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Performance and Stability of some bread wheat genotypes under heat stress conditions in new land at middle and upper Egypt

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ABSTRACT

This study aimed to assess the heat tolerance of twelve bread wheat genotypes under eight different environments. Wheat genotypes were sown in two locations (Tomas, Luxor governorate, representing Upper Egypt and Alfashn in Bani Suef governorate, representing Middle Egypt) at two planting dates 25th November (recommended) and 25th December (late) during two seasons of 2018/2019 and 2019/2020. The experiment was grown in a randomized complete block design with three replications in each environment. The combined analysis of variance showed that number of spikes/m^2, number of kernels/spike, 1000-kernel weight and grain yield were significantly affected by locations, and planting dates. Parameters of phenotypic stability indicated that wheat genotypes Misr2 and Giza171 were highly adapted to recommended environments for grain yield (ton/ha) in Luxor and Bani-Suef governorates, respectively. Whereas, Misr2 and Giza168 could be grown under heat stress environments for grain yield (ton/ha) in Luxor and Bani-Suef governorates, respectively. According to GE biplot and ASV, the most desired and stable genotypes were Shandaweel 1, Line#2, Sids 14 for number of spikes/m²; Misr 2, Sids 14 ,Giza 171 for number of kernels/spike; Line#2, Shandaweel1, Misr 2, Giza 168, Giza 171 for 1000-kernel weight and Line#1, Giza168, Sids12 and Misr2 for grain yield (ton/ha).

KEYWORDS: Stability; Genotypes; Environments; Grain yield; Wheat

1. INTRODUCTION

Due to limited cultivated area in Egypt, government started big project to reclaim 1.5 million feddans to insure food security for the increasing population. Wheat is considered the most important crop and has the highest priority in state policy due to the gap between production and consumption which reached about 45%. Newly reclaimed lands will contribute largely in revealing food security for the population especial in wheat and other crops. Therefore, increasing wheat production becomes an important national target to reduce wheat imports and to save foreign currency Mohiy 2016.

The phenotypic stability is purposive for selection of wheat varieties in the breeding programs. Plant breeders confront genotype × environment interaction (G×E) when testing varieties across the different planting dates. Yield genetic gains can be increased in part from narrowing the adaptation of varieties, thus maximizing yield in particular areas by exploiting genotype × environment interaction (G× E).

G×E is importance, because it gives information about the influences of different environments on cultivar performance and has a major role for assessment of performance stability of the breeding materials Salous 2019.

Heat stress is a common abiotic stress that causes stunted plants, reduced tillering, and accelerates development leading to small heads, shriveled grains and finally low yields Tawfelis 2006 b. Temperatures accelerate organ development in few days without any increase in net photosynthesis and assimilate resulting in smaller biomass Fischer 1985 and Shpiler and Blum, 1986. Yield in stress environments depends upon susceptibility or tolerate level of grown plants. Therefore, the productive genotypes under stress conditions are the most tolerant genotypes for these conditions.

Additive Main effect and Multiplicative Interaction (AMMI) method proposed by Gauch 1992 was a significant advance in the analysis and interpretation of G×E interaction. With this method main effects (genotypes and environments) are initially accounted by a regular analysis of variance, and then the interaction (G×E) is analyzed through a principal component analysis which leads to identification of stable genotypes as well as to widely or specifically adapted genotypes in an easier manner.

AMMI has been successfully employed to estimate stability and its adaptation and G×E elucidation in different crops. Genotypes with first principal-component axis value close to zero indicate general adaptation to environments. The AMMI stability value measure was proposed by Purchase 1997 and Purchase et al., 2000. ASV is the distance from zero in a two dimensional scattergam of IPCA1 score against IPCA2. The genotype with least ASV is the most stable.

The objective of the study was to evaluate the yield and its components of twelve bread wheat genotypes in different planting dates and to determine their stability to identify the most stable genotypes under these conditions.

2. MATERIAL AND METHODS

Twelve wheat genotypes were evaluated at two different planting dates 25th November (recommended planting date) and 25th December (late planting date), at two locations in two different regions representing Middle and Upper Egypt, i.e., Tomas (Luxor) and Alfashn (Bani-Suef) and two seasons 2018/2019 and 2019/2020 under new land condition.

Combined analyses of variance over environments were conducted as outlined by Allard 1960. Stability parameter was estimated using the Eberhart and Russell, 1966 method. Two stability parameters i.e., regression coefficient (bi) and deviations from regression (s^2di) were worked out and tested by using t-test and F-test separately from the pooled analysis. The additive main effects and multiplicative interaction method (AMMI) proposed by Gauch 1992.

The experiment was laid out in a randomized complete block design (RCBD), with three replications for each planting date. Each plot consisted of 6 rows, 3 m long and 20 cm apart. All other cultural practices were applied as recommended. The measured characteristics were No. of spikes/m^2, No. of kernels/spike, 1000-kernel weight (g.) and grain yield (ton/ha.). The pedigree and origin of the studied bread wheat genotypes are presented in (Table1).

Table 1. Pedigree, selection history and origin of the twelve bread wheat genotypes used in this study.

No.	Genotypes	Pedigree and selection history	Origin
1	**Sids14**	**BOW "S"/VEE"S"//BOW"S"/TSI/3/ BANI SEWEF 1.** SD293-1SD-2SD-4SD-0SD.	EGYPT
2	**Sids12**	**BUC//7C/ALD/5/MAYA74/ON//1160-147/BB/GLL/4/CHAT "S"/6/MAYA/VUL//CMHAT6304/*SX.** SD70964-SD-1SD-1SD-0SD.	EGYPT
3	**Misr1**	**OASIS/KAUZ//4*BCN/3/2*PASTOP.** CMss00Y01881T-050M-030Y-030M-030WGY-33M-0Y-0S.	EGYPT
4	**Misr2**	**SKAUZ/BAV92.** CMss96M03611S-1M-0105Y-010M-010SY-8M-0y-0S.	EGYPT
5	**Shandaweel1**	**SITE/MO/4/NAC/TH.AC//3*PVN/3/MIRLO/BUC.** CMss93B00567S-72Y-010M-010Y-010M-3Y-0M-0THY-0SH.	EGYPT
6	**Gemmeiza11**	**Bow"s"/Kz"s"//7C/aeri 82/3/Giza 168/Sakha 61.** GM78922-GM-1GM-2GM-1GM-0GM.	EGYPT
7	**Gemmeiza12**	**OTUS /3/ SARA / THB // VEE.** CMSS97Y00227S-5Y-010M-010Y-010M-2Y-1M-0Y-0GM.	EGYPT
8	**Giza171**	**Sakha 93/Gemmeiza 9.** Gz 2003-101-1Gz-4Gz-1Gz-2Gz-0Gz.	EGYPT
9	**Sakha94**	**OPATA/RAYON//KAUZ.** CMBW90Y3180-0TOPM-3Y-010M-010M-010Y-10M-015Y-0Y-0AP-0S.	EGYPT
10	**Giza168**	**MRL/BUC //SERI.** CM93046-8M-0Y-0M-2Y-0B-0SH.	EGYPT
11	**Line #1**	**TRAP#1/BOW//PFAU/3/MILAN/4/ETBW4922/5/PFAU/MILAN.** ICW08-50397-6AP-0AP -040SD-4SD -0SD.	ICARDA (ESBWTT-YP) 2017/2018
12	**Line #2**	**ALMAZ-26/ETBW4921/4/URES/BOW// OPATA/3/ HD2206/HORK'S'.** ICW08-50311-7AP-0AP -040SD-2SD -0SD.	ICARDA (ESBWTT-YP) 2017/2018

Mean daily maximum and minimum temperatures from planting to booting (SB1), booting to heading (BH2) and heading to maturity (HM3) of recommended and late planting dates are given in (Table 2).

The difference in the maximum temperatures at Luxor location between the late and recommended planting dates were - 4.10 ºC, 4.76 ºC and 5.19 ºC in SB1, BH2 and HM3 respectively. In Bani-Suef location, they were – 3.73 ºC, 4.50 ºC and 4.45 ºC in SB1, BH2 and HM3, respectively.

Table 2. Climate information includes temperature in recommended and late planting dates at Luxor and Bani-Suef locations during two seasons.

Location	Month	Season			
		2018/2019		2019/2020	
		Max	Min	Max	Min
Tomas	**November**	28.03	14.91	30.56	16.84
Alfashn		25.64	16.63	27.14	18.08
Tomas	**December**	21.87	9.46	23.83	9.65
Alfashn		20.93	14.19	20.47	12.43
Tomas	**January**	20.78	7.24	20.65	7.67
Alfashn		18.14	9.58	17.08	10.04
Tomas	**February**	24.12	10.30	23.61	9.72
Alfashn		21.16	11.81	20.10	11.77
Tomas	**March**	27.25	12.63	28.90	14.73
Alfashn		22.60	13.65	22.92	13.78
Tomas	**April**	32.63	17.52	32.73	18.83
Alfashn		25.94	14.69	26.86	16.36
Tomas	**May**	40.09	24.18	38.32	23.60
Alfashn		34.55	21.09	32.19	19.87

Locations	Planting Dates	Planting to Booting (SB1)		Booting to Heading (BH2)		Heading to Maturity (HM3)	
		Max	Min	Max	Min	Max	Min
Tomas	**25th November**	27.22	12.04	23.38	13.66	32.46	17.91
	25th December	23.12	8.28	28.14	16.54	37.65	22.55
Alfashn	**25th November**	24.00	13.00	21.19	12.00	29.55	16.00
	25th December	20.27	9.62	25.69	14.49	34.00	19.63

Tomas (Luxor governorate): 25˚17'40"N 32˚33'01"E
Alfashn (Bani-Suef governorate): 28˚49'19"N 30˚53'58"E

3. RESULTS AND DISCUSSION

Heat stress determines wheat growth and reduces productivity per unit area. Data showed variation of the temperature over the two seasons. Temperatures at different growing stages of the same planting date were unstable in the two seasons. In addition, temperature fluctuates with different locations and growing seasons during plant growth stages.

3.1. Analysis of variance:

The analysis of variance (Table 3) revealed highly significant differences between environments and genotypes for all studied characters. Results explained the large differences in climate conditions with different locations and growing seasons. The results showed that genotypes differently responded to the different environmental conditions which suggest the importance of the assessment of genotypes under different environments to identify the best genotype for a certain environment.

The interaction of environments x genotypes was highly significant effect for number of kernels/spike and grain yield, and significant effect was found for number of spikes/m^2 and 1000-kernel weight, indicating the different influences of climatic conditions on planting dates. These results were obtained by El-Morshidy et al., 2001, Abd El-majeed et al., 2005, Tawfelis 2006a and Menshawy 2007.

Table 3. Combined analysis of variance mean squares for grain yield and its components.

S.O.V	d.f	M.S			
		No. of spikes/m^2	No. of kernels/spike	1000 - kernel weight (g)	Grain yield (ton/h)
Environment	7	250737.633**	2707.960**	2460.435**	33.451**
Error (a)	16	1353.618	21.510	24.033	1.213
Genotype	11	5396.665**	254.622**	92.578**	1.541**
Env x Gen	77	643.895*	51.839**	15.871*	0.692**
Error	176	448.845	26.984	10.965	0.293

*P<0.05, ** P<0.01

3.2. Genotypes Performance:

Planting at the recommended date increased all studied characters. Number of spikes/m^2, number of kernels/spike, 1000-kernel weight (g) and grain yield (ton/ha), characters were increased under Luxor and Bani-Suef locations. These results indicated that genotypes responded differently when grown under different environments.

3.2.1. Number of spikes m^{-2}

Means of number spikes m^{-2} of the twelve genotypes at each of the eight environments are given in Table 4. Analysis of variance (Table 3) revealed highly significant differences between environments and genotypes. Significant variation in number spikes/m^2 among wheat genotypes were under recommended and late planting dates averaged over twelve genotypes and the environmental mean ranged from 250 for E4 to 492 spike for E7 indicating that a wide range of variation.

Number of spikes/m^2 decreased by 29.32% and 26.53% by delaying planting date under Luxor and Bani-Suef locations, respectively. Heat stress reduced the size of plant organs such as leaves, tillers, and spikes are reduced **Tawfelis 2006a, Seleem 2007** and **Mohiy 2016.** The mean of maximum temperature in Luxor and Bani-Suef at the beginning of wheat growth stages ranged between 21.9 - 23.9 and 20.4 - 21 C^o, respectively, while average of minimum temperature ranged from about 9.46 - 9.65 and 12.4 – 14.19 C^o under Luxor and Bani-Suef locations, respectively, (Table 2). **Fischer 1985** reported that mean temperature of 16-20 C^o is favorable for crown root initiation and tillering development in hot environments. Therefore, the number of spikes / m^2 was affected due to the heat stress imposed on late period of life span. These results suggest that the reduction of spike number may be due to failure of fertilization process or the high mortality rate of young spikes because of the heat stress.

Table 4. Average of number of spikes/m^2 for the twelve wheat genotypes across the eight environments.

Genotypes	Environments								Mean
	E1	E2	E3	E4	E5	E6	E7	E8	
	L1S1D1	L1S1D2	L1S2D1	L1S2D2	L2S1D1	L2S1D2	L2S2D1	L2S2D2	
Sids 14	338	225	328	220	454	365	497	410	**355**
Sids 12	369	253	351	243	445	358	486	400	**363**
Misr 1	387	281	377	275	487	392	535	441	**397**
Misr 2	395	289	383	277	449	361	485	399	**380**
Shandaweel 1	381	275	372	271	463	372	506	416	**382**
Gemmeiza 11	343	231	337	230	455	366	478	393	**354**
Gemmeiza 12	359	251	345	244	427	343	490	403	**358**
Giza 171	391	279	377	273	432	347	463	381	**368**
Sakha 94	333	219	327	216	438	352	478	393	**345**
Giza 168	381	276	367	273	408	328	489	402	**366**
Line #1	364	259	351	248	428	344	512	421	**366**
Line #2	356	237	343	230	420	337	480	395	**350**
Average	**366**	**256**	**355**	**250**	**442**	**355**	**492**	**405**	**365**
L.S.D 0.05%									
Environments	**18.38**								
Genotypes	**12.18**								
Env x Gen	**34.44**								

L1 (Tomas - Luxor). **S1 (First season).** **D1 (Recommended swing date).**
L2 (Alfashn Bani-Suef). **S2 (Second season).** **D2 (Late sowing date).**

3.2.2. Number of kernels spike-1

Data (Table 5) shows the means of number of kernel spike^{-1} of the twelve genotypes at each of the eight environments. The mean of genotypes ranged from 41 for Sids 12 and Gemmeiza 12 to 50 for Misr 2, while the mean of environments ranged from 34 for E2 and E4 to 57 for E7.

Late planting date reduced number of kernels/spike compared to recommended planting date under Luxor and Bani-Suef locations. It might be due to high temperature during the reproductive phase which can cause pollen sterility and adverse effects on floral organs (Table 2), consequently, decreased number of grain per spike Prasad et al., 2008. Similar results were reported by Seleem 2007 and Mohiy 2016.

3.2.3. 1000 - kernel weight (g)

The performance of the studied genotypes in the eight environments for 1000-kernel weight is presented in (Table 6). Highest 1000- kernel weight was 54.87g for Giza171, under the recommended planting date at Bani-Suef location (E7), and the lowest was 22.78g for line#1 under late planting date at Luxor location (E4). Recommended planting date increase 1000-kernel weight by 25.23 (E1-E2) and 19.65% (E5-E6) compared to late planting date at Luxor and Bani-Suef locations, respectively.

High temperatures during grain filing period under late planting date reduced 1000- kernel weight which resulted in shrinked grains (Table 2). This may be due to high temperatures affecting the grain maturity which resulted in shrinked kernels. Similar results were found by, Menshawy (2007).

Table 5. Average of number of kernels/spike for the twelve wheat genotypes across the eight environments.

Genotypes	Environments								Mean
	E1 L1S1D1	E2 L1S1D2	E3 L1S2D1	E4 L1S2D2	E5 L2S1D1	E6 L2S1D2	E7 L2S2D1	E8 L2S2D2	
Sids 14	51	42	49	41	56	45	60	50	**49**
Sids 12	40	30	39	33	49	40	54	45	**41**
Misr 1	43	36	40	34	67	54	54	44	**47**
Misr 2	48	40	47	39	64	51	62	51	**50**
Shandaweel 1	42	35	37	31	49	40	54	45	**42**
Gemmeiza 11	38	31	33	27	58	47	63	52	**44**
Gemmeiza 12	41	33	37	30	48	38	55	46	**41**
Giza 171	46	36	42	35	53	43	59	49	**45**
Sakha 94	35	26	36	29	61	49	58	48	**43**
Giza 168	44	36	43	38	65	52	56	46	**48**
Line #1	39	31	34	28	58	47	55	46	**42**
Line #2	46	36	45	38	43	35	49	41	**42**
Average	**43**	**34**	**40**	**34**	**56**	**45**	**57**	**47**	**45**
L.S.D 0.05%									
Environments	**2.32**								
Genotypes	**2.99**								
Env x Gen	**8.44**								

L1 (Tomas - Luxor). **S1 (First season).** **D1 (Recommended swing date).**
L2 (Alfashn Bani-Suef). **S2 (Second season).** **D2 (Late sowing date).**

3.2.4. Grain yield (ton/ha)

The differences between genotypes as well as between environments were highly significant (Table 3). Average grain yield of genotypes in different environments is shown in (Table7). All genotypes exhibited higher grain yield (yield potential) in the non-stress environment than the stress environments. Mirs2 genotype grown in Luxor location gave the highest grain yield 5.420 (E1) and 4.093 (E2) ton/ha under the recommended and late planting dates, respectively. On the other hand at Bani-Suef location the highest grain yield was 7.083 ton/ha for Gemmeiza12 under the recommended planting date (E7) and 5.833 ton/ha for the same genotype under late planting date (E8). Looking at the reduction percentage of grain yield, we find that late planting date reduced grain yield by 30.21 (E3-E4) and 17.72%

Table 6. Average of 1000-kernel weight (g) for the twelve wheat genotypes across the eight environments.

Genotypes	Environments								Mean
	E1 L1S1D1	E2 L1S1D2	E3 L1S2D1	E4 L1S2D2	E5 L2S1D1	E6 L2S1D2	E7 L2S2D1	E8 L2S2D2	
Sids 14	38.61	28.56	36.95	27.28	39.65	31.89	44.17	36.43	**35.44**
Sids 12	32.89	26.29	31.86	24.77	48.32	38.82	51.85	42.65	**37.18**
Misr 1	36.77	27.22	35.51	26.33	42.72	34.34	45.56	37.51	**35.75**
Misr 2	37.54	29.91	34.81	27.23	45.11	36.26	47.98	39.44	**37.29**
Shandaweel 1	34.41	26.86	33.08	24.88	46.43	37.30	51.07	42.03	**37.01**
Gemmeiza 11	41.49	30.34	39.16	29.08	44.76	35.93	49.15	40.42	**38.79**
Gemmeiza 12	33.49	25.41	32.11	24.58	48.92	39.30	51.12	42.03	**37.12**
Giza 171	38.90	29.76	37.57	28.39	52.60	42.25	54.87	45.15	**41.19**
Sakha 94	31.91	24.02	31.12	22.79	47.18	37.93	50.23	41.32	**35.81**
Giza 168	36.41	25.39	36.20	25.28	50.52	40.60	50.49	41.62	**38.31**
Line #1	34.94	24.41	33.69	22.78	39.40	31.68	44.59	36.74	**33.53**
Line #2	37.34	26.85	35.80	27.56	47.73	38.32	52.45	43.24	**38.66**
Average	**36.23**	**27.09**	**34.82**	**25.91**	**46.11**	**37.05**	**49.46**	**40.72**	**37.17**
L.S.D 0.05%									
Environments	**2.45**								
Genotypes	**1.90**								
Env x Gen	**5.38**								

L1 (Tomas - Luxor). **S1 (First season).** **D1 (Recommended swing date).**
L2 (Alfashn Bani-Suef). **S2(Second season).** **D2 (Late sowing date).**

Table 7. Average of grain yield (ton/ha) for the twelve wheat genotypes across the eight environments.

Genotypes	Environments								Mean
	E1 L1S1D1	E2 L1S1D2	E3 L1S2D1	E4 L1S2D2	E5 L2S1D1	E6 L2S1D2	E7 L2S2D1	E8 L2S2D2	
Sids 14	4.627	3.153	4.490	2.963	6.324	5.081	6.067	4.943	**4.706**
Sids 12	4.703	3.233	4.597	3.107	4.595	3.721	5.703	4.707	**4.296**
Misr 1	5.160	3.897	5.007	3.433	5.331	4.304	5.080	4.180	**4.549**
Misr 2	5.420	4.093	5.270	3.797	5.623	4.526	6.290	5.170	**5.024**
Shandaweel 1	4.280	3.400	4.150	3.213	6.171	4.957	6.523	5.367	**4.758**
Gemmeiza 11	4.077	3.097	3.890	2.857	6.185	5.484	5.483	4.513	**4.448**
Gemmeiza 12	4.360	3.187	4.160	2.970	6.303	5.054	7.083	5.833	**4.869**
Giza 171	5.390	3.707	5.243	3.570	5.192	4.151	5.760	4.753	**4.721**
Sakha 94	4.073	2.963	3.927	2.860	5.873	4.693	6.153	5.067	**4.451**
Giza 168	5.133	3.350	4.833	3.260	6.484	5.220	5.510	4.533	**4.790**
Line #1	4.187	3.220	4.040	2.670	5.692	4.554	5.693	4.700	**4.345**
Line #2	4.713	3.290	4.553	3.100	5.665	4.526	4.283	3.520	**4.206**
Average	**4.677**	**3.383**	**4.513**	**3.150**	**5.787**	**4.689**	**5.802**	**4.774**	**4.597**
L.S.D 0.05%									
Environments	**0.550**								
Genotypes	**0.311**								
Env x Gen	**0.880**								

L1 (Tomas - Luxor). **S1 (First season).** **D1 (Recommended swing date).**
L2 (Alfashn Bani-Suef). **S2 (Second season).** **D2 (Late sowing date).**

(E7-E8) compared to recommended planting date under Luxor and Bani-Suef locations, respectively.

These results indicated that delayed planting decreased grain yield due to the optimum environmental factors dominating in the recommended planting date compared to late planting and consequently plants became more efficient in utilizing growth factors such as nutrients, water and light which was reflected in growth with high yielding potential. Guilioni et al., 2003 and Tawfelis 2006a.

3.3. Regression analysis:

Stability analysis of variance of wheat grain yield and its components (Table 8) indicated highly significant mean squares of wheat genotypes for all studied characters. The GxE interaction was further partitioned into linear and non-linear (pooled deviation) components. Highly significant environment + (genotype x environment) component and environment "linear" mean squares were recorded for all studied characters, showed that the studied characters were highly affected by the combination of environmental components (seasons, locations and planting dates). Highly significant environment "linear" interactions were shown for number of spikes/m², number of kernels/spike, 1000-kernel weight and grain yield.

Linear interaction (GxE linear) was highly significant when tested against pooled deviation for number of spikes m^{-2}, number of kernels $spike^{-1}$, 1000 - kernel weight and grain yield, suggesting that differences in linear response among genotypes across environments had occurred, and the linear regression and the deviation from linearity were the main components for differences. Non-linear responses were highly significant for number of spikes m^{-2}, number of kernels $spike^{-1}$ and 1000 - kernel weight, revealing that differences in linear response between genotypes overall environments did not account for all the GxE interaction effects, so that, the difference in the performance of genotypes in different environments was not fully predictable. Previous reports Al-Otayk 2010, Arian et al., 2011, Hassan et al., 2013, Abdel-Shafi et al., 2014 and Mohiy 2016.

According to the definition of Eberhart and Russell (1966), a stable genotype is one with a high mean performance, unit regression coefficient (bi=1) and deviation from regression equal to zero (S2di =0).

Table 8. Joint regression analysis of variance for grain yield and its components of twelve bread wheat genotypes over eight environments.

S. O. V	d . f	Mean squares (M.S.)			
		No. of spikes/m^2	No. of kernels/spike	1000 - kernel weight (g)	Grain yield (ton/ha)
Genotypes	**11**	1799.12**	84.52**	30.90**	0.51**
Env. + G x Env.	**84**	7161.03**	91.06**	73.20**	1.14**
a- Env.(linear)	**1**	585007.9**	6316.75**	5741.00**	78.05**
b- G x Env. (linear)	**11**	705.47**	53.13**	19.30**	0.47**
c- pooled dev.	**72**	121.65**	10.39**	2.70**	0.17
Pooled error	**176**	149.81	9.00	3.70	0.097

3.3.1. Number of spikes/m^2

Results in (Table 9) indicated that Sids12, Shandaweel1, Giza171, Line #1 and Line #2 genotypes were high mean performance and gave bi and S2di did not differ significantly from a unit and the zero, respectively, indicating that these genotypes may be considered as stable for number of spikes/m2 when compared with grand mean. The other genotypes were unstable (bi was significant from unity and/or S2d was significant from zero). The most desired and stable genotypes can be considered when their regression coefficient equal one (bi=1) with lower values of S2di Eberhart and Russell, 1966. Our results are in line with those obtained by Tawfelis., et al 2010, Mohamed and Said, 2014 and Salous 2019.

3.3.2. Number of kernels/spike

Three genotypes; Misr2, Giza168 and Giza171 (Table 9) have high average and insignificant bi and S^2d from unity and the zero, indicating that these genotypes may be considered as stable for such trait. The other genotypes were unstable because bi was significant from unity and/or S^2d was significant from zero. Misr2 and Giza168 were stable and performed better in recommended environments (bi>1), while Giza171 was stable and performed better in unrecommended environment and considered specially adapted to heat. These results accepted with Tawfelis et al., 2010, Mohiy 2016 and Salous 2019.

3.3.3. 1000-kernel weight (g)

Regarding the 1000-kernel weight, results in (Table 10) revealed that four genotypes Misr1, Shandaweel1, Giza171 and Line #2 exhibited insignificant stability parameters from unity and from zero for the regression coefficient (bi) and deviation from regression (S^2d), respectively. Additionally, the same genotypes were the most desired genotypes for 1000-kernel weight and showed high mean performance when compared with grand mean beside their stability, El-Ameen 2012, and Mohiy 2016.

Table 9. Stability parameters for number of spikes / m^2 and Number of kernels / spike of twelve bread wheat genotypes under eight environments.

Genotypes	No. of spikes / m^2			No. of kernels / spike		
	Mean	bi	S²d	Mean	bi	S²d
Sids 14	354.45	1.18**	47.84	49.15	0.70**	1.43
Sids 12	363.12	1.01	132.01	41.23	0.89	4.95
Misr 1	397.04	1.09**	99.52	46.41	1.13	19.77**
Misr 2	379.66	0.85**	33.94	50.14	1.01	7.74
Shandaweel1	381.98	1.15	139.95	41.59	0.86*	4.19
Gemmeiza11	354.22	1.08**	50.68	43.53	1.47**	2.92
Gemmeiza12	357.88	0.96	122.69	40.97	0.91	2.45
Giza 171	367.96	1.25	70.66	45.32	0.92	3.94
Sakha 94	344.60	1.12**	36.74	42.89	1.48**	5.77
Giza 168	365.49	0.84**	177.39*	47.61	1.04	3.89
Line #1	365.91	1.04	3.83	42.31	1.25**	3.16
Line #2	349.61	1.02	123.50	41.49	0.33**	12.21*
Average	**365.16**	**----**	**----**	**44.39**	**----**	**----**
LSD 0.05	**10.12**	**----**	**----**	**2.48**	**----**	**----**

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

3.3.4. Grain yield (ton/ha)

In consideration to the stability parameters bi and S^{2}d, out of the twelve genotypes, six genotypes were stable overall the studied environments; i.e. their bi and S^{2}di were insignificant and presented in (Table 10). The other genotypes were unstable (bi was significant from unity and /or S^{2}di was significant from zero). Four out of six genotypes had grain yield above the grand mean. According to ascending orders of yields to these genotypes were Misr2, Giza168, Shandaweel1 and Sids14 (5.024, 4.791, 4.758 and 4.706 ton/ha), respectively. However, Gemmeiza12 and Giza171 gave reasonable mean yield but had high value of bi and S^{2}di than the remaining genotypes, which make their performance unpredictable under varying environments and thus less stable. The most desired and stable genotypes can be considered when their regression coefficient equal one (bi=1) with lower values of S^{2}di Eberhart and Russell, 1966. Accordingly in this study four genotypes Misr2, Giza168, Shandaweel1 and Sids14 were considered as desired and stable for grain yield when compared to grand mean. These results are in line with those obtained by Tawfelis et al., 2010, Abd El-Shafi et al., 2014, Mohiy 2016 and Salous 2019.

Table 10. Stability parameters for 1000 - kernel weight (g) and Grain yield (ton/ha) of twelve bread wheat genotypes under eight environments.

Genotypes	1000 - kernel weight (g)			Grain yield (ton/ha)		
	Mean	bi	S²d	Mean	bi	S²d
Sids 14	35.44	0.63**	3.20	4.706	1.24	0.09
Sids 12	36.92	1.18**	0.26	4.296	0.78**	0.13*
Misr 1	35.75	1.05	2.14	4.549	0.60**	0.07
Misr 2	37.29	0.84**	2.87	5.024	1.08	0.09
Shandaweel 1	37.01	1.10	2.47	4.758	1.21	0.05
Gemmeiza 11	38.79	0.79**	1.07	4.448	1.14	0.17
Gemmeiza 12	37.12	1.19**	0.39	4.868	1.44**	0.17*
Giza 171	41.18	1.16	2.78	4.721	0.72**	0.12*
Sakha 94	35.81	1.21**	0.54	4.451	1.23**	0.01
Giza 168	38.31	1.16**	0.86	4.791	1.06	0.05
Line #1	33.53	0.86**	0.71	4.344	1.09	0.06
Line #2	38.66	1.08	3.09	4.197	0.70**	0.25**
Average	**37.15**	**----**	**----**	**4.596**	**----**	**----**
LSD 0.05	**1.58**	**----**	**----**	**0.258**	**----**	**----**

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

3.4. Additive main effects and multiplicative interaction method (AMMI)

(Table 11) show mean squares (M.S.) from AMMI analysis for grain yield and its components of twelve bread wheat genotypes across eight environments. The analysis of variance of AMMI revealed that environments (E), genotypes (G) and the GxE interaction were highly significant for the studied characters. Also, the AMMI analysis of variance showed 44.85, 63.18, 36.14 and 67.58% of the total sum of squares were attributable to environmental effects, 20.15, 15.12, 32.15 and 9.27% to genotypic effects and 27.12, 38.15, 19.20 and 16.35% to GEI effects for number of spikes/m², number of kernels/spike, 1000-kernel weight and grain yield, respectively. This result indicates that the contribution of environmental effect was much higher than the effect of genotype for the variation in grain yield, possibly due to environmental variation. This suggests that environments of the current study can be sub-grouped into mega environments.

The genotype x environment interaction (GEI) was portioned into two interaction principle components analysis axis (IPCA) for grain yield and its components. The results showed that these two IPCAs were highly significant. IPCA1 and IPCA2 accounted for 78.84 and 19.01% for number of spikes/m², 73.46 and 21.91% for number of kernels/spike, 90.69 and 5.30% for 1000-kernel weight and 64.92 and 31.45% for grain yield, respectively. The two IPCAs represent 97.85, 95.37, 95.99 and 96.37% of the interaction variation for number of spikes/m², number of kernels/spike, 1000-kernel weight and grain yield, respectively. Similar trends were detected by Mohamed 2009, Aktas, 2016 and Ferhat et al., 2019.

Table 11. Mean squares (M.S.) from AMMI analysis for grain yield and its components of twelve bread wheat genotypes across eight environments.

S.O.V	D.f	No. of spikes / m^2			No. of kernels / spike		
		S.S	M.S	%	S.S	M.S	%
Environment (E)	**7**	1755024	250718**	44.85	18950	2707.2**	63.18
Genotype (G)	**11**	59371	5397**	20.15	2789	253.6**	15.12
G x E	**77**	49557	644**	27.12	3998	51.9**	38.15
IPCA1	**17**	39071	2298**	78.84	2937	172.8**	73.46
IPCA2	**15**	9419	628**	19.01	876	58.4**	21.91
G x E Residuals	**45**	1066	24		185	4.1	
Pooled Error	**176**	79101	449		4752	27.0	
S.O.V	**D.f**	**1000-kernel weight (g)**			**Grain yield (ton/ha)**		
		S.S	**M.S**	**%**	**S.S**	**M.S**	**%**
Environment (E)	**7**	17223	2460.4**	36.14	234.20	33.452**	67.58
Genotype (G)	**11**	1018	92.6**	32.15	17.00	1.542**	9.27
G x E	**77**	1222	15.9**	19.20	53.30	0.692**	16.35
IPCA1	**17**	1108	65.2**	90.69	34.60	2.035**	64.92
IPCA2	**15**	65	4.3**	5.30	16.80	1.117**	31.45
G x E Residuals	**45**	49	1.10		1.90	0.043	
Pooled Error	**176**	1930	11.0		51.5	0.293	

The AMMI stability value measure was proposed by Purchase 1997 and Purchase et al., 2000. ASV is the distance from zero in a two dimensional scatter gam of IPCA1 score against IPCA2, genotype with least ASV is the most stable.

For number of spikes/m² (Table12 and Figure 1), most stable genotypes were Shandaweel1, Line #2, Sids14 and Gemmeiza12 with high yield potential, whereas genotypes Line #1, Misr1 and Gemmeiza11 were partially stable, from them Misr 1was high yield potential, whereas Gemmeiza11 and Line #1 were moderate one. Otherwise, wheat genotypes Sakha94, Misr2, Giza168, Sids12 and Giza171 were unstable and affected by different environments.

With regard to number of kernels/spike (Table 12 and Figure 2), the most desired and stable genotypes were Misr2, Sids14, Giza171 and Gemmeiza12 from them, Misr2 exhibited high yield potential whereas, Sids14, Giza171 and Shandaweel1 were moderate one. Moreover, the genotypes Giza168, Line#, Sids12 and Misr1 appeared to be moderate stability, whereas, the genotypes Gemmeiza11, Sakha94 and Line #2 were less stable and more vulnerable to changing environments.

Table 12. AMMI stability value over eight environments of twelve wheat genotypes for number of spikes / m^2 and number of kernels / spike.

Genotype	No. of spikes/m^2				No. of kernels/spike			
	IPCA 1	IPCA 2	A.S.V	Rank	IPCA 1	IPCA 2	A.S.V	Rank
Sids 14	4.94	-0.07	20.48	**11**	-1.69	0.17	5.68	**8**
Sids 12	-0.30	1.01	1.61	**3**	-0.80	-0.45	2.72	**2**
Misr 1	-2.28	-0.34	9.47	**6**	1.62	2.34	5.92	**9**
Misr 2	3.67	2.19	15.41	**9**	0.14	0.57	0.73	**1**
Shandaweel 1	0.23	0.78	1.23	**1**	-0.85	-0.64	2.90	**4**
Gemmeiza 11	-3.06	2.78	13.01	**7**	1.82	-2.21	6.50	**10**
Gemmeiza 12	0.16	-1.66	1.79	**4**	-0.82	-1.11	2.96	**5**
Giza 171	5.22	3.09	21.87	**12**	-0.82	-0.84	2.86	**3**
Sakha 94	-3.36	0.73	13.98	**8**	2.43	-0.36	8.15	**11**
Giza 168	4.77	-3.07	20.06	**10**	0.90	1.74	3.49	**6**
Line #1	-0.18	-4.23	4.30	**5**	1.39	-0.04	4.67	**7**
Line #2	0.07	-1.20	1.24	**2**	-3.33	0.81	11.19	**12**

Concerning 1000-kernel weight, the most desired and relatively stable genotypes were Line#2, Shandaweel1 and Misr2. Genotype Misr2, has the highest productivity, whereas, Line#2 and Shandaweel1 were moderate yield potential. Otherwise, wheat genotypes Giza168, Giza171, Line #1, Misr1, Gemmeiza12, Sids14, Sakha94, Gemmeiza11 and Sids12 were unstable as showing in (Table 13 and Figure 3).

For grain yield (ton/ha), genotypes Line#1, Giza168, Sids12 and Misr2 were the highest yielding and the most stable. Genotype Misr2 gave the highest yield potentiality, whereas, Giza168 and Sids12 were moderate yield potentiality. Moreover, cultivars Sids14, Gemmeiza11 and Sakha94 appeared to be moderate stability, whereas, the genotypes Shandaweel1, Giza171, Line#2, Misr1 and Gemmeiza12 were unstable and more responsive, from them, Misr1 and Gemmeiza12 have high yield potentiality, whereas Shandaweel1 and Giza171 was moderate yield potentiality as showing in (Table 13 and Figure 4).

Table 13. AMMI stability value over eight environments of twelve wheat genotypes for 1000 - kernel weight (g) and Grain yield (ton/ha).

Genotype	1000 - kernel weight (g)				Grain yield (ton/ha)			
	IPCA 1	IPCA 2	A.S.V	Rank	IPCA 1	IPCA 2	A.S.V	Rank
Sids 14	-2.33	0.11	39.93	**12**	-0.32	-0.19	0.69	**3**
Sids 12	1.37	0.75	23.54	**9**	0.38	0.69	1.06	**5**
Misr 1	-1.19	-0.26	20.48	**7**	0.76	-0.07	1.57	**11**
Misr 2	-0.76	0.51	12.99	**3**	0.41	0.45	0.95	**4**
Shandaweel 1	0.66	0.78	11.37	**2**	-0.55	0.16	1.16	**8**
Gemmeiza 11	-1.58	-0.17	27.16	**11**	-0.43	-0.63	1.09	**6**
Gemmeiza 12	1.37	0.03	23.52	**8**	-0.85	0.38	1.80	**12**
Giza 171	0.91	-0.35	15.56	**5**	0.64	0.42	1.39	**9**
Sakha 94	1.43	0.17	24.42	**10**	-0.53	0.12	1.11	**7**
Giza 168	0.88	-1.71	15.18	**4**	0.11	-0.56	0.61	**2**
Line #1	-1.12	0.01	19.10	**6**	-0.24	-0.01	0.49	**1**
Line #2	0.36	0.14	6.18	**1**	0.63	-0.75	1.50	**10**

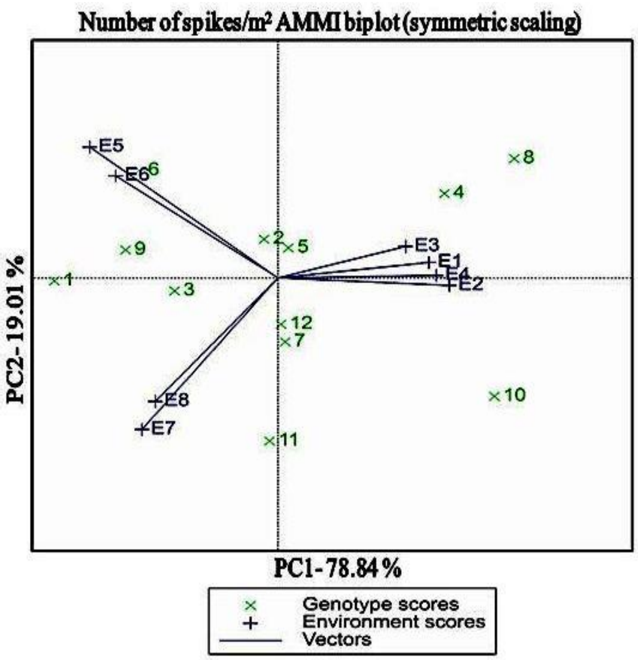

Fig (1): Number of spikes/m²

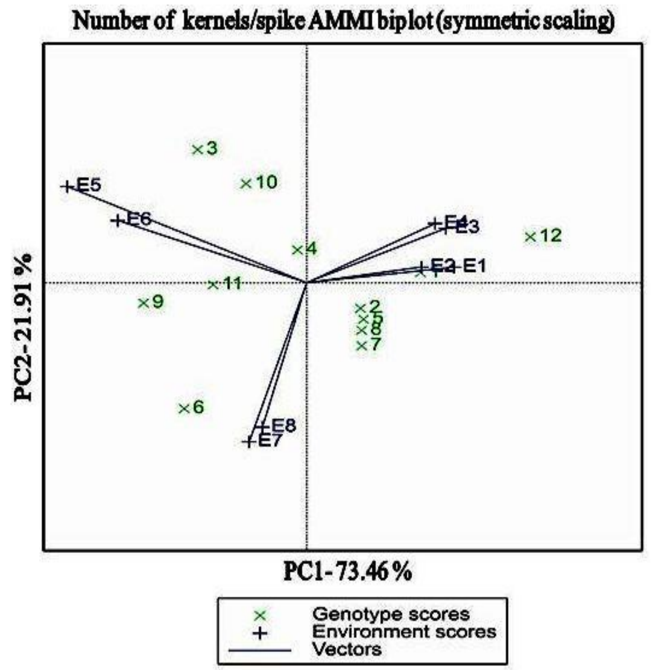

Fig (2): Number of kernels/spike

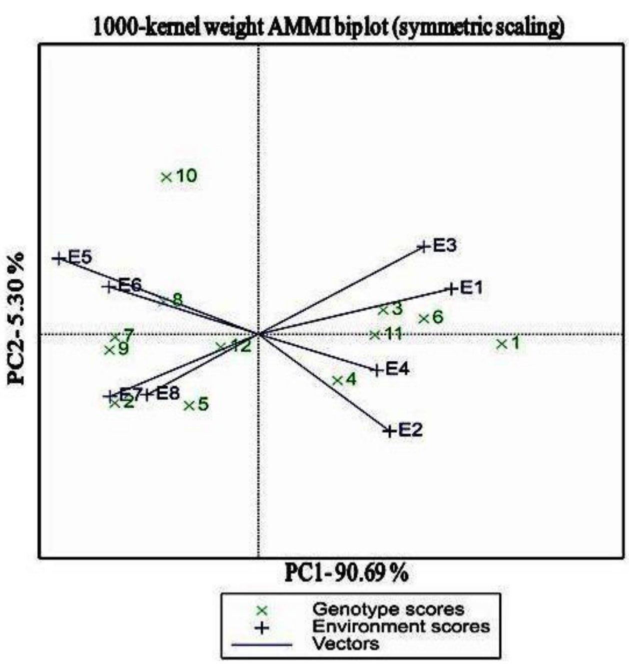

Fig (3): 1000-kernels weight

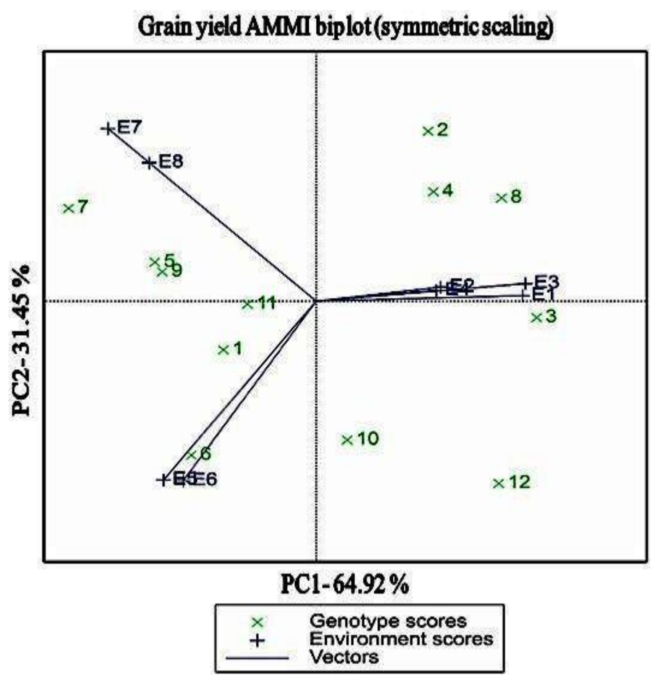

Fig (4): Grain yield

4. CONCLUSION

Generally, after studying the genetic behavior of twelve varieties of bread wheat under heat stress in the new land at middle and upper Egypt conditions namely genotypes Sids12, Sids14, Misr1, Misr2, Shandaweel1 and Giza171 are characterized by high yield and stability, therefore, it can be used in the breeding programs to develop new varieties of wheat with resistance to Heat stress.

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الملخص العربي

الآداء والثبات لبعض التراكيب الوراثية من قمح الخبز تحت ظروف الإجهاد الحراريفي الأراضي الجديدة بمصر الوسطى والعليا

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أجريت هذه الدراسة بهدف تقييم ثبات إثنى عشر تركيباً وراثياً من قمح الخبز وذلك لصفات المحصول ومكوناته تحت ظروف الإجهاد الحراري بالأراضي الجديدة بمنطقتي مصر الوسطى (منطقة الفشن بمحافظة بني سويف) ومصر العليا (منطقة توماس إسنا بمحافظة الأقصر) تحت ثماني بيئات مختلفة (موسمان زراعيان × ميعادين زراعة × موقعين زراعيين). أظهر تحليل التباين معنوية عالية لصفة المحصول ومكوناته لجميع البيئات والتراكيب الوراثية والتفاعل بينهم . كما أظهر تحليل الثبات الوراثي أن متوسط مربعات الإنحرافات للبيئات والتراكيب الوراثية والتفاعل بينهما ذات معنوية عالية لجميع الصفات المدروسة ،وكان أكثر االتراكيب الوراثية ثباتاً هي سدس ١٤، شندويل ١ والسلالة ٢ لصفة عدد السنابل/م٢، مصر ٢ ، سدس ١٤ وجيزة ١٧١ لصفة عدد حبوب السنبلة، السلالة ٢ ، شندويل ١ ، مصر ٢، جيزة ١٦٨ وجيزة ١٧١ لصفة وزن الألف حبة و السلالة ١، جيزة ١٦٨ ، سدس ١٢، مصر ٢ لصفة محصول الحبوب (طن /هكتار).