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RESEARCH ARTICLE

Mean performance and stability parameters for comparing some bread wheat cultivars under different environments

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Abstract

The present study was conducted to selecting wheat stable cultivars with high productivity across various environments. Five wheat cultivars *viz*, Shandweel 1, Sids 1, Sids 12, Giza 168 and Misr 2 were grown in a randomized complete block design with four replications under sixteen environments (2 years × 2 locations × 4 sowing dates) to evaluate yield and yield components. Pooled analysis of variance for grain yield and its components revealed significant differences due to genotypes, environments, and their interactions, indicating that they varied in their responses to different environments. Highest significant grain yield across varied environments was found by Sids 12 (14.60 ardab/feddan) followed by Shandweel 1 (13.61 ardab/feddan). The cultivar Shandweel 1 was stable for grain yield and other studied traits; no. of spikes/plant, spike length and 1000-kernel weight according to stability parameters (bi near to one, S^2di non-significant, α stability value not significantly differed from zero and the λ statistic was not significantly differed from one). Meanwhile, cultivar Sids 12 were stable over all the studied environments for grain yield according to Eberhart & Russell method.

Keywords: *Triticum aestivum;* Stability parameters; Grain yield; Environments**.**

Introduction

Wheat (*Triticum aestivum* L.) is considered one of the most vital cereal crops not only in Egypt but also all over the world, supplying 20% calories and 21% of protein of the food for world population (Braun *et al.*, 2010). Climatic variability in these semiarid environments causes large annual fluctuations in yield. Environmental factors like temperature, solar radiation and rainfall play pivotal role in determining the performance of a crop cultivar. However, increases in local temperatures can generate devastating agricultural losses and can be critical if they coincide with key stages of crop development (Wollenweber et al., 2003). Also, High temperature along with low water availability at terminal growth phase of wheat crop is major contributing factor towards less wheat production in tropics and subtropics (Abdul Sattar et al., 2020). Moreover, Sowing date is an important factor that

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affects grain yield and its components of wheat (Kiss et al., 2014). The use of different sowing dates allows us to expose wheat cultivars to different atmospheric temperatures, which is considered the major environmental factor drastically reducing wheat production.

Many research workers are of the view that average high yield should not be the only criteria for genotype superiority unless its superiority in performance is confirmed over different types of environmental conditions (Qari, et al., 1990; Golmirzaie, et al., 1990; Kinyua, 1992; Liu et al., 1992). Hence, identification of genotypes with a high potential for yield and stability across environments is an essential task in plant breeding. Stability in performance of a genotype over a range of environments is a desirable attribute and depends upon the magnitude of genotype x environment interactions (GEI) (Ahmed, et al., 1996).

There are various statistical methods for describing the effects of GEI along with identifying and recommending stable genotypes in breeding programs. However, the widely used methods are those based on regression models, variance components and multivariate analysis. Two statistical methods are available for estimating phenotypic stability as proposed by Eberhart and Russell (1966) and Tai (1971). According to Eberhart and Russell (1966), the stability is expressed in terms of two parameters being the slope value (bi) and deviation from regression (S^2di) when determining the performance of one cultivar across various environments. Meanwhile, Tai (1971) in this method, environmental effects (αi) and deviation from the linear response (λi) can be regarded as special form of the regression parameters (bi) and (S^2di). The objectives of this research were to study the performance for grain yield and its components of fife bread wheat cultivars under different environments and to determine the stable cultivar across environments.

Materials and Methods

Field experiments

Two field experiments were conducted to evaluate five bread wheat cultivars; Shandwel1, Sids 1, Sids 12, Giza 168 and Misr 2 under sixteen different environments; two seasons (2017/2018 and 2018/2019), two locations (Sohag and Qena Agriculture Research Farms) and four sowing dates (November 25, December 10, December 25 & January 10). Monthly mean maximum and minimum air temperatures (ºC) during two growing seasons under two locations are presented in Table 1.

The field experiments were laid out in split plot design arranged in RCBD design with four replications. The main plots were devoted to the four sowing dates, the sub-plots were allocated to wheat cultivars. The plot area was 10.5 m^2 (15 rows, 3.5 m long and 20 cm apart). The grain yield (ardab/feddan) (feddan = 0.42 hectare) was obtained by converting plot grain yield (kg) to productivity ardab per feddan (ardab = 150 kg). All recommended cultural practices for wheat production were applied. Data were collected for number of spikes/m^2, spike length (cm), 1000-kernel weight (g), grain yield (ard./fed.) and harvest index = (Grain yield)/(Grain + straw yield).

Statistical analyses

The combined analysis was performed on the recorded data of grain yield and its components of the five cultivars over all environments according to Gomez and Gomez (1994). Means were compared by Least Significant Difference (LSD) at 5% level of significant (Steel and Torrie, 1980).

Table 1. Mean maximum and minimum air temperatures (ºC) during 2017/2018 and 2018/2019 growing seasons under two locations.

location	season	Temp.	Month					
			Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Sohag government	2017/2018	Max.	26.7	23.6	20.8	26.6	33.1	35.0
		Min.	13.2	10.0	7.7	11.7	15.6	17.7
		Max.	28.7	24.1	22.5	24.7	29.1	34.0
		Min.	13.4	8.4	6.7	8.3	11.6	16.4
Qena government	2018/2019	Max.	28.0	26.5	22.5	27.5	35.0	36.5
		Min.	13.0	11.5	7.5	11.0	16.5	18.5
		Max.	29.0	22.5	20.5	24.5	27.5	32.5
		Min.	13.0	9.0	6.5	10.0	11.5	15.0

Four parametric stability methods including: the joint regression coefficient (bi) and deviation from regression (S^{2}di) were estimated by using Eberhart and Russell's model (1966) and liner response to environmental effects, which measured by statistic (α) and the deviation from linear response, which measured by statistic (λ) were estimated by using Tai (1971).

Result and Discussion

Analysis of variance

Combined analysis of variance for number of spikes/m^2, spike length, 1000-kernel weight, grain yield and harvest index are presented in Table 4 2. Differences among environments were highly significant ($P < 0.01$) for all studied traits. The large environmental sum of squares showed that environments were diverse, with large differences among environmental means causing most of the variation in all studied traits. The five cultivars differed significantly ($P < 0.05$) for all traits over two years. The cultivars × environments interaction were significant ($P < 0.05$) for all studied traits, suggesting that there were substantial differences in cultivars response over environments.

Number of spikes/m^2:

There was significant genotypic variation for number of spikes/m^2 among the 5 bread wheat cultivars used in the stability analysis. Results indicated that Shandweel 1 had the highest mean number of spikes/m^2 (176.42 spikes/m^2), while the lowest mean number of spikes/m^2 was obtained from Misr 2 (137.88 spikes/m^2) with an average 163.06 spikes/m^2 (Table 3). According to Eberhart and Russell (1966), three cultivars (Shandweel 1, Sids 1 and Sids 12) were stable due to their b_i's and S^2d_i's did not differ from a unit and the zero, respectively plus showing high yield compared with mean over all cultivars (Table 2 and figure 1).

Table 2. Analysis of variance across cultivars and environments.

S.O. V	d.f	Mean squares				
		No. of spikes	Spike length	1000-kernel weight	Harvest index	Grain yield
Environments	15	53699.71**	12033**	1073.26**	22.58**	553.26**
Error (a)	32	108.69	0.82	8.29	11.17	2.79
Cultivars	4	11322.05**	2.06*	33.65**	16.91*	120.75**
Cult. × Env.	60	475.02**	1.42**	13.51**	10.29*	3.01**
Error (b)	128	123.10	0.79	6.69	6.64	1.89
C.V. (%)		6.82	11.55	6.69	8.89	10.98

*, ** significant at 0.05 and 0.01 level of probability, respectively.

Similar results were reported by Saqib et al. (2013), Mohamed and Said (2014) and Ibrahim and Hamada (2016), Abd El-Rady and Koubisy (2017) and Ibrahim and Said (2020). Meanwhile, Tai's stability estimates (α_i, λ_i) is shown in Table 3and figure 2, the average stability region included two cultivars (Shandweel 1 and Sids 1) within these cultivars. Moreover, Shandweel 1 gave the highest number of spikes/m^2 (176.42) over sowing dates and two location conditions. **Gomaa et al. (2018)** indicated that wheat genotypes 6 and 14 showed average degree of stability, while genotype 8 showed below average degree of stability at all probability levels for the number of spikes m^{-2}.

Mean performance and stability parameters

Numerous methods have been used to determine the stability of potential cultivars over different environments. The first description was by Eberhart and Russell (1966) proposed that an ideal genotype is the one which has the highest yield across a broad range of environments, a regression coefficient (b_i) value of 1.0 and deviation mean squares of zero, indicates less response to environmental changes, and hence showing more adaptiveness. Tai (1971) presents a method of genotypic stability analysis, in this method the G × E interaction effect of a genotype is partitioned into two components: Liner response to environmental effects, which measured by statistic (α) and the deviation from linear response, which measured by statistic (λ). A perfectly stable variety has (α, λ) = (-1, 1) and variety with average stability has (α, λ) = (0, 1).

Table 3. Mean performance and stability parameters of cultivars for no. of spikes/m^2 and spike length traits.

Genotypes	No. of spikes / m^2					Spike length (cm)				
	Mean	b_i	S^2d_i	α	λ	Mean	b_i	S^2d_i	α	λ
Shandweel 1	176.42	0.92	79.51	-0.05	1.68	8.09	0.98	0.22	-0.37	1.34
Sids 1	171.21	1.00	75.66	0.00	1.86	7.63	1.03	0.08	-0.10	1.99
Sids12	171.75	1.03	32.50	0.01	3.29*	8.23	1.66	0.17	0.40	1.90
Giza 168	158.04	1.01	178.65**	-0.01	3.18*	7.24	0.49	0.08	-0.21	1.17
Misr 2	137.88	1.04	115.38**	0.05	5.65**	7.46	0.85	0.18	0.27	0.96
Mean	163.06					7.73				
L.S.D. 0.05	4.48					0.36				

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

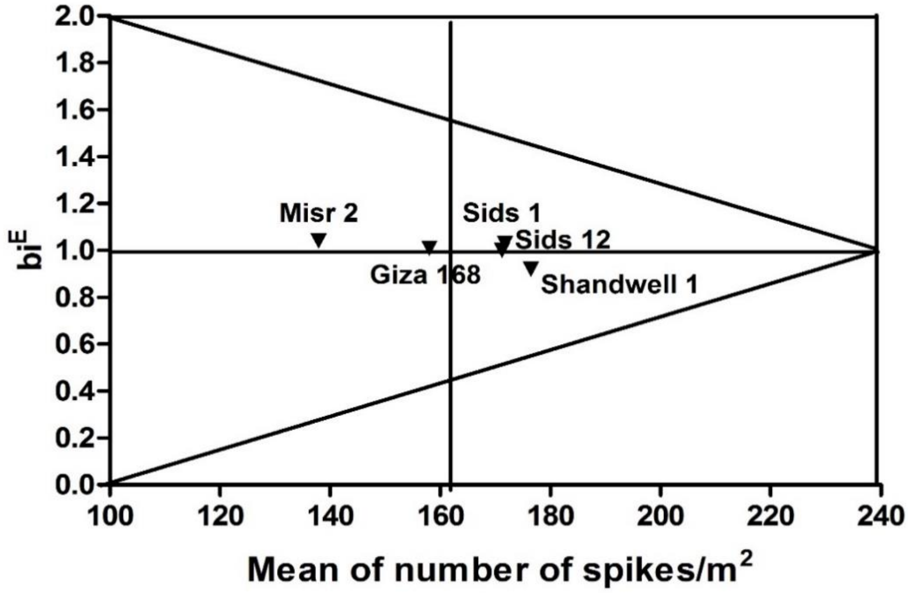

Fig. 1:. Present graphically the relationships between the stability parameters (b_i) and its mean performance of each cultivar for number of spikes/m^2.

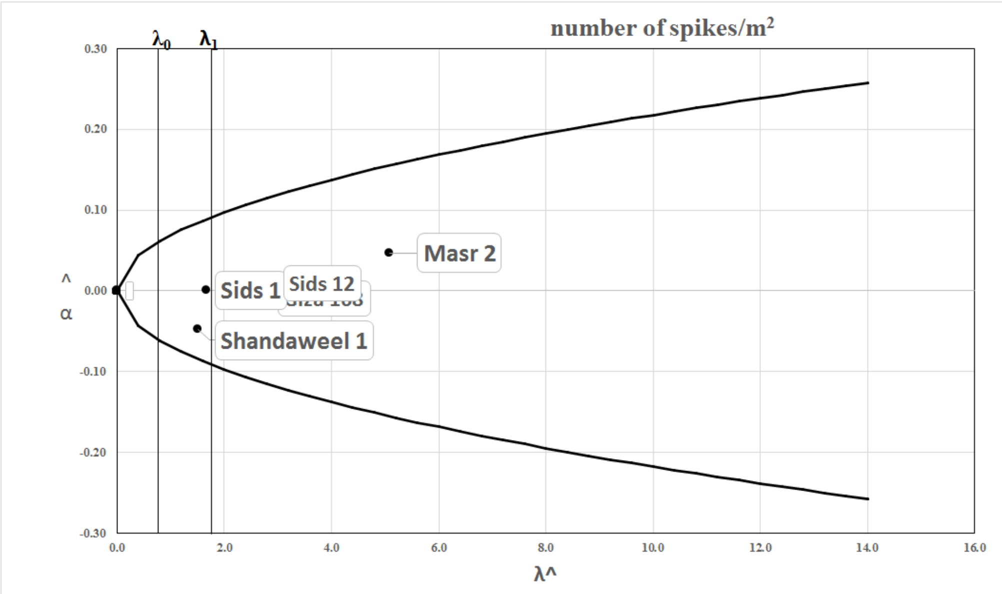

Fig. 2: Genotypic stability parameters of 5 cultivars for number of spikes/m^2.

Table 4. Mean performance and stability parameters of cultivars for1000-kernel weight and harvest index traits.

Genotype	1000-kernel weight (gm)					Harvest index (%)				
	Mean	b_i	S^2d_i	α	λ	Mean	b_i	S^2d_i	α	λ
Shandwell 1	39.47	1.09	1.93	0.06	1.66	29.25	1.08	1.65	-0.01	1.31
Sids 1	40.44	0.96	3.79	-0.02	2.00	28.86	0.63	2.35	-0.36	1.22
Sids12	38.97	0.88	4.53**	-0.05	1.56	29.67	0.57	3.29*	-0.76	1.62
Giza 168	38.95	1.04	4.19*	0.03	1.98	28.80	1.27	3.58**	0.49	2.05
Misr 2	38.84	1.02	3.08	-0.03	3.08*	28.06	1.45	3.68**	0.64	1.69
Mean	39.33					28.93				
L.S.D. 0.05	1.05					1.04				

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

Spike length:

The mean spike length ranged from 8.23 cm (Sids 12) to 7.24 cm (Giza 168) with an average of 7.73 cm (Table 5). Using the parameters, b_i and S^2d_i as selection criteria to the stability, three cultivars (Shandweel 1, Sids 1 and Masr 2) have a regression coefficient value near 1.0 and deviation not significantly different from zero. Out of them, one cultivar (Shandweel 1) has the highest spike length compared with the grand mean over sowing dates and locations (Table 3 and figure 3). Moreover, Sids 12 performed consistently better in favourable environments because the regression coefficient (bi) was more than one. Meanwhile, Giza 168 was relatively better in stress environments because bi was less than one (bi < 1). Similar results were obtained by Al-Otayk (2010) and Khan (2018).

According Tai analysis (Table 3 and figure 4), the average stability region included three cultivars (Shandawel1, Giza 168 and Masr 2).

1000 kernel weight (gm):

Means of 1000 kernel weight ranged from 38.84gm for Masr 2 to 40.44 gm for Sids 1 with an average 39.33 gm. Three cultivars (Shandweel 1, Sids 1 and Masr 2) were stable (Table 4 and Fig. 5) because the regression coefficient of this genotype equal one (b_i = 1), the deviation from regression (S^2d_i) was insignificant from zero,

two of them (Shandweel 1 and Sids 1) had a high mean of performance when compared with the mean overall cultivars. Similar results were obtained by EI-Morshidy et al. (2000), Mustăţea1 et al. (2009), El-Hosary (2011), Mohamed and Said (2014) and Ibrahim and Said (2020). According to Tai's (1971) regression coefficient (Alpha), two cultivars (Shandweel 1 and Sids 12) were in average stability region (Table 6 4 and Figure 6). Gomaa et al. (2018) revealed that the average stability for 100 kernel weight are in the figure contained genotypes 4, 7, 9, 12 and 14 with α stability values not significantly differed from zero. Also, the λ statistics were not significantly differed from λ=1 for the genotypes, indicating that they were of average stable under the studied environments.

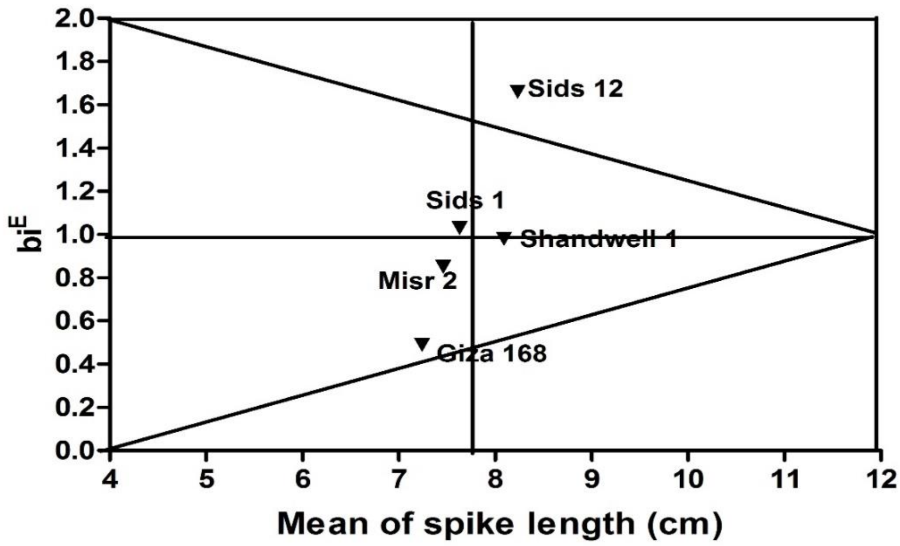

Fig. 3.Present graphically the relationships between the stability parameters (bi) and its mean performance of each cultivar for spike length.

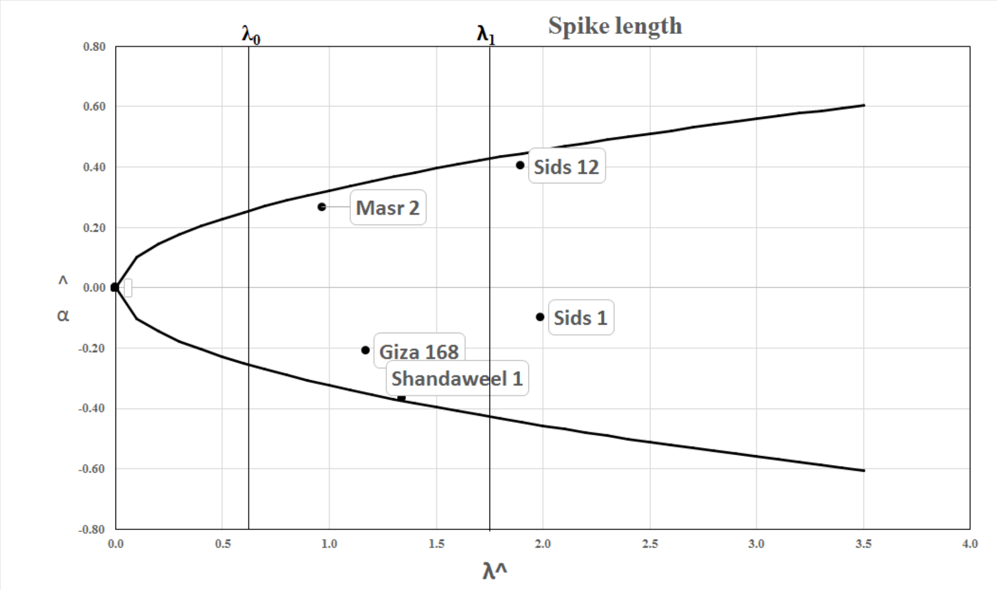

Fig. 4. Genotypic stability parameters of 5 cultivars forspike length.

Harvest index (%):

The cultivar Sids 12 gave the highest harvest index (29.67%) and Masr 2 gave the lowest harvest index (28.06%) under different environments. Based on b_i and S^2d_i values, Table 4 and figure 7 further indicates that Shandwel1 is highly stable, i.e. their bi closed unit, S^2d_i was insignificant and above the grand mean. These results are in agreement with those obtained by Salem et al. (1990), Al-Otayk (2010) and Mohamed and Said (2014). Tai's stability analysis showed that all cultivars except Giza 168 were exhibited average genotypic performance stability across over sowing dates and location conditions (Table 4 and Figure 8).

Grain yield (ardab/feddan):

The studied cultivars appeared to have a wide range of variability in average grain yield over sowing dates and locations as shown in Table 5. Mean grain yield ranged from 10.78 (Giza 168) to 14.60 ardab/feddan (Sids 12) with an average of 12.53 ardab/feddan. According to Eberhart and Russell (1966), two cultivars (Shandweel 1 and Sids 12) were stable over all the studied environments because the regression coefficient (b_i) of these cultivars closed one, the deviation from regression (S^2d_i) was insignificant from zero and a high mean when compared with the mean overall cultivars (Figure 9). Our results are in line with those obtained by EI-Morshidy et al. (2000), Kabir et al. (2009), Mustăţea et al. (2009), Koumber et. al. (2011), Hassan et al. (2013), Motawea et al. (2015), Abd El-Rady and Koubisy (2017) and Ibrahim and Said (2020). On the other hand, Tai's stability analysis showed that two cultivars namely Shandweel 1 and Misr 2 were exhibited average stability (Table 5 and Figure 6), (α, λ) = (0, 1).

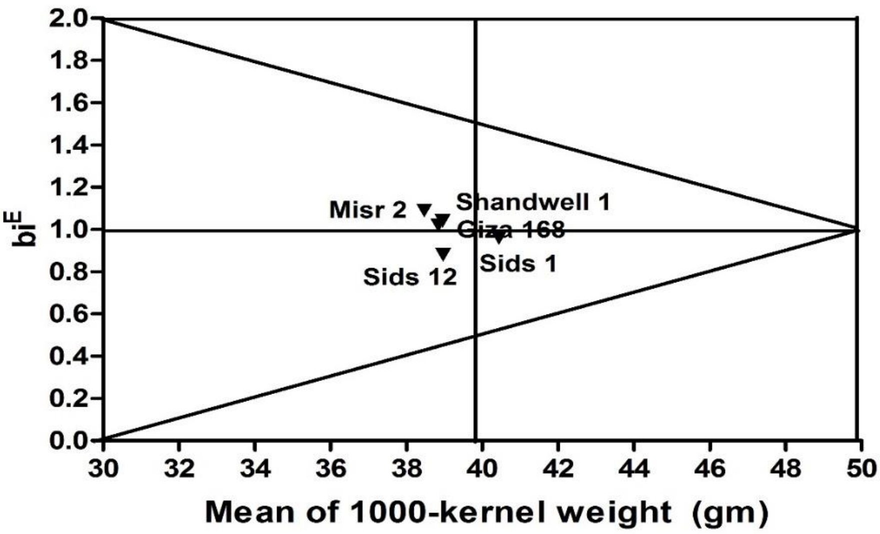

Fig. 5. Present graphically the relationships between the stability parameters (bi) and its mean performance of each cultivar for 1000 kernel weight.

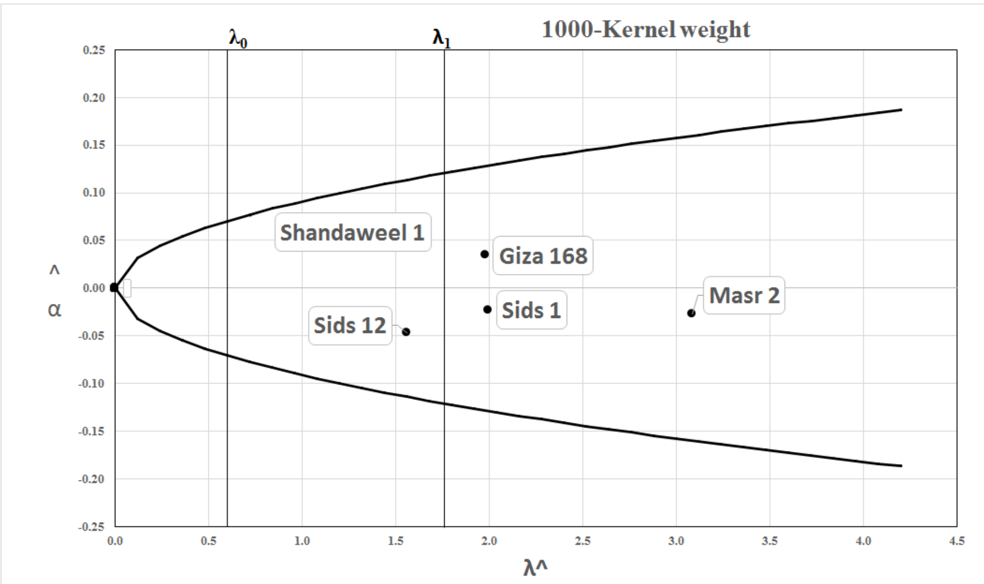

Fig. 6. Genotypic stability parameters of 5 cultivars for 1000 kernel weight.

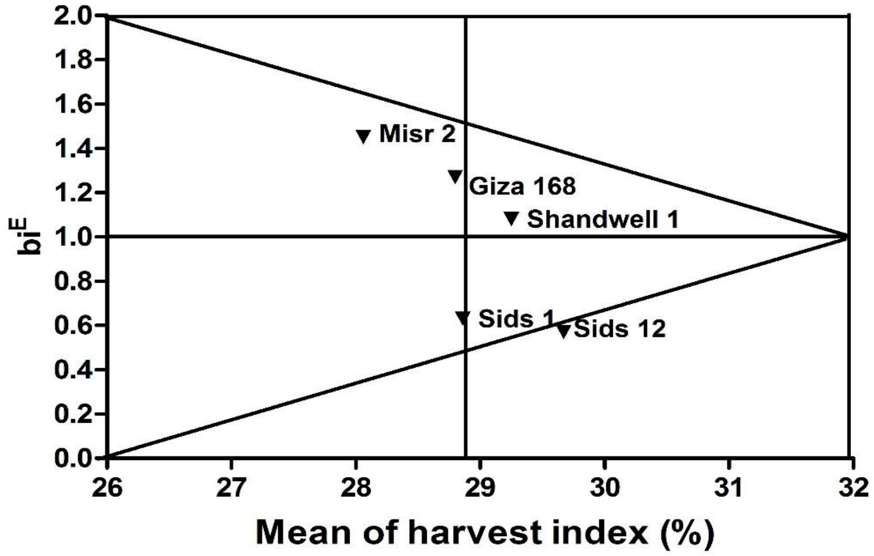

Fig. 7. Present graphically the relationships between the stability parameters (bi) and its mean performance of each cultivar for harvest index.

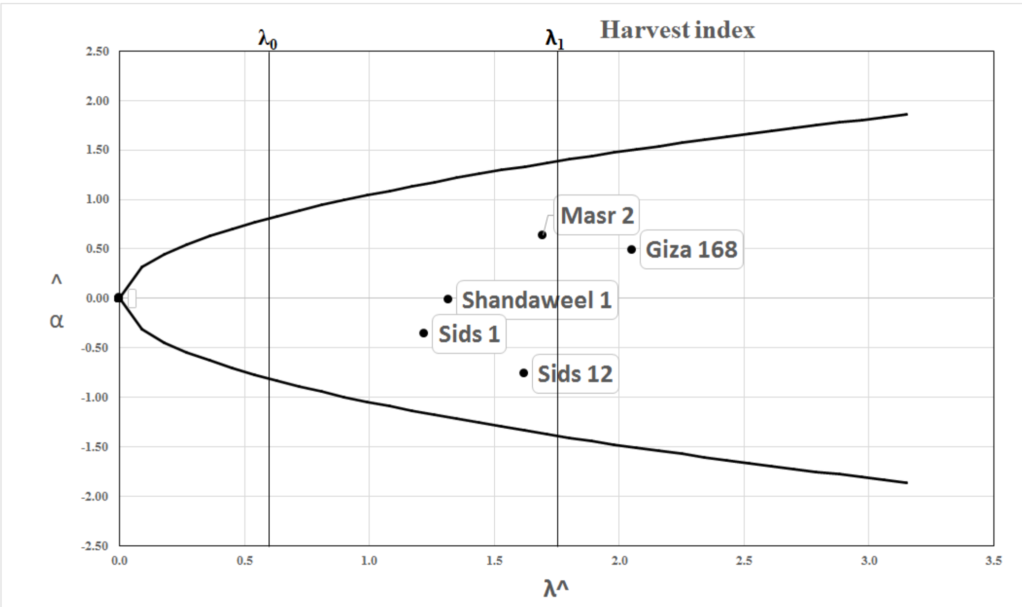

Fig. 8: Genotypic stability parameters of 5 cultivars for harvest index.

Meanwhile, Giza 168 was above average stability, (α, λ) = (-1, 1) and low mean when compared with the mean overall cultivars (figure 10). These results were in accordance with those previously reached by Gomaa et al. (2018). Correlation matrix (Table 6) showed that mean yield was highly significant and positively associated with bi ($r = 0.988^{**}$) and α ($r = 0.988^{**}$), while yield was positive but non-significant with S^2d_i ($r = 0.168^{ns}$) and λ ($r = 0.734^{ns}$). Also, the result of correlation analysis revealed that the stability parameters b_i and α for both the methods (Eberhart and Russell and Tai) were highly positive significant (r = 0.955**).

Conclusion

According to Eberhart and Russell (1966) and Tai (1971), the cultivar Shandweel 1 may be considered superior under different environmental conditions (two growing seasons, two locations and four planting dates) because it showed high mean performance for grain yield over these environments (13.61 ardab/feddan) when compared with grand mean beside acceptable stability parameters (bi near to one by 1.09, S^2d_i non-significant by 0.43,α stability value not significantly differed from zero by 0.06 and the λ statistic was not significantly differed from one by 1.14.

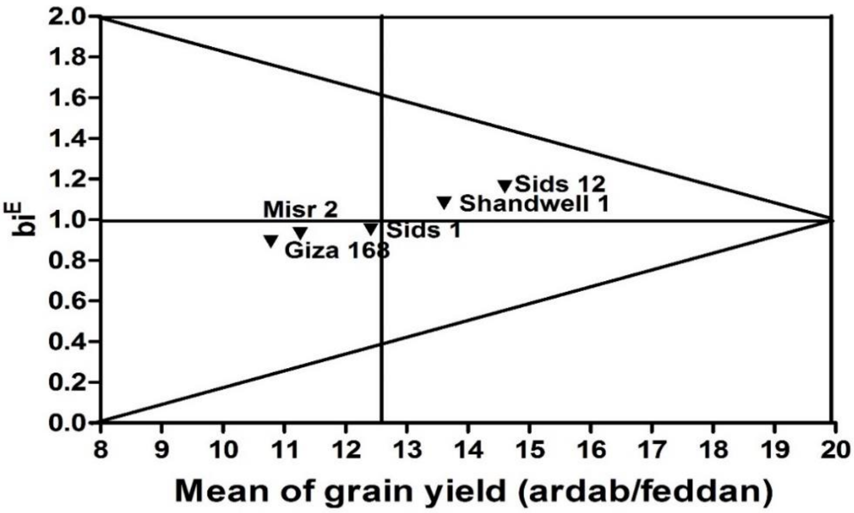

Fig. 9. Present graphically the relationships between the stability parameters (bi) and its mean performance of each cultivar for grain yield.

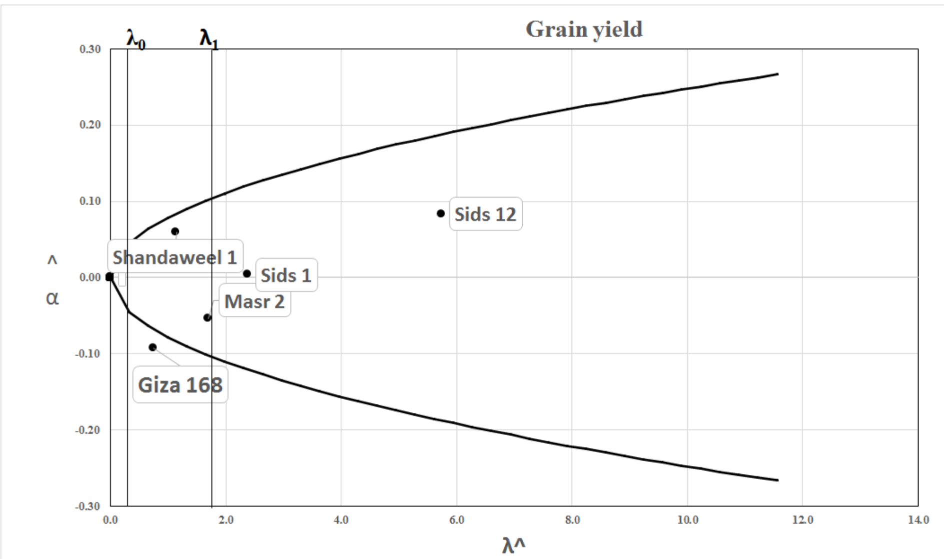

Fig. 10. Genotypic stability parameters of 5 cultivars for grain yield.

Table 5. Mean performance and stability parameters of cultivars for grain yield trait.

Genotypes	Grain yield (ardab/feddan)																				
	Environments																Stability of parameters				
	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	E_{12}	E_{13}	E_{14}	E_{15}	E_{16}	Mean	b_i	S^2d_i	α	λ
Shandweel 1	23.84	20.00	19.38	17.67	20.46	20.05	18.50	17.03	11.37	10.24	10.11	9.31	5.19	5.00	4.92	4.63	13.61	1.09	0.43	0.06	1.14
Sids 1	20.89	18.85	16.72	14.69	18.38	17.25	17.52	16.30	10.37	10.04	9.67	8.52	5.35	5.06	4.65	4.28	12.41	0.95	0.17	0.00	2.38*
Sids12	24.70	22.75	20.70	18.13	23.54	21.09	19.46	16.08	12.90	11.83	11.00	9.54	6.18	5.39	5.52	4.86	14.60	1.16	0.66	0.08	5.75**
Giza 168	18.31	17.24	14.91	14.92	15.96	15.96	14.68	14.65	7.92	7.54	7.38	6.08	4.76	4.36	3.86	3.97	10.78	0.89	0.57	-0.09	0.75
Misr 2	17.34	17.46	15.24	13.76	18.34	17.27	16.09	15.69	9.77	8.30	7.81	7.55	4.49	3.64	3.77	3.68	11.26	0.93	0.48	-0.05	1.70
Mean	**21.02**	**19.26**	**17.39**	**15.63**	**19.34**	**18.33**	**17.25**	**15.95**	**10.47**	**9.59**	**9.19**	**8.20**	**5.19**	**4.69**	**4.54**	**4.28**	**12.53**				
L.S.D 0.05	4.87	4.11	3.27	2.47	2.80	2.97	2.24	2.52	2.46	1.73	1.70	1.71	0.738	1.85	1.46	1.05	0.550				

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

Table 8. Correlation matrix among various stability parameters for grain yield in wheat.

Parameters	b_i	S^2d_i	α	λ
Yield	0.975^{**}	0.168^{ns}	0.988^{**}	0.734^{ns}
b_i	-	0.354^{ns}	0.955^{**}	0.711^{ns}
S^2d_i	-	-	0.062^{ns}	0.349^{ns}
α	-	-	-	0.655^{ns}

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

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