J. Plant Production, Mansoura Univ., Vol. 8 (2): 261 - 275, 2017

Stability Analysis of Bread Wheat Genotypes under Different Nitrogen Fertilizer Levels

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ABSTRACT

Sixteen bread wheat genotypes were evaluated for days to 50% heading, plant height, 1000-grain weight, grain yield and biological yield under six varied environments which are the combination between, two seasons 2009/2010 and 2010/2011 and three nitrogen fertilizer levels (50, 80 and 110 kg N/fad.). The combined analyses of variance showed highly significant differences were registered between genotypes, environments as well as G x E for all studied traits. Low nitrogen stress significantly reduced these traits for all wheat genotypes under 1st and 2nd compared with the 3rd level. Joint regression analysis of variance revealed highly significant G x E "linear" for all characters. Environment + Genotype x Environment (E + G x E), Environment (linear) and G x E (linear) were highly significant for all studied characters. Phenotypic stability parameters revealed that wheat genotypes, Gemmeiza 7 was highly adapted to favorable environments for days to 50% heading and 1000-grain weight; Gemmeiza 9 for plant height, grain yield and biological yield; Misr1 and Line1 for grain yield and biological yield. Genotypic stability parameters indicated that wheat genotypes Gemmeiza 9 was highly adapted to favorable environments for plant height, 1000-grain weight, grain yield and biological yield; Giza 168, Line 1 and Misr 1 for grain yield and biological yield and Line 7 for plant height and 1000-grain weight. The AMMI analysis of variance showed highly significant difference between genotypes, environments, G x E, IPCA1 and IPCA2. AMMI stability value (ASV) and GE biplot revealed that, the most desired and stable genotypes were Sakha 93, Gemmeiza 7 and Line 8 for days to 50% heading; Line 8, Line 2, Sids1 and Gemmeiza 9 for plant height; Gemmeiza 9, Sids 1, Gemmeiza 7 and Line 4 for 1000-grain weight; Line1, Gemmeiza 10, Giza 168, Sakha 94 and Line 3 for grain yield and Giza 168, Gemmeiza 9, Line1, Misr1 and Gemmeiza 10 for biological yield. According to GGE biplots, the ideal genotype was Gemmeiza 7 for days to 50% heading; Gemmeiza 10 for plant height; line 7 for 1000-grain weight; Giza 168 for grain yield and Misr 1 for biological yield.

Keywords: Wheat, genotype x environment, phenotypic and genotypic stability, AMMI, nitrogen stress

INTRODUCTION

Wheat is the most strategic cereal crops in Egypt and the world. With increasing human the policy of the country aims to improve wheat production in sandy soils based on new technologies as using, irrigation systems, fertilizers, biofertilizers and developed new wheat varieties, thus to meet the increasing demand of local consumption. The total annual national production of wheat can be mainly increased by increasing the wheat area especially in newly reclaimed soils and introducing high yielding wheat genotypes which show high response to macro and micro nutrients. In newly reclaimed sandy soils irrigation and fertilization and their interaction are the most important factors for increasing grain yield production (Shaaban, 2006).

Wheat crop is known to have high nitrogen requirement, and the applied nitrogen fertilization level significantly affect the grain yield produced. In Egypt, the optimum nitrogen fertilization level for wheat crop differs widely depending on characteristics and soils fertility level, fluctuating between 80 up to 160 kg N/fed (Atta Allah and Mohamed, 2003). Wheat genotypes display different behavior with different levels of available nitrogen across locations and growing seasons (An *et al.* 2006 and Mahjourimajd *et al.,* 2016).

Nitrogen manure is the most limiting nutrient for grain yield production of wheat that affects the rapid plant growth and improves wheat quality. Nitrogen fertilizer is required to support a photosynthetically active wheat canopy ensuring grain yield and to produce storage protein in the wheat grain hence end-use quality Cormier *et al.* (2013). Several researchers in different countries reported that grain yield of semidwarf wheat genotypes were the same or more than old tall genotypes under low nitrogen fertility conditions (Entz and Fowler 1989 and Austin *et al.,* 1993).

Ortiz-Monasterio *et al.,* (1997) proposes that the level of nitrogen in the soil plays a very essential role in the genetic expression of uptake and nitrogen utilization efficiency in wheat. At the low nitrogen levels, there is a better expression of uptake, conversely at high nitrogen levels in the soil, utilization efficiency is better expressed. This suggests that in theory the nitrogen level in the soil could be employed together with the genetic diversity of the wheat crop as a breeding tool for the development of wheat genotypes with improved uptake and/or N use efficiency.

Selection of different wheat genotypes under environmental stress conditions is one of the main tasks of crop breeders for exploiting the genetic variations to improve the stress-tolerant wheat cultivars (Khan and Mohammad, 2016). Sylvester-Bradley and Kindred (2009) reported that grain yield and the nitrogen nutrient demand to maximize yield evolved simultaneously.

Various studies detected significant genotype x nitrogen (G × N) interactions for agronomic characters (Bänziger *et al.* 1997, Ortiz-Monasterio *et al.* 1997; Barraclough *et al.* 2010 and Cormier *et al.* 2013). Significance of genotype x nitrogen interactions directly affects the correlations of genetic values between different nitrogen levels and so the best wheat cultivars at high nitrogen may not be the best at low nitrogen (Cormier *et al.* 2013).

The use of new reclaimed soils will present new stress problems. Consequently, stability analysis of wheat genotypes for yielding ability and its contributing traits enables the crop breeder to have sufficient information, and provides an adequate basis for selecting the desired genotypes for specific environments (Ismail 1995).

Several statistical methods have been suggested to find out the stability of new wheat cultivars. The joint regression analysis of either phenotypic values (b_i and S^2_{di}) was first proposed by Yates and Cochran (1938) and was modified and used by Finlay and Wilkinson(1963)and Eberhart and Russell (1966).The genotypic stability was discussed by Tai (1971), whereas used two stability measures (α_i and λ_i).

The additive main effects and multiplicative interaction (AMMI) model was suggested by Gauch, (1988 and 1992). The AMMI has proven useful for understanding complex genotype x environment interactions. The AMMI Stability value (ASV) proposed by Purchase, 1997 and Purchase, *et al.* (2000). The AMMI and SREG models were used for obtaining the GE and GGE biplots, respectively. Biplots of the first two principal components were used to illustrate these relationships (Gabriel, 1971 and Kempton, 1984).

The objectives of the present study were to evaluate response of sixteen bread wheat genotypes under different nitrogen fertilizer levels over two years at newly reclaimed sand soils and study and partitioning the genotype by environment interaction to its stability parameters, using joint regression, genotypic stability, the AMMI and SREG methods.

MATERIALS AND METHODS

Sixteen genetically diverse bread wheat genotypes were used in this study (Table 1), eight of which were lines developed by Prof. Dr. Hassan A. Awaad, Agron. Dep., Fac. Agric., Zagazig Univ. The field trials were carried out during 2009/2010 and 2010/2011 seasons at Agricultural Experimental Station, Faculty of Agriculture, Zagazig University at El-Khattara. Field experiments were carried out in six environments which are the combination between, 2 years and 3 nitrogen fertilizer levels (50, 80 and 110 Kg N/fad.). The amount of nitrogen in the form of ammonium sulphate (20.6% N) were applied in six equal doses, first split was applied at sowing while the other five doses were applied from 14 days after sowing and in 14 days intervals. Phosphate and potassium fertilizer were applied at the rates of 150 kg/fad (15 % P_2O_5) and 50 Kg/fad (48 % K_2O), respectively before sowing for phosphate fertilizer and after 20 days from sowing for potassium fertilizer. Sowing date was 21 and 20th of November in the 1st and 2nd seasons, respectively. Sprinkler irrigation system was used. The experimental layout at each environment was a randomized complete block design with three replications. In each environment, the plot area was 6 m^2 included 10 rows, 3m long and 20cm apart. Seeds were hand drilled. All other cultural practices were applied as recommended. The soil of the experimentation site is sandy and the mechanical and chemical analyses of the soil in the experimental sites are given in Table 2. Data were recorded on: days to 50% heading (day), plant height (cm), 1000-grain weight (g), grain yield (ard./fad.) and biological yield (ton/fad.).

Table 1. List of the 16 bread wheat genotypes and its origin

Genotype code	Name	Origin
G1	Line 1	Promising inbred lines Developed at Agron. Dept., Fac. Agric., Zagazig Univ., Egypt
G2	Line 2	
G3	Line 3	
G4	Line 4	
G5	Line 5	
G6	Line 6	
G7	Line 7	
G8	Line 8	
G9	Giza 168	Egypt local cultivars
G10	Gemmeiza 7	
G11	Gemmeiza 9	
G12	Gemmeiza 10	
G13	Sakha 93	
G14	Sakha 94	
G15	Sids 1	
G16	Misr 1	

Table 2. Soil mechanical and chemical analyses of the experimental sites

Properties	Sand %	Silt %	Clay %	Texture class	Organic matter (%)	Available (N) ppm	Available (P) ppm	Available (K) ppm	pH
2009/2010	91.4	3.5	5.1	sandy	0.25	16.3	4.5	59.3	7.7
2010/2011	88.4	4.9	6.7	sandy	0.32	19.4	5.6	68.4	8.1

The combined analyses of variance were performed according to Gomez and Gomez (1984). The phenotypic stability analysis was computed as outlined by Eberhart and Russel (1966). The genotypic stability analysis was calculated according to Tai (1971). The additive main effects and multiplicative interaction method (AMMI) was computed as proposed by Gauch (1992). Differences among means were tested using a revised L.S.D. test at the 0.05 level according to Steel and Torrie (1980).

RESULTS AND DISCUSSION

Analysis of variance

The combined analyses of variance for days to 50% heading, plant height, 1000-grain weight, grain yield (ard./fad.) and biological yield (ton / fad.) (Table 3) showed highly significant differences among environments for the forgoing traits, suggesting that the environments under study were different. Moreover, the highly significant effects among years (Y) were obtained for all traits, this result reflect the wide differences in climatic conditions prevailing during the growing seasons. The main effect of nitrogen fertilizers (N) was highly significant for all studied traits. The studied genotypes (G) had also highly significant differences for all characters, reflecting the wide genetic diversity.

Highly significant G x E items were detected for all studied traits, provide evidence that the studied bread wheat genotypes differed in their response to the environmental conditions, my suggest that is essential to determine the degree of stability for each genotype.

The first order interaction of years x nitrogen fertilizers (Y x N) differed significantly for all traits except 1000-grain weight, indicating the different influences of climatic conditions on nitrogen fertilizers. Also, highly significant interactions between genotypes x years (G x Y) were found for all traits except biological yield. The genotype-years interaction component (G x Y) accounted for the most part of total G x E interaction for studied traits, indicating that growing season had the major effect on the relative genotypic potential of this character. Moreover, the combined analyses of variance showed highly significant interactions between genotypes and nitrogen fertilizers (G x N) for all characters.

For the second order (G x Y x N) interaction, there were a differential response between genotypes to years and nitrogen fertilizer for days to 50% heading, 1000-grain weight and grain yield. These results reflected the importance of environmental factors of each year and nitrogen fertilizer levels on the performance of genotype regarding these traits. Similar results were obtained by El Morshidy *et al.* (2001), Tammam and Abd El Rady (2010) and Tawfelis *et al.* (2011). On the other hand, second order (G x Y x N) interactions were not significant for plant height and biological yield.

Table 3.The combined analyses of variance over two years, nitrogen fertilizer and genotypes for studied traits

Source of variation	df	Days to 50 % heading	Plant height (cm)	1000-grain weight (g)	Grain yield (ard. / fad.)	Biological yield (ton / fad.)
Environments (E)	5	565.64**	4218.57**	572.79**	70.40**	54.44**
Reps / Env. (Error a)	12	2.53	12.62	3.81	0.11	0.13
Years (Y)	1	1152.00**	3028.37**	927.17**	10.84**	15.71**
Y x N	2	8.95**	307.51**	11.57	9.07**	1.05**
Nitrogen fertilizer levels (N)	2	829.16**	8724.72**	956.83**	161.51**	127.19**
Genotypes (G)	15	59.73**	209.89**	69.97**	16.57**	1.64**
G x E	75	3.40**	44.79**	14.44**	1.18**	0.24**
G x Y	15	5.39**	42.62**	17.89**	0.95**	0.10
G x N	30	4.02**	71.27**	19.51**	1.65**	0.43**
G x Y x N	30	1.78*	19.40	7.65*	0.84**	0.12
Pooled Error (Error b)	180	1.15	15.15	4.33	0.37	0.09

*** , ** Significant at 0.05 and 0.01 levels of probability, respectively.**

Mean performance

The analyses of variance revealed significant differences for all studied traits among the sixteen wheat genotypes in both 1st and 2nd seasons of three nitrogen fertilizer levels. Severe nitrogen fertilizer (level 1) significantly reduced studied traits for all wheat genotypes (Table 4). It is clear that, the nitrogen stress caused a reduction in days to 50% heading in the 1st year by an average of 6% and 3.26% and in the 2nd year by an average of 5.33% and 2.56% under 1st and 2nd nitrogen fertilizer levels, respectively, compared with the 3rd level (optimum). For plant height, the reduction percentages were 23.64% and 13.13% in the 1st year and 26.89% and 17.21% in the 2nd year under 1st and 2nd nitrogen fertilizer levels, respectively, compared with the 3rd level (optimum).

Reduction percentages for 1000-grain weight were 15.33% and 12.07% in the 1st year and 13.28% and 6.37% in the 2nd year under 1st and 2nd nitrogen fertilizer levels, respectively, compared with the 3rd level.

Grain yield reduced in the 1st year by an average of 20.12% and 11.32% and in the 2nd year by an average of 25.93% and 10.94% under 1st and 2nd nitrogen fertilizer levels, respectively, compared with the 3rd level. Also, reduction percentages for biological yield were 48.46% and 5.88% in the 1st year and 50.04% and 4.19% in the 2nd under 1st and 2nd nitrogen fertilizer levels, respectively, compared with the 3rd level.

Generally, grain yield and other traits were severely decreased at the first and second nitrogen fertilizer levels when compared with the third level. Similar results were reported by Hamam and Khaled (2009) and El-Badawy (2012).

Table 4. Means and reduction percentage of studied traits as affected by environments

Environments	Days to 50 % heading		Plant height (cm)		1000-grain weight (g)		Grain yield (ard. / fad.)		Biological yield (ton / fad.)	
	Mean	Reduction%	Mean	Reduction%	Mean	Reduction%	Mean	Reduction%	Mean	Reduction%
E1(2009/2010 50kg N / fad.)	90.13	6.00	64.46	23.64	40.30	15.33	8.57	20.12	2.10	48.46
E2 (2009/2010 80kg N / fad.)	92.75	3.26	73.33	13.13	41.85	12.07	9.51	11.32	3.84	5.88
E3 (2009/2010 110kg N / fad.)	95.88		84.42		47.59		10.73		4.08	
E4 (2010/2011 50kg N / fad.)	94.00	5.33	70.65	26.89	42.93	13.28	8.46	25.93	2.30	50.04
E5 (2010/2011 80kg N / fad).	96.75	2.56	80.00	17.21	46.35	6.37	10.17	10.94	4.42	4.19
E6 (2010/2011 110kg N / fad.)	99.29		96.63		49.50		11.42		4.61	
Over all mean	94.80		78.25		44.75		9.81		3.56	
L.S.D $_{0.05}$	1.22		4.43		2.37		0.69		0.35	

The average of days to 50% heading over all environments ranged from 89.83 to 95.83 for Sakha 93 and Line 6, respectively, with an average 94.26. In continuous, and as shown in Table (7) it is worthy to note that, plant height varied from 66.86 to 80.83 for Sakha 93 and Sakha 94 with an average of 77.49. For 1000- grain weight, it ranged from 41.14 g to 48.65g for line-2 and Misr-1 with an average of 44.23g across 6 environments (Table 8). Meanwhile, grain yield varied from 8.427 to 12.072 for Gemmeiza 7 and Misr 1 with an average of 9.882 (ard./fad.) Moreover, biological yield ranged from 3.104 to 4.076 for Sakha 93 and Line 4 with an average of 3.528 (ton/fad.) over six environments (Table 9). These results are in well agreement with those of Hamam and Khaled (2009); Tammam and Abd El Rady (2010); Tawfelis *et al.* (2011) and Dawwam *et al.* (2013)

Regression analysis

The mean square of joint regression analysis of variance for days to 50% heading, plant height, 1000-grain weight, grain yield and biological yield of the sixteen bread wheat genotypes under six environments (Table 5) revealed highly significant differences among genotypes (G), environments (E) and the G x E interaction for all traits, indicating the presence of genetic and environmental variability among the studied genotypes. Environment + Genotype x Environment (E + G x E) had highly significant effects for all characters. The G x E interaction was further partitioned into linear and non-linear (pooled deviation) components. The mean squares due to environment (linear) were highly significant for all traits, indicating that differences existed between environments and revealed predictable component shared G x E interaction with un-predictable. The linear interaction (G x E linear) were highly significant when tested against pooled deviation for all these characters, showing genetic differences among genotypes for their regression on the environmental-index, so it could be proceeded in the stability analysis (Eberhart and Russell 1966) for these characters.

The non-linear responses as measured by pooled deviations from regressions were significant, indicating that differences in linear response among genotypes across environments did account for all the G x E interaction effects, and therefore, the fluctuation in performance of genotypes grown in various environments was fully predictable. Highly significant effects for G x E interaction for many wheat characters were previously reported (Hamam and Khaled, 2009; El Ameen, 2012 and El-Moselhy *et al*., 2015).

Table 5. Joint regression analysis of variance over two years, nitrogen fertilizer and genotypes for studied traits

Source of variation	df	Days to 50 % heading	Plant height (cm)	1000-grain weight (g)	Grain yield (ard./fad.)	Biological yield (ton / fad.)
Model	95	209.59**	1491.08**	219.07**	29.38**	18.772**
Genotypes (G)	15	1.13**	69.96**	23.32**	5.52**	0.55**
Environments (E)	5	2.53**	1406.19**	190.93**	23.47**	18.15**
G x E	75	19.91**	14.93**	4.81**	0.39**	0.08**
E + G x E	80	12.85**	101.88**	16.45**	1.84**	1.21**
Environment (linear)	1	589.21**	4394.34**	596.66**	73.33**	56.71**
G x E (linear)	15	24.68**	212.15**	30.81**	3.59**	2.35**
Pooled deviation	64	1.07**	8.97*	4.01**	0.31**	0.07**
Pooled Error	180	0.35	5.05	1.44	0.13	0.03

*** , ** Significant at 0.05 and 0.01 levels of probability, respectively.**

Days to 50% heading

Phenotypic stability parameters have been computed according to Eberhart and Russel (1966), for evaluating the sixteen bread wheat genotypes for mentioned traits.

The importance of both linear (b_i) and non-linear (s^2_{di}) sensitivity for the expression of the trait was thus evident. Eberhart and Russell (1966) procedure involves the use of joint linear regression where the yield of each genotype is regressed on the environmental mean yield.

On the average, the regression coefficient (b_i) of bread wheat genotypes ranged from 0.74 (Line 5) to 1.27 (line 4) for days to 50% heading (Table 7), indicating the genetic variability among wheat genotypes in their regression response. However, the obtained (b_i) values were not deviated significantly from unity in all wheat genotypes for days to 50% heading, indicating that these genotypes could be grown under wide range of environments.

Five wheat genotypes i.e., Line 7, Gemmeiza 9, Sakha 94, Sids 1 and Misr 1 exhibited regression coefficient (b_i) values equal unity (1.05, 1.04, 1.03, 1.02 and 1.08, respectively). Meanwhile, the wheat genotypes Line 4, Giza 168, Gemmeiza7 and Gemmeiza10 had $b_i > 1$ and not significant. According to Breese (1969) genotypes with regression coefficient greater than unity would be adapted to more favorable environments. While, those with coefficient less than one would relatively be better adapted to less favorable growing conditions.

The deviations from regression (s^2_{di}) ranged from 0.19 (Gemmeiza 7) to 3.51 (Line 6). The stable genotype with lowest s^2_{di} values were Gemmeiza 7 (0.19), Gemmeiza 10 (0.31), Gemmeiza 9 (0.37), Line 8 (0.4) and Line 2 (0.46). The unstable genotype with the highest and significant s^2_{d}values were Line 3 (1.11**), Line 4 (2.52**), Line 5 (0.98*), Line 6 (3.51**), Sakha 94 (1.24**) and Sids 1 (2.48**).

When the mean performance ($\bar{g}$), regression coefficient value (b_i) and the deviation from the regression (s^2_{di}) are considered together, then the most stable genotype would be Sakha 93 with an earliest mean $\bar{g}$= 89.83, b = 0.97 and s^2_{di} = 0.79, Gemmeiza 7 with $\bar{g}$ = 90.89, b = 1.10 and s^2_{di}= 0.19, Giza 168 with $\bar{g}$ = 91.83, b = 1.12 and s^2_{di} = 0.58 and Misr 1 with $\bar{g}$ =

92.06, b = 1.08 and the s^2_{di} = -0.83. These genotypes could be useful in wheat breeding programs for improve this trait under nitrogen stress.

Genotypic stability parameters of Tai's (1971) measured the deviation from the linear response in terms of the magnitude of error variance, and proposed partitioning the G x E interaction effect of the i^{th} genotype into two statistics measures namely linear response to environmental effects (α_i) and the deviation from linearity (λ_i).

Perfectly stable wheat genotypes would not change its performance from one environment to another. This is corresponding to stating that $\alpha_i = -1$ and $\lambda_i=1$. Because perfectly stable wheat genotypes probably do not exist, wheat breeders will have to be satisfied with the accessible levels of stability, *i.e.* average stability $\alpha = 0.0$ and $\lambda_i=1$, below average stability $\alpha_i > 0$ and $\lambda_i=1$ and above average stability $\alpha_i < 0$ and $\lambda_i=1$. Table (7) and Figure (1) showed that all wheat genotypes were stable and insignificant for linear response to environmental effects (α_i), as well as for the deviation from linear (λ_i) except Line 4, Line 6, Sakha 94 and Sids 1.

The AMMI model combines the analysis of variance for the wheat genotype and environment main effects with the principal components analysis of the G x E interaction. Lopez (1990) and Kang (2002) reported that a cultivar is considered as stable if its 1st and 2nd correspondence-analysis scores are near zero.

The analyses of variance showed that environments (E), wheat genotypes (G) and the G x E interaction mean squares were highly significant for days to 50% heading (Table 6). The IPCA scores of a bread wheat genotypes in the AMMI and SREG analyses were significant for IPCA1 and IPCA2. Variance components (%) of the sum of squares varied from 21.34% for genotypes, 67.36% for environments and 6.07% for GEI. IPCA 1 score explained 65.70 % and IPCA 2 had 21.22% of the total GEI for AMMI models. Also, IPCA 1 score explained 78.98% and IPCA 2 had 14.46% of the total GEI for SREG models.

Table 6.AMMI analyses of variance over six environments (two years and three nitrogen fertilizer)for studied traits

Source of variation	df	Days to 50 % heading		Plant height (cm)		1000-grain weight (g)		Grain yield(ard./fad.)		Biological yield(ton/fad.)	
		M.S.	**Percent**	**M.S.**	**Percent**	**M.S.**	**Percent**	**M.S.**	**Percent**	**M.S.**	**Percent**
Environments (E)	5	565.64**	67.36	4218.57**	69.20	572.79**	49.21	70.40**	46.38	54.44**	81.74
Reps. / Env.	12	2.53		12.62		3.81		0.11		0.13	
Genotypes (G)	15	59.73**	21.34	209.89**	10.33	69.97**	18.03	16.57**	32.74	1.64**	7.38
G x E	75	3.40**	6.07	44.79**	11.02	14.44**	18.61	1.18**	11.70	0.24**	5.43
IPCA1	19	8.81**	65.70	111.62**	63.13	21.95**	38.50	2.16**	46.16	0.51**	53.44
IPCA2	17	3.18**	21.22	34.44**	17.43	21.12**	33.15	1.07**	20.44	0.25**	23.35
IPCA3	15	1.26	7.41	23.78	10.62	9.78*	13.54	1.11*	18.79	0.13	11.05
G x E Residuals	24	0.60	5.67	12.35	8.83	6.68	14.81	0.54	14.60	0.09	12.15
Pooled Error	180	1.05		15.16		4.32		0.38		0.09	

*** , ** Significant at 0.05 and 0.01 levels of probability, respectively.**

A bread wheat genotype with the smaller AMMI stability value (ASV) is considered as more stable. According to the ASV ranking in Table (7) and either Figure (2), the genotypes, Sakha 93 (G13), Gemmeiza 7 (G10), Line 8 (G8) and Gemmeiza 10 (G12) were more stable (0.53, 0.68, 0.72 and 0.78, respectively), while the genotypes Line 4 (G4), Line 6 (G6), Sids1 (G15), Line 5 (G5) and Sakha 94 (G14) were unstable.

Figure (2) shows the graphic display of the GEI biplot for 16 bread wheat genotypes (assessed G1 to G16) and six environments (assessed E1-E6) in the AMMI and SREG models for days to 50% heading.

The bread wheat genotypes and environments that were located far away from the origin were more responsive. Environments E1, E6 and E2 were the most differentiating environments, while environments E5 and E3 were less reactive. Furthermore, the vertex wheat genotypes G3 (Line 3), G15 (Sids1), G4 (Line 4), G14 (Sakha 93), G6 (Line 6) and G5 (Line 5) were located far away from the origin, which were more responsive to environment change and are considered as specifically adapted bread wheat genotypes, as they have the longest distance from the origin in their direction and wheat genotypes with long vectors were assigned as either the best or the poorest performers in the environment. Based on the genotype-focused scaling, the genotype Sakha 93 (G13), Gemmeiza 7 (G10), Line 8 (G8) and Gemmeiza 10 (G12) were the desirable, they located near the origin and less responsive than the corner wheat genotypes.

Concerning GGE biplot for the SREG model (Figure 2) show graphic display of the GGE biplot for sixteen bread wheat genotypes for grain yield assessed (G1 – G16) and the six environments considered (E_1-E_6) in the SREG model.

An ideal bread wheat genotype should have the lowest mean performance for days to 50% heading and be absolutely stable (*i.e.,* perform the best in all environments). Gemmeiza 7 (G10) was ideal wheat cultivar, it had the lowest vector length of the lower wheat genotype and with zero GEI, as represented by the arrow pointing to it (Fig. 2).

The angle between the vectors of two environments is related to the correlation coefficient among them. The environments E_2, E_3 and E_5 were positively correlated because all angles among them were smaller than 90°, while the environments E_2 had negatively correlated with E_4 (Fig. 2).

Table 7. Genotype means over six environments and stability parameters of the sixteen wheat genotypes for days to 50 % heading and plant height

Genotypes	Days to 50 % heading							Plant height (cm)						
	Mean ($\bar{g}_i$)	P_i	b_i	S^2_{di}	α_i	λ_i	ASV	Mean ($\bar{g}_i$)	P_i	b_i	S^2_{di}	α_i	λ_i	ASV
Line 1	93.89	-0.37	0.92	0.73	-0.08	1.78	1.45	79.39	1.90	1.39*	11.66	0.39*	1.96	6.45
Line 2	95.50	1.24	0.90	0.46	-0.11	1.11	1.38	78.97	1.48	0.95	5.79	-0.05	0.98	0.72
Line 3	95.67	1.41	0.80	1.11**	-0.20	2.69	1.87	78.33	0.84	1.22	12.11	0.22	2.04	2.38
Line 4	95.56	1.30	1.27	2.52**	0.27	6.11*	4.10	77.89	0.40	1.31*	10.25	0.32	1.73	5.88
Line 5	93.44	-0.81	0.74	0.98*	-0.26	2.37	2.55	77.61	0.12	1.36*	16.62*	0.36	2.80*	7.17
Line 6	95.83	1.57	0.86	3.51**	-0.14	8.54*	4.25	77.64	0.15	1.27*	3.35	0.27*	0.56	4.71
Line 7	94.33	0.07	1.05	0.58	0.05	1.42	1.54	78.81	1.31	1.21	5.60	0.21	0.94	3.90
Line 8	94.17	-0.09	0.95	0.40	-0.05	0.96	0.72	77.33	-0.16	0.97	1.11	-0.03	0.19*	0.26
Giza 168	91.83	-2.43	1.12	0.58	0.12	1.42	1.35	76.57	-0.92	0.80	11.79	-0.20	1.99	4.87
Gemmeiza 7	90.89	-3.37	1.10	0.19	0.10	0.46	0.68	77.83	0.34	0.55**	1.84	-0.45	0.30*	6.12
Gemmeiza 9	95.11	0.85	1.04	0.37	0.04	0.89	1.20	78.17	0.67	1.00	4.06	0.00	0.69	0.95
Gemmeiza 10	94.89	0.63	1.15	0.31	0.15	0.74	0.78	71.36	-6.13	0.67	8.07	-0.33*	1.36	5.63
Sakha 93	89.83	-4.43	0.97	0.79	-0.03	1.91	0.53	66.86	-10.63	0.97	17.34*	-0.03	2.93*	3.08
Sakha 94	92.78	-1.48	1.03	1.24**	0.03	3.02*	2.12	80.83	3.34	0.45**	7.47	-0.55*	1.25	8.10
Sids 1	94.56	0.30	1.02	2.48**	0.02	6.02*	3.48	79.49	2.00	1.07	14.91*	0.07	2.52	2.52
Misr 1	92.06	-2.20	1.08	0.83	0.08	2.03	1.71	78.25	0.76	0.82	11.59	-0.18	1.96	4.06
Mean ($\bar{x}$)	94.26							77.49						
L.S.D' 0.05	0.63							2.32						
r ($\bar{g}_i$, b_i)	-0.17							0.13						

$\bar{g}_i$ = Mean of genotype, (P_i)= Phenotypic index ($\bar{g}_i - \bar{x}$), b_i= regression of coefficient and S^2_{di}= mean square deviations from linear regression, α_i= linear response to environmental effects, λ_i = the deviation from linear response and ASV =AMMI stability value.
*** , ** Significant at 0.05 and 0.01 levels of probability, respectively.**

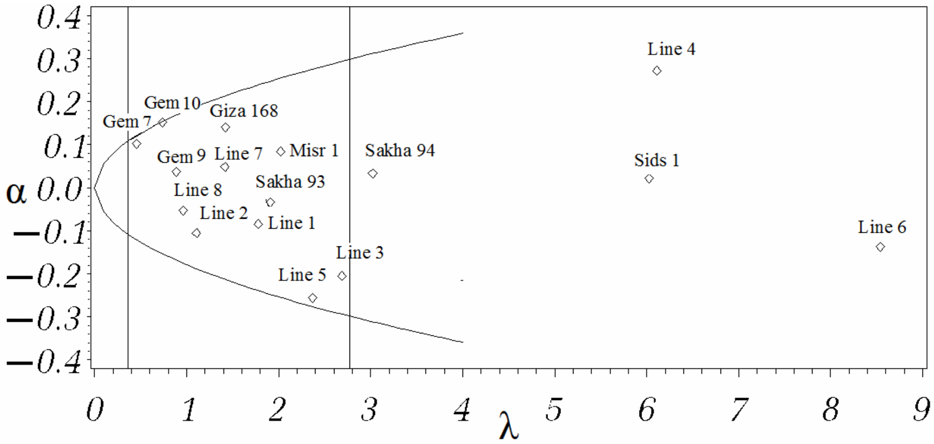

Fig. 1. Genotypic stability parameters (α and λ) for 16 bread wheat genotypes of days to 50% heading

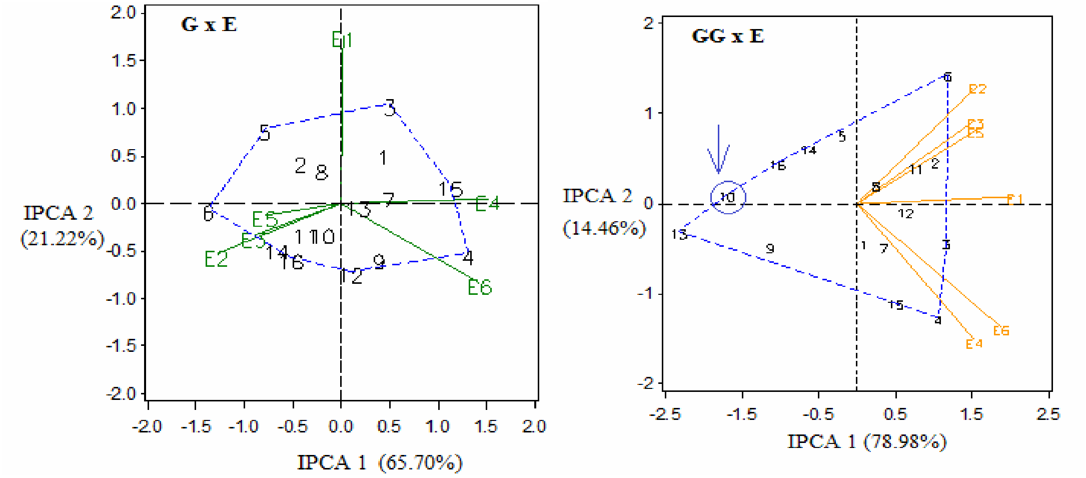

Fig. 2. Graphics display of the GE and GGE biplots for 16 wheat genotypes (assessed G1 - G16) and six environments (assessed E1- E6) in the AMMI and SREG models, respectively for days to 50 % heading

The ideal test environment was E1, it had large IPCA1 scores (more power to differentiate bread wheat genotypes in terms of the wheat genotypic main effect) and small (absolute) IPCA2 scores (more representative of the overall environments). The favorable environments were E_6 and E_3, while the unfavorable ones were E_2 and E_4.

Plant height

The regression coefficient of 16 bread wheat genotypes ranged from 0.45 (Sakha 94) to 1.39 (line 1), indicating the genetic variability among wheat genotypes in their regression response for plant height (Table 7). The obtained (b_i) values were deviated significantly from unity (bi>1) in Line 1, Line 4, Line 5 and Line 6, therefore they good adapted to favorable environments, whereas, the (b_i) values were significantly less than unity (b_i<1) in Gemmeiza 7, Gemmeiza 10 and Sakha 94, hereby they relatively better adapted to low nitrogen level as less favorable environment. However, wheat genotypes, *i.e.*, Line 3, Line 4, Line 7, Line 8, Giza 168, Gemmeiza 9, Sakha 93, Sids 1 and Misr 1 had the (b_i) values were not deviated significantly from unity and thus could be grown under wide range of environments (Table 7).

The deviations from regression (S^2_{di}) for plant height ranged from 1.11 (Line 8) to 17.34 (Sakha 93). The stable wheat genotypes with lowest S^2_{di} values were Line 8 (1.11), Gemmeiza 7 (1.84), Line 6 (3.35), Gemmeiza 9 (4.06) and Line 7 (5.60). The unstable genotypes with the highest and significant S^2_{di} values were Line 5 (16.62**), Sakha 93 (17.34**) and Sids 1 (14.91**). The best stable genotypes according to phenotypic stability for plant height were Line 8 with a mean performance across environments $\bar{g}$ = 77.33, b = 0.97 and the S^2_{di} = 1.11, followed by Gemmeiza 9 ($\bar{g}$ = 78.17, b = 1.0 and Sd_i^2 = 4.06), then Line 2 ($\bar{g}$ = 78.97, b = 0.95 and S^2_{di} =5.79).

Regarding genotypic stability parameters, (Table 7 and Figure 3) showed that all wheat genotypes were stable and insignificant for linear response to environmental effects (α_i) except Line 1, Line 6, Gemmeiza 7, Gemmeiza 10 and Sakha 94 and also for the deviation from linear (λ_i) except Line 5, Line 8, Gemmeiza 7 and Sakha 93. Gemmeiza 9, Line 2 and Line 7 had the best genotypic stability values ($\alpha_=$ 0.00, -0.05 and 0.21 and $\lambda_{i=}$ 0.69, 0.98 and 0.94, respectively).

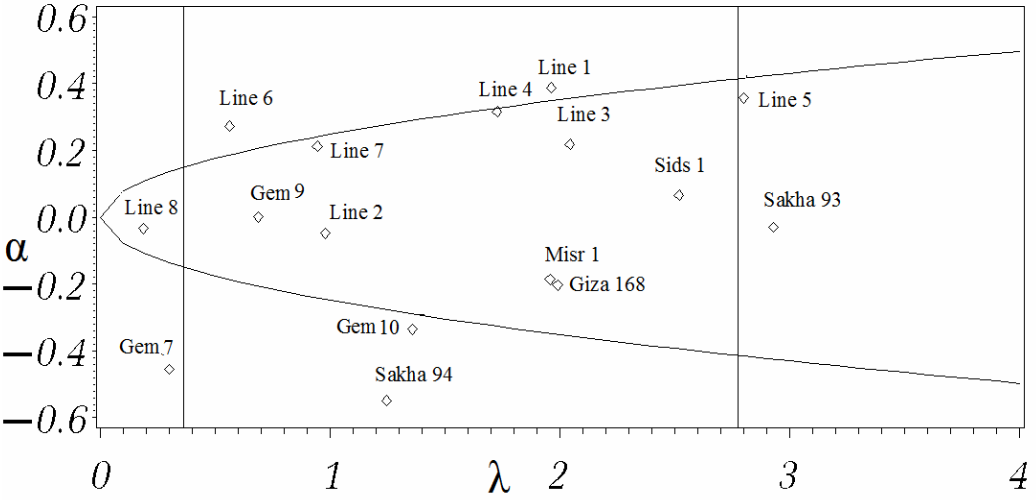

Fig. 3. Genotypic stability parameters (α and λ) for 16 wheat genotypes of the plant height

AMMI analyses showed that environments (E), bread wheat genotypes (G) and the G x E interaction mean squares were highly significant for plant height Table (6). The IPCA scores of a wheat genotype in the AMMI and SREG analyses were significant for IPCA1 and IPCA2. Variance components (%) of the sum of squares varied from 10.33% for wheat genotypes, 11.02% for environments and 11.02% for GEI. IPCA 1 score explained 63.13 % and IPCA 2 had 17.39% of the total GEI for AMMI model. While for SREG model, IPCA 1 score exhibited 55.09% and IPCA 2 had 28.34% of the total GGEI.

According to the ASV ranking Table 7 and either Figure 4, the wheat genotypes, Line 8 (G8), Line 2 (G2), Gemmeiza 9 (G11), Line 3 (G3) and Sids 1 (G15) were more stable (0.26, 0.72, 0.95, 2.38 and 2.52, respectively), while the wheat genotypes Line 4 (G4), Line 6 (G6), Sids1 (G15), Line 5 (G5) and Sakha 94 (G14) were unstable for plant height.

GE biplot graph for the AMMI indicated that, environments *i.e,* E1, E6 and E5 were the most differentiating environments, conversely environments E3, E2 and E4 were less responsive for plant height. Furthermore, the vertex wheat genotypes G3 (Line 3), G1 (Line 1), G5 (Line 5), G15 (Sids1), G13 (Sakha 94), G12 (Gemmeiza 10) and G14 (Sakha 93) were located far away from the origin, which were more responsive to environment change and are considered as specifically adapted genotypes. The genotype-focused scaling showed that, the bread wheat genotypes Line 8 (G8), Line 2 (G2), Gemmeiza 9 (G11), Line 3 (G3) and Sids 1 (G15) were the desirable, these wheat genotypes were located near the origin were less responsive than the corner wheat genotypes.

Based on GGE biplot for the SREG model showed that, Gemmeiza 10 (G12) was ideal genotype for plant height, it had the lowest vector length of the lower wheat genotype and with zero GE, as represented by the mark with an arrow pointing to it in (Fig. 4). The environments E_1, E_2, E_5 and E_4 were positively correlated because all angles among them were smaller than 90˚, while the environment E_6 had negatively correlated with E_1 and E_2 , but it positively correlated with E_3.The ideal test environment was E_3, it had large IPCA1 scores and absolute IPCA2 scores. The favorable environment was E_6 and the unfavorable ones were E_1 and E_2.

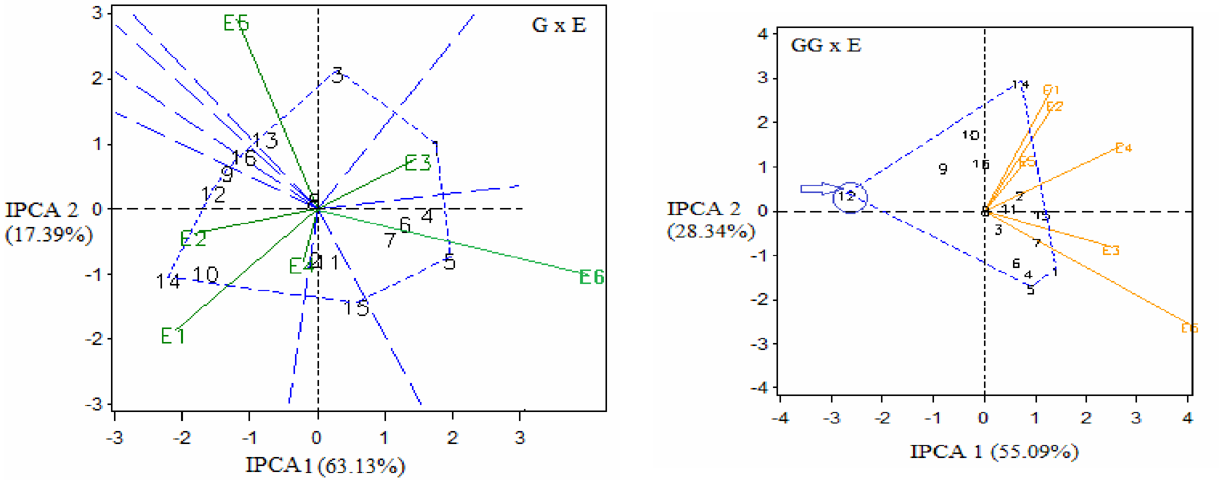

Fig. 4. Graphics display of the GE and GGE biplots for 16 wheat genotypes (assessed G1 - G16) and six environments (assessed E1- E6) in the AMMI and SREG models, respectively for plant height

1000-grain weight

Phenotypic stability parameters revealed that, regression coefficient (b_i) for 1000-grain weight of sixteen bread wheat genotypes ranged from 0.41 (Line 2) to 1.82 (line 5), indicating the genetic variability among wheat genotypes in their regression response for 1000-grain weight (Table 8). The (b_i) values were deviated significantly from unity (bi>1) in Line 5 and less than unity (b_i<1) in Line 2 and Line 3. On the other side, wheat genotypes, *i.e.,* Line1, Line 4, Line 6, Line 7, Line 8, Giza 168, Gemmeiza 7, 9 and 10, Sakha 93, Sakha 94, Sids 1 and Misr 1 had the (b_i) values were not deviated significantly from unity, indicating that these bread wheat genotypes were adapted well under wide range of environments for 1000-grain weight.

The deviations from regression (S^2_{di}) for 1000-grain weight ranged from 0.77 (Line 3) to 10.07 (Line 8). The stable wheat genotypes with lowest (S^2_{di}) values and not significantly different from zero were Line 3 (0.77), Line 6 (0.67), Gemmeiza 7 (1.71) and Gemmeiza 9 (2.83). In contrast, the unstable genotypes with the highest and significant (S^2_{di}) values were Line 1 (4.97**), Line 5 (5.54**), Line 8 (10.07**), Giza 168 (5.01*), Gemmeiza 10 (8.41**), Sakha 93 (4.38**), Sakha 94 (4.0*) and Misr 1 (4.29*).

The best stable wheat genotypes according the three phenotypic stability parameters ($\bar{g}$, bi and S^2_{di}) for 1000-grain weight were Line 7 with $\bar{g}$= 46.02, b = 1.09 and the S^2_{di} = 2.27, followed by Gemmeiza 7 ($\bar{g}$= 45.27, b = 0.95 and S^2_{di} = 1.71), then Line 4 ($\bar{g}$= 46.26, b = 0.94 and S^2_{di} =3.14). These genotypes gave mean values above grand mean and their regression coefficients (b_i) did not differ significantly from unity with minimum deviation mean squares S^2_{di}, revealing that these wheat genotypes were more phenotypic stable than others under the environmental studies for this trait.

Results of genotypic stability parameters (Table 8 and Fig. 5) showed that all bread wheat genotypes were stable and insignificant for linear response to environmental effects (α_i) except Line 2, Line 3, Line 5 and Line 6. Moreover, for the deviation from linear (λ_i), all wheat genotypes were stable and insignificant except Line 1, Line 5, Line 8, Giza 168 and Gemmeiza 10. A simultaneous consideration of the two stability measures (α_i and λ_i), the most desired and stable wheat genotypes were Gemmeiza 9, Line 7, Gemmeiza 7 and Line 4 (α = 0.09, 0.09, -0.05 and -0.06, respectively and λ_i = 1.68, 1.35, 1.02 and 1.86, respectively).

AMMI analysis showed that environments (E), wheat genotypes (G) and the G x E interaction mean squares were highly significant for 1000-grain weight (Table 6). The IPCA scores of wheat genotypes in the AMMI and SREG models were significant for IPCA1 and IPCA2. Variance components (%) of the sum of squares varied from 18.03% for bread wheat genotypes, 49.21% for environments and 18.61% for GEI. IPCA 1 score explained 38.50 % and IPCA 2 had 33.14% of the total GEI for AMMI model. Moreover, For SREG model, IPCA 1 score exhibited 59.43% and IPCA 2 had 18.85% of the total GGEI.

A wheat genotype with least ASV is the most stable, in respect to 1000-grain weight as given in Table (8) and illustrated in Fig. 6 the bread wheat genotypes Gemmeiza 9 (G11), Sids 1 (G15), Gemmeiza 7 (G10), Line 4 (G4) and Line 7 (G7) were the most desired and stable genotypes for 1000- grain weight (0.32, 0.38, 0.51, 0.63 and 0.68, respectively), whereas genotypes Line 6 (G6), Line 3 (G3) and Misr 1 (G16) were moderate one. Otherwise, bread wheat genotypes Line 2 (G2), Line 5 (G5), Line 8 (G8), Gemmeiza 10 (G12), and Sakha 93 (G13) were unstable for 1000-grain weight and more responsive to the environmental changes.

GEI biplot graph for the AMMI showed that, Environments E_5, E_3, E_1 and E_4 were the most differentiating environments for 1000-grain weight. On the other side, environments E_2 and E_6 were less responsive for this trait. Furthermore, the vertex wheat genotypes G5 (Line 5), G8 (Line 8), G13 (Sakha 93), G14 (Sakha 94) and G12 (Gemmeiza 10) were located far away from the origin, which were more responsive to environmental change and are considered as specifically adapted wheat genotypes. Based on the genotype-focused scaling, the bread wheat genotypes Gemmeiza 9 (G11), Line 6 (G6), Line 7 (G7), Line 3 (G3), Line 4 (G4), Gemmeiza 7 (G10) and Sids 1 (G15) were the desirable and stable genotypes.

Table 8. Genotype means over six environments and stability parameters of the sixteen wheat genotypes for 1000- grain weight and grain yield

Genotypes	1000- grain weight (g)							Grain yield (ard. / fad.)						
	Mean ($\bar{g}_i$)	P_i	b_i	S^2_{di}	α_i	λ_i	ASV	Mean ($\bar{g}_i$)	P_i	b_i	S^2_{di}	α_i	λ_i	ASV
Line 1	44.81	0.58	1.24	4.97**	0.24	2.94*	1.41	10.073	0.19	1.01	0.10	0.01	0.64	0.24
Line 2	41.14	-3.09	0.41**	2.86	-0.60*	1.67	1.73	9.560	-0.32	0.52**	0.16	-0.48*	1.06	1.70
Line 3	42.57	-1.67	0.61**	0.77	-0.39*	0.45	0.85	10.044	0.16	0.74	0.36*	-0.26	2.42	0.74
Line 4	46.26	2.03	0.94	3.14	-0.06	1.86	0.63	10.584	0.70	0.64*	0.45**	-0.36	3.05*	1.72
Line 5	46.56	2.33	1.82**	5.54**	0.83*	3.24*	2.57	9.179	-0.70	0.95	0.41*	-0.05	2.76	0.99
Line 6	45.73	1.50	1.27	0.67	0.27*	0.40	0.79	10.164	0.28	1.33*	0.52**	0.33	3.48*	1.18
Line 7	46.02	1.79	1.09	2.27	0.09	1.35	0.68	8.994	-0.89	1.21	0.63**	0.22	4.26*	1.59
Line 8	44.92	0.69	0.87	10.07**	-0.13	5.97*	1.77	9.868	-0.01	1.40**	0.37*	0.40	2.51	1.67
Giza 168	42.44	-1.79	0.70	5.01*	-0.30	2.97*	1.03	11.438	1.56	1.06	0.18	0.06	1.21	0.37
Gemmeiza 7	45.27	1.04	0.95	1.71	-0.05	1.02	0.51	8.427	-1.46	1.12	0.36*	0.12	2.41	0.79
Gemmeiza 9	42.35	-1.88	1.09	2.83	0.09	1.68	0.32	10.909	1.03	0.91	0.30	-0.09	2.04	0.81
Gemmeiza 10	42.72	-1.51	1.25	8.41**	0.25	4.98*	1.88	9.351	-0.53	0.94	0.49**	-0.06	3.34*	0.35
Sakha 93	43.74	-0.50	0.58	4.38*	-0.42	2.59	1.65	9.172	-0.71	1.21	0.29	0.21	1.99	1.12
Sakha 94	44.20	-0.03	0.88	4.00*	-0.12	2.37	1.13	9.444	-0.44	1.15	0.17	0.15	1.16	0.54
Sids 1	45.68	1.44	1.24	3.30	0.24	1.95	0.38	9.229	-0.65	0.41**	0.07	-0.59*	0.48	1.78
Misr 1	48.65	4.42	1.06	4.29*	0.06	2.54	0.88	12.072	2.19	1.40**	0.06	0.40*	0.38	0.94
Mean	44.23							9.882						
L.S.D' 0.05	1.236							0.352						
r ($\bar{g}_i$, b_i)	0.56*							0.16						

$\bar{g}_i$ = Mean of genotype, (P_i)= Phenotypic index ($\bar{g}_i$ - $\bar{\bar{x}}$), b_i= regression of coefficient and S^2_{di}= mean square deviations from linear regression, α_i= linear response to environmental effects, λ_i = the deviation from linear response and ASV =AMMI stability value.

, ** Significant at 0.05 and 0.01 levels of probability, respectively.

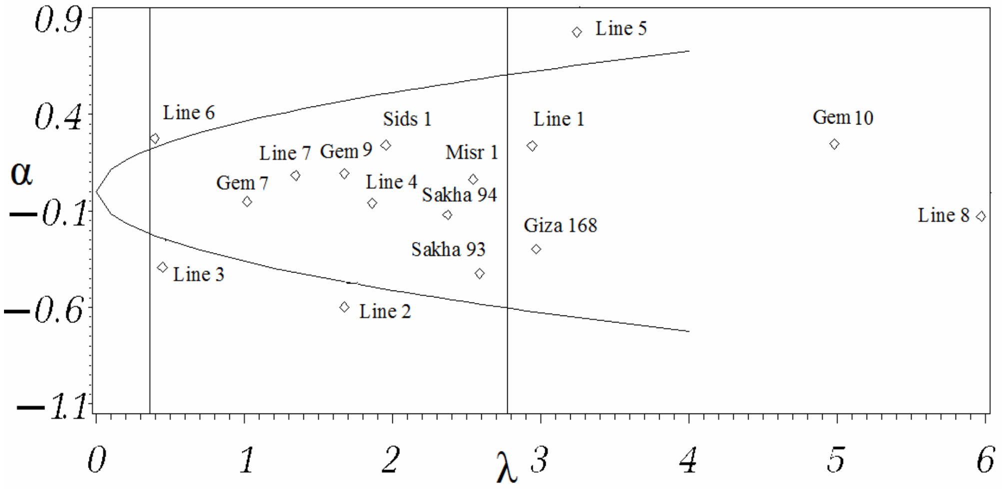

Fig. 5. Genotypic stability parameters (α and λ) for 16 wheat genotypes of the 1000-grain weight

GGEI biplot graph for the SREG model showed that, Line 7 (G7) was ideal wheat genotype for 1000-grain weight, it had the heaviest vector length of the heavier genotype and with zero GEI, as represented by arrow pointing to it in Fig. 6. Wheat genotypes G6 (Line 6), G4 (Line 4), G15 (Sids 1), G1 (Line 1) and G10 (Gemmeiza 7) were more desirable genotypes, they were located closer to the ideal genotype. The environments E_3, E_2, E_4 and E_6 were positively correlated because all angles among them were smaller than 90°, while the environment E_1 had negatively correlated with E_3 the angle among them was higher than 90°.The ideal test environment was E_6, it had large IPCA1 scores and small IPCA2 scores. The favorable environment was E_3 and E5, but the unfavorable ones were E_4 and E_2.

Grain yield (ard./fad.)

Phenotypic stability indicated that, regression coefficient (b_i) for grain yield of sixteen bread wheat genotypes ranged from 0.41 (Sids 1) to 1.40 (line 8 and Misr 1), indicating the genetic variability among bread wheat genotypes in their regression response for grain yield (Table 8). The (b_i) values were deviated significantly from unity (bi > 1) in Line 6, Line 8 and Misr 1, indicating greater sensitivity to environmental changes and were relatively suitable in favorable environments with soil fertility, adequate water and other inputs. Meanwhile, the (b_i) values were deviated significantly and less than unity ($b_i < 1$) in Line 2, Line 4, and Sids 1, thus they were adapted to stress nitrogen environments. On the other side, wheat genotypes, *i.e.*, Line1, Line 5, Line7, Giza 168, Gemmeiza 7, Gemmeiza 9, Gemmeiza 10, Sakha 93 and Sakha 94 had the (b_i) values were not deviated significantly from unity, therefore these wheat genotypes were adapted well under wide range of environments for grain yield (ard./fad.).

The deviations from regression (S^2_{di}) for grain yield varied from 0.06 to 0.63 for Misr 1 and Line 7, respectively. The stable wheat genotypes with lowest

S^2_{di} values and not significantly different from zero were Misr 1 (0.06), Sids 1 (0.07), Line 1 (0.10), Line 2 (0.16), Sakha 94 (0.17), Giza 168 (0.18) and Gemmeiza 9 (0.30). Conversely, the unstable bread wheat genotypes with the highest and significant S^2_{di} values were Line 3 (0.36*), Line 4 (0.45**), Line 5 (0.41*), Line 6 (0.52*), Line 7 (0.63**), Line 8 (0.37*), Gemmeiza 7 (0.36*) and Gemmeiza 10 (0.49**).

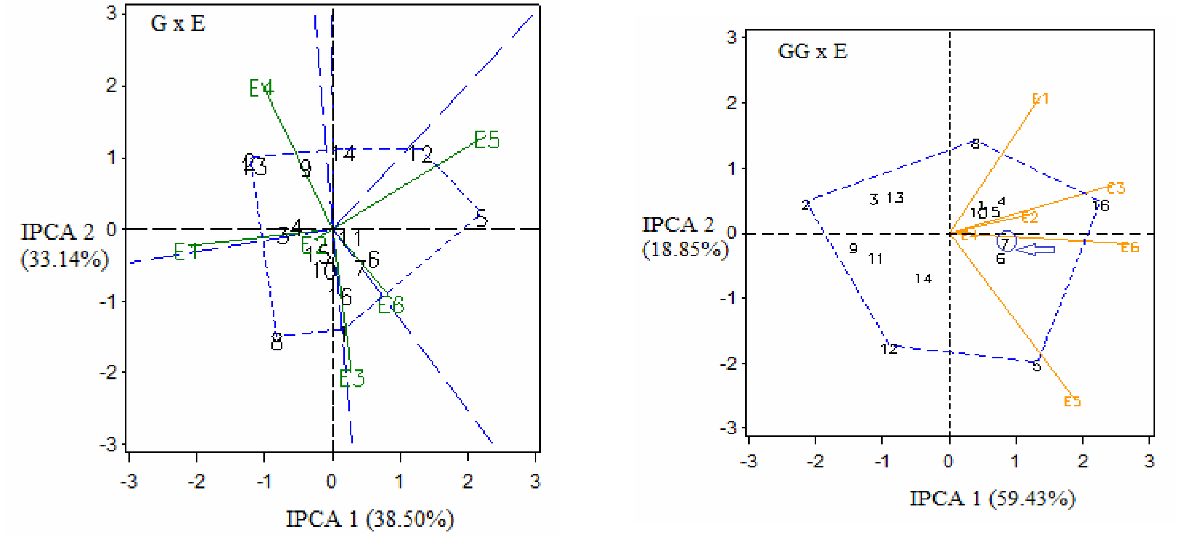

Fig. 6. Graphics display of the GE and GGE biplots for 16 wheat genotypes (assessed G1 - G16) and six environments (assessed E1- E6) in the AMMI and SREG models, respectively for 1000-grain weight

The desirable and stable wheat genotypes according to three stability parameters ($\bar{g}$, b_i and S^2_{di}) for grain yield were Giza 168 with a mean yield $\bar{g}$= 11.438, b = 1.06 and the S^2_{di} = 0.18; Line 1 ($\bar{g}$= 10.073, b = 1.01 and S^2_{di} = 0.10); Gemmeiza 9 ($\bar{g}$= 10.909, b = 0.91 and S^2_{di} =0.30) and Misr 1 ($\bar{g}$= 12.072, b = 1.4 and S^2_{di} =0.06). These genotypes gave mean values above grand mean and their regression coefficients (b_i) did not differ significantly from unity, also, minimum deviation mean squares (S^2_{di}) were detected. Furthermore, these results showed that the wheat commercial cultivars Giza 168, Gemmeiza 9 and Misr 1as well as new pure line (Line 1) proved to be widely adapted genotypes for soil fertility in newly reclaimed sandy soils.

Genotypic stability parameters for grain yield (Table 8 and Fig. 7) showed that all bread wheat genotypes were stable and insignificant for linear response to environmental effects (α_i) except Line 2, Sids 1 and Misr 1. Moreover, for the deviation from linear (λ_i), all wheat genotypes were stable and insignificant except Line 4, Line 6, Line 7 and Gemmeiza 10. A simultaneous consideration of the two stability parameters (α_i and λ_i), the most desired and stable wheat genotypes were Giza 168, Sakha 94 and Gemmeiza 9 (α = 0.06, 0.15 and -0.09 respectively and λ_i = 1.21, 1.16 and 2.04, respectively).

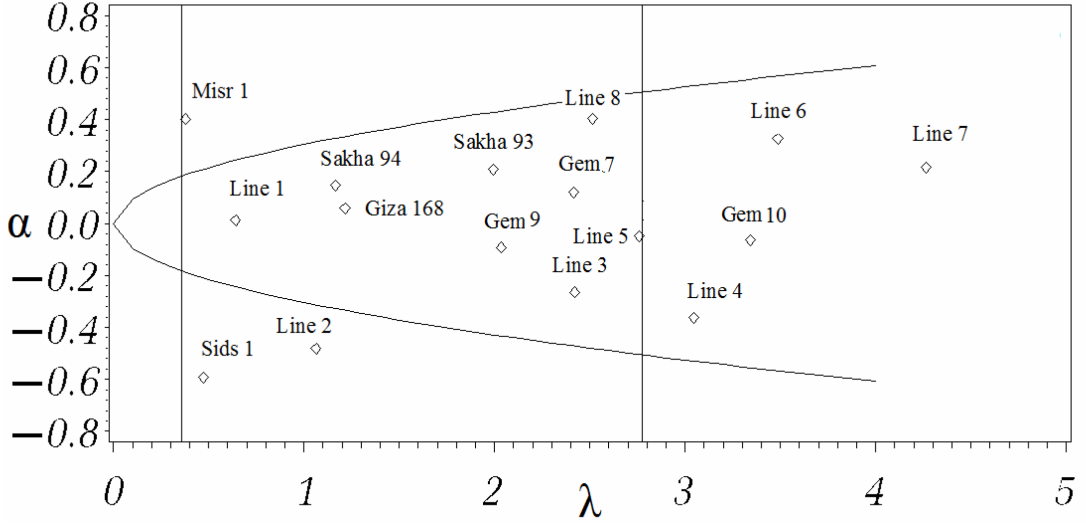

Fig. 7. Genotypic stability parameters (α and λ) for 16 wheat genotypes of the grain yield (ard. /fad.)

AMMI analysis of variance showed that environments (E), wheat genotypes (G) and the G x E interaction mean squares were highly significant for grain yield (Table 6). The IPCA scores of a wheat genotype in the AMMI and SREG analyses were significant for IPCA1 and IPCA2. Variance components (%) of the sum of squares varied from 32.74% for genotypes, 46.38% for environments and 11.70% for GEI. IPCA 1 score had 46.15 % and IPCA 2 had 20.44% of the total GEI for AMMI models. For SREG model, IPCA 1 score exhibited 74.33% and IPCA 2 had 11.75% of the total GGEI.

A wheat genotype with least ASV is the most stable, in respect to grain yield as given in (Table 8) and illustrated in (Fig. 8) the bread wheat genotypes Line 1 (G1), Gemmeiza 10 (G12), Giza 168 (G9), Sakha 94 (G14) and Line 3 (G3) were the most desired and stable genotypes (0.24, 0.35, 0.37, 0.54 and 0.74, respectively), whereas wheat genotypes Misr 1 (G16), Line 5 (G5) and Gemmeiza 9 (G11) were moderate one. Otherwise, bread wheat genotypes Sids 1 (G15), Line 2 (G2), Line 4 (G4), Line 7 (G7) and Line 8 (G8) were unstable for this trait and more responsive to the soil fertility changes.

GE biplot graph for the AMMI model illustrated that, environments E_1, E_2, E_5, E_6 and E_3 were the most differentiating environments for grain yield, they were located far away from the origin and they were more responsive to environmental changes (Fig. 8). Whereas environment E_4 was less responsive for grain yield. Furthermore, the vertex genotypes G15 (Sids 1), G4 (Line 4), G5 (Line 5), G6 (Line 6), G8 (Line 8) and G7 (Line 7) were located far away from the origin, which were more responsive to environments change and are considered as specifically adapted genotypes. Based on the genotype-focused scaling, the bread wheat genotypes Line 1 (G1), Gemmeiza 10 (G12), Giza 168 (G9), Sakha 94 (G14) and Line 3 (G3) were the desirable and stable, these wheat genotypes were located near the origin, they were less responsive than the corner genotypes.

GGE biplot graph for the SREG model as illustrated in (Fig. 8) showed that, Giza 168 (G9) was ideal wheat genotype for grain yield, it had the highest vector length of the high yielding genotypes and with zero GE, as represented by the dot with an arrow pointing to it in (Fig. 8). A wheat genotype is more desirable if it is located closer to the ideal wheat genotype, thus Misr 1, Gemmeiza 9, Line 1 and Line 3 were desirable genotypes. The environments E_2 with $E_{4,}$ E_1 with (E_5 and E_4) and E_3 with E_6 were positively correlated°. Whereas, the environment E_2 had negatively correlated with E_3 and E_6 the angle among them was higher than 90°.The ideal test environment was E_5, it had large IPCA1 scores and small IPCA2 scores. The favorable environment was E_3 and E6, but the unfavorable ones were E_1 and E_4 for grain yield.

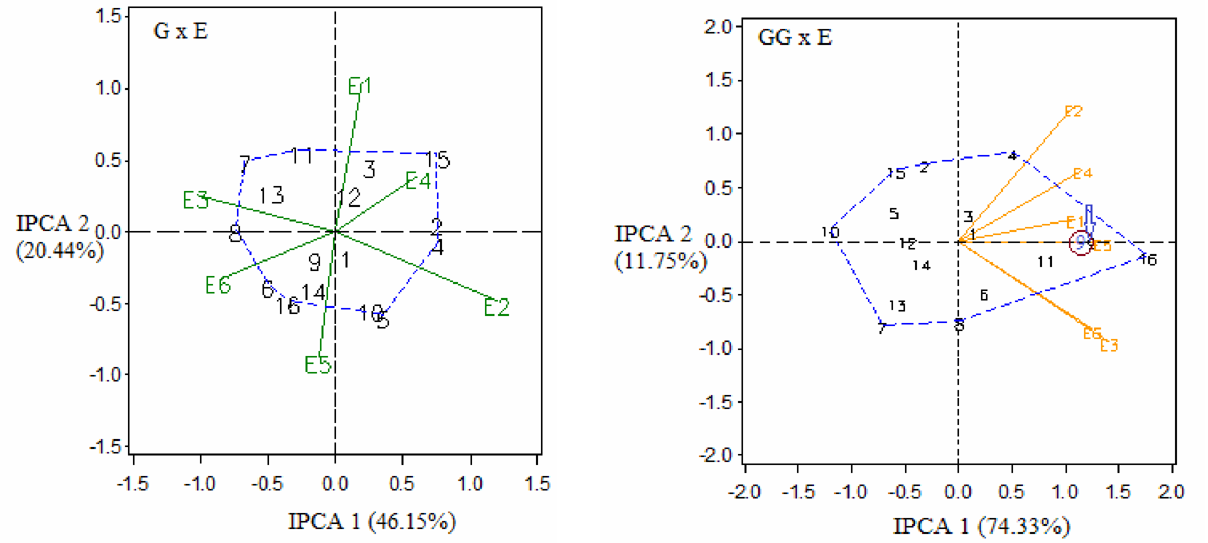

Fig. 8. Graphics display of the GE and GGE biplots for 16 wheat genotypes (assessed G1 - G16) and six environments (assessed E1- E6) in the AMMI and SREG models, respectively for grain yield (ard. /fad.)

Biological yield (ton/fad.)

Phenotypic stability analysis showed that, the regression coefficient (b_i) for biological yield of sixteen bread wheat genotypes ranged from 0.76 to 1.19 for Gemmeiza 7 and line 5, respectively, indicating the genetic variability among wheat genotypes in their regression response for biological yield (Table 9). The (b_i) values were deviated significantly and less than unity (b_i<1) in Line 6, Gemmeiza 7 and Gemmeiza 10, therefore these wheat genotypes were adapted to low soil fertility environments. On the other side, the remaining wheat genotypes exhibited regression coefficient values not deviated significantly from unity in Line1, Line 2, Line 3, Line 4, Line 7, Giza 168, Gemmeiza 9, Sakha 93, Sakha 94, Sids 1 and Misr 1, indicating that these genotypes were adapted well under wide range of environments for biological yield (ton/fad.).

The deviations from regression (S^2_{di}) for this trait varied from 0.017 to 0.176 for Gemmeiza 9 and Sakha 94, respectively. The most stable bread wheat genotypes with lowest S^2_{di} values and not significantly different from zero were Gemmeiza 9 (0.017), Line 1 (0.02), Giza 168 (0.0.33), Misr 1 (0.032) and Gemmeiza 7 (0.046). Whereas, the unstable wheat genotypes with the highest and significant S^2_{di} values were Line 4 (0.094*), Line 5 (0.089*), Line 6 (0.166**), Line 7 (0.096*), Sakha 94 (0.176**) and Sids (0.115**).

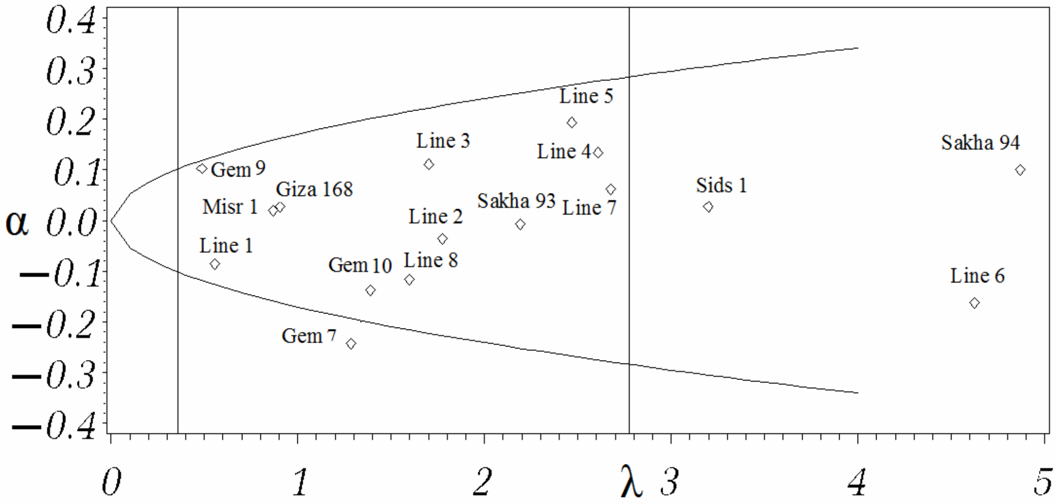

Fig. 9. Genotypic stability parameters (α and λ) for 16 wheat genotypes of the biological yield (ton /fad.)

In the present investigation, the simultaneous consideration of three phenotypic stability parameters ($\bar{g}$, b_i and S^2_{di}) for the individual genotype revealed that Misr 1 ($\bar{g}$= 3.813, b = 1.02 and S^2_{di} = 0.032); Gemmeiza 9 ($\bar{g}$= 3.816, b = 1.10 and S^2_{di} = 0.017); Giza 168 ($\bar{g}$= 3.735, b = 1.03 and S^2_{di} =0.033) and Line 1 ($\bar{g}$= 3.718, b = 0.92 and S^2_{di} =0.02). Obviously, these bread wheat genotypes gave mean values above grand mean and their regression coefficients (b_i) did not differ significantly from unity. Also, minimum deviation mean squares (S^2_{di}) were detected, revealing that these wheat genotypes were more phenotypic stable than others under the environmental studies for biological yield. Accordingly, these genotypes could be useful in wheat breeding programs for improve this trait under soil fertility in newly reclaimed sandy soils.

Genotypic stability parameters are given for biological yield in (Table 9 and Fig. 9) showed that, all bread wheat genotypes were stable and insignificant for linear response to environmental effects (α_i) except Gemmeiza 7. Moreover, for the deviation from linear (λ_i), all wheat genotypes were stable and insignificant except Line 6, Sakha 94 and Sids 1. A simultaneous consideration of the two genotypic stability parameters (α_i and λ_i), the most desired and stable wheat genotypes were Misr 1, Giza 168, Gemmeiza 9 and Line 1 (α = 0.02, 0.03, 0.10 and -0.08, respectively and λ_i = 0.87, 0.91, 0.47 and 0.55, respectively).AMMI analysis of variance showed that, environments (E), genotypes (G) and the G x E interaction mean squares were highly significant for biological yield (Table 6). The IPCA scores of a genotype in the AMMI and SREG analyses were significant for IPCA1 and IPCA2. Variance components (%) of the sum of squares varied from 7.38% for genotypes, 81.74% for environments and 5.43% for GEI. IPCA 1 score explained 53.46 % and IPCA 2 had 23.36% of the total GEI for AMMI models. For SREG model, IPCA 1 score explained 69.18% and IPCA 2 had 12.66% of the total GGEI.

Based on ASV as given in Table (9) and illustrated in Fig. 10 the bread wheat genotypes Giza 168 (G9), Gemmeiza 9 (G11), Line 1 (G1), Misr1 (G16), Gemmeiza 10 (G12) and Line 3 (G3) were the most desired and stable genotypes (0.05, 0.13, 0.16, 0.48, 0.49 and 0.52, respectively), whereas wheat genotypes Sakha 93 (G13), Gemmeiza 7 (G10) and Line 2 (G2) were moderate one. Otherwise, bread wheat genotypes Line 4 (G4), Line 5 (G5), Line 6 (G6), Sakha 94 (G14) and Sids 1 (G15) were unstable for this trait and more responsive to the soil fertility changes.

GE biplot graph for the AMMI model showed that environments E_2, E_5, E_6 and E_3 were the most differentiating environments for biological yield, they were located far away from the origin and they were more responsive to environmental changes (Fig. 10). Conversely, environments E_1 and E_4 were less responsive for biological yield. Furthermore, the vertex wheat genotypes G6 (Line 6), G4 (Line 4), G5 (Line 5), G14 (Sakha 94), G15 (Sids 1) and G10 (Gemmeiza 7) were located far away from the origin, which were more responsive to environment change and are considered as specifically adapted genotypes. Based on the genotype-focused scaling, the bread wheat genotypes Giza 168 (G9), Gemmeiza 9 (G11), Line 1 (G1), Misrl (G16), Gemmeiza 10 (G12) and Line 3 (G3) were the desirable and stable.

GGE biplot graph for the SREG model showed that, Misr 1 (G16) was ideal wheat genotype for biological yield, it had the greatest vector length of the high yielding genotypes and with zero GEI, as represented by the an arrow pointing to it in (Fig. 10). A wheat genotype is more desirable if it is located closer to the ideal genotype, such as Line 1 (G1), Giza 168 (G9), Line 4 (G4) and Gemmeiza 9 (G11). The environments E_2 with E_5, E_3 with E_6 and E_1 with E_4 were positively correlated because all angles among them were smaller than 90°. Whereas, the environment E_3 and E_6 had negatively correlated with E_2 and E_5 the angle among them was higher than 90°. The favorable environment was E_3 and E6, but the unfavorable ones were E_1 and E_4 for biological yield.

Table 9. Genotype means over six environments and stability parameters of the sixteen wheat genotypes for biological yield (ton / fad.)

	Biological yield (ton / fad.)							
Genotypes	**Mean ($\bar{g}_i$)**	**P_i**	**b_i**	**S^2_{di}**	**α_i**	**λ_i**	**ASV**	**Ranking**
Line 1	3.718	0.19	0.92	0.020	-0.08	0.55	0.16	3
Line 2	3.414	-0.11	0.97	0.064	-0.03	1.77	0.73	8
Line 3	3.324	-0.20	1.11	0.062	0.11	1.70	0.52	6
Line 4	4.076	0.55	1.13	0.094*	0.13	2.61	1.06	12
Line 5	3.559	0.03	1.19	0.089*	0.19	2.46	1.11	13
Line 6	3.620	0.09	0.84*	0.166**	-0.16	4.59*	1.16	15
Line 7	3.289	-0.24	1.06	0.096*	0.06	2.65	0.88	11
Line 8	3.467	-0.06	0.89	0.058	-0.12	1.60	0.85	10
Giza 168	3.735	0.21	1.03	0.033	0.03	0.91	0.05	1
Gemmeiza 7	3.147	-0.38	0.76**	0.046	-0.24*	1.27	0.77	9
Gemmeiza 9	3.816	0.29	1.10	0.017	0.10	0.47	0.13	2
Gemmeiza 10	3.177	-0.35	0.86*	0.050	-0.14	1.39	0.49	5
Sakha 93	3.104	-0.42	0.99	0.079	-0.01	2.17	0.60	7
Sakha 94	3.175	-0.35	1.10	0.176**	0.10	4.86*	1.37	16
Sids 1	3.111	-0.42	1.03	0.115**	0.03	3.18*	1.11	14
Misr 1	3.813	0.28	1.02	0.032	0.02	0.87	0.48	4
Mean	3.528							
L.S.D' 0.05	0.202							
r ($\bar{g}_i$, b_i)	0.29							

$\bar{g}_i$ = Mean of genotype, (P_i)= Phenotypic index ($\bar{g}_i - \bar{\bar{x}}$), b_i= regression of coefficient and S^2_{di}= mean square deviations from linear regression, α_i= linear response to environmental effects, λ_i = the deviation from linear response and ASV =AMMI stability value.
, ** Significant at 0.05 and 0.01 levels of probability, respectively.

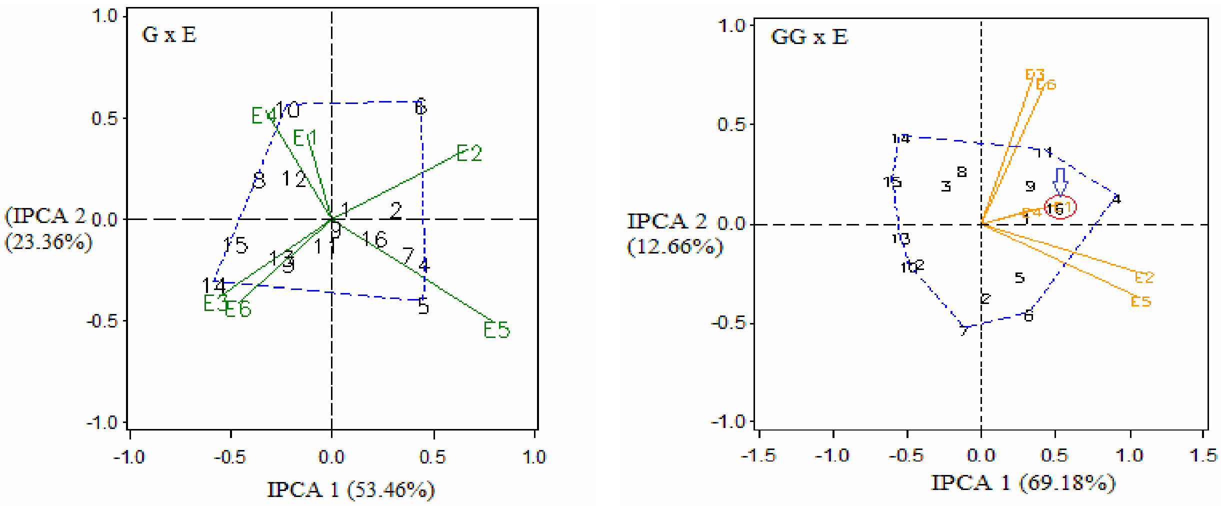

Fig. 10.Graphics display of the GE and GGE biplots for 16 wheat genotypes (assessed G1 - G16) and six environments (assessed E1- E6) in the AMMI and SREG models, respectively for biological yield (ton / fad.)

Correlation between stability parameters

The results in Table (10) showed that the mean yield for biological yield was positively correlated with linear response to environmental effects (α_i) and regression of coefficient (b_i), mean square deviations from linear regression (s^2_{di}), the deviation from linear response (λ_i) and AMMI stability value (ASV).

A rank correlation coefficient of 1.0 was found between regression of coefficient (b_i) and linear response to environmental effects (α_i). This indicated that the two procedures were equivalent for ranking purposes. Also, a rank correlation coefficient of 1.0 was found between Eberhart and Russell procedure (s^2_{di}) and Tai's (λ_i). While, regression coefficient (b_i) and linear response to environmental effects (α_i) had limited correspondence to the procedures of Eberhart and Russell (s^2_{di}), Tai's (λ_i) and ASV. The Eberhart and Russell procedure (s^2_{di}) and Tai's (λ_i) showed highly significant correspondence with the procedures of ASV ($r = 0.90^{**}$). This showed a similarity to the procedures of Eberhart and Russell (S^2_{di}), Tai (λ_i) and ASV from AMMI stability.

Nitrogen stress reduced growth and yield of wheat plants. Reducing these characters under soil fertility stress caused a great reduction in grain and biological yield. Positive correlation was found for days to 50% heading, plant height and 1000-grain weight with grain yield (0.09, 0.16 and 0.1, respectively) and biological yield (0.28, 0.29 and 0.23, respectively) under nitrogen stress. These results are in the line with those of obtained by Serrano *et al.* (2000) and Groos *et al.* (2003), they reported that a significant relationship between yield and biomass and thousand kernel weight with application of N fertilizer.

The correlation between mean ($\bar{g}$) and regression coefficient (b_i) was negative (-0.17) for days to 50% heading and positive (0.13, 0.56*, 0.16 and 0.29) for plant height, 1000-grain weight, grain yield and biological yield, respectively (Tables 7, 8 and 9).

Table 10. Spearman' rank correlation coefficients between various stability parameters for biological yield

	Mean	b_i	S^2_{di}	α_i	λ_i	ASV
Mean	1.00					
bi	0.27	1.00				
S^2_{di}	0.34	-0.12	1.00			
α_i	0.27	1.00**	-0.12	1.00		
λ_i	0.34	-0.12	1.00**	-0.12	1.00	
ASV	0.35	-0.12	0.90**	-0.12	090**	1.00

b_i= regression of coefficient and S^2_{di}= mean square deviations from linear regression, α_i= linear response to environmental effects, λ_i = the deviation from linear response and ASV =AMMI stability value.

CONCLUSION

Days to 50% heading (earliness), plant height and 1000-grain weight are major selection criteria used to develop low soil fertility tolerant genotype in newly reclaimed sandy soils.

Accordingly, the three stability methods*, i.e.* phenotypic stability, genotypic stability and AMMI, the most desired and stable genotypes were Gemmeiza 7, Sakha 93 and Line 8 for days to 50% heading; Line 2, Line 8, Gemmeiza 9 and Line 7 for plant height; Line 4, Line 7, Gemmeiza 7 and Gemmeiza 9 for 1000-grain weight and Line 1, Giza 168, Gemmeiza 9 and Misr1 for grain yield (ard/fad.) and biological yield (ton / fad.). These genotypes could be useful in wheat breeding programs for improve these traits under soil fertility stress in newly reclaimed sandy soils.

Therefore from GGE biplots, the ideal genotype was Gemmeiza 7 for days to 50% heading, Gemmeiza 10 for plant height, line 7 for 1000-grain weight, Giza 168 for grain yield and Misr 1 for biological yield. These genotypes had the most appropriate in the adverse environment conditions.

ACKNOWLEDGMENT

The author gratefully acknowledges prof. Dr. Hassan A. Awaad who gave great support and supplying eight new wheat lines used in this study.

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تحليل الثبات للتراكيب الوراثية لقمح الخبز تحت مستويات مختلفة من السماد الآزوتى

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أجريت هذه الدراسة بهدف تقييم ١٦ تركيب وراثي من قمح الخبز لصفات طرد ٥٠% من السنابل، ارتفاع النبات، وزن الالف حبة، محصول الحبوب والمحصول البيولوجي، وذلك تحت ٦ بيئات مختلفة (موسمين زراعيين خلال الاعوام ٢٠٠٩ /٢٠١٠ و ٢٠١٠ / ٢٠١١ وثلاث مستويات سماد نيتروجيني بمعدل٥٠ ، ٨٠ و ١١٠ وحده للفدان تحت ظروف الأراضي الرملية). أظهرت نتائج التحليل التجميعي وجود اختلافات عالية المعنوية بين التراكيب الوراثية تحت الدراسة وكذلك البيئات والتفاعل بين التركيب الوراثي x البيئة لجميع الصفات تحت الدراسة. أظهرت النتائج انخفاض قيم جميع الصفات تحت الدراسة تحت مستوى التسميد الآزوتي الاول والثاني مقارنة بمستوى التسميد الثالث (الامثل). أظهرت نتائج تحليل الثبات المظهري وفقا لـ Eberhart and Russel (1966) وجود اختلافات عالية المعنوية للتفاعل الخطى بين التركيب الوراثي x البيئة لجميع الصفات تحت الدراسة ، كذلك بالنسبة للتفاعل البيئة + التركيب الوراثى x البيئة. أظهرت مقاييس الثبات المظهري تميز وثبات سلوك الصنف جميزة ٧ لصفات عدد الايام حتى ظهور ٥٠% من السنابل ووزن الالف حبة ، بينما تميز الصنف جميزة ٩ بالثبات لصفات ارتفاع النبات ومحصول الحبوب والمحصول البيولوجي ، بينما أظهر الصنف مصر١ والسلالة ١ ثبات لصفات محصول الحبوب والمحصول البيولوجي .أظهرت نتائج تحليل الثبات الوراثى وفقا لـ Tai (1971) تميز الصنف جميزة ٩ بالثبات لصفات ارتفاع النبات ووزن الالف حبة ومحصول الحبوب والمحصول البيولوجي، والصنف جيزة ١٦٨ والسلالة ١ ومصر ١ لصفتي محصول الحبوب والمحصول البيولوجي وتميزت السلالة ٧ بالثبات لصفتي ارتفاع النبات ووزن الالف حبة .بينما أظهر تحليل الثبات الوراثي (AMMI) اختلافات عالية المعنوية بين التراكيب الوراثية والبيئات والتفاعل بين التركيب الوراثي x البيئة، وأوضحت نتائج التحليل أن تراكيب قمح الخبز الاكثر ثباتاً كانت سخا ٩٣ ، جميزة ٧ و السلالة ٨ لصفة عدد الايام حتى طرد ٥٠% من السنابل، والسلالة ٨ والسلالة ٢ وسدس ١ وجميزة ٩ لصفة ارتفاع النبات، وجميزة ٩ وسدس ١ وجميزة ٧ والسلالة ٤ لصفة وزن الالف حبة والسلالة ١ وجميزة ١٠ وجيزة ١٦٨ وسخا ٩٤ والسلالة ٣ لمحصول الحبوب وجيزة ١٦٨وجميزة ٩ والسلالة ١ ومصر١ وجميزة ١٠ للمحصول البيولوجي. واظهر تحليل التفاعل GGE ان التركيب الوراثى النموذجي كان جميزة ٧ لصفة عدد الايام حتى طرد ٥٠% من السنابل ، جميزة ١٠ لصفة ارتفاع النبات ، السلالة ٧ لصفة وزن الالف حبة، جيزة ١٦٨ لصفة محصول الحبوب و مصر ١ لصفة المحصول البيولوجي ، مما يشير الى أهمية هذه التراكيب الوراثية فى برامج تربية القمح لتحسين انتاجية محصول الحبوب والمحصول البيولوجي تحت ظروف إجهاد النيتروجين وضعف خصوبة التربة خاصة الأراضي المستصلحة حديثا.