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GENOTYPE x ENVIRONMENT INTERACTION AND PHENOTYPIC STABILITY ANALYSIS FOR GRAIN YIELD AND ITS COMPONENTS OF BARLEY

S.H. Saleh[1] and H.I. Farag[2]

1. Dept. of Agron., Fac. of Agric., Ain Shams University, Cairo, Egypt
2. Plant Genetic Resources Dept., Desert Res. Center, Cairo, Egypt.

ABSTRACT

Forty barley lines were evaluated for genotype x environment their interaction with 8 different environments and phenotypic stability for grain yield and its components (spike length, spikelets /spike, spikes/ plant, kernels/spike and 1000-kernel weight). The 8 different environments were the combination between four location; Ras Suds, Maryout, El-Maghara and Siwa and two growing seasons; 2013/2014 and 2014/2015. The results revealed highly significant mean squares due to differences among barley lines, environments and their interactions for all studied traits, indicating that barley lines differed in their response to the changes in environments. The two environments; E5 and E6 (El-Maghara location during the two seasons) produced higher mean values for grain yield and its components than other studied environments. Moreover, the two lines; 37 and 40 were the best lines for grain yield and most its components across different environments. Results of phenotypic stability indicated that the two lines; 32 and 34 were considered as the most desirable and stable for grain yield / plant and its components under a wide range of environments.

Key words**: *Hordeum vulgare, G x E interaction, Stability, Regression, Locations.***

INTRODUCTION

Barley (*Hordeum vulgare* L.) is considered one of the most important crops ranking the fourth in the world cereal crops production. It is grown across a wide range of soil variability and under many diverse climatic conditions compared with many other cereal crops. It has a good tolerance to abiotic stresses such as salinity, drought, frost and heat. Also, it is used mainly for animal feeding, brewing malts and human food in some areas. Thus, breeding for increased barley grain yield has become, in recent years, one of the main breeding goals in many countries. Since barley genotypes have shown narrower adaptation and fluctuation in various environments, the development of high yielding and stable barley varieties is very important. Varieties and promising lines to deal with erratic and unpredictable climatic conditions have been evaluated in multi-location trials and determined by stability tests (Jackson *et al* 1994, Akcura *et al* 2005, Dehghani *et al* 2006, Amer *et al* 2012 and Abd El- Moneam *et al* 2014). Backer and Leon (1988) reported that a genotype is considered stable if its performance is consistent regardless of any variation in environmental conditions. Also, the ideal situation would be to have a highly stable genotype with high potential (Finlay and Wilkinson 1963 and Smith 1982). Several statistical methods have been proposed to determine the stability of genotypes in explaining G x E interactions. The most commonly used parameter is the joint regression approach and the deviation mean squares

from the regression line (S^2d_i) proposed by Eberhart and Russell (1966). The present study aimed to evaluate 40 new improved lines of barley for agronomic traits under 8 environments (4 locations x 2 seasons) and to estimate the phenotypic stability to identify the best lines, which can be used as useful genetic sources in barley breeding programs.

MATERIALS AND METHODS

The present investigation was carried out to study genotype x environment interaction and stability parameters of some agronomic traits using 40 new improved lines of barley which were introduced from three different regions; 1- International Center for Agricultural Research in the Dry Areas (ICARDA) (lines No's; 1 to 15), 2- International Center for Biosaline Agriculture (ICBA) (lines No's; 6 to 21) and 3- (The Arab Center for the Studies of Arid zones and Dry lands (ACSAD) (lines No's; 22 to 40) and supported by Plant breeding unit, Plant Genetic Resources Department, Desert Research Center (DRC), Egypt. The lines were grown under 8 different environments, which were the combinations between two winter successive seasons (2013/2014 and 2014/2015) and four locations: 1- Ras Suds Research Station, Desert Research Center (South Sinai Governorate, Egypt), 2- Maryout Research Station, Desert Research Center (South Alexandria with about 31 km between longitude 29°47′ and 15°27′ E and latitudes 31°00′ and 18°37′ N), 3- El-Maghara Research Station, Desert Research Center (South El Arish the middle of Sinai) and 4- Siwa Oasis, Tegzerty Research Station, Desert Research Center (South West of Marsa Matrouh Governorate, Egypt; 26.0°N, 29.0°E and 0-22 m under mean sea level). Sowing date was the second week of November in the two seasons at the four locations (E1= Ras Suds in 2013/2014, E2= Ras Suds in 2014/2015, E3= Maryout in 2013/2014, E4 = Maryout in 2014/2015, E5= El-Maghara in 2013/2014, E6= El-Maghara in 2014/2015, E7= Siwa in 2013/2014 and E8 = Siwa in 2014/2015). The 40 barley lines were sown in a randomized complete block design with three replications in each of the 8 environments. The experimental plot consisted of 3 rows. Each row was 2.5 m in length and 20 cm wide. Grains were spaced at 10 cm within rows and one plant was left per hill. Nitrogen (250 kg /fed.) was added in the form of ammonium nitrate (33.5% N) in three doses; the first dose was at sowing and the other two doses were applied at 20 and 40 days after sowing. The other cultural practices were followed as recommended for barley production in each region. Mechanical and chemical analysis of soil for the four locations are shown in Table (1).

Table 1. Mechanical and chemical analysis of experimental soil at the experimental locations (Ras Sudr, Maryout, El-Maghara and Siwa).

Constituents	Ras Sudr	Maryout	El-Maghara	Siwa
Mechanical analysis				
Clay%	15.33	23.26	1.43	8.20
Silt%	20.48	21.67	2.00	19.00
Sand%	64.19	55.07	96.57	72.80
Texture	Sandy loam	Loamy clay	Sandy	Sandy loam
Chemical analysis				
pH	7.39	7.8	7.7	7.75
EC ds/m	8.54	3.3	1.12	12.32
Ca^{++} Cations (meq/L)	21.21	10.7	3.53	34.70
Mg^{++}	10.86	2.43	0.82	17.52
Na^{+}	48.04	19.3	2.35	59.85
K^{+}	5.62	0.56	0.12	2.04
Cl^{-} Anions (meq/L)	43.8	22	3.38	85.40
$Co3^{- -}$	…	…	…	…
$HCo3^{-}$	10.85	5.2	1.5	2.45
$SO4^{--}$	25.2	5.8	1.94	35.40

At harvest, ten competitive plants from each plot were taken for recording data for; spike length (cm), number of spikes/ plant, number of spikelets/spike, number of kernels/ spike, 1000-kernel weight (g) and grain yield/ plant (g). The combined analysis of variance across environments was computed according to Gomez and Gomez (1984). LSD was computed to compare differences among means of environments, genotypes and their interaction at 5% level. Stability analysis was performed whenever the genotype x environment interaction was determined to be statistically significant ($P<0.01$) according to Eberhart and Russell (1966) under 8 environments (4 locations x 2 seasons).

RESULTS AND DISCUSSION

Analysis of variance and mean performance across environments

The combined analysis of variance due to the effect of environmental conditions (locations and seasons) on the studied traits of 40 lines of barley (Table. 2) reveals presence of highly significant variances for environments, lines and their interactions, suggesting that the combination of environmental components were sufficient to obtain reliable information about the studied barley lines.

Table 2. Mean squares of combined analysis of variance over 8 environments (four locations and two seasons) for the studied traits of barley lines.

SOV	df	Spike length (cm)	No.of spikelets/spike	No.of spikes/plant	No.of grains/spike	1000-grain weight (g)	Grain yield/plant (g)
Environments (E)	7	107.89**	21.52**	18.21**	2658.68**	3517.78**	260.14**
Lines (L)	39	29.20**	22.36**	34.12**	1373.01**	487.77**	411.06**
E x L	273	4.72**	1.56**	4.29**	261.86**	217.29**	22.02**
Error	638	2.17	0.04	1.28	6.36	22.68	0.60

**** = denote significant at 0.01 level of probability.**

These results are in agreement with those reported by Jackson *et al* 1994, Abdel-Sattar 2005, Akcura *et al* 2005, Dehghani *et al* 2006, Mohamed *et al* 2011, Amer *et al* 2012, Farag *et al* 2012 and Abd El-Moneam *et al* 2014.

The mean performances of the 40 lines barley across 8 different environments for the studied traits are presented in Tables (3 to 8). Regarding spike length, the individual environments gave mean values ranging from 10.05 cm at E4 (Maryout in 2014/2015) to 12.61 cm at E8 (Siwa in 2014/2015). Moreover, the environments; E1, E2, E5, E6, E7 and E8 produced higher mean values for this trait than the average of all environments. The mean values for genotypes ranged from 9.88 cm for the line 8 to 13.39 cm for the line 30 with an average of 11.63 cm.

For no. of spikelets/spike, the means of individual environments ranged from 18.42 spikelets at E2 to 19.46 spikelets at E8. Moreover, the environments; E5, E6, E7 and E8 produced higher mean values than the overall mean of environments. The mean values for genotypes ranged from 17.02 spikelets for the line 23 to 21.12 spikelets for the line 30 with an average of 18.93 spikelets.

Table 3. Mean performance of spike length (cm) for 40 barley lines (L) across 8 environments (E) (two seasons and four locations).

Location	Ras Sudr		Maryout		El-Maghara		Siwa		Mean (L)
Season	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015	
Environment	E1	E2	E3	E4	E5	E6	E7	E8	
L. No. 1	10.60	10.39	9.70	8.86	11.53	11.54	12.40	12.39	10.93
2	11.47	11.48	9.57	9.58	10.20	10.22	10.73	10.75	10.50
3	10.83	11.01	10.23	10.04	9.73	9.84	12.20	12.32	10.78
4	12.73	12.32	10.20	9.88	13.53	13.37	12.63	12.48	12.14
5	11.77	11.26	10.77	10.27	12.57	12.51	12.33	12.11	11.70
6	10.63	10.06	10.07	9.51	11.03	10.88	13.23	13.07	11.06
7	12.83	12.64	10.40	10.23	10.73	10.85	10.37	10.49	11.07
8	11.00	10.79	9.80	9.62	10.73	10.64	8.13	8.29	9.88
9	12.20	12.22	10.07	10.08	11.10	11.23	10.87	10.99	11.10
10	11.53	11.04	9.83	9.43	11.20	11.28	9.63	9.70	10.46
11	11.67	11.29	9.43	9.13	10.30	10.31	13.10	13.09	11.04
12	10.80	11.16	9.50	9.68	10.73	10.74	10.67	10.68	10.50
13	10.97	10.36	9.53	9.01	11.67	11.79	9.83	9.94	10.39
14	11.50	11.32	9.77	9.63	12.13	11.99	11.80	11.66	11.23
15	11.70	10.73	9.83	9.01	10.30	10.44	12.00	12.16	10.77
16	12.27	12.29	8.57	8.58	11.47	11.34	11.57	11.42	10.94
17	12.23	12.90	9.67	9.89	9.93	9.80	12.17	12.21	11.10
18	11.13	10.78	9.50	9.20	10.70	10.55	12.77	12.59	10.90
19	12.73	12.50	9.67	9.27	11.17	11.29	11.57	11.69	11.24
20	10.77	10.18	9.30	8.79	11.37	11.44	11.37	11.44	10.58
21	10.63	10.49	10.33	10.23	12.37	12.36	13.80	13.79	11.75
22	11.37	11.13	10.03	9.84	9.83	9.85	12.57	12.50	10.89
23	12.33	12.35	8.60	8.50	9.27	9.27	12.10	12.22	10.58
24	12.30	12.28	10.50	9.92	11.43	11.45	12.30	12.32	11.56
25	11.77	11.40	10.77	10.42	10.90	11.01	12.33	12.46	11.38
26	8.53	7.86	11.07	10.35	12.43	12.30	13.53	13.38	11.18
27	12.67	11.96	10.53	9.95	11.33	11.34	12.20	12.40	11.55
28	11.97	11.61	12.07	11.35	10.57	10.42	12.57	12.39	11.62
29	14.73	14.44	11.47	11.21	14.37	14.53	12.83	12.98	13.32
30	15.57	15.59	11.63	11.65	11.47	11.35	15.00	14.84	13.39
31	12.60	12.80	11.27	10.60	12.57	12.71	12.87	12.93	12.29
32	14.87	14.39	10.73	10.39	11.33	11.41	13.37	13.46	12.49
33	14.47	14.69	10.40	10.65	14.43	15.43	13.20	13.34	13.33
34	13.10	12.37	10.97	10.36	12.23	12.25	13.93	13.96	12.40
35	12.80	12.77	10.83	10.69	12.67	12.80	12.83	12.96	12.29
36	12.43	11.40	10.17	9.32	15.07	14.88	13.33	13.18	12.47
37	12.27	12.29	11.77	11.79	14.77	14.96	14.27	14.46	13.32
38	11.57	12.40	12.13	12.76	13.23	13.08	15.77	15.59	13.32
39	14.07	13.62	11.50	11.14	11.83	11.83	12.10	12.44	12.32
40	13.73	13.35	11.60	11.13	13.23	13.58	12.93	13.28	12.85
Mean (E)	12.13	11.82	10.34	10.05	11.74	11.75	12.58	12.61	11.63
LSD 0.05	Environment (E) =0.37				Lines (L) =0.84		E x L = 2.36		

Table 4. Mean performance of number of spikelets/spike for 40 barley lines) across 8 environments (E) (two seasons and four locations).

Location	Ras Sudr		Maryout		El-Maghara		Siwa		Mean (L)
Season	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015	
Environment	E1	E2	E3	E4	E5	E6	E7	E8	
L. No. 1	18.33	18.01	17.33	15.83	20.33	20.35	19.00	19.01	18.52
2	17.00	17.02	18.33	18.36	17.33	17.36	17.33	17.36	17.51
3	16.67	16.82	20.33	19.85	20.33	20.54	19.67	19.86	19.26
4	20.33	19.69	18.67	18.09	20.33	20.11	20.33	20.11	19.71
5	16.33	15.71	17.67	17.03	18.00	17.99	18.33	18.33	17.42
6	19.33	18.28	18.67	17.64	18.00	17.73	21.00	20.68	18.92
7	18.33	17.81	18.33	17.81	18.33	18.52	18.00	18.18	18.17
8	17.67	17.33	19.33	18.93	18.00	17.82	17.00	16.79	17.86
9	17.33	17.36	19.00	19.04	19.00	19.22	14.67	14.74	17.54
10	18.67	17.34	18.00	17.37	19.33	19.46	17.67	17.78	18.20
11	19.00	18.39	18.33	17.75	18.67	18.70	18.33	18.39	18.45
12	18.00	18.11	18.00	18.18	20.33	20.36	17.67	17.69	18.54
13	16.67	15.75	18.67	17.64	17.67	17.84	18.33	18.52	17.64
14	19.33	18.80	18.33	17.81	20.33	20.09	19.33	19.15	19.15
15	21.00	19.25	18.33	16.81	16.33	16.55	18.67	18.90	18.23
16	17.67	17.69	18.00	18.03	16.67	16.46	18.67	18.44	17.70
17	19.33	19.92	18.33	19.51	17.33	17.32	20.67	20.67	19.14
18	16.33	15.82	18.00	17.42	16.33	16.09	19.67	19.37	17.38
19	18.67	17.99	16.33	15.71	17.33	17.54	20.33	20.54	18.06
20	17.67	16.70	17.33	16.39	16.67	16.79	18.67	18.79	17.37
21	18.67	18.80	18.00	17.81	19.33	19.31	19.00	19.05	18.75
22	17.00	16.66	18.00	17.58	14.67	14.69	19.00	19.03	17.08
23	19.67	19.69	16.33	16.36	15.67	15.74	16.33	16.36	17.02
24	17.33	17.83	18.67	18.23	19.33	19.37	17.33	17.36	18.18
25	18.33	17.75	18.00	17.42	18.67	18.85	20.67	20.88	18.82
26	19.33	18.60	18.67	18.30	20.67	20.40	20.67	20.40	19.63
27	19.67	18.61	19.33	18.28	19.67	19.66	18.67	18.67	19.07
28	17.33	16.82	21.67	21.77	19.33	19.05	20.67	20.38	19.63
29	18.33	17.95	20.33	19.91	20.33	20.56	19.33	19.56	19.54
30	22.33	22.37	19.67	19.70	19.67	19.46	23.00	22.73	21.12
31	18.33	18.33	21.00	19.21	18.67	18.88	21.67	21.94	19.75
32	21.00	20.35	19.00	18.42	19.33	19.46	22.67	22.83	20.38
33	19.33	19.87	20.33	20.89	21.67	21.69	20.33	20.36	20.56
34	19.67	18.61	21.00	19.84	20.67	20.70	23.00	23.03	20.81
35	18.67	18.80	18.33	18.80	21.00	21.18	19.00	19.20	19.37
36	20.00	18.34	20.67	18.94	21.33	21.05	20.00	19.78	20.01
37	19.33	19.37	19.67	19.70	21.67	21.95	21.67	21.96	20.66
38	19.67	20.93	21.00	21.29	19.67	19.43	22.67	22.39	20.88
39	23.33	22.57	19.33	18.70	20.33	20.34	18.33	18.34	20.16
40	21.00	20.58	21.67	21.54	20.33	20.86	20.33	20.86	20.90
Mean (E)	18.80	18.42	18.90	18.45	18.97	18.99	19.44	19.46	18.93
LSD 0.05		Environment (E) = 0.29			Lines (L) =0.64		E x L =1.81		

Table 5. Mean performance of number of spikes/plant for 40 barley lines (L) across 8 environments (E) (two seasons and four locations).

Season	Ras Suder		Maryout		EL-Maghara		Siwa		Mean (L)
	2013/ 2014	2014/ 2015	2013/ 2014	2014/ 2015	2013/ 2014	2014/ 2015	2013/ 2014	2014/ 2015	
Environment	E1	E2	E3	E4	E5	E6	E7	E8	
L. No. 1	1.97	1.92	3.00	2.74	1.93	1.94	2.13	2.01	2.21
2	1.60	1.4.2	4.03	4.20	2.90	2.90	2.50	2.51	2.58
3	1.90	1.85	3.60	3.80	3.30	3.33	2.93	2.96	2.96
4	1.70	1.65	3.23	3.13	3.43	3.39	3.10	3.06	2.84
5	1.97	1.89	3.70	3.60	4.00	4.22	3.23	3.24	3.23
6	2.10	1.99	4.33	4.10	2.90	2.86	3.43	3.39	3.14
7	3.30	3.20	3.67	3.73	3.07	3.10	3.93	3.98	3.50
8	2.93	2.87	4.07	3.99	3.43	3.39	3.77	3.73	3.52
9	3.50	3.51	3.20	3.21	3.23	3.27	2.27	2.29	3.06
10	3.93	3.56	4.00	3.55	3.67	3.69	3.13	3.15	3.59
11	3.40	3.30	2.17	2.10	4.83	4.80	2.53	2.50	3.20
12	4.13	4.15	2.50	2.60	4.20	4.20	2.70	2.84	3.42
13	3.10	2.93	3.03	2.87	3.00	3.03	2.93	2.96	2.98
14	3.07	2.97	4.20	4.16	2.33	2.31	3.43	3.39	3.23
15	3.97	3.64	3.93	3.61	3.33	3.38	3.83	3.89	3.70
16	2.70	2.71	3.67	3.51	3.73	3.69	3.83	3.79	3.45
17	3.40	3.36	3.57	3.80	2.47	2.47	3.47	3.40	3.24
18	2.10	2.03	4.43	4.29	2.03	2.01	2.50	2.48	2.73
19	2.97	2.82	4.23	4.08	2.23	2.26	3.67	3.71	3.25
20	3.37	3.19	5.10	4.81	3.10	3.12	2.07	2.10	3.36
21	3.00	2.90	2.33	2.38	3.97	3.60	2.63	2.60	2.93
22	2.87	2.80	4.07	3.97	5.10	5.11	2.53	2.40	3.61
23	3.13	3.14	3.67	3.67	4.70	4.35	3.63	3.22	3.69
24	2.07	2.46	4.43	4.16	3.33	3.54	2.90	2.7.2	2.86
25	2.73	2.65	3.40	3.29	3.80	3.91	2.21	2.36	3.04
26	2.67	2.60	3.63	3.50	3.77	3.72	4.83	4.78	3.69
27	3.13	2.96	4.00	3.78	4.57	4.33	4.97	4.74	4.06
28	2.93	2.84	5.30	5.31	3.97	3.92	5.20	5.13	4.33
29	2.60	2.54	5.57	5.46	4.90	4.95	5.53	5.60	4.64
30	3.07	3.07	4.60	4.60	3.63	3.59	4.57	4.42	3.94
31	3.50	3.19	4.23	4.13	5.17	5.23	4.77	4.82	4.38
32	4.13	4.01	5.93	5.75	4.97	5.00	3.87	3.92	4.70
33	4.93	5.04	6.20	6.33	5.60	5.50	5.93	5.84	5.67
34	3.97	3.75	5.93	5.61	5.77	5.98	3.90	3.95	4.86
35	5.50	5.41	5.53	5.51	6.03	6.10	4.27	4.31	5.33
36	4.93	4.52	6.20	5.68	7.30	7.22	5.57	5.50	5.87
37	5.97	5.98	6.43	6.44	7.27	7.36	4.30	4.74	6.06
38	4.20	5.03	4.67	5.43	4.17	4.12	6.50	6.43	5.07
39	3.93	3.81	5.23	5.07	4.87	4.87	4.23	4.55	4.57
40	3.40	3.24	5.77	5.59	7.77	7.97	6.11	6.13	5.75
Mean (E)	3.24	3.14	4.27	4.19	4.09	4.09	3.75	3.67	3.81
LSD 0.05		Environment (E)=0.05			Lines (L) =0.12		E x L = 0.33		

Table 6. Mean performance number of kernels/ plant for 40 barley lines (L) across 8 environments (E) (two seasons and four locations).

Location	Ras Sudr		Maryout		El-Maghara		Siwa		Mean (L)
Season	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015	
Environment	E1	E2	E3	E4	E5	E6	E7	E8	
L. No. 1	37.67	36.93	43.33	39.58	42.33	43.22	47.67	48.58	42.41
2	39.00	39.06	36.33	36.40	57.67	58.41	38.33	39.21	43.05
3	41.33	40.70	37.00	37.36	36.67	37.05	43.00	42.43	39.44
4	35.67	34.52	39.00	37.78	53.33	52.70	41.33	40.80	41.89
5	44.00	42.07	45.00	42.98	45.33	46.35	40.33	41.33	43.42
6	39.33	37.15	44.00	41.52	43.33	42.73	59.00	58.18	45.66
7	67.33	67.62	37.67	36.29	47.33	48.84	32.33	35.26	46.58
8	50.67	49.61	41.67	40.79	49.67	50.41	43.00	42.53	46.04
9	59.33	59.42	35.33	35.39	51.33	52.91	49.00	50.14	49.11
10	36.67	41.44	36.00	33.16	50.67	51.00	32.33	33.14	39.30
11	68.67	66.44	34.00	32.94	37.33	38.29	35.67	35.65	43.62
12	44.00	44.86	37.67	38.34	47.67	48.81	37.00	38.07	42.05
13	50.33	47.49	46.67	44.12	50.00	51.22	33.33	33.14	44.54
14	48.33	47.50	41.67	40.90	54.33	53.71	31.67	32.13	43.78
15	77.00	70.58	39.00	35.75	39.67	40.21	30.00	33.27	45.69
16	58.33	58.41	29.33	29.45	60.33	59.63	30.33	29.97	44.47
17	57.33	59.60	29.67	31.38	47.67	48.67	66.00	61.22	50.19
18	48.33	46.79	37.33	36.15	48.00	47.37	46.00	45.36	44.42
19	51.00	49.11	36.33	34.31	44.00	45.84	45.33	46.86	44.10
20	45.33	42.84	35.67	33.73	47.00	48.31	50.00	49.33	44.03
21	45.67	44.86	54.33	54.76	46.33	45.39	65.00	66.41	52.84
22	49.00	47.90	36.33	35.59	41.33	42.36	50.00	51.04	44.19
23	68.33	68.43	33.67	34.55	34.33	35.62	34.24	23.39	41.57
24	60.33	62.51	32.00	33.09	40.00	41.32	35.00	34.04	42.29
25	63.33	61.27	41.67	40.30	49.67	50.14	36.14	35.36	47.24
26	40.00	38.82	56.00	53.57	51.67	52.01	54.33	53.66	50.01
27	51.33	48.46	46.33	43.79	50.67	51.14	48.63	47.66	48.50
28	44.67	44.86	55.67	56.44	64.67	63.83	52.33	51.64	54.26
29	61.67	60.33	53.67	52.13	57.33	58.95	50.00	49.55	55.45
30	78.00	78.14	50.67	51.41	54.33	53.83	44.00	43.59	56.75
31	61.00	62.80	61.67	53.49	47.67	48.22	64.33	65.08	58.03
32	64.00	61.93	47.33	45.85	51.67	52.02	67.67	68.12	57.32
33	61.00	62.24	41.33	42.15	69.33	70.35	54.67	55.56	57.08
34	55.33	52.29	39.00	36.87	65.67	66.77	61.47	60.75	54.77
35	52.00	51.46	42.67	43.21	67.67	68.36	50.00	51.24	53.33
36	39.33	36.06	41.00	37.58	67.67	66.83	58.67	57.99	50.64
37	56.33	56.39	75.67	76.15	78.33	79.39	64.00	65.14	68.93
38	59.33	60.49	62.22	68.24	64.00	63.26	69.00	68.20	64.34
39	70.00	67.78	56.67	54.89	54.67	55.69	48.33	49.36	57.17
40	74.00	70.95	49.00	47.54	76.00	78.04	53.00	54.42	62.87
Mean (E)	53.86	53.00	43.49	42.50	52.17	52.73	47.31	47.22	49.03
LSD 0.05		Environment (E) =0.64			Lines (L) =1.43		E x L=4.04		

Table 7. Mean performance of 1000-kernel weight (g) for 40 barley lines (L) across 8 environments (E) (two seasons and four locations).

Location	Ras Sudr		Maryout		El-Maghara		Siwa		Mean (L)
Season	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015	
Environment	E1	E2	E3	E4	E5	E6	E7	E8	
L. No. 1	17.23	16.86	42.79	39.13	24.23	25.11	17.76	18.66	25.22
2	32.28	31.21	45.23	46.28	25.70	26.74	35.66	36.54	34.96
3	34.78	32.56	49.21	47.57	51.12	52.45	39.49	40.86	43.51
4	23.72	22.88	39.34	38.08	45.05	44.43	36.81	37.32	35.95
5	43.78	42.14	36.99	34.91	43.78	44.77	48.19	49.22	42.97
6	43.85	42.59	36.16	34.20	50.81	51.13	25.24	24.86	38.61
7	31.65	30.30	56.60	57.18	33.08	34.39	33.77	34.14	38.89
8	31.51	30.92	47.27	46.20	41.77	42.23	31.98	32.71	38.07
9	40.55	39.24	52.74	51.76	45.47	46.96	20.69	21.96	39.92
10	18.85	24.71	57.19	51.08	44.72	45.03	33.58	34.79	38.74
11	36.31	35.11	55.18	53.41	43.38	42.15	15.50	16.62	37.21
12	22.23	21.13	45.07	44.70	44.43	45.65	20.04	21.14	33.05
13	44.95	42.62	44.03	41.59	45.84	46.33	33.21	32.46	41.38
14	17.97	18.75	37.28	35.83	41.88	42.37	18.35	17.20	28.70
15	27.64	25.32	48.19	44.16	53.00	54.21	36.77	37.25	40.82
16	50.47	49.23	47.37	47.45	42.73	43.25	36.82	37.22	44.32
17	36.07	42.87	62.91	60.90	36.15	37.36	27.55	26.45	41.28
18	50.85	49.22	30.79	29.91	47.54	46.84	42.49	41.78	42.43
19	16.80	14.63	78.01	75.02	39.76	40.24	18.22	19.38	37.76
20	46.95	44.38	33.10	31.16	42.79	43.08	36.09	37.32	39.36
21	29.07	28.91	33.35	30.64	42.23	43.15	28.34	29.42	33.14
22	39.31	38.62	53.54	52.55	38.70	39.66	16.55	17.57	37.06
23	42.72	42.78	31.93	32.36	19.10	18.88	33.40	34.25	31.93
24	45.58	43.85	43.55	41.12	49.68	48.42	50.87	51.25	46.79
25	47.62	46.13	40.79	39.63	46.54	45.33	32.62	31.55	41.28
26	28.95	27.84	40.52	39.06	21.59	22.61	24.56	25.13	28.78
27	48.61	45.92	44.40	41.98	36.58	37.69	36.79	37.15	41.14
28	41.49	42.29	39.14	38.74	27.68	28.42	42.67	43.45	37.99
29	45.62	44.68	39.16	38.78	50.52	51.10	18.23	17.72	38.23
30	30.47	31.22	42.04	43.21	42.61	43.13	28.34	27.94	36.12
31	32.86	28.35	38.21	37.48	51.81	52.38	43.97	44.30	41.17
32	37.99	36.76	47.57	46.05	34.33	35.12	36.46	37.34	38.95
33	29.92	30.10	58.51	60.01	34.42	35.36	32.24	31.79	39.04
34	38.30	36.10	54.46	51.37	29.42	30.86	35.80	36.77	39.14
35	40.98	39.70	53.49	50.61	30.43	31.02	40.61	41.00	40.98
36	28.74	26.34	52.28	47.90	45.05	44.53	40.21	39.26	40.54
37	32.04	33.11	32.08	33.14	39.07	40.36	28.32	29.62	33.47
38	34.74	35.44	40.30	39.27	43.52	42.97	29.36	28.02	36.70
39	40.26	38.95	47.66	46.10	33.77	34.63	34.49	35.14	38.88
40	34.39	33.57	55.93	54.53	45.39	46.61	37.76	38.79	43.37
Mean (E)	35.45	34.68	45.86	44.38	40.14	40.67	32.00	32.38	38.20
LSD 0.05	Environment (E) = 1.21		Lines (L) = 2.70		E x L =7.64				

Table 8. Mean performance of grain yield/ plant (g) for 40 barley lines (L) across 8 environments (E) (two seasons and four locations).

Location	Ras Sudr		Maryout		El-Maghara		Siwa		Mean (L)
Season	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015	
Environment	E1	E2	E3	E4	E5	E6	E7	E8	
L. No. 1	4.42	4.00	7.01	6.41	3.52	4.53	3.50	4.00	9.17
2	1.90	2.00	8.82	9.00	5.49	6.50	5.24	6.25	5.65
3	3.93	4.36	8.22	9.56	4.81	5.85	5.66	6.54	6.12
4	2.36	3.29	6.22	7.03	10.06	9.94	6.72	7.61	6.65
5	4.87	5.42	9.65	10.26	11.10	12.11	9.83	8.38	8.95
6	6.22	5.89	10.67	11.07	6.60	7.21	8.25	7.85	7.97
7	8.33	9.36	11.16	12.36	6.62	8.70	6.03	7.08	8.71
8	6.29	7.16	9.96	10.74	9.20	10.11	7.62	8.57	8.71
9	10.35	11.37	8.80	9.81	8.41	9.48	3.59	4.64	8.31
10	6.17	7.05	10.30	9.10	10.91	11.98	3.17	4.19	7.86
11	7.29	8.08	5.32	6.14	10.41	11.42	2.14	3.25	6.76
12	7.25	8.36	5.54	6.73	9.14	10.21	3.52	4.52	6.91
13	8.09	7.66	9.32	8.82	7.63	8.71	2.62	3.65	7.06
14	4.60	5.49	8.87	9.89	9.18	10.08	3.73	4.70	7.07
15	8.55	7.84	8.92	9.17	9.11	8.21	5.02	4.08	7.61
16	7.86	8.45	6.88	7.88	11.25	12.14	4.57	5.50	8.07
17	6.65	8.24	6.86	7.03	5.42	6.42	9.08	8.82	7.32
18	6.27	7.08	7.41	6.46	6.89	5.92	7.13	6.07	6.65
19	10.50	9.40	8.70	9.32	4.95	5.00	7.21	6.29	7.67
20	10.15	9.57	9.69	10.36	8.84	7.82	6.65	5.68	8.60
21	5.60	6.76	6.98	7.09	10.86	11.28	8.05	7.05	7.96
22	7.60	8.42	10.49	11.04	11.23	10.63	4.25	3.25	8.36
23	10.84	11.00	5.95	6.61	8.82	7.80	4.49	3.51	7.38
24	6.48	8.07	8.10	7.49	6.16	7.17	6.36	5.85	6.96
25	7.04	6.82	8.83	9.11	12.71	13.89	5.60	4.64	8.58
26	4.83	5.47	11.00	10.41	8.25	7.89	11.03	10.91	8.72
27	10.89	9.24	10.42	9.86	12.03	13.25	12.85	11.85	11.30
28	7.68	8.57	15.58	14.69	7.94	8.89	12.36	12.02	10.97
29	10.27	11.06	15.60	16.23	16.74	17.33	9.79	8.87	13.24
30	11.24	12.14	13.47	14.36	11.59	12.74	9.08	10.04	11.83
31	9.82	10.79	12.92	13.04	15.40	16.25	16.13	17.33	13.96
32	12.74	13.42	18.56	17.99	11.79	12.85	13.84	12.93	14.27
33	14.18	14.38	17.85	18.14	17.25	16.44	15.26	14.77	16.03
34	10.34	9.81	17.43	16.47	18.36	17.70	12.28	11.67	14.26
35	18.03	17.25	16.02	15.73	15.03	16.34	13.30	12.43	15.52
36	12.32	11.29	14.09	12.92	28.05	27.71	19.76	18.54	18.09
37	18.38	19.36	20.63	21.21	30.04	31.25	12.09	12.24	20.65
38	14.83	16.99	16.95	18.94	14.10	13.94	20.33	19.66	16.97
39	14.30	13.84	18.36	17.78	12.03	13.26	11.25	10.10	13.87
40	10.66	11.20	20.18	19.24	30.39	28.93	15.76	16.18	19.07
Mean (E)	8.75	9.15	11.19	11.39	11.46	11.95	8.63	9.44	10.24
LSD 0.05	Environment (E) = 0.20			Lines (L) =0.44			E x L =1.25		

Regarding no. of spikes/ plant, the individual environments gave mean values varied from 3.14 spikes at E2 to 4.27 spikes at E3. Moreover, the environments; E3, E4, E5, and E6 produced higher mean values for this trait than the average of all environments. The mean values for genotypes ranged from 2.21 spikes for the Line 1 to 6.06 spikes for the line 37 with an average of 3.81 spikes.

Concerning no. of kernels/ spike, the means of individual environments ranged from 42.50 kernels at E4 to 53.86 kernels at E1. Moreover, the environments; E1, E2, E5 and E6 produced higher mean values than the overall mean of environments. The mean values for genotypes ranged from 39.30 kernels for the line 10 to 64.34 kernels for the line 38 with an average of 49.03 kernels.

For 1000-kernel weight, the individual environments ranged from 32.00 g at E7 to 45.86 g at E3. Moreover, the environments; E4, E5, E6 and E7 produced higher mean values than the average environments. The mean values for genotypes ranged from 25.22 g for the Line -1 to 46.79 g for the Line- 24 with an average of 38.20 g for this trait.

With respect to grain yield/ plant, the individual environments ranged from 8.63 g at E7 to 11.95 g at E6. Moreover, the environments; E3 and E4 (Maryout location during the two seasons) and E5 and E6 (El-Maghara location during the two seasons) produced higher mean values for grain yield/ plant than the average mean of all studied environments. These environments may be considered as more suitable environments for such barley lines. The mean values for genotypes ranged from 5.65 g for the line 2 to 20.65 g for the line 37 with an average of 10.24 g for grain yield/ plant.

In generally, the two environments; E5 and E6 (El-Maghara location during the two seasons) produced higher mean values for grain yield and its components than other studied environments. However, the increases obtained in yield and its components at this location might be due to suitable environmental conditions in most growth periods especially soil conditions (Table 1). At the same time, the two lines; 37 and 40 exhibited the best performance across different environments for grain yield and most of yield components.

Phenotypic Stability

Phenotypic stability was analyzed for grain yield / plant and other studied traits in a set of 10 barley lines selected from the genetic materials used in the present work on the basis of their high yielding ability across 8 environments (4 locations × 2 seasons). The ten lines were No's; 31, 32, 33, 34, 35, 36, 37, 38, 39 and 40. The method of Eberhart and Russell (1966) was utilized for estimating stability of the individual lines for all studied traits. Pooled analysis of variance Table (9) reveals that the line mean squares (L) were highly significant for all studied traits, indicating the presence of genetic variability among entries in these traits.

Table 9. Mean squares of stability analysis of variance for the studied traits of 10 barley lines across 8 environments according to Eberhart and Russells model (1966).

Source of variance	df	Spike length (cm)	No. of spikelets /spike	No. of spikes /plant	No. of kernels /spike	1000-kernel weight	Grain yield /plant
Lines(L)	9	5.16**	2.13**	2.82**	239.74**	58.25**	44.98**
Environment (E)+(LxE)	70	4.72**	1.73**	0.95**	100.20**	64.41**	19.75**
Environment (Linear)	1	128.21**	17.87**	26.19**	1855.77**	1998.98**	386.27**
L x E (Linear)	9	6.83**	3.97**	1.65**	226.68**	92.56**	55.66**
Pooled deviation	60	2.34**	1.13**	0.43**	51.97**	27.94**	8.25**
Line							
31	6	11.22**	1.32**	0.28**	50.92**	84.72**	6.98**
32	6	2.15**	1.65**	0.38**	85.10**	8.03	7.48**
33	6	3.82**	0.75	0.20**	11.75**	9.52	1.09**
34	6	0.15	0.38	0.17**	9.01**	17.96	1.01**
35	6	0.14	1.24*	0.42**	15.39**	45.66**	4.16**
36	6	2.06*	0.93*	0.15**	83.19**	26.20**	24.48**
37	6	0.96	0.41	0.85**	108.31**	20.39*	18.33**
38	6	1.5	1.47**	1.00**	15.87**	29.19**	5.75**
39	9	1.03	2.92**	0.06**	71.62**	15.35	9.71**
40	9	0.37	0.23	0.74**	68.57**	4.41	3.51**
Pooled error	160	0.73	0.43	0.01	2.13	7.68	0.2·

*** and** = denote significant differences at 0.05 and 0.01 levels, respectively.**

Environment (E) + genotype x environment (L x E) and environment (linear) mean squares were also highly significant for all studied traits, providing evidence that genotypes were more sensitive to changes in the environments. These results are in line with the findings of Backer and Leon (1988), Bahrami *et al* (2009), Zerihun (2012) and Gebremedhin *et al* (2014) who reported that the response to environments was genetically controlled and revealing the differential response of barley genotypes to different agro-climates. The mean squares of genotype x environment interaction (Linear) were highly significant for all studied traits, indicating that the traits were highly influenced by changes in the environmental conditions. Similar trend was also reported in wheat by Jackson *et al* (1994), Akcura *et al* (2005), Dehghani *et al* (2006), Amer *et al* (2012) and Abd El- Moneam *et al* (2014) who indicated that (G x E) interaction played a great role and accounted for appreciable amount to the total variation. Concerning the mean squares for pooled deviations, the results revealed highly significant values for all studied traits, indicating that the genotypes differed considerably with respect to their stability for such traits.

The results of stability parameters for the studied traits are presented in Table (10). Concerning spike length, the lines; 34, 35, 37, 38 and 40 were

Table 10. Stability parameters for the studied traits of 10 barley genotypes across 8 environments.

Genotypes	Spike length (cm)			No .of spikelets/spike			No. of spikes/plant		
	$\bar{X}$	b_i	$S^2 d_i$	$\bar{X}$	b_i	$S^2 d_i$	$\bar{X}$	b_i	$S^2 d_i$
31	12.29	2.96**	10.49**	19.75	2.16*	0.89**	4.38	0.94	0.27**
32	12.49	0.79	1.42**	20.38	1.02	1.22**	4.7	1.00	0.37**
33	13.33	1.05	3.09**	20.56	0.39	0.32	5.67	0.48**	0.19**
34	12.4	0.91	-0.58	20.82	1.06	-0.05	4.86	1.13	0.16**
35	12.29	0.65	-0.59	19.37	0.71	0.81*	5.33	0.56**	0.41**
36	12.47	1.18	1.33*	20.01	0.96	0.50*	5.87	1.52**	0.14**
37	13.32	0.80	0.23	20.67	2.15*	-0.02	6.06	1.11	0.84**
38	13.32	0.78	0.77	20.88	1.03	1.04**	5.07	-0.49**	0.99**
39	12.32	0.30**	0.30	20.16	-2.10**	2.49**	4.57	0.79**	0.05**
40	12.85	0.57	-0.36	20.9	-0.46**	-0.2	5.75	2.52**	0.73**
Average	12.71			20.35			5.23		
	No. of kernels/spike			1000-kernel weight			Grain yield/plant		
Genotypes	$\bar{X}$	b_i	$S^2 d_i$	$\bar{X}$	b_i	$S^2 d_i$	$\bar{X}$	b_i	$S^2 d_i$
31	58.03	-0.53**	48.79**	41.17	0.14**	77.04**	13.96	0.52**	6.78**
32	57.32	0.92	8.97**	38.95	0.80	0.35	14.27	0.92	0.28**
33	57.08	2.05**	9.62**	39.04	2.30**	1.84	16.03	0.54**	0.89**
34	54.77	1.08	6.88**	39.14	1.34	8.28	14.26	1.07	0.81**
35	53.33	1.76**	13.26**	40.98	0.97	37.98**	15.52	-0.03**	3.96**
36	50.64	2.04**	81.06**	40.54	1.44*	18.52**	18.09	2.10**	24.28**
37	68.93	0.03**	106.18**	33.47	0.10**	12.71*	20.65	2.50**	18.13**
38	64.34	-0.11**	13.74**	36.7	0.57*	21.51**	16.97	-0.51**	5.55**
39	57.17	-0.05**	69.49**	38.88	0.76	7.67	13.87	0.24**	9.51**
40	62.87	2.05**	66.44**	43.37	1.58**	-3.27	19.07	3.04**	3.31**
Average	58.45			39.22			16.27		

*** and** = denote significant differences at 0.05 and 0.01 probability levels, respectively. $\bar{X}$, b_i and $S^2 d_i$ = Mean, regression coefficient and deviation from regression.**

The above five stable lines and line 32 had $b_i<1$, therefore, they are considered specially adapted to abnormal environments. While, the two lines; 33 and 36 had $b_i>1$ showing that these genotypes were not responsive to the changes in environmental conditions and they were relatively well adapted under normal environments. With respect to no. of spikelets/ spike, the two lines; 33 and 34 were stable (b_i and $S^2 d_i$ non-significantly differed from one and zero, respectively). The three lines; 32, 34 and 38 responded for favourable environments as they recorded high "b_i" value ($b_i>1$) and low $S^2 d_i$i. While, the three lines 33, 35 and 36 had low "b_i" value ($b_i<1$) and low $S^2 d_i$, indicating that these lines could be grown under less favourable environmental conditions. For no. of spikes/ plant, the three lines; 32, 34 and 37 were stable because the "b_i" value did not significantly differ from stable (b_i and $S^2 d_i$ did not significantly differ from one and zero, respectively). one with low values of $S^2 d_i$ and performed consistently better

under favourable environments because the regression coefficient (b_i) was more than one. While, the line 31 had low value of (b_i and S^2d_i), indicating that this line could be grown under less favourable environmental conditions.

Regarding no. of kernels/ spike, the two lines; Line 32 and Line 34 proved to be stable genotypes under the different environmental conditions indicated by "b_i" values approached near unity and did not significantly differ from one with the lowest S^2d_i. The line stable 32 had $b_i<1$, therefore, it is considered specially adapted to abnormal environments. While, the stable line 34 had $b_i >1$ showing that this line was not responsive to the changes in environmental conditions and it was relatively well adapted under normal environments. With respect to 1000-kernel weight, the lines 32, 34 and 39 were stable (b_i and S^2d_i did not significantly differ from one and zero, respectively). The three lines; 32, 35 and 39 responded for favourable environments as they recorded high "b_i" value ($b_i>1$) and low S^2d_i. While, the line 34 had low "b_i" value ($b_i<1$) and low S^2d_i, indicating that this line could be grown under less favourable environmental conditions.

Stability parameters for grain yield/ plant in Table (10) reveal that the two lines 32 and 34 were stable because the "b_i" value did not significantly differ from one with low values of S^2d_i. It is clear that the line 32 was stable and exhibited below average response to different environments ($b_ii<1$); it is considered relatively better in stress environments. While, the line 34 performed consistently better in normal environments because the (b_ii) was more than one.

It could be concluded that the two lines; L-32 and L-34 performed well for stability for grain yield and its components. Thus these lines may be recommended to be grown commercially as new elite varieties.

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التفاعل بين التركيب الوراثي والبيئة والثبات المظهري لمحصول الحبوب ومكوناته في الشعير

سمير حسن صالح[١] – حسام ابراهيم فرج[٢]

١. قسم المحاصيل– كلية الزراعة– جامعة عين شمس– القاهرة– مصر

٢. قسم الاصول الوراثيه– مركز بحوث الصحراء – القاهرة– مصر

تم تقييم ٤٠ سلاله من الشعير من حيث تفاعل التركيب الوراثي مع البيئة وكذلك الثبات المظهري لمحصول الحبوب ومكوناته (طول السنبله، عدد السنيبلات/سنبله، عدد السنابل/نبات، عدد الحبوب/سنبلة و وزن الالف حبة) وذلك تحت ٨ بيئات مختلفة (٤ مواقع هي: رأس سدر، مريوط، المغارة و سيوة X موسمين زراعيين هما: 2013/2014 و 014/2015). وتتلخص اهم النتائج فيما يلي: وجود تباينات عالية المعنوية ترجع للتراكيب الوراثية (السلالات) والبيئات وكذلك تفاعل التركيب الوراثي مع البيئة لجميع الصفات المدروسة مما يشير الي أختلاف التراكيب الوراثية في استجابتها للتغيرات البيئية مع كفاية هذة البيئات لتقييم تلك السلالات للصفات المدروسة. سجلت البيئتين E5 و E6 (موقع المغاره خلال موسمي الزراعه) أعلي قيم لصفات محصول حبوب النبات ومكوناته مقارنة بالبيئات الاخري, علاوة علي ذلك كانت التراكيب الوراثية (السلاله ٣٧ و السلاله ٤٠) الافضل عبر البيئات المختلفه لصفات محصول حبوب النبات ومعظم مكوناته. أظهر تحليل الثبات المظهري للتراكيب الوراثية ان السلالتين ٣٢ و ٣٤ كانتا الافضل ثباتا والأعلي في محصول حبوب النبات ومعظم مكوناته تحت مدي واسع من البيئات.

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