain yield/faddan revealed significant and highly significant effects due to locations (L) on all traits except harvest index (Table 1). Whereas years (Y) effect was significant only for seed index. Grains weight/ spike and seed index were significantly affected by YL interaction. These results indicated that most of these traits were mainly influenced by soil type and fertility (locations); whereas seed weights was affected by fluctuations in both soil and climatic conditions. These results support the previously reported by several wheat investigators, (Hindi *et al* 1990, Abdel-Moniem and Hassan 1992 and Salem *et al* 2000).

Planting dates (D) and varieties (V) as two main sources of variation were found to affect significantly all studied traits. The magnitude mean squares of the four main sources of variation revealed that appreciable amount of the total variation in most of the studied traits was due to location effects following planting dates and/or varieties, while the seasonal changes had little effects. This detected trend was in line with those reported by Salem *et al* (1990) and Hassan (1997). The present findings reflect that evaluating varieties in diverse locations has greater importance than in different years for obtaining accurate information concerning the varietal differential responses. In this connection Hassan (1997) suggested that location was the first factor affecting the trait performances in wheat.

The combined analysis of variance (Table 1) revealed significant mean square values for most cases of the studied traits due to the first, second and third-order interactions between varieties and the environmental factors. The largest magnitude effect on grains weight/ spike and seed index was due to LV interactions, reflecting the necessity of testing genotypes at multiple locations over a few number of seasons. Number of spikes/m^2, grains weight/ spike and grain yield/ faddan were mainly affected by DV, LYV and YV interactions, respectively. Grain yield/faddan was insignificantly affected by YDV and LYDV interactions, indicating that the response of the tested varieties was in the same direction, but with different magnitudes, under the combinations of locations, sowing dates and years. Another interpretation for these insignificant YDV and LYDV interactions on grain yield/faddan may be based on that same of the first (or second order interactions including two (or three) of factors were consistent over the third (or forth) factor.

Table1. Mean squares of different sources of variation affecting grain yield and its attributes of 8 wheat varieties grown across 8 environments.

S.V	d.f.	Mean squares				
		Spikes/m^2	Grains weight /Spike(g)	Seed index (g)	Harvest index %	Grain yield /Fed.
Locations(L)	1	103416.3**	2.859*	10.944**	15.413$^{n.s}$	325.00**
Years (Y)	1	1054.7$^{n.s}$	0.645$^{n.s}$	1.570*	22.825$^{n.s}$	4.201$^{n.s}$
LY	1	77.5$^{n.s}$	1.237*	2.030*	5.333$^{n.s}$	9.992$^{n.s}$
Planting date (D)	1	97740.8**	7.328**	5.845**	102.083*	56.350**
LD	1	11470.1$^{n.s}$	0.048$^{n.s}$	1.327*	16.217$^{n.s}$	0.853$^{n.s}$
YD	1	3350.0$^{n.s}$	0.0002$^{n.s}$	0.134$^{n.s}$	9.720$^{n.s}$	7.130$^{n.s}$
LYD	1	4313.0$^{n.s}$	0.313$^{n.s}$	0.002$^{n.s}$	1.367$^{n.s}$	0.007$^{n.s}$
Error (a)	2	897.8	0.047	0.033	1.318	1.008
Varieties (V)	7	62329.4**	8.131**	1.446*	43.784**	63.939**
LV	7	2604.1**	0.259**	0.385**	20.995**	6.049**
YV	7	852.6$^{n.s}$	0.102*	0.030$^{n.s}$	6.522*	9.162**
DV	7	4213.5**	0.159**	0.071*	10.876**	4.796**
LYV	7	776.1$^{n.s}$	0.368**	0.258**	5.978*	4.384**
LDV	7	2837.9**	0.227**	0.096**	8.361**	1.944*
YDV	7	1010.4*	0.133**	0.085**	14.551**	1.353$^{n.s}$
LYDV	7	1333.9*	0.117*	0.046$^{n.s}$	7.822**	1.487$^{n.s}$
Error (b)	126	533.5	0.450	0.031	2.534	0.744

*, ** Significant at 0.05 and 0.01 probability , respectively

The relative large and significant YV interaction affecting grain yield/faddan, reflects the differential response of the tested genotypes over years, and consequently indicates that evaluation of wheat varieties should be stressed using more diverse environments with great emphasis on multiyear. Similar results were previously reached by Hassan (1997) and Salem *et al.* (2000). However, El-Shouny *et al* (1990) reported that grain yield/plot was mainly affected by LxYxG interaction.

The present variability results clearly showed that grain yield and/ or its attributes were markedly affected, in most cases, by any different orders of interaction between varieties and each one (1st order) or pair (2nd-order) of L, D and Y. Significant first order interaction indicated that there were changes in the relative rankings or magnitudes of differences among varieties over locations, sowing dates and years. Significant second order interaction indicated that VY or VD effects were inconsistent among locations.

Therefore, the yield performance of the tested varieties which showed different rankings across 8 environments due to VE interaction (Table 2), will be discussed on the basis of each year (Y_1& Y_2) and sowing dates (D_1&D_2) in each location (old land and new reclaimed land) to facilitate the interpretation of the obtain results.

Table2. Combined grain yield (ard/fad) of 8 wheat varieties (V_i) grown across 8 environments (E_j).

Var. /Env.	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	mean
Sids 7(V_1)	22.99	22.55	20.67	19.45	21.20	19.03	18.36	17.67	20.24
Sids 1(V_2)	19.67	20.10	15.24	18.09	17.69	18.21	13.49	14.96	17.18
Sakha 8 (V_3)	16.58	19.93	14.12	15.94	14.38	15.48	10.88	14.00	15.16
Sakha 69 (V_4)	23.11	20.65	21.05	19.07	17.08	19.16	13.73	14.88	18.59
Giza 164 (V_5)	20.50	18.55	16.32	16.83	15.92	16.91	13.51	14.67	16.65
Giza 167 (V_6)	19.67	19.10	14.29	15.87	18.16	18.36	10.69	13.29	16.18
Gemmiza 3 (V_7)	19.85	20.27	16.35	16.64	18.32	18.83	15.58	15.39	17.65
Gemmiza 5 (V_8)	23.32	20.10	19.54	17.48	19.41	19.11	15.82	16.31	18.89
Mean	20.71	20.16	17.20	17.42	17.77	18.14	14.01	15.14	17.57

LSD0.05 For V_i= 0.495, For E_j = 0.535 and For ExV = 1.40

2- Yield performance:

Grain yield/faddan of the eight tested varieties showed significant differences in the two years of experimentation in both locations (Table 3). This result revealed varietal differential to both edafic and climatic conditions.

In old land, although the grand genotypic means were similar in Y_1 (18.95) and Y_2 (18.79 ardab/faddan), the individual varietal means in each year were significantly different, reflecting their varied response to the climatic effects. It was found that V_1, V_4, V_5 and V_8 produced higher yield in Y_1 than in Y2, whereas V_2, V3, V_6 and V_7 showed reverse behaviour. But the changes of varietal yield potential were significantly different, where the differences (Y_1-Y_2) ranged from - 2.59 for V_3 to 2.64 ard./fad. for V_8. These results strongly support the large magnitude and significant YV interaction detected herein for grain yield/ faddan. As mean over years, V_1, V_4 and V_8 produced highest yields, whereas the other varieties yielded lesser than the grand mean and among them V_3 gave the lowest yield.

On the other side, wheat varieties in new reclaimed land responded differently compared to those in old land, where all of them except V_1 produced higher yield in Y_2 than in Y_1, indicating their sensitivity for agro-climatic condition. However, V_1 showed reverse sensitivity or in other words tolerated the unfavourable conditions which may be dominated during the first year in this land. In this concern, Joppa *et al* (1971) reported that the cultivar may yield relatively more than other cultivars in low yielding environment and relatively less in high yielding environment due to its inherent response. It was shown that changes in seasonal conditions affected the varietal performances and resulted in varied yield differences ranged from -2.10 for V_3 to 1.43 ard./fad. for V_1, explaining the presence of significant VY interaction mentioned above. As mean over years, V_1 produced the highest grain yield followed by V_8 and V_7, whereas V_3 was the lowest yielding variety.

With considering the least yearly difference as an indicator for the variety yield fluctuation, it could be concluded that V_1 in the old land as well as V_8 and V_7 followed by V_1 in the new reclaimed land are well adapted and highly yielding varieties.

Table3. Grain yield (ard./fed.) of 8 wheat varieties in two seasons (Y_1 & Y_2) over two planting dates, in old and new reclaimed lands.

Varieties	Old Land				New Land				Mean
	Y_1	Y_2	Y_1-Y_2	Mean	Y_1	Y_2	Y_1-Y_2	Mean	
V1	21.83	21.00	0.83	21.41	19.78	18.35	1.43	19.06	20.24
V2	17.45	19.10	-1.64	18.28	15.59	16.59	-0.99	16.09	17.18
V3	15.35	17.94	-2.59	16.64	12.63	14.74	-2.10	13.68	15.16
V4	22.08	19.86	2.22	20.97	15.40	17.02	-1.62	16.21	18.59
V5	18.41	17.69	0.72	18.05	14.71	15.79	-1.08	15.25	16.65
V6	16.98	17.48	-0.51	17.23	14.43	15.83	-1.40	15.13	16.18
V7	18.10	18.46	-0.36	18.28	16.95	17.11	-0.16	17.03	17.65
V8	21.43	18.79	2.64	20.11	17.61	17.71	-0.10	17.66	18.89
Mean	18.95	18.79	0.16	18.87	15.89	16.64	-0.75	16.26	17.57
LSD	0.69	0.73	0.58	0.49	1.22	1.27	0.56	0.86	0.98

In regard to sowing dates, it was found that all varieties responded positively to the early sowing (D_1) compared to the late one (D_2) but with varied mean differences in the old (4.7) and new reclaimed (1.8 ard./fad.) lands (Table 4). Significant differences among varieties were detected in each sowing date at both locations. The results support the evidence of varietal differential response to environmental factors. Similar results were reported by Salem *et al.* (2000) who suggested that the combinations of sowing dates and years were sufficient to obtain reliable information about the response of wheat genotypes studied by them. At the present two sowing dates in both kinds of land, V_1 was the highest potential variety, but with moderate yield difference.

In old land, V_4 produced yield comparable to that of V_1 in both dates, but with relatively small yield difference. Therefore, V_4 followed by V_1 could be recommended as high yielding and well adapted varieties for growing in the old land, even if they planted at different dates. V_8 ranked as the third highly potential variety at both sowing dates, but it exhibited relatively large fluctuated yield. However, V_3 followed by V_6 gave low yield and showed great influencing by sowing dates, which may be due to their narrow inherent adaptability.

Table 4. Grain yield (ard./fed.) of 8 wheat varieties planted an two dates (D1 & D2) over two years, in old and new reclaimed lands.

Varieties	Old Land				New Land				Mean
	D_1	D_2	D_1-D_2	Mean	D_1	D_2	D_1-D_2	Mean	
V1	22.77	20.06	2.71	21.41	20.12	18.01	2.10	19.06	20.24
V2	19.88	16.67	3.22	18.28	17.95	14.23	3.72	16.09	17.18
V3	18.25	15.03	3.22	16.64	14.93	12.44	2.49	13.68	15.16
V4	21.88	20.06	1.82	20.97	18.12	14.31	3.81	16.21	18.59
V5	19.52	16.58	2.95	18.05	16.41	14.09	2.33	15.25	16.65
V6	19.38	15.08	4.31	17.23	18.26	11.99	6.27	15.13	16.18
V7	20.06	16.49	3.57	18.28	18.58	15.49	3.09	17.03	17.65
V8	21.71	18.51	3.19	20.11	19.26	16.06	3.20	17.66	18.89
Mean	20.43	17.31	3.12	18.87	17.95	14.58	3.38	16.26	17.57
LSD	0.84	0.55	0.58		1.35	1.13	0.88		

In new reclaimed land, all varieties produced lower yields than those of the old land. V_8 was the second highest yielding variety (after V_1) and exhibited the same yield difference of that of the old land, indicating its consistency. However, V_4 in the contrary of its behavior in the old land, showed obvious yield fluctuation due to change in sowing dates. The greatest influenced variety by this change in sowing dates was V_6.

To sum, the above discussion revealed that the studied wheat varieties showed different rank performance due to their differential responses to single and/or combinations of the environmental effects, i.e. L, D and Y. Variances of the main factors across a set of environments tend to be smaller if the environments are more diverse (Comstock and Moll, 1963). Pinthus (1973) suggested that genotype-environment interactions are strongly affected the expression of most quantitative traits, particularly yield, and selection for these traits has to be based on evaluation at diverse environments. Therefore, to obtain an accurate identification of the eight wheat varieties, concerning their consistency across environments, stability parameters for yield and some of its attributes were estimated.

3. Stability Parameters:

Following detection of significant VE interaction, Bartlett's test was used and indicated the presence of homogeneity among error terms of individual environments for all studied characters, enabling a combined analysis. The data in Table (5) presented the combined analysis of variance for grain yield/faddan and four of its attributes. Highly significant differences were found among varieties, environments (linear) and variety x environment for all characters, indicating the varied varietal responses and performances from one environment to another. Highly significant mean squares of varieties as well as variety x environment interaction may be revealed that the varieties had inherent inconsistency from one environment to another.

Table 5. Mean squares of ANOVA across all environments (E) of 8 wheat varieties (V) for grain yield and its contributing variables.

S.V	d.f.	Mean squares				
		No. Spikes./ m^2	Grains weight /Spike(g)	Seed index (g)	Harvest index	Grain yield /Fad. (ard.)
Varieties (V)	7	62328.43**	8.131204**	1.445487**	43.78125**	63.9375**
Environments (E)	7	31631.57**	1.776071**	3.122053**	24.6981**	121.9361**
V x E	49	1947.061**	0.19497**	0.138973**	10.72983**	4.16757**
Heterogeneity(Linear)	7	3831.662*	0.181543$^{n.s}$	0.056069$^{n.s}$	7.405413$^{n.s}$	4.354012$^{n.s}$
		28.113%	13.302%	5.764%	9.86%	14.896%
Residual (non-Linear)	42	1632.961**	0.197208**	0.152791**	11.2839**	4.136497**
Pooled error	112	559.35	0.047	0.032	2.562	0.747

*, ** Significant at 0.05 and 0.01 probability, respectively

Mean squares of heterogeneity (Linear) components were insignificant for all studied characters except number of spikes/ m^2. The percentages of sums of squares attributed to heterogeneity component, calculated to assess its influences in the linear genotypic response to the environmental index, were relatively small 5.76- 14.99% for seed index, harvest index, grains weight/ spike, and grain yield/ faddan, compared to that of number of spikes/m^2 (28.11%). This means that the VE linear component is present for the latter character. The analysis of variance showed also that the residual (non-linear) or pooled deviation was highly significant for all studied characters, indicating that the varieties differed markedly with respect to their deviation from their respective average linear response.

3.1 Stability for number of spikes/m^2

The stable genotype as defined by Eberhart and Russell (1966) is one which has a regression coefficient (b_i) of about 1.0 and deviation mean square from regression (S^2d_i) near zero. The data presented in Table (6) show that V_5 and V_7 followed by V_8, V_4, V_2 and V_3 had b_i values of approximate 1.0 indicating their stability for this character. However, S^2d_i values were significantly different from zero, revealing instability of all studied varieties for number of spikes/ m^2. This contradicted results of the two parameters may be due to the significant heterogeneity (linear) which indicated that a major portion of VE interaction was accounted for the linear component. On the other hand, coefficient of determinations (r_i^2) were high for all varieties except V_1, exhibiting stability for this character in almost all tested varieties. Coefficient of variability (CV_i%) values were mostly in line with those of b_i, where V_2, V_5 and V_8 followed by V_1 and V_3 had low percentage. Duarte and Zimmerman (1995) reported that several of the stability statistics probably gave similar values of phenotypic stability. Only V_5 showed insignificant variance statistic (σi^2), indicating its stability. Simultaneous yield-stability statistic, developed by Kang (1993), characterized V_2, V_4, V_5 and V_8 as superior and stable varieties. It is worth to mention that almost all parameters (except S^2d_i) showed stability of these latter four varieties for this character.

3.2 Grains weight/ spike (g):

Regression coefficient (b_i) values were insignificantly different from unity for V_7 and V_4 followed by V_8, V_5 and V_1, indicating their stability for this character (Table 6). Full uniformity was observed between S^2d_i and r^2, where both showed stability for all studied varieties. CV_i% values were relatively low for V_1 and V_5, and the latter variety showed insignificant σi^2 reflecting their stability for this character. The values of Ys_i showed stability

Table 6. Mean number of spikes per m^2, grains weight per spikes (g) and estimates of stability parameters in 8 wheat varieties based on 8 environments.

Characters	No. Spikes/ m^2								Grains weight / Spike (g)							
Varieties	Mean	b_i	S^2d_i	r_i^2	$C.V_i\%$	σ_i^2	Adj. rank Yield	YS_i	Mean	b_i	S^2d_i	r_i^2	$C.V_i\%$	σ_i^2	Adj. rank[redacted] Yiel	YS_i
V1	268.21	0.234**	-35.69**	0.089	4.50	3288.8**	-2	-10	3.970	1.268	0.021	0.872**	4.83	0.1147*	11	7+
V2	450.04	1.211	-2.90*	0.925**	3.01	541.6**	11	11+	2.140	0.425	0.072	0.953**	13.79	0.3647**	-2	-10
V3	369.92	0.788	27.14**	0.817**	3.95	648.6**	2	0	2.220	0.586	0.018	0.986**	8.33	0.1353**	-1	-9
V4	406.04	1.137	496.83**	0.745**	6.44	2117.8**	10	2+	2.390	1.096	0.055	0.974**	11.16	0.2133**	1	-7
V5	383.29	1.096	-82.17**	0.947**	2.66	80.95ns	7	7+	2.430	1.216	-0.012	0.990**	2.48	-0.006ns	3	3+
V6	376.46	1.497	1202.0**	0.712**	9.90	5734.8**	5	-3	2.420	1.426	0.107	0.939**	14.51	0.4426**	2	-6
V7	366.87	0.928	762.25**	0.582**	8.40	2956.3**	1	-7	2.460	0.936	0.022	0.986**	7.92	0.099*	4	0+
V8	397.17	1.110	-49.22**	0.933**	3.09	209.9**	6	6+	2.710	1.046	0.051	0.976**	9.53	0.1968**	9	1+
Mean	377.25	1.00						0.75	2.59	1.00						-2.63
$LSD_{0.05}$	11.32								0.104							

*,** Denote significant at P= 0.05 and 0.01, respectively and significantly different from 1.0 for regression coefficients and from 0.0 for deviation mean squares at P= 0.05 and 0.01 respectively.

+ Selected genotypes on the basis of YS_i

of V1, V_5, V_8 and V_7. Stability of these four varieties was confirmed by most the used parameter.

3.3 Seed index (g):

The statistical parameters; b_i, S^2d_i and r_i^2 showed similar behaviour as those mentioned for grain weight/spike. b_i values were insignificant from unity for V_3, V_7, V_8 and V_1 followed by V_4 and V_5 indicating their stability for this character (Table 7). S^2d_i and r_i^2 showed exactly similar results, where both showed stability for all varieties. These results confirmed the opinion of Duarte and Zimmermann (1995) and suggesting that one of both parameters is enough to determine phenotypic stability. In this concern, Becker *et al.* (1982) regarded the mean square of deviation from regression to be the most appropriate criterion for measuring phenotypic stability in an agronomic sense because it measures the predictability of genotypic reaction to environments. Low coefficient of variation (CV_i%) values were relatively low for V_3, V_7 and V_5 followed by V_1 and V_8, showing similar results of those of b_i. V_3 showed least σ_i^2value reflecting its stability for seed index. Simultaneous yield-stability parameter (Ys_i) characterized V_1, V_7 and V_8 followed by V_3, but with considering adjacent yield the varieties become in the order of V_8 , V_7 and V_1. It was observed that most parameters provide stability for V_1, V_6 and V_8 for the present character.

3.4 Harvest index:

According to the assumptions of Eberhart and Russell (1966) V_4, V_5 followed by V_1which showed b_i equal to unity, as well as V_4 and V_3 followed by V_1 which showed S^2d_i near to zero, were stable for this character (Table 7). Coefficient of determination (r_i^2) developed by Pinthus (1973) who advocated it as best measure of phenotypic stability because of its value lay between zero and one, showed stability for V_4, V_6 followed V_7 and V_3. Coefficient of variation (CV_i%) showed exactly similar results as those of S^2d_i, where it showed relatively small values for V_4, V_3 followed by V_1. This result confirmed again that it is enough to use one of these similar parameters. Only V_4 and V_3 showed insignificant σi^2 indicating their stability for harvest index. Ys_i values showed stability for V_1, V_5 and V_8 (with high mean) followed by V_4 (with relatively low mean). All of the used parameters were in line for determining stability of V_1 and V_4 for harvest index.

Table 7. Mean seed index (g), harvest index and estimates of stability parameters in 8 wheat varieties based on 8 environments.

Characters	Seed index (g)								Harvest index							
Varieties	Mean	b_i	S^2d_i	r_i^2	$C.V_i\%$	σ_i^2	Adj. rank Yield	YS_i	Mean	b_i	S^2d_i	r_i^2	$C.V_i\%$	σ_i^2	Adj. rank Yield	YS_i
V1	5.062	0.891	0.003	0.893**	2.34	0.012 n.s	9	9+	29.984	1.173	2.100	0.013	5.72	8.532**	1 1	3+
V2	4.580	0.773	0.104	0.441**	7.4	0.397**	-2	-10	27.375	0.381	2.320*	0.052	6.50	10.706**	[illegible]	-5
V3	4.742	0.982	0.000	0.937**	2.13	0.0119 n.s	2	2+	25.592	1.140	0.896	0.472*	5.16	4.27 n.s	[illegible]	-4
V4	4.965	1.045	0.033	0.790**	4.21	0.127**	6	-2	27.371	0.825	-0.226	0.567*	2.89	0.48 n.s	[illegible]	2+
V5	4.665	1.102	0.014	0.882**	3.39	0.006*	-1	-5	28.908	0.434	4.318**	0.042	7.85	17.30**	[illegible]	1+
V6	4.699	1.252	0.085	0.716**	6.59	0.339**	0	-8	26.950	1.931	2.509*	0.573*	6.79	13.35**	[illegible]	-8
V7	5.123	0.957	0.007	0.887**	2.59	0.038 n.s	10	8+	28.329	1.647	2.702*	0.479*	6.64	12.21**	[illegible]	-2
V8	5.248	0.997	0.025	0.806**	3.6	0.099**	11	3+	28.567	0.470	4.845**	0.045	8.34	18.98**	[illegible]	(-1)+
Mean	4.89	1.00						-0.375	27.88	1.00						-1.75
$LSD_{0.05}$	0.086								0.766							

*,** Denote significant at P= 0.05 and 0.01, respectively and significantly different from 1.0 for regression coefficients and from 0.0 for deviation mean squares at P= 0.05 and 0.01, respectively.

+ Selected genotypes on the basis of YS_i

3.5 Grain yield/ faddan (ard.)

The ideal variety as proposed by Eberhart and Russell (1966) would have a high mean yield over a range of environment, a regression coefficient (b_i) of one, and deviation mean square from regression (S^2d_i) of zero. The data presented in Table (8) show that V_8, V_2, V_3 and V_5 had b_i value equal approximately one reflecting their average stability across environments. While V_7 and V_1 had b_i lesser than one, indicating their stability and adaptability under less favorable conditions. According to Breese (1969) varieties with regression coefficient greater than one would be adapted to more favourable environments, while those with regression coefficient lesser than one would relatively better adapted to less favourable growing conditions. In this connection V_4 and V_6, which showed (b_i) values greater than one may be, stable and has response for high yielding environments. With considering yield potentiality and b_i parameter, V_1, V_8 followed V_7 and V_4considered stable varieties (Table 8 and Fig.1). Low S^2d_i values with no significance from zero were detected for V_5, V_7 and V_2 followed by V_1. However, coefficient of determination (r_i^2) showed significant high values (stability) for all studied varieties. Coefficient of variation (CV_i%) showed results similar to those of S^2d_i, where it showed stability of V_5, V_7, V_1 followed by V_8 and V_2. Only V_5 showed significant σ_i^2 indicating its stability. Ys_i values exhibited yielding ability and stability for V_1, V_8 and V_4 followed by V_5 and V_2. It was observed that the stability of the varieties 1 , 2, 5, 7 and 8 was confirmed by most of the tested parameters for grain yield/ faddan.

He previous discussion revealed that; there were great similarities between CV_i% and each of r_i^2, S^2d_i and/ or b_i, as well as between r_i^2 and S^2d_i, indicating that one or two of these parameters together with Ys_i may be enough for determining phenotypic stability of crop varieties. The results showed also that V_1 (Sids 7), V_8 (Gemmiza 5) and V_4 (Sakha 69) followed by V_2 (Sids 1) are the most high yielding and stable varieties and could be recommended for growing under these environmental conditions.

Table 8. Mean grain yield (ard/ fad) and the stability parameters of 8 wheat varieties, based on 8 environments.

Varieties	Grain yield / Feddan (ardab)							
	Mean	b_i	S^2d_i	r_i^2	C.V$_i$%	σ_i^2	Adj. rank Yield	YS$_i$
V1	20.20	0.758	0.711	0.780**	4.84	3.8162*	11	3+
V2	17.15	0.986	0.497	0.886**	5.03	1.8156*	3	(-1)+
V3	15.13	0.986	1.782	0.740**	9.40	6.3235*	-2	-10
V4	18.53	1.258	2.170	0.795**	8.37	8.8158*	9	1+
V5	16.61	0.929	0.126	0.932**	3.68	0.7154ns	0	0+
V6	16.13	1.332	1.144	0.883**	7.29	6.3281*	-1	-9
V7	17.60	0.785	0.370	0.855**	4.46	2.3833*	6	-2
V8	18.85	0.966	0.856	0.834**	5.57	3.1387*	10	2+
Mean	17.52	1.00						-2
$LSD_{0.05}$	0.414							

*,** Denote significant at P= 0.05 and 0.01, respectively and significantly different from 1.0 for regression coefficients and from 0.0 for deviation mean squares at P= 0.05 and 0.01, respectively.

+ Selected genotypes on the basis of YS$_i$

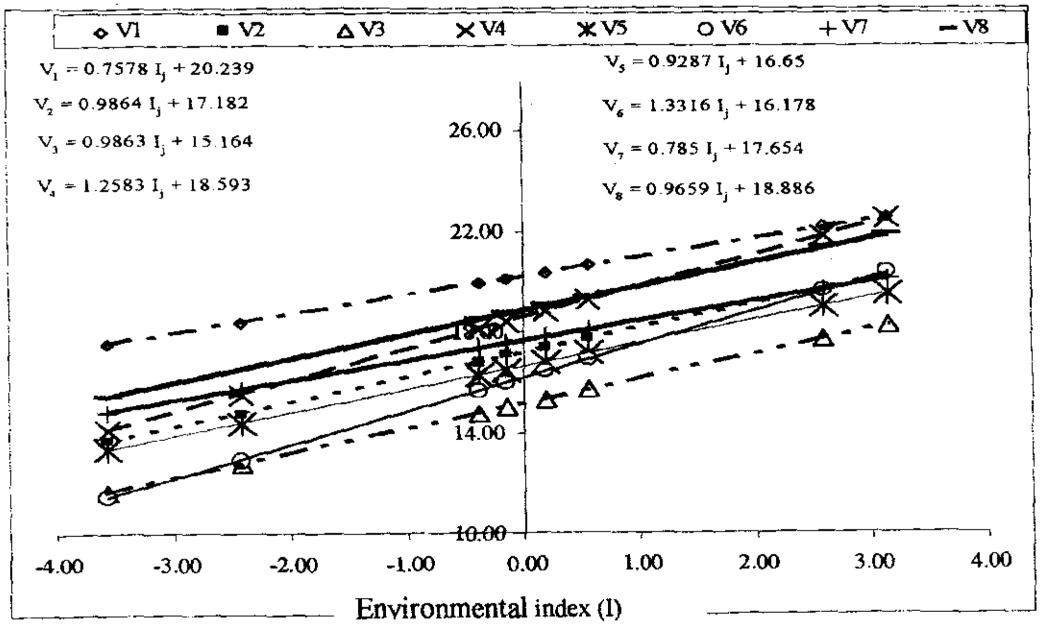

Figure 1. Linear response of 8 wheat varieties to change in environmental indexes for grain yield per faddan (ardab).

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التفاعل البيئي الوراثي، الأداء المحصولى والثبات لأصناف القمح النامية في بيئات مختلفة

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أقيمت تجربة حقلية (باستخدام تصميم القطاعات الكاملة العشوائية في قطع منشقة)في موقعين مختلفين:(ارض قديمة وارض حديثة الاستصلاح) خلال عامي ١٩٩٩/٩٨، ٢٠٠٠/٩٩ لاختبار ثمانية أصناف تجارية محلية من القمح زرعت في موعدين. وعليه فقد تم تقييم الأصناف تحت ظروف ثمانية بيئات مختلفة (٤ في الأرض القديمة، ٤ في الأرض الحديثة) وتم تحليل بيانات صفات كل بيئة على حدة، واتضح من اختبار تجانس التباينات وجود تجانس في صفة المحصول وأربعة من مكوناته وعلية تم عمل التحليل المشترك لها، وكذلك تم تحليل بياناتها للثبات، وقد اختبرت ستة معالم إحصائيه لقياس ثبات كل صنف بالنسبة للمحصول وبعض مكوناته.

واتضح من التحليل المشترك للتباين تأثر جميع الصفات معنويا بموعد الزراعة، وتأثر معظمها بالموقع، كما ظهر تأثير معنوي لمعظم حالات التفاعل. ونظرا للتأثير الواضح للتفاعل البيئي الوراثي على محصول جميع الأصناف مما انعكس في اختلاف ترتيبها في البيئات المختلفة فقد نوقشت صفة المحصول على مستوى السنة، وموعد الزراعة في كل موقع واتضح أن الأصناف ١، ٤، ٨ (في الأراضي القديمة) والأصناف ١، ٨، ٧ (في الأرض الجديدة) كانت عالية المحصول والتأقلم، بينما كان الصنف ٣ هو الأقل آداءا في كلا النوعين من الأراضي.

وظهر من بيانات معالم الثبات أن هناك تشابه بين كفاءة ($CV_i\%$) وكل من (r_i^2)، (S^2d_i)، وأيضا (b_i) وكذلك بين (r_i^2)، (S^2d_i)، في تحديد ثبات صفات الأصناف. ودلت النتائج أن سدس(٧)، جميزة (٥)، وسخا(٦٩) وأيضا سدس(١) هي الأعلى محصولا والأكثر ثباتا والتي يمكن التوصية بها للزراعة تحت ظروف هذه البيئات.

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