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Heat Stress Impact and Genetic Diversity among Some Bread Wheat Genotypes

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WHEAT is the most widely grown crop in the world especially in the developing countries. Recently, the climatological extremes including high temperatures is predicted to have a general negative effect on wheat production due to the damaging effect on plant development especially during anthesis stage. Heat tolerance is a complex trait and influenced by different components. A panel of 40 wheat genotypes evaluated for 8 yield and yield-contributing traits under recommended sowing date of the Egyptian Ministry of Agriculture as a control and two other different sowing dates as plants will face heat-stressed conditions at anthesis and grain-filling phases. All measured phenotypic traits exhibited highly significant differences both among evaluated accessions and sowing dates in both growing seasons. A continuous phenotypic variation in all measured traits found, indicating a polygenic inheritance of measured traits. The ANOVA revealed highly significant genotype × environment interaction which is expected for quantitative traits. Cluster analysis revealed two distinct groups with respect to stress tolerance index with substantial diversity among genotypes either susceptible or tolerant to heat stress. Cophenetic correlation between ultrametric similarities of tree and similarity matrix was found to be relatively high ($r = 0.76$, $P < 0.01$), suggesting that the cluster analysis strongly represents the similarity matrix.

Keywords: Wheat, *Triticum*, Heat stress, Cluster analysis.

A substantial increase in world food supply of 70–100% is required to feed the expected 9 billon world population in 2050 (Godfray *et al*., 2010). Because of limited possibilities to extend existing crop-growing areas, a substantial increase in crop productivity is essential to guarantee future food security (Parry *et al*., 2011 and Reynolds *et al*., 2011). Wheat is one of the most widely grown cereal crops, consumed as food, with an average of 53% in the developed world and close to 85% in the developing countries (FAO, 2014). This widely grown possesses some adaptive resilience which is the ability to display some phenotypic changes in responses to environmental conditions. High temperatures at the end of wheat-growing season in Mediterranean climate regions like Egypt are a major abiotic stress affecting yield and its components (Joshi *et al*., 2007 and Said *et al.,* 2015). The consequences of climate changes are likely to include continuous increase in ambient temperatures and hence an increase in the frequency and extent of heat stress periods in the near future for the

Mediterranean. Therefore, high temperature is considered as a key stress factor with high potential impact on crop yield (Suzuki *et al*., 2014). Such increases in temperature can cause heat stress which as a great threat to wheat production in many developing countries, particularly when it occurs during reproductive and grain-filling phases (Fischer & Byerlee, 1991).

Heat tolerance is a complex quantitative trait involved epistatic interactions among loci and strong genotype × environment interactions and not correlated to a single ‘thermotolerant’ gene in cereals (Maestri *et al.*, 2002) and understanding the genetic basis of tolerance to high temperature is important for improving the productivity of wheat (*Triticum aestivum* L.) particularly under heat stress regions (Yang *et al.*, 2002). The impact of high temperature stress is a complex function of intensity, duration, and rate of temperature change. High temperature stress can alter multiple aspects of cellular physiology such as membrane fluidity, nucleic acid and protein structures, as well as metabolite and osmolyte concentrations (Wahid *et al*., 2007 and Wang *et al*., 2003). Heat shock proteins, low-molecular-weight proteins, are generally produced only in response to environmental stress particularly high temperature. These proteins have been reported to have a role in stabilizing the structure of other proteins and have been reported to serve as molecular chaperones that participate in adenosine triphosphate-dependent protein unfolding or assembly/disassembly reactions and prevent protein denaturation during stress (Gorantla *et al*., 1984 and Wahid *et al*., 2007).

Stress tolerance can be improved by selecting and developing wheat genotypes with heat resistance. Improvement in grain yield under heat stress implies selecting genotypes for grain size (Farooq *et al*., 2011; Fokar *et al*., 1998 and Wardlaw *et al*., 2002). Therefore, establishment of breeding strategies is of great importance in the development of cultivars with improved tolerance to climatic and environmental changes (Stratonovitch & Semenov, 2015). By understanding of the causes of genotypic-environment interaction we can stablish breeding objectives, identify ideal test conditions, and formulate recommendations for areas of optimal cultivar adaptation (Weikai & Hunt, 2001).

The potential goal of the current study is to screen the primary gene pool of wheat to identify heat tolerant genotypes as an initial step towards devolving heat stress tolerant cultivars.

Materials and Methods

Plant Material and experiments

A panel of 40 bread wheat genotypes (*Triticum aestivum*) were included in the current study (18 local cultivars, 6 imported cultivars, 5 promising inbred lines developed in Agronomy Department Assiut University and 11 landraces) (Table 1). Three experiments were conducted in clay soil type with pH 7.73 and 7.8 in 2013/2014 and 2014/2015 growing seasons, respectively, at Assiut University Experimental Farm (lat 27° 03' N, long 31° 01' and alt 70 m asl). Each experiment consists of 40 genotypes which did not differ significantly in heading dates (data not shown) were grown in the field with plant to plant distance of 15 cm and row to row distance of 20 cm with 3 replications (Each replication consisted of one nursery row 3 m in length. Genotypes were sown in three sowing dates: i) recommended sowing date of the Egyptian Ministry of Agriculture in upper Egypt as the favorable sowing date (FSD) on Dec. 1, 2013 and Dec. 3, 2014 (where plants will not face high temperature during anthesis and grain-filling phases by the end of Feb.), ii) the moderately heat-stressed sowing date (MHSD) on Jan. 1, 2013, and Jan. 6, 2014 (where plants have experienced terminal high temperature during anthesis and grain-filling phases by the end of March) and iii) the severely heat-stressed sowing date (SHSD) on Feb. 1, 2013 and Feb. 9, 2014 (where plants have experienced terminal high temperature during anthesis and grain-filling phases by the middle of April) (Table 2). The experiments were fully fertilized and well service irrigated (6 irrigations every 21 days intervals) to avoid any nutritional or water deficit stress according to the recommended treatments in the experiment region. It rarely to have rain in the experimental site as it rained only one time on Mar. 9^{th} 2014 and we skipped the irrigation of this month and there were no rains in 2014/2015season. By the end of May after maturity, a sample of 3 guarded plants from each row was harvested then kept in green house till well dry in the two growing seasons.

Phenotypic evaluation

Phenotypic data was assessed on 8 agronomic traits including; plant height in cm (PH; height of main stem at maturity), biological (above-ground dry matter) yield per plant in gram (BY), weight grain yield per plant in gram (GY), harvest index (HI), spike length in cm (SL; length from neck node to the tip of spike at maturity), number of spikes per plant (SN), spikelet number per spike (SNS) and 100 kernel weight in gram (100KW). In addition, the average over all the tow growing seasons of stress tolerance index (STI) was calculated for all studied traits following the formula described by Fernandez (1992) as $STI = \frac{Ys * Yp}{\bar{Y}p^2}$

where Ys and Yp are severe stress and non-stress potential yield of a given genotype, respectively. $\bar{Y}p$ is the average yield of all genotypes under non-stress conditions (Table 3).

Statistical analysis

Randomized complete block design combined over sowing dates and seasons was used with three replications for a genotype in each planting date. Analysis of variance (ANOVA) was carried out using Proc Mixed of SAS package version 9.2 (SAS 2008) and means were compared by revised Least Significant Difference (LS D’) at 5% level of significant (Steel & Torrie, 1981). For cluster analysis, stress tolerance index (STI) was used. The Euclidean distance matrix with un-weighted pair-group method based on arithmetic averages (UPGMA) in the software NTSYS-pc ver 2.1 (Rohlf, 2000) was implemented to develop a dendogram. The output was analyzed using an agglomerative hierarchical clustering method with complete linkage strategy. Data was subjected to analysis to produce a matrix of dissimilarity values and the phenotypic distance between each pair of accessions was estimated as Euclidean distance.

TABLE 1. List of the 40 genotypes and its origin.

Type	Originated location	Name
Egypt Local cultivars	Originated from Regional Agricultural Research Station in northern Delta	Sakha 8
		Sakha 69
		Sakha 92
		Sakha 93
	Originated from Regional Agricultural Research Station in Central Delta	Gemmeza 7
		Gemmeza 10
		Misr 1
		Misr 2
	Originated from Agricultural Research Station in Giza	Giza 160
		Giza 165
		Giza 168
		Giza 171
	Originated from Regional Research Station of Central Egypt	Sids 1
		Sids 4
		Sids 13
		Sids 12
	Originated from Regional Research Station of Upper Egypt	Sahel 1
		Shandaweel 1
Imported from Canada		Canada 462
		Canada 515
Imported from Sudan		Beknora
		Debera
		Nelen
		Snora
Agronomy Department Assiut University, Egypt	Promising inbred lines	Assiut 108
		Assiut 204
		Assiut 724
		MK 1-20
		MK 7-83
Landraces		L 1203
		L 1290
		L 1351
		L 1457
		L 741
		L 780
		L 887
		line 1
		line 3
		line 4
		line 5

TABLE 2. Assiut monthly average of minimum (Min), average of maximum (Max) and general mean of air temperature (°C) during the two growing seasons 2013/2014 and 2014/2015.

Month	Min. Temperature		Max. Temperature		General mean	
	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015
December	7.63	8.75	21.44	23.25	14.54	16.00
January	6.35	5.52	22.42	20.48	14.39	13.00
February	7.50	7.93	23.89	22.75	15.70	15.34
March	11.41	12.23	26.73	27.16	19.07	19.69
April	15.83	14.59	32.80	29.10	24.32	21.84
May	19.81	19.71	35.48	35.48	27.65	27.60
June	22.55	21.37	37.72	36.60	30.14	28.98

http://eg.freemeteo.com/weather/?language=english & country = Egypt.

Results

Phenotypic evaluation

All measured phenotypic traits exhibited highly significant differences and continuous phenotypic variations among evaluated accessions, sowing dates and their interaction in both growing seasons (Table 4) which is expected for quantitative traits.

Plant height (PH)

Plant height (PH) was measured as the height of main stem at maturity. Heat stress conditions led to a significant reduction in plant height as revealed by ANOVA (Table 4). The genotype Assiut 108 revealed the tallest plants under the favorable cultivation conditions (FSD) in both growing seasons (95.89 and 95.33 cm, in the first and second growing seasons, respectively). Under moderately heat-stressed conditions (MHSD), line 1 showed the lowest reduction in plant height (2.55 % and 0.21%) in the 1^{st} and 2^{nd} seasons, respectively, as compared with the normal conditions. On the other hand, the highest plants recorded by cultivars Giza 165 in the first growing season (82.22 cm) and Sakha 8 in the second season (88.00 cm). Under severely heat-stressed conditions (SHSD) line 1457 and cultivar Gemmeza 7 showed the lowest reduction on (PH) (15.96 % and 4.09%) in the first and the second seasons, respectively, as compared with normal conditions, while Giza168 and Gemmeza 7 exhibited the tallest plants in the first and the second seasons, respectively (Table 5).

TABLE 3. Average of stress tolerance index (STI) of all evaluated traits under severe stress conditions in the two growing seasons.

	Trait	PH	BY	GY	HI	SL	SN	SNS	100 KW
Genotypes (G)	Sakha 8	1.09	0.45	0.41	0.94	1.01	0.44	0.96	1.28
	Sakha 69	0.92	0.31	0.25	0.83	0.86	0.47	0.82	1.02
	Sakha 92	0.77	0.13	0.10	0.72	0.90	0.63	0.90	0.86
	Sakha 93	0.72	0.14	0.11	0.76	0.88	0.40	0.85	0.98
	Gemmeza 7	0.78	0.43	0.38	0.87	1.04	0.32	1.03	0.98
	Gemmeza 10	0.70	0.25	0.13	0.52	0.93	0.28	0.96	0.79
	Misr 1	0.67	0.15	0.12	0.83	0.81	0.36	0.80	0.81
	Misr 2	0.60	0.16	0.10	0.64	0.74	0.15	0.75	0.92
	Giza 160	0.69	0.35	0.33	1.00	0.74	0.42	0.78	0.93
	Giza 165	0.60	0.36	0.33	0.91	0.83	0.47	0.82	0.81
	Giza 168	0.80	0.25	0.17	0.68	0.99	0.18	0.82	0.87
	Giza 171	0.50	0.23	0.21	0.95	0.76	0.47	0.71	0.66
	Seds 1	0.63	0.32	0.19	0.61	0.82	0.36	0.87	0.57
	Seds 4	0.53	0.30	0.21	0.71	0.79	0.63	0.81	0.60
	Seds 12	0.46	0.29	0.27	0.91	0.71	0.26	0.71	0.55
	Seds 13	0.62	0.18	0.12	0.64	0.61	0.30	0.65	0.65
	Sahel 1	0.71	0.46	0.41	0.90	1.05	0.62	0.89	0.76
	Shandaweel 1	0.68	0.19	0.13	0.66	0.83	0.27	0.81	0.59
	Canada 462	0.64	0.31	0.33	1.04	0.70	0.50	0.75	0.77
	Canada 515	0.90	0.20	0.11	0.57	0.98	0.35	0.88	0.60
	Beknora	0.49	0.24	0.19	0.81	0.61	0.54	0.62	0.69
	Debera	0.59	0.07	0.05	0.74	0.83	0.26	0.87	0.56
	Nelen	0.71	0.38	0.37	0.97	0.50	0.45	0.70	1.09
	Snora	0.78	0.24	0.22	0.90	0.62	0.33	0.70	0.70
	Assiut 108	0.86	0.24	0.23	0.96	0.90	0.43	0.94	0.97
	Assiut 204	0.80	0.17	0.16	0.98	1.14	0.29	0.91	0.77
	Assiut 724	0.47	0.27	0.12	0.44	0.92	0.26	0.78	0.77
	MK 1-20	0.42	0.12	0.12	0.98	0.61	0.29	0.73	0.43
	MK 7-83	0.75	0.20	0.11	0.54	1.02	0.19	0.93	1.18
	L 1203	0.57	0.12	0.11	0.93	1.29	0.20	0.97	0.95
	L 1290	0.85	0.24	0.18	0.77	0.39	0.52	0.53	0.80
	L 1351	0.67	0.13	0.09	0.73	0.59	0.39	0.74	0.66
	L 1457	0.90	0.25	0.17	0.69	0.57	0.45	0.60	0.54
	L 741	0.86	0.29	0.15	0.53	0.71	0.40	0.75	0.82
	L 780	0.60	0.10	0.10	1.01	0.61	0.24	0.82	0.41
	L 887	0.60	0.14	0.11	0.79	0.68	0.30	0.80	0.63
	line 1	0.52	0.18	0.16	0.88	0.62	0.30	0.63	0.68
	line 3	0.72	0.11	0.09	0.89	0.64	0.25	0.74	0.66
	line 4	0.62	0.22	0.18	0.78	0.59	0.51	0.67	0.67
	line 5	0.67	0.23	0.19	0.83	0.61	0.51	0.63	0.70

TABLE 4. Analysis of variance (ANOVA) of evaluated traits for the 40 wheat genotypes.

S.O.V	D.F	Mean Square							
Trait name		PH	BY	GY	HI	SL	SN	SNS	100 KW
Season (S)	1	309.42 **	1946.31 NS	338.53 NS	95.04 *	0.10 NS	4.96 NS	12.23 NS	13.16 **
Sowing date (T)	2	39981.05 **	476812.66 **	77263.47 **	3790.01 **	414.89 **	8972.34 **	1192.95 **	67.58 **
S*T	2	685.02 **	407.49 NS	54.09 NS	44.54 NS	0.50 NS	1.80 NS	9.66 NS	0.80 NS
Error (S)	12	45.37	2765.41	457.61	20.13	1.96	13.30	3.85	0.43
Genotypes (G)	39	650.67 **	3297.54 **	560.83 **	165.83 **	25.95 **	124.17 **	29.19 **	3.60 **
G*S	39	288.47 **	320.76 **	62.21 **	17.25 **	7.97 **	10.09 **	12.39 **	1.60 **
T*G	78	185.02 **	2434.04 **	413.60 **	75.17 **	2.17**	64.42 **	6.54 **	0.60 **
S*G*T	78	54.56 **	247.40 **	51.40 **	20.61 **	0.79 **	8.60 **	1.96 **	0.26 **
Error	468	10.49	74.50	10.25	7.20	0.29	4.33	0.80	0.03

NS = Non significant differences
*, ** = significant and highly significant differences respectively.

TABLE 5. Plant height (PH) mean performance.

Season (S)		2013/2014				2014/2015				Over all Mean			(G) Mean
Sowing Date (T)		FSD	MHSD	SHSD	Mean	FSD	MHSD	SHSD	Mean	FSD	MHSD	SHSD	
Genotypes (G)	Sakha 8	90.44	77.00	65.89	**77.78**	93.33	88.00	67.67	**83.00**	91.89	82.50	66.78	**80.39**
	Sakha 69	83.89	68.56	63.33	**71.93**	92.33	87.17	70.83	**83.44**	88.11	77.86	67.08	**77.69**
	Sakha 92	69.00	54.56	47.22	**56.93**	91.00	84.67	73.33	**83.00**	80.00	69.61	60.28	**69.96**
	Sakha 93	67.22	52.22	39.89	**53.11**	89.83	81.33	73.33	**81.50**	78.53	66.78	56.61	**67.31**
	Gemmeza 7	93.22	74.11	46.67	**71.33**	77.33	76.83	74.17	**76.11**	85.28	75.47	60.42	**73.72**
	Gemmeza 10	92.89	75.33	52.22	**73.48**	80.17	69.33	53.17	**67.56**	86.53	72.33	52.69	**70.52**
	Misr 1	80.00	60.56	52.78	**64.44**	78.33	65.67	57.00	**67.00**	79.17	63.11	54.89	**65.72**
	Misr 2	83.00	78.56	39.56	**67.04**	75.33	68.00	58.83	**67.39**	79.17	73.28	49.19	**67.21**
	Giza 160	94.11	67.56	52.67	**71.44**	80.33	66.83	50.33	**65.83**	87.22	67.19	51.50	**68.64**
	Giza 165	88.89	82.22	50.00	**73.70**	72.83	63.28	46.00	**60.70**	80.86	72.75	48.00	**67.20**
	Giza 168	87.56	80.78	72.22	**80.19**	76.67	67.00	53.50	**65.72**	82.11	73.89	62.86	**72.95**
	Giza 171	78.22	76.11	36.33	**63.56**	69.67	63.28	51.33	**61.43**	73.94	69.69	43.83	**62.49**
	Seds 1	80.44	70.44	54.11	**68.33**	80.17	64.00	47.67	**63.94**	80.31	67.22	50.89	**66.14**
	Seds 4	75.00	57.78	50.11	**60.96**	62.56	59.00	50.11	**57.22**	68.78	58.39	50.11	**59.09**
	Seds 12	83.22	65.56	44.44	**64.41**	55.11	52.33	42.78	**50.07**	69.17	58.94	43.61	**57.24**
	Seds 13	90.44	71.78	46.67	**69.63**	90.17	70.67	42.22	**67.69**	90.31	71.22	44.44	**68.66**
	Sahel 1	91.89	60.89	50.00	**67.59**	93.83	60.33	49.83	**68.00**	92.86	60.61	49.92	**67.80**
	Shandaweel 1	76.33	60.44	57.56	**64.78**	75.50	63.33	58.33	**65.72**	75.92	61.89	57.94	**65.25**
	Canada 462	78.56	73.22	47.56	**66.44**	76.33	74.33	59.00	**69.89**	77.44	73.78	53.28	**68.17**
	Canada 515	89.11	70.44	64.11	**74.56**	89.67	70.17	66.78	**75.54**	89.39	70.31	65.44	**75.05**
	Beknora	62.78	61.11	50.44	**58.11**	64.17	61.67	48.89	**58.24**	63.47	61.39	49.67	**58.18**
	Debera	75.00	70.89	51.67	**65.85**	75.00	70.33	50.83	**65.39**	75.00	70.61	51.25	**65.62**
	Nelen	87.56	63.44	46.67	**65.89**	87.83	64.17	57.83	**69.94**	87.69	63.81	52.25	**67.92**
	Snora	80.00	69.00	60.56	**69.85**	80.00	70.33	65.44	**71.93**	80.00	69.67	63.00	**70.89**
	Assiut 108	95.89	65.33	61.11	**74.11**	95.33	74.50	55.83	**75.22**	95.61	69.92	58.47	**74.67**
	Assiut 204	84.22	81.33	57.78	**74.44**	85.33	80.50	64.67	**76.83**	84.78	80.92	61.22	**75.64**
	Assiut 724	74.00	70.89	42.22	**62.37**	71.50	70.33	42.50	**61.44**	72.75	70.61	42.36	**61.91**
	MK 1-20	62.00	58.44	40.44	**53.63**	62.00	58.17	47.78	**55.98**	62.00	58.31	44.11	**54.81**
	MK 7-83	79.56	75.11	57.22	**70.63**	79.83	75.67	64.78	**73.43**	79.69	75.39	61.00	**72.03**
	L 1203	71.33	55.44	51.33	**59.37**	70.50	57.67	52.11	**60.09**	70.92	56.56	51.72	**59.73**
	L 1290	87.22	67.22	62.33	**72.26**	85.83	68.89	65.00	**73.24**	86.53	68.06	63.67	**72.75**
	L 1351	76.44	67.89	55.11	**66.48**	76.17	67.33	58.22	**67.24**	76.31	67.61	56.67	**66.86**
	L 1457	83.56	76.56	70.22	**76.78**	83.83	79.83	69.33	**77.67**	83.69	78.19	69.78	**77.22**
	L 741	92.11	71.56	62.22	**75.30**	92.67	71.83	58.44	**74.31**	92.39	71.69	60.33	**74.81**
	L 780	76.44	72.22	47.78	**65.48**	76.17	70.83	55.00	**67.33**	76.31	71.53	51.39	**66.41**
	L 887	80.44	59.56	46.33	**62.11**	80.17	59.83	51.28	**63.76**	80.31	59.69	48.81	**62.94**
	line 1	82.67	80.56	40.44	**67.89**	81.00	80.83	42.44	**68.09**	81.83	80.69	41.44	**67.99**
	line 3	78.56	67.56	55.89	**67.33**	78.83	71.83	63.17	**71.28**	78.69	69.69	59.53	**69.31**
	line 4	71.11	66.56	52.89	**63.52**	71.67	66.83	59.17	**65.89**	71.39	66.69	56.03	**64.70**
	line 5	86.67	61.56	49.56	**65.93**	87.50	61.83	50.67	**66.67**	87.08	61.69	50.11	**66.30**
Mean		**81.52**	**68.51**	**52.39**	**67.47**	**79.65**	**69.47**	**56.74**	**68.62**	**80.59**	**68.99**	**54.56**	**68.05**

LSD’ 0.05 (S) 1.10

LSD’ 0.05 (T) 1.21

LSD’ 0.05 (S*T) 1.80

LSD’ 0.05 (G) 1.86

LSD’ 0.05 (G*S) 2.63

LSD’ 0.05 (G*T) 3.32

LSD’ 0.05 (G*S*T) 5.10

Biological yield per plant (BY)

Selection for Biological yield may be useful trait for yield improvement in wheat (Sharma, 1993). In this study (BY) was severely decreased under heat-stressed conditions (Table 6). Under the favorable sowing, superiority was scored by Gemmeza 7 and Nelen in the first and second growing seasons, respectively. Meanwhile, under MHSD minimum reduction in BY was recorded by line Assiut 204 (22.3%) in both growing seasons as compared with normal conditions. Finally, under SHSD, Assiut 204 recorded the lowest reduction as compared with FSD on (BY) in the 1st season, whereas in the 2nd season line 887 was scored the lowest reduction (Table 6).

Grain yield/ plant (GY)

Grain yield is a complex trait that highly influenced by many genetic and environmental factors (Liu *et al*., 2008). Grain yield (GY) was significantly decreased under heat-stressed conditions as compared by the normal sowing conditions, (Table 3 and 7). Under (FSD) Gemmeza 7 and Nelen yielded the highest grain yield/ plant (80.88 and 87.21 gm/ plant, in the first and second growing seasons, respectively). Under MHSD grain yield was decreased with all genotypes in this study, cultivar Sahel 1 yielded the highest grain yield/ plant (17.77) in the 1st season, while in the second season cultivar Seds 4 recorded the highest yield (22.85 gm/ plant). Under SHSD, the lowest reduction in GY was recorded by line Assiut 204 in the 1st season and cultivar line 887 in the second season, moreover superiority in GY under sever condition was recorded by cultivar Beknora (10.24 gm/ plant) in the first season and Giza 160 (14.42 gm/ plant) in the second season (Table 7).

Harvest index (HI)

Harvest index was measured as the ratio of economic yield to biological yield following the method of Donald & Hamblin (1976). Harvest index was highly significantly influenced by genotypes, sowing dates and their interaction (Table 3). In normal sowing conditions Giza 171 and Canada 462 exhibited the highest HI (46.51 and 46.99) in the first and second growing seasons, respectively. On the other hand, Debera gave the best performance in HI ((40.47%) under MHSD conditions in the 1st season, but in the 2nd season the superiority was to Giza 168 (42.49%). Under SHSD conditions, L780 and cultivar Giza165 exhibited the highest HI (41.34 and 37.01) in the first and second growing seasons, respectively (Suppl. Table 8), while the maximum reduction in HI was recorded by cultivar Gemmeza 10 in both growing seasons.

TABLE 6. Mean performance of biological yield per plant (BY).

Season (S)		2013/2014				2014/2015				Over all Mean			(G) Mean
Sowing Date (T)		FSD	MHSD	SHSD	Mean	FSD	MHSD	SHSD	Mean	FSD	MHSD	SHSD	
Genotypes (G)	Sakha 8	179.65	40.40	29.55	**83.20**	179.65	41.51	29.55	**83.57**	179.65	40.96	29.55	83.39
	Sakha 69	81.81	39.27	32.80	**51.29**	131.62	42.18	34.49	**69.43**	106.71	40.72	33.65	60.36
	Sakha 92	82.60	32.27	19.55	**44.81**	77.10	45.78	19.55	**47.48**	79.85	39.03	19.55	46.14
	Sakha 93	68.70	29.27	18.10	**38.69**	71.95	47.25	27.63	**48.94**	70.33	38.26	22.87	43.82
	Gemmeza 7	206.63	31.63	26.77	**88.34**	181.55	32.68	25.41	**79.88**	194.09	32.16	26.09	84.11
	Gemmeza 10	118.20	32.17	26.71	**59.03**	108.20	38.00	24.77	**56.99**	113.20	35.08	25.74	58.01
	Misr 1	64.41	37.26	25.37	**42.34**	78.22	35.38	24.28	**45.96**	71.31	36.32	24.83	44.15
	Misr 2	73.13	35.80	29.40	**46.11**	69.29	52.80	23.35	**48.48**	71.21	44.30	26.38	47.29
	Giza 160	105.17	59.80	26.07	**63.68**	118.50	63.89	45.47	**75.95**	111.83	61.85	35.77	69.82
	Giza 165	135.63	33.18	31.03	**66.61**	140.43	49.21	30.62	**73.42**	138.03	41.20	30.83	70.02
	Giza 168	123.84	33.53	26.50	**61.29**	112.82	38.45	23.12	**58.13**	118.33	35.99	24.81	59.71
	Giza 171	130.53	28.80	18.67	**59.33**	116.45	35.35	24.44	**58.75**	123.49	32.08	21.55	59.04
	Seds 1	111.30	35.32	30.13	**58.92**	114.18	42.88	35.84	**64.30**	112.74	39.10	32.99	61.61
	Seds 4	103.00	37.99	32.56	**57.85**	103.63	66.12	35.98	**68.58**	103.31	52.05	34.27	63.21
	Seds 12	108.75	38.00	32.17	**59.64**	108.75	40.92	31.20	**60.29**	108.75	39.46	31.68	59.96
	Seds 13	99.38	33.77	24.80	**52.65**	77.27	29.25	22.02	**42.84**	88.32	31.51	23.41	47.75
	Sahel 1	181.06	52.59	30.21	**87.95**	195.08	54.53	27.17	**92.26**	188.07	53.56	28.69	90.11
	Shandaweel 1	91.93	31.78	23.07	**48.93**	87.35	39.70	27.87	**51.64**	89.64	35.74	25.47	50.28
	Canada 462	122.23	28.59	24.38	**58.40**	143.40	48.20	30.40	**74.00**	132.82	38.39	27.39	66.20
	Canada 515	95.53	34.94	26.93	**52.47**	71.20	35.17	28.12	**44.83**	83.37	35.06	27.53	48.65
	Beknora	93.84	44.73	32.70	**57.09**	99.07	31.05	24.52	**51.54**	96.46	37.89	28.61	54.32
	Debera	46.65	29.93	17.76	**31.45**	46.65	27.13	19.62	**31.13**	46.65	28.53	18.69	31.29
	Nelen	143.54	35.73	25.87	**68.38**	203.27	46.54	25.39	**91.73**	173.41	41.14	25.63	80.06
	Snora	159.49	34.24	21.80	**71.84**	115.18	29.47	18.19	**54.28**	137.34	31.86	20.00	63.06
	Assiut 108	115.32	45.37	21.93	**60.87**	146.43	30.35	21.40	**66.06**	130.88	37.86	21.67	63.47
	Assiut 204	61.69	47.92	30.46	**46.69**	79.48	61.73	26.48	**55.90**	70.59	54.83	28.47	51.29
	Assiut 724	117.97	36.73	20.10	**58.27**	124.68	44.03	31.58	**66.76**	121.32	40.38	25.84	62.51
	MK 1-20	76.07	26.93	13.34	**38.78**	72.65	31.94	25.78	**43.46**	74.36	29.44	19.56	41.12
	MK 7-83	100.84	32.47	19.67	**50.99**	126.32	60.93	21.05	**69.43**	113.58	46.70	20.36	60.21
	L 1203	73.20	23.10	19.19	**38.50**	63.45	32.03	20.78	**38.76**	68.33	27.57	19.99	38.63
	L 1290	96.93	39.57	26.99	**54.50**	125.85	59.21	23.43	**69.50**	111.39	49.39	25.21	62.00
	L 1351	80.10	34.00	16.57	**43.56**	101.35	32.46	17.75	**50.52**	90.73	33.23	17.16	47.04
	L 1457	141.35	33.87	21.51	**65.58**	141.35	53.88	20.57	**71.93**	141.35	43.88	21.04	68.75
	L 741	157.67	36.34	19.28	**71.10**	147.75	43.57	24.93	**72.08**	152.71	39.96	22.11	71.59
	L 780	68.24	26.11	15.40	**36.59**	73.22	27.09	18.40	**39.57**	70.73	26.60	16.90	38.08
	L 887	62.10	33.35	23.53	**39.66**	62.10	34.17	29.76	**42.01**	62.10	33.76	26.65	40.83
	line 1	94.27	31.01	22.60	**49.29**	95.60	29.63	22.02	**49.08**	94.93	30.32	22.31	49.19
	line 3	74.08	28.38	21.47	**41.31**	65.07	45.02	15.82	**41.97**	69.57	36.70	18.64	41.64
	line 4	115.91	37.13	25.97	**59.67**	76.22	38.96	28.90	**48.03**	96.06	38.05	27.43	53.85
	line 5	122.22	43.23	21.28	**62.24**	118.08	38.95	22.85	**59.96**	120.15	41.09	22.06	61.10
Mean		**107.12**	**35.66**	**24.30**	**55.70**	**109.26**	**41.93**	**25.76**	**58.99**	**108.19**	**38.80**	**25.03**	**57.34**

LSD' $_{0.05}$ (S)	NS	LSD' $_{0.05}$ (G)	4.95
LSD' $_{0.05}$ (T)	9.46	LSD' $_{0.05}$ (G*S)	8.10
LSD' $_{0.05}$ (S*T)	NS	LSD' $_{0.05}$ (G*T)	8.57
		LSD' $_{0.05}$ (G*S*T)	14.47

TABLE 7. Mean performance of grain yield per plant (GY).

Season (S)	2013/2014				2014/2015				Over all Mean			(G) Mean
Sowing Date (T) / Genotypes (G)	FSD	MHSD	SHSD	Mean	FSD	MHSD	SHSD	Mean	FSD	MHSD	SHSD	
Sakha 8	63.90	12.23	10.03	**28.72**	67.95	13.35	10.80	**30.70**	65.93	12.79	10.42	29.71
Sakha 69	30.80	12.76	10.00	**17.85**	53.17	14.32	10.25	**25.91**	41.98	13.54	10.13	21.88
Sakha 92	34.47	8.28	4.90	**15.88**	31.32	15.79	4.90	**17.34**	32.90	12.03	4.90	16.61
Sakha 93	20.32	11.41	5.53	**12.42**	26.29	15.63	9.50	**17.14**	23.31	13.52	7.52	14.78
Gemmeza 7	80.88	10.79	8.51	**33.40**	69.84	11.43	8.22	**29.83**	75.36	11.11	8.37	31.61
Gemmeza 10	42.00	6.47	4.83	**17.77**	40.06	7.67	5.55	**17.76**	41.03	7.07	5.19	17.77
Misr 1	24.73	11.30	7.35	**14.46**	28.50	10.38	8.16	**15.68**	26.61	10.84	7.75	15.07
Misr 2	20.50	13.17	7.62	**13.76**	22.83	15.50	7.92	**15.42**	21.67	14.33	7.77	14.59
Giza 160	43.86	16.14	9.13	**23.04**	47.63	19.83	14.42	**27.29**	45.75	17.99	11.78	25.17
Giza 165	54.67	11.34	8.13	**24.71**	57.63	17.86	11.35	**28.95**	56.15	14.60	9.74	26.83
Giza 168	39.31	13.37	7.47	**20.05**	38.37	16.33	7.01	**20.57**	38.84	14.85	7.24	20.31
Giza 171	60.87	10.21	5.29	**25.46**	49.39	13.22	7.84	**23.48**	55.13	11.71	6.57	24.47
Seds 1	39.98	10.86	7.14	**19.33**	40.36	11.93	8.85	**20.38**	40.17	11.40	8.00	19.86
Seds 4	34.04	12.64	10.17	**18.95**	30.96	22.85	11.57	**21.80**	32.50	17.75	10.87	20.37
Seds 12	42.45	13.38	9.60	**21.81**	42.45	13.24	11.34	**22.34**	42.45	13.31	10.47	22.08
Seds 13	35.36	11.68	6.93	**17.99**	26.07	9.31	5.53	**13.64**	30.72	10.49	6.23	15.81
Sahel 1	77.12	17.77	9.48	**34.79**	77.34	20.59	8.16	**35.36**	77.23	19.18	8.82	35.08
Shandaweel 1	32.55	9.15	6.12	**15.94**	28.39	10.36	7.83	**15.53**	30.47	9.76	6.98	15.74
Canada 462	55.99	9.66	7.67	**24.44**	67.43	17.35	9.84	**31.54**	61.71	13.51	8.75	27.99
Canada 515	32.08	9.53	6.44	**16.02**	23.86	8.72	6.87	**13.15**	27.97	9.13	6.65	14.58
Beknora	33.90	16.21	10.24	**20.12**	35.65	11.07	7.84	**18.19**	34.77	13.64	9.04	19.15
Debera	18.38	12.10	4.33	**11.61**	18.30	10.04	5.64	**11.33**	18.34	11.07	4.99	11.47
Nelen	55.90	13.70	8.36	**25.99**	87.21	17.17	8.95	**37.78**	71.56	15.44	8.65	31.88
Snora	64.36	13.50	7.44	**28.43**	46.48	11.15	5.40	**21.01**	55.42	12.33	6.42	24.72
Assiut 108	46.29	13.76	7.57	**22.54**	59.86	9.21	7.11	**25.39**	53.08	11.48	7.34	23.97
Assiut 204	25.09	13.50	10.16	**16.25**	31.63	19.90	9.23	**20.25**	28.36	16.70	9.69	18.25
Assiut 724	34.00	13.63	4.03	**17.22**	40.50	15.39	6.50	**20.80**	37.25	14.51	5.27	19.01
MK 1-20	34.16	9.60	4.14	**15.97**	31.29	10.12	8.38	**16.60**	32.73	9.86	6.26	16.28
MK 7-83	32.97	9.90	3.82	**15.57**	39.43	20.47	5.84	**21.92**	36.20	15.19	4.83	18.74
L 1203	31.87	7.57	5.90	**15.11**	25.56	8.72	6.71	**13.67**	28.72	8.15	6.30	14.39
L 1290	35.05	12.29	8.62	**18.65**	45.53	20.26	6.57	**24.12**	40.29	16.28	7.59	21.39
L 1351	30.24	8.71	4.48	**14.48**	38.40	8.59	4.71	**17.23**	34.32	8.65	4.60	15.85
L 1457	41.55	8.73	7.31	**19.20**	41.55	22.32	6.49	**23.45**	41.55	15.52	6.90	21.33
L 741	49.03	7.60	5.01	**20.55**	45.08	10.16	5.81	**20.35**	47.05	8.88	5.41	20.45
L 780	26.09	8.09	6.30	**13.49**	25.97	10.02	6.55	**14.18**	26.03	9.06	6.43	13.84
L 887	22.25	10.40	7.12	**13.26**	22.25	11.06	9.71	**14.34**	22.25	10.73	8.42	13.80
line 1	34.28	11.10	7.28	**17.55**	37.73	9.36	7.23	**18.11**	36.00	10.23	7.26	17.83
line 3	30.99	8.55	5.03	**14.86**	26.88	18.29	5.80	**16.99**	28.94	13.42	5.42	15.92
line 4	53.61	12.81	6.70	**24.38**	31.79	14.25	7.69	**17.91**	42.70	13.53	7.19	21.14
line 5	48.47	13.65	6.05	**22.72**	48.30	13.05	7.18	**22.84**	48.38	13.35	6.61	22.78
Mean	**40.36**	**11.44**	**7.06**	**19.62**	**41.23**	**13.91**	**7.88**	**21.01**	**40.80**	**12.67**	**7.47**	**20.31**

LSD' $_{0.05}$ (S)	NS	LSD' $_{0.05}$ (G)	1.84
LSD' $_{0.05}$ (T)	3.85	LSD' $_{0.05}$ (G*S)	2.87
LSD' $_{0.05}$ (S*T)	NS	LSD' $_{0.05}$ (G*T)	3.18
		LSD' $_{0.05}$ (G*S*T)	5.06

TABLE 8. Mean performance of harvest index per plant (HI).

Season (S)	2013/2014				2014/2015				Over all Mean			(G) Mean
Sowing Date (T)	FSD	MHSD	SHSD	Mean	FSD	MHSD	SHSD	Mean	FSD	MHSD	SHSD	
Genotypes (G)												
Sakha 8	36.58	30.35	34.39	**33.77**	37.95	32.51	36.66	**35.71**	37.27	31.43	35.53	34.74
Sakha 69	37.31	32.44	30.56	**33.44**	40.30	33.84	29.73	**34.63**	38.81	33.14	30.14	34.03
Sakha 92	41.86	25.74	24.73	**30.78**	40.63	33.56	24.98	**33.06**	41.25	29.65	24.85	31.92
Sakha 93	29.57	38.95	30.47	**33.00**	36.34	34.15	34.35	**34.95**	32.95	36.55	32.41	33.97
Gemmeza 7	39.13	34.02	31.65	**34.93**	38.45	34.89	32.21	**35.18**	38.79	34.46	31.93	35.06
Gemmeza 10	35.57	20.18	18.06	**24.60**	37.06	20.10	22.39	**26.51**	36.32	20.14	20.22	25.56
Misr 1	38.32	30.34	29.05	**32.57**	36.47	29.22	33.61	**33.10**	37.39	29.78	31.33	32.83
Misr 2	28.00	36.77	25.77	**30.18**	32.88	30.52	33.25	**32.22**	30.44	33.64	29.51	31.20
Giza 160	41.70	27.34	34.99	**34.68**	40.28	30.92	32.43	**34.54**	40.99	29.13	33.71	34.61
Giza 165	40.30	34.20	26.19	**33.56**	41.03	37.00	37.01	**38.35**	40.66	35.60	31.60	35.96
Giza 168	31.86	39.79	28.19	**33.28**	34.10	42.49	30.24	**35.61**	32.98	41.14	29.22	34.45
Giza 171	46.51	35.36	28.73	**36.87**	42.28	37.37	31.67	**37.11**	44.40	36.36	30.20	36.99
Seds 1	35.93	30.74	23.52	**30.06**	35.35	27.76	24.66	**29.26**	35.64	29.25	24.09	29.66
Seds 4	33.05	33.27	31.45	**32.59**	29.88	34.45	32.18	**32.17**	31.46	33.86	31.81	32.38
Seds 12	39.00	35.21	29.64	**34.62**	39.02	32.62	36.40	**36.02**	39.01	33.91	33.02	35.32
Seds 13	35.39	34.83	27.92	**32.71**	33.53	31.80	24.79	**30.04**	34.46	33.31	26.35	31.38
Sahel 1	43.06	33.76	31.46	**36.10**	39.74	37.74	29.98	**35.82**	41.40	35.75	30.72	35.96
Shandaweel 1	35.37	28.51	26.67	**30.18**	32.47	26.12	28.31	**28.97**	33.92	27.31	27.49	29.57
Canada 462	45.78	33.71	31.50	**36.99**	46.99	36.20	31.78	**38.32**	46.38	34.95	31.64	37.66
Canada 515	33.58	27.30	23.76	**28.21**	33.50	24.81	24.38	**27.56**	33.54	26.05	24.07	27.89
Beknora	36.10	36.09	31.53	**34.57**	35.98	35.47	31.99	**34.48**	36.04	35.78	31.76	34.53
Debera	39.59	40.47	24.42	**34.83**	39.28	36.94	28.42	**34.88**	39.44	38.71	26.42	34.85
Nelen	38.73	38.22	32.14	**36.36**	42.77	37.00	35.25	**38.34**	40.75	37.61	33.69	37.35
Snora	40.09	38.73	34.08	**37.63**	40.25	37.63	29.71	**35.86**	40.17	38.18	31.90	36.75
Assiut 108	40.14	30.81	32.89	**34.62**	40.86	30.33	34.06	**35.08**	40.50	30.57	33.47	34.85
Assiut 204	40.23	28.14	34.20	**34.19**	39.89	31.74	34.79	**35.47**	40.06	29.94	34.50	34.83
Assiut 724	28.75	37.27	20.51	**28.84**	32.44	35.03	20.48	**29.32**	30.59	36.15	20.49	29.08
MK 1-20	44.55	35.94	30.63	**37.04**	42.95	31.64	32.59	**35.73**	43.75	33.79	31.61	36.38
MK 7-83	32.71	30.53	19.63	**27.62**	31.25	32.34	28.26	**30.62**	31.98	31.43	23.95	29.12
L 1203	43.43	32.82	30.62	**35.62**	40.15	27.23	32.29	**33.22**	41.79	30.03	31.45	34.42
L 1290	36.16	30.51	31.82	**32.83**	36.18	33.28	28.08	**32.51**	36.17	31.89	29.95	32.67
L 1351	37.71	25.94	27.74	**30.46**	37.88	26.41	26.57	**30.29**	37.79	26.18	27.16	30.37
L 1457	29.79	25.96	33.99	**29.91**	29.49	40.47	31.47	**33.81**	29.64	33.22	32.73	31.86
L 741	31.09	20.84	25.81	**25.91**	30.50	23.27	23.29	**25.68**	30.79	22.05	24.55	25.80
L 780	38.36	31.03	41.34	**36.91**	35.52	37.01	35.77	**36.10**	36.94	34.02	38.56	36.51
L 887	35.70	31.32	30.16	**32.39**	35.80	32.42	32.67	**33.63**	35.75	31.87	31.41	33.01
line 1	36.34	35.37	32.31	**34.67**	39.45	31.49	33.55	**34.83**	37.90	33.43	32.93	34.75
line 3	41.90	30.07	23.61	**31.86**	41.32	39.88	37.00	**39.40**	41.61	34.97	30.30	35.63
line 4	46.12	34.51	25.57	**35.40**	40.87	36.62	25.00	**34.16**	43.49	35.57	25.29	34.78
line 5	40.02	31.32	27.61	**32.98**	41.01	33.47	30.56	**35.01**	40.51	32.40	29.08	34.00
Mean	**37.63**	**32.22**	**28.98**	**32.94**	**37.55**	**32.94**	**30.57**	**33.69**	**37.59**	**32.58**	**29.78**	**33.32**

$LSD'_{0.05}$ (S)	0.75	$LSD'_{0.05}$ (G)	1.58
$LSD'_{0.05}$ (T)	0.81	$LSD'_{0.05}$ (G*S)	2.87
$LSD'_{0.05}$ (S*T)	NS	$LSD'_{0.05}$ (G*T)	2.81
		$LSD'_{0.05}$ (G*S*T)	4.61

Spike length (SL)

Grain yield is influenced by spike properties and spike length (Martincic *et al.*, 1996). Spike length (SL) was measured as the length from neck node to the tip of spike at maturity. Elhani *et al.* (2007) reported that, spike length mainly affected by the growing environment. In our study heat stress conditions led to a significant reduction in spike length. The overall average of spike length was reduced from 11.56 under FSD conditions to 10.07 and 8.94 cm under MHSD and SHSD conditions, respectively (Table 3 and 9). Under normal conditions cultivars Giza 168 and Sakha 92 recorded the longest spike (15.00 and 15.25 cm in the first and second growing seasons, respectively). Moreover, Giza 168 was superior in spike length (14.33cm) in the 1^{st} season and Sakha 93 (12.83 cm) in the 2^{nd} season under MHSD conditions. Meanwhile, under SHSD conditions L 1203 produced the longest spike (12.50 cm) in the first growing season and Assiut 204 surpassed all wheat genotypes (11.75 cm) in the second growing season (Table 9).

Number of spikes/ plant (SN)

Number of spikes per plant (SN) was significantly influenced by genotypes, sowing date and their interaction (Table 3). Heat-stressed conditions led to a significant reduction in spike number (Table 10). Under FSD conditions the highest SN was observed with cultivar Sahel 1 on both growing seasons, while the lowest number of spikes (11.50 and 10 spikes/ plant) produced by L887 and Misr 2 (in the first and second growing seasons, respectively. Under MHSD conditions line Assiut 724 produced the lowest number of spikes (5.67 spikes/ plant) in the 1^{st} season and cultivar Giza 168 (6.50 spikes/ plant) in the 2^{nd} season, while Line 1290 produced the highest number of spikes (16.33 and 17.50 spikes/ plant, in the first and second growing seasons, respectively). Under conditions of SHSD, cultivars Giza 168 and Misr 2 produced the lowest number of spikes/ plant (4.33 and 4.58, in the first and second growing seasons, respectively). Meanwhile, cultivar Sakha 92 produced the highest number of spikes/ plant (12.50 in both growing seasons) (Table 10).

Spikelet number per spike (SNS)

There is interdependence and correlation between spike length and spikelet number per spike and spikelet number per spike plays a very important role in the possible increase of grain yield of new genotypes (Martincic *et al*., 1996). In this study as an average over all genotypes spikelet number per spike (SNS) was significantly reduced from 20.97 to 18.85 and 16.51 due to MHSD and SHSD stress conditions, respectively (Table 11). The highest SNS was recorded by cultivar Gemmeza 10 (25 spikelet per spike) in the 1^{st} season, while Line Assiut 108 (25 spikelet per spike) surpassed all studied genotypes under this study in the 2^{nd} season under normal conditions. Meanwhile, under MHSD conditions Giza 171 and Sakha 8 was superior (22.11 and 22.33) in the 1^{st} and 2^{nd} growing seasons, respectively. Finally, under SHSD, superiority was recorded to Seds 1 (19.67) in the first growing season and Sakha 8 (20.67) in the 2^{nd} growing season (Table 11).

TABLE 9. Mean performance of spike length (SL).

Season (S)		2013/2014				2014/2015				Over all Mean			(G) Mean
Sowing Date (T)		FSD	MHSD	SHSD	Mean	FSD	MHSD	SHSD	Mean	FSD	MHSD	SHSD	
Genotypes (G)	Sakha 8	12.11	10.17	9.89	**10.72**	13.25	12.25	9.33	**11.61**	12.68	11.21	9.61	11.17
	Sakha 69	10.61	10.00	8.39	**9.67**	14.33	11.67	9.83	**11.94**	12.47	10.83	9.11	10.81
	Sakha 92	10.28	9.11	8.17	**9.19**	15.25	12.75	10.17	**12.72**	12.76	10.93	9.17	10.95
	Sakha 93	9.44	8.78	7.72	**8.65**	14.00	12.83	11.50	**12.78**	11.72	10.81	9.61	10.71
	Gemmeza 7	13.39	11.00	10.94	**11.78**	12.83	11.42	10.33	**11.53**	13.11	11.21	10.64	11.65
	Gemmeza 10	14.00	11.78	10.06	**11.94**	11.58	10.17	9.33	**10.36**	12.79	10.97	9.69	11.15
	Misr 1	11.56	9.61	8.78	**9.98**	11.25	10.67	10.17	**10.69**	11.40	10.14	9.47	10.34
	Misr 2	11.50	9.61	9.11	**10.07**	10.92	9.75	8.50	**9.72**	11.21	9.68	8.81	9.90
	Giza 160	11.06	10.44	8.78	**10.09**	12.00	9.83	8.42	**10.08**	11.53	10.14	8.60	10.09
	Giza 165	12.61	11.50	9.28	**11.13**	11.92	9.92	8.72	**10.19**	12.26	10.71	9.00	10.66
	Giza 168	15.00	14.33	10.67	**13.33**	12.00	10.33	8.67	**10.33**	13.50	12.33	9.67	11.83
	Giza 171	12.78	12.11	7.44	**10.78**	11.50	10.17	9.33	**10.33**	12.14	11.14	8.39	10.56
	Seds 1	14.17	10.61	9.72	**11.50**	11.00	8.55	7.33	**8.96**	12.58	9.58	8.53	10.23
	Seds 4	11.67	10.83	10.28	**10.93**	10.64	9.58	8.60	**9.61**	11.15	10.21	9.44	10.27
	Seds 12	13.00	11.89	8.83	**11.24**	10.00	9.00	7.56	**8.85**	11.50	10.44	8.19	10.05
	Seds 13	10.00	9.33	8.56	**9.30**	10.00	9.25	7.75	**9.00**	10.00	9.29	8.15	9.15
	Sahel 1	13.50	10.89	10.56	**11.65**	13.50	10.33	10.31	**11.38**	13.50	10.61	10.43	11.51
	Shandaweel 1	11.50	9.78	8.67	**9.98**	11.50	11.17	10.50	**11.06**	11.50	10.47	9.58	10.52
	Canada 462	10.67	10.11	8.00	**9.59**	11.50	10.67	8.81	**10.32**	11.08	10.39	8.40	9.96
	Canada 515	13.83	10.22	9.56	**11.20**	13.00	10.14	9.92	**11.02**	13.42	10.18	9.74	11.11
	Beknora	10.00	8.94	8.03	**8.99**	9.83	8.58	8.39	**8.94**	9.92	8.76	8.21	8.96
	Debera	12.11	10.00	9.22	**10.44**	11.42	10.33	9.75	**10.50**	11.76	10.17	9.49	10.47
	Nelen	10.00	6.78	6.44	**7.74**	10.00	8.86	6.92	**8.59**	10.00	7.82	6.68	8.17
	Snora	9.78	8.83	8.61	**9.07**	9.92	9.25	8.31	**9.16**	9.85	9.04	8.46	9.12
	Assiut 108	13.67	10.33	8.94	**10.98**	13.25	9.50	8.83	**10.53**	13.46	9.92	8.89	10.75
	Assiut 204	13.89	11.83	10.67	**12.13**	13.33	12.25	11.75	**12.44**	13.61	12.04	11.21	12.29
	Assiut 724	14.44	10.94	8.33	**11.24**	14.17	10.67	8.83	**11.22**	14.31	10.81	8.58	11.23
	MK 1-20	9.78	8.33	7.83	**8.65**	10.03	9.17	8.58	**9.26**	9.90	8.75	8.21	8.95
	MK 7-83	12.89	11.39	11.11	**11.80**	12.33	12.08	10.50	**11.64**	12.61	11.74	10.81	11.72
	L 1203	14.89	12.89	12.50	**13.43**	14.33	12.33	11.17	**12.61**	14.61	12.61	11.83	13.02
	L 1290	7.67	7.00	6.67	**7.11**	8.08	7.17	6.58	**7.28**	7.88	7.08	6.63	7.19
	L 1351	9.33	8.89	8.28	**8.83**	9.75	8.97	8.33	**9.02**	9.54	8.93	8.31	8.93
	L 1457	9.22	8.33	7.94	**8.50**	9.75	8.83	8.08	**8.89**	9.49	8.58	8.01	8.69
	L 741	10.56	9.61	9.11	**9.76**	10.83	9.42	8.61	**9.62**	10.69	9.51	8.86	9.69
	L 780	11.22	8.67	6.61	**8.83**	11.08	8.83	7.92	**9.28**	11.15	8.75	7.26	9.06
	L 887	10.56	9.22	8.67	**9.48**	10.83	9.08	8.33	**9.42**	10.69	9.15	8.50	9.45
	line 1	10.61	10.44	7.80	**9.62**	11.17	10.17	7.42	**9.58**	10.89	10.31	7.61	9.60
	line 3	9.89	9.72	9.00	**9.54**	9.75	9.08	8.33	**9.06**	9.82	9.40	8.67	9.30
	line 4	10.33	9.17	7.89	**9.13**	9.50	8.75	8.08	**8.78**	9.92	8.96	7.99	8.95
	line 5	10.00	9.44	8.00	**9.15**	10.00	9.17	8.25	**9.14**	10.00	9.31	8.13	9.14
Mean		**11.59**	**10.07**	**8.88**	**10.18**	**11.53**	**10.07**	**8.95**	**10.19**	**11.56**	**10.07**	**8.91**	**10.18**

LSD’ $_{0.05}$ (S)	NS	LSD’ $_{0.05}$ (G)	0.31
LSD’ $_{0.05}$ (T)	0.25	LSD’ $_{0.05}$ (G*S)	0.44
LSD’ $_{0.05}$ (S*T)	NS	LSD’ $_{0.05}$ (G*T)	0.58
		LSD’ $_{0.05}$ (G*S*T)	0.93

TABLE 10. Mean performance of spike number per plant (SN).

Season (S)	2013/2014				2014/2015				Over all Mean			(G) Mean
Sowing Date (T)	**FSD**	**MHSD**	**SHSD**	**Mean**	**FSD**	**MHSD**	**SHSD**	**Mean**	**FSD**	**MHSD**	**SHSD**	
Genotypes (G)												
Sakha 8	21.30	12.00	7.50	**13.60**	23.50	13.50	7.50	**15.83**	22.40	12.75	7.50	14.22
Sakha 69	17.67	12.67	10.00	**13.44**	21.00	11.83	8.75	**13.86**	19.34	12.25	9.38	13.66
Sakha 92	19.78	14.00	12.50	**15.43**	18.67	15.00	12.50	**15.39**	19.23	14.50	12.50	15.41
Sakha 93	20.00	9.00	7.00	**12.00**	20.00	11.67	8.33	**13.33**	20.00	10.33	7.67	12.67
Gemmeza 7	17.67	8.33	8.00	**14.67**	16.00	9.17	6.25	**13.81**	16.84	8.75	7.13	10.91
Gemmeza 10	17.00	8.00	7.22	**10.74**	15.75	8.22	5.83	**9.94**	16.38	8.11	6.53	10.34
Misr 1	14.56	12.00	9.56	**12.04**	16.83	11.00	8.11	**11.98**	15.70	11.50	8.83	12.01
Misr 2	11.67	10.78	6.00	**9.48**	10.00	9.17	4.58	**7.92**	10.84	9.97	5.29	8.70
Giza 160	16.67	12.25	6.67	**11.86**	18.75	14.46	11.38	**14.86**	17.71	13.35	9.02	13.36
Giza 165	21.00	11.11	8.11	**13.41**	22.25	15.03	8.67	**15.31**	21.63	13.07	8.39	14.36
Giza 168	15.33	6.33	4.33	**8.67**	14.50	6.50	4.75	**8.58**	14.92	6.42	4.54	8.63
Giza 171	23.67	9.44	7.67	**15.26**	22.00	9.78	8.17	**13.31**	22.84	9.61	7.92	13.46
Seds 1	16.33	15.67	6.56	**12.85**	18.25	15.50	9.33	**14.36**	17.29	15.58	7.94	13.60
Seds 4	22.33	11.78	8.33	**14.15**	27.75	14.33	10.83	**17.64**	25.04	13.06	9.58	15.89
Seds 12	16.50	9.33	6.33	**10.72**	16.50	11.83	5.50	**11.28**	16.50	10.58	5.92	11.00
Seds 13	16.78	8.67	8.00	**11.15**	15.67	7.67	6.00	**9.78**	16.23	8.17	7.00	10.47
Sahel 1	24.44	11.89	10.33	**16.22**	23.67	13.83	9.39	**18.96**	24.06	12.86	9.86	15.59
Shandaweel 1	17.33	8.67	6.78	**10.93**	14.00	8.33	6.50	**9.61**	15.67	8.50	6.64	10.27
Canada 462	21.78	9.11	7.67	**12.85**	23.17	11.28	9.33	**14.59**	22.48	10.19	8.50	13.72
Canada 515	17.00	11.78	9.33	**12.70**	13.25	9.50	8.33	**10.36**	15.13	10.64	8.83	11.53
Beknora	23.00	14.00	9.56	**15.52**	20.50	11.28	9.33	**13.70**	21.75	12.64	9.44	14.61
Debera	13.00	10.11	7.89	**10.33**	13.00	10.17	7.17	**10.11**	13.00	10.14	7.53	10.22
Nelen	20.22	11.00	8.78	**15.33**	22.33	10.28	7.50	**16.70**	21.28	10.64	8.14	13.35
Snora	20.44	8.44	6.33	**15.07**	20.17	8.17	6.17	**11.50**	20.31	8.31	6.25	11.62
Assiut 108	20.78	15.56	7.67	**14.67**	24.67	9.00	6.75	**13.47**	22.73	12.28	7.21	14.07
Assiut 204	12.17	11.28	8.56	**10.67**	13.83	11.00	8.33	**11.06**	13.00	11.14	8.44	10.86
Assiut 724	17.67	5.67	5.00	**9.44**	18.50	7.33	5.83	**10.56**	18.09	6.50	5.42	10.00
MK 1-20	20.78	8.33	4.56	**11.22**	17.17	11.33	7.50	**12.00**	18.98	9.83	6.03	11.61
MK 7-83	13.33	8.33	5.56	**9.07**	15.00	11.08	4.67	**10.25**	14.17	9.71	5.11	9.66
L 1203	14.00	5.89	5.67	**8.52**	11.50	9.33	6.50	**9.11**	12.75	7.61	6.08	8.81
L 1290	18.11	16.33	10.78	**15.07**	23.67	17.50	8.67	**16.61**	20.89	16.92	9.72	15.84
L 1351	17.33	10.50	8.00	**11.94**	20.25	9.72	8.00	**12.66**	18.79	10.11	8.00	12.30
L 1457	20.40	14.33	9.22	**21.35**	21.50	12.33	7.33	**20.06**	20.95	13.33	8.28	14.19
L 741	17.67	9.78	8.11	**11.85**	17.25	11.17	9.28	**12.56**	17.46	10.47	8.69	12.21
L 780	16.22	12.11	5.33	**11.22**	17.33	8.58	5.75	**10.56**	16.78	10.35	5.54	10.89
L 887	11.50	10.67	9.00	**10.39**	13.75	11.50	9.00	**11.42**	12.63	11.08	9.00	10.90
line 1	15.89	12.22	7.67	**11.93**	17.83	10.17	6.00	**11.33**	16.86	11.19	6.83	11.63
line 3	17.56	7.33	5.67	**10.19**	17.83	8.58	5.00	**10.47**	17.70	7.96	5.33	10.33
line 4	23.00	10.89	9.33	**14.41**	18.00	12.17	9.75	**13.31**	20.50	11.53	9.54	13.86
line 5	19.00	16.22	9.67	**14.96**	19.00	16.67	11.00	**15.56**	19.00	16.44	10.33	15.26
Mean	**18.02**	**10.80**	**7.76**	**12.63**	**18.36**	**11.12**	**7.74**	**12.84**	**18.19**	**10.96**	**7.75**	**12.30**

LSD’ $_{0.05}$ (S) NS

LSD’ $_{0.05}$ (T) 0.66

LSD’ $_{0.05}$ (S*T) NS

LSD’ $_{0.05}$ (G) 1.19

LSD’ $_{0.05}$ (G*S) 2.13

LSD’ $_{0.05}$ (G*T) 2.15

LSD’ $_{0.05}$ (G*S*T) 3.76

TABLE 11. Spikelet number per spike (SNS) mean performance.

Season (S)		2013/2014				2014/2015				Over all Mean			(G) Mean
Sowing Date (T)		**FSD**	**MHSD**	**SHSD**	**Mean**	**FSD**	**MHSD**	**SHSD**	**Mean**	**FSD**	**MHSD**	**SHSD**	
Genotypes (G)	Sakha 8	20.78	19.00	15.89	**18.56**	24.67	22.33	20.67	**22.56**	22.72	20.67	18.28	20.56
	Sakha 69	20.00	19.00	16.78	**18.59**	22.00	20.67	17.67	**20.11**	21.00	19.83	17.22	19.35
	Sakha 92	20.78	17.67	15.89	**18.11**	24.33	21.00	19.00	**21.44**	22.56	19.33	17.44	19.78
	Sakha 93	17.89	17.00	15.22	**16.70**	23.67	22.00	20.00	**21.89**	20.78	19.50	17.61	19.30
	Gemmeza 7	23.89	19.89	18.11	**20.63**	22.33	20.33	19.53	**20.73**	23.11	20.11	18.82	20.68
	Gemmeza 10	25.00	21.00	19.00	**21.67**	21.67	19.33	17.00	**19.33**	23.33	20.17	18.00	20.50
	Misr 1	19.22	17.89	17.67	**18.26**	19.67	19.50	18.67	**19.28**	19.44	18.69	18.17	18.77
	Misr 2	21.00	19.67	15.89	**18.85**	20.33	18.67	15.89	**18.30**	20.67	19.17	15.89	18.57
	Giza 160	20.89	19.22	17.00	**19.04**	20.67	19.17	16.17	**18.67**	20.78	19.19	16.58	18.85
	Giza 165	24.11	21.00	16.78	**20.63**	21.17	17.67	14.89	**17.91**	22.64	19.33	15.83	19.27
	Giza 168	22.78	21.89	17.22	**20.63**	21.50	19.00	15.33	**18.61**	22.14	20.44	16.28	19.62
	Giza 171	23.00	22.11	13.22	**19.44**	19.78	18.67	16.17	**18.20**	21.39	20.39	14.69	18.82
	Seds 1	22.89	21.00	19.67	**21.19**	21.00	17.00	15.00	**17.67**	21.94	19.00	17.33	19.43
	Seds 4	21.89	18.11	17.89	**19.30**	19.44	18.00	16.28	**17.91**	20.67	18.06	17.08	18.60
	Seds 12	23.00	21.00	14.11	**19.37**	19.00	17.33	15.56	**17.30**	21.00	19.17	14.83	18.33
	Seds 13	21.00	17.33	13.89	**17.41**	21.00	18.00	13.22	**17.41**	21.00	17.67	13.56	17.41
	Sahel 1	22.11	19.89	17.22	**19.74**	22.67	19.33	17.78	**19.93**	22.39	19.61	17.50	19.83
	Shandaweel 1	21.00	16.11	16.11	**17.74**	21.00	19.17	17.67	**19.28**	21.00	17.64	16.89	18.51
	Canada 462	21.22	19.22	14.11	**18.19**	22.33	20.33	16.11	**19.59**	21.78	19.78	15.11	18.89
	Canada 515	23.00	19.89	16.11	**19.67**	23.00	19.33	17.67	**20.00**	23.00	19.61	16.89	19.83
	Beknora	19.44	17.44	13.22	**16.70**	18.67	17.67	15.33	**17.22**	19.06	17.56	14.28	16.96
	Debera	21.89	19.00	17.22	**19.37**	21.33	19.00	18.00	**19.44**	21.61	19.00	17.61	19.41
	Nelen	21.00	15.56	13.44	**16.67**	21.00	17.78	15.83	**18.20**	21.00	16.67	14.64	17.44
	Snora	19.00	17.00	15.78	**17.26**	19.00	18.17	16.61	**17.93**	19.00	17.58	16.19	17.59
	Assiut 108	25.00	17.22	15.89	**19.37**	25.00	17.33	17.00	**19.78**	25.00	17.28	16.44	19.57
	Assiut 204	21.00	19.44	17.67	**19.37**	21.67	19.67	19.67	**20.33**	21.33	19.56	18.67	19.85
	Assiut 724	21.89	21.00	15.22	**19.37**	21.33	21.00	16.33	**19.56**	21.61	21.00	15.78	19.46
	MK 1-20	20.11	18.11	15.00	**17.74**	20.67	18.67	16.33	**18.56**	20.39	18.39	15.67	18.15
	MK 7-83	21.89	20.78	18.33	**20.33**	21.67	20.67	19.33	**20.56**	21.78	20.72	18.83	20.44
	L 1203	23.67	20.11	18.33	**20.70**	22.00	20.67	19.22	**20.63**	22.83	20.39	18.78	20.67
	L 1290	15.67	15.00	15.00	**15.22**	16.78	15.00	14.00	**15.26**	16.22	15.00	14.50	15.24
	L 1351	19.00	18.11	17.00	**18.04**	19.00	18.39	17.33	**18.24**	19.00	18.25	17.17	18.14
	L 1457	16.11	15.22	15.00	**15.44**	18.00	16.67	15.67	**16.78**	17.06	15.94	15.33	16.11
	L 741	20.11	19.00	16.11	**18.41**	20.67	19.00	16.28	**18.65**	20.39	19.00	16.19	18.53
	L 780	20.78	19.44	17.00	**19.07**	21.00	20.00	17.67	**19.56**	20.89	19.72	17.33	19.31
	L 887	21.00	17.89	17.00	**18.63**	21.00	17.33	16.67	**18.33**	21.00	17.61	16.83	18.48
	line 1	19.22	19.00	14.78	**17.67**	20.33	19.00	13.22	**17.52**	19.78	19.00	14.00	17.59
	line 3	19.00	18.11	17.67	**18.26**	19.00	18.67	16.67	**18.11**	19.00	18.39	17.17	18.19
	line 4	20.56	17.67	14.89	**17.70**	18.33	16.00	15.67	**16.67**	19.44	16.83	15.28	17.19
	line 5	18.78	17.44	14.11	**16.78**	19.00	18.33	15.33	**17.56**	18.89	17.89	14.72	17.17
Mean		**21.01**	**18.76**	**16.16**	**18.65**	**20.92**	**18.90**	**16.81**	**18.88**	**20.97**	**18.83**	**16.49**	**18.76**

LSD’ $_{0.05}$ (S) NS

LSD’ $_{0.05}$ (T) 0.35

LSD’ $_{0.05}$ (S*T) NS

LSD’ $_{0.05}$ (G) 0.51

LSD’ $_{0.05}$ (G*S) 0.75

LSD’ $_{0.05}$ (G*T) 0.95

LSD’ $_{0.05}$ (G*S*T) 1.57

100 kernel weight (100KW)

It is a well-known fact that 1000- seed weight had a significant effect on yield in cereals (Birol & Necmettin, 2011). As a general mean of all genotypes the average weight of 100 kernel was significantly reduced from 4.36 under FSD conditions to 3.77 and 3.30 gm under MHSD and SHSD conditions, respectively (Table 12). Under FSD conditions, cultivars Giza 160 and Sakha 8 produced the highest values of 100KW (5.66 and 5.98 gm) in the 1^{st} and 2^{nd} growing seasons, respectively. For MHSD conditions cultivars Nelen exhibited the highest values of 100KW (4.55 and 5.00 gm) in the first and second season, respectively. Finally, under SHSD conditions, superiority in 100KW was recorded to Giza 168 (4.02 gm in the first growing season) and Sakha 92 (4.87 gm in the second growing season) (Table 12).

Cluster analysis

Cluster analysis using stress tolerance indices (STIs) for all measured traits was performed based on the Euclidean distance matrix with un-weighted pair-group method based on arithmetic averages (UPGMA) in the software NTSYS-pc ver 2.1 (Fig. 1). Cluster analysis revealed two distinct groups with respect to heat tolerance with substantial diversity among genotypes either susceptible or tolerant to heat stress (GI and GII; Fig. 1). The first group (GI) consists of 20 genotypes which are heat stress tolerant, while the remaining 20 heat-stress susceptible genotypes were clustered to group II (GII). Cophenetic correlation between ultrametric similarities of tree and similarity matrix was estimated as $r = 0.76$, $P < 0.01$.

Discussion

Projection of climatic and environmental changes necessitates the need for breeding strategies that improve both yield potential and resilience to extreme weather events such as high temperatures and drought. Heat stress around sensitive stages of wheat development has been identified as a possible threat to wheat production. However, no estimates have been made to determine yield losses due to increased frequency and magnitude of high temperature stress under climate change (Stratonovitch & Semenov, 2015).

In the current study plants of 40 *Triticum aestivum* genotypes were grown under favorable and heat-stressed conditions in two successive growing seasons. Sowing dates were arranged so that plants grown under heat-stressed conditions experience hot days when they reached the booting stage. All measured morphological and agronomic traits responded differently to raising temperature during booting stages. Continuous phenotypic variations for all studied traits were observed, indicating a quantitative inheritance of heat stress tolerance. Heat stress reduces plant photosynthetic capacity through metabolic limitations and oxidative damage to chloroplasts and, potentially, cell death as a result of production of elevated concentrations of ROS (reactive oxygen species), with concomitant reductions in dry matter accumulation and grain yield (Apel & Hirt, 2004 and Farooq *et al.*, 2011).

TABLE 12. 100 kernel weight (100 KW) mean performance.

	Season (S)	2013/2014				2014/2015				Over all Mean			(G) Mean
	Sowing Date (T)	**FSD**	**MHSD**	**SHSD**	**Mean**	**FSD**	**MHSD**	**SHSD**	**Mean**	**FSD**	**MHSD**	**SHSD**	
Genotypes (G)	Sakha 8	4.45	3.70	3.70	**3.95**	5.98	4.70	3.48	**4.72**	5.21	4.20	3.59	4.33
	Sakha 69	3.79	3.15	3.13	**3.35**	4.37	4.22	3.14	**3.91**	4.08	3.69	3.14	3.64
	Sakha 92	3.62	2.93	2.36	**2.97**	5.04	4.93	4.87	**4.94**	4.33	3.93	3.62	3.96
	Sakha 93	4.73	3.76	3.31	**3.93**	4.74	4.66	4.60	**4.67**	4.73	4.21	3.95	4.30
	Gemmeza 7	5.27	3.76	3.44	**4.15**	4.49	4.37	4.26	**4.37**	4.88	4.06	3.85	4.26
	Gemmeza 10	4.37	3.19	2.91	**3.49**	4.19	4.17	4.15	**4.17**	4.28	3.68	3.53	3.83
	Misr 1	4.48	3.72	3.17	**3.79**	4.12	4.06	4.02	**4.07**	4.30	3.89	3.59	3.93
	Misr 2	4.98	4.38	3.84	**4.40**	4.00	3.98	3.96	**3.98**	4.49	4.18	3.90	4.19
	Giza 160	5.66	3.69	3.52	**4.29**	3.92	3.90	3.88	**3.90**	4.79	3.79	3.70	4.09
	Giza 165	5.07	3.25	3.14	**3.82**	3.85	3.83	3.81	**3.83**	4.46	3.54	3.47	3.82
	Giza 168	4.76	4.39	4.02	**4.39**	3.77	3.71	3.68	**3.72**	4.26	4.05	3.85	4.05
	Giza 171	3.95	3.92	3.08	**3.65**	3.65	3.61	3.53	**3.60**	3.80	3.77	3.31	3.62
	Seds 1	3.56	3.52	2.83	**3.30**	3.51	3.47	3.36	**3.44**	3.53	3.49	3.10	3.37
	Seds 4	3.87	3.66	3.54	**3.69**	3.26	3.02	2.81	**3.03**	3.56	3.34	3.17	3.36
	Seds 12	4.14	3.94	3.46	**3.84**	2.70	2.60	2.31	**2.54**	3.42	3.27	2.88	3.19
	Seds 13	3.86	3.10	3.03	**3.33**	4.11	3.44	3.17	**3.57**	3.98	3.27	3.10	3.45
	Sahel 1	4.45	3.46	3.00	**3.63**	4.90	3.71	3.23	**3.94**	4.67	3.58	3.11	3.79
	Shandaweel 1	3.61	3.25	2.97	**3.27**	3.86	3.41	3.04	**3.43**	3.73	3.33	3.00	3.35
	Canada 462	4.37	3.21	2.97	**3.51**	4.82	3.83	3.38	**4.01**	4.59	3.52	3.17	3.76
	Canada 515	3.70	3.03	2.85	**3.19**	3.95	3.60	3.17	**3.57**	3.82	3.32	3.01	3.38
	Beknora	3.81	3.71	3.09	**3.54**	4.45	4.03	3.22	**3.90**	4.13	3.87	3.15	3.72
	Debera	3.88	3.78	2.67	**3.44**	4.33	4.03	2.50	**3.62**	4.10	3.90	2.59	3.53
	Nelen	5.25	4.55	3.52	**4.44**	5.70	5.00	4.08	**4.92**	5.47	4.77	3.80	4.68
	Snora	3.74	3.54	3.28	**3.52**	3.94	3.90	3.71	**3.85**	3.84	3.72	3.49	3.68
	Assiut 108	4.78	3.76	3.72	**4.08**	5.23	4.05	3.67	**4.31**	5.00	3.90	3.69	4.20
	Assiut 204	4.67	3.66	3.05	**3.79**	5.12	3.91	2.97	**4.00**	4.89	3.78	3.01	3.89
	Assiut 724	4.12	4.06	3.21	**3.80**	5.13	3.86	3.17	**4.05**	4.62	3.96	3.19	3.92
	MK 1-20	3.14	3.04	2.47	**2.88**	3.39	3.29	2.56	**3.08**	3.26	3.16	2.52	2.98
	MK 7-83	5.38	4.54	3.76	**4.56**	5.83	4.99	4.27	**5.03**	5.60	4.76	4.01	4.79
	L 1203	4.60	3.84	3.77	**4.07**	5.05	4.29	3.74	**4.36**	4.82	4.06	3.75	4.21
	L 1290	4.71	3.88	3.06	**3.88**	4.57	4.22	3.55	**4.11**	4.64	4.05	3.30	4.00
	L 1351	4.10	3.15	3.01	**3.42**	4.55	3.40	2.80	**3.58**	4.32	3.27	2.90	3.50
	L 1457	3.73	2.82	2.65	**3.07**	3.98	3.07	2.70	**3.25**	3.85	2.95	2.67	3.16
	L 741	5.04	3.74	3.12	**3.97**	5.49	3.85	2.81	**4.05**	5.26	3.80	2.96	4.01
	L 780	3.18	3.08	2.30	**2.85**	3.43	3.33	2.42	**3.06**	3.30	3.20	2.36	2.95
	L 887	3.84	3.72	3.14	**3.56**	4.09	3.49	2.93	**3.50**	3.96	3.60	3.03	3.53
	line 1	4.46	4.32	2.89	**3.89**	4.91	4.77	2.63	**4.10**	4.68	4.54	2.76	3.99
	line 3	3.88	3.62	2.82	**3.44**	4.33	3.92	3.26	**3.83**	4.10	3.77	3.04	3.64
	line 4	3.83	3.43	3.06	**3.44**	4.08	3.68	3.38	**3.71**	3.95	3.55	3.22	3.57
	line 5	4.98	2.98	2.47	**3.47**	5.43	3.21	2.68	**3.77**	5.20	3.10	2.57	3.62
Mean		**4.30**	**3.61**	**3.13**	**3.68**	**4.41**	**3.89**	**3.37**	**3.89**	**4.35**	**3.75**	**3.25**	**3.78**

LSD' $_{0.05}$ (S)	0.10	LSD' $_{0.05}$ (G)	0.10
LSD' $_{0.05}$ (T)	0.12	LSD' $_{0.05}$ (G*S)	0.14
LSD' $_{0.05}$ (S*T)	NS	LSD' $_{0.05}$ (G*T)	0.17
		LSD' $_{0.05}$ (G*S*T)	0.25

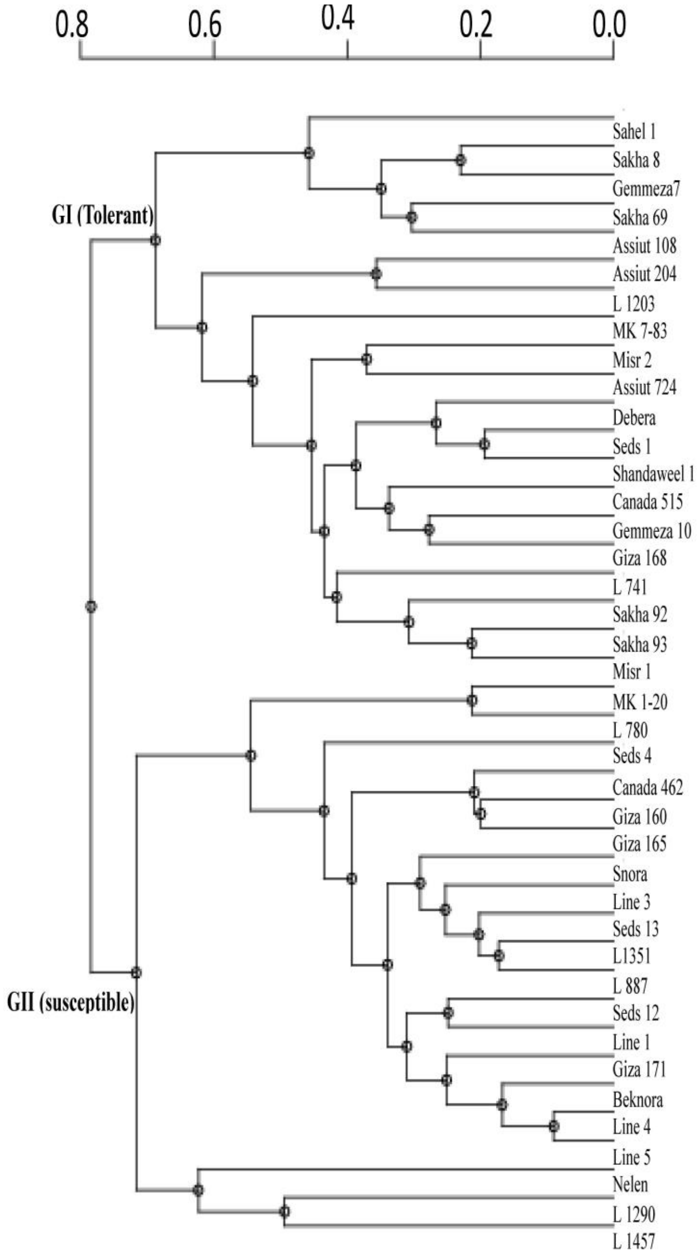

Fig. 1. Dendrogram generated by UPGMA cluster analysis showing relationship among 40 wheat genotypes based on Nei and Li similarity estimate (Nei & Li, 1979).

The dramatic decrease in all studied yield and yield-contributing traits under heat-stressed conditions might be due to the inhibition of photosynthesis as one of the most apparent effects of heat stress on photosynthetic tissues. High temperatures damage the OEC (oxygen evolving complex) of PSII (photosystem II), reduce Rubisco activity, and cause disorganization of the thylakoid membranes. Besides, the reduction of photosynthetic capacity during reproductive transition ultimately results in reduction of parental resources available for reproduction (Gorantla *et al*., 1984 ; Law & Crafts-Brandner, 1999 and Strasser, 1997). Furthermore, flowering plants are highly sensitive to temperature stresses during the reproductive phase, which covers floral initiation to seed maturity, with even a single hot day sometimes being determinant to reproductive success. (Zinn *et al*., 2010).

Cluster analysis revealed two distinct groups based on heat stress tolerance. Cophenetic correlation between ultrametric similarities of tree and similarity matrix was found to be relatively high (r = 0.76, P < 0.01), suggesting that the cluster analysis strongly represents the similarity matrix.

In conclusion, screening the primary gene pool of wheat for heat tolerance identified six genotypes represent variable degrees of tolerance to heat stress. The current study has demonstrated that screening the primary gene pool of wheat is a useful source for improving quantitative heat stress tolerance related traits. Besides, our data could serve as a vitally important tool in improving barley breeding for heat stress conditions by exploiting the identified heat tolerant genotypes in wheat breeding programs.

Finally we could conclud that the successful process of wheat breeding based on the knowledge of characteristics of genotypes, environment and their interaction. As in current study we could found that there are some new promising genotypes gaining the ability to be tolerant to sever heat stress during post anthesis and grain-filling phases stage depend on the purpose of breeding programs. For example if the program aims to produce high biomass yield some lines proved its ability such as L1457, Assiut 204 and L887. Also we can conclude that, genotypes which have been developed in hot regions can produce high yield in heat stress conditions such as cultivar Bicnora. In contrary also genotypes which developed in regions without a biotic stress face a big reduction when transferred to stress regions such as cultivar Gemmeza 10 which recorded the highest reduction in HI in sever conditions.

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تاثير الاجهاد الحرارى والتنوع الوراثى على مجموعة من التراكيب الوراثية لقمح الخبز

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يعتبر القمح من المحاصيل واسعة الانتشار خاصة فى الدول النامية ولكن حديثا أثرت التغيرات المناخية القاسية المرتبطة بالزيادة فى درجات الحرارة بالسلب على محصول القمح وذلك لتأثيرها على مراحل النمو وخاصة مرحلة التزهير وامتلاء الحبوب. تعتبر صفة المقاومة للحرارة من الصفات المعقدة حيث أنها تتاثر بالكثير من المكونات فى النبات. تم تقييم حولى ٤٠ تركيب وراثى لثمان صفات تضمنت صفة المحصول والصفات المرتبطة به تحت ميعاد الزراعة الأمثل الموصى به من وزارة الزراعة المصرية بالاضافة إلى ميعادين اضافيين تم اختيارهم بحيث يتعرض النبات لظروف الحرارة القاسية فى مرحلة الازهار وامتلاء الحبوب.

أظهرت جميع الصفات قيد الدراسة استجابة معنوية سواء لمواعيد الزراعة او للاختلافات الوراثية فيما بينها فى كلا موسمى الزراعة هذا و قد اظهرت البيانات الماخوذة دلالة على أن هذه الصفات قد تكون تحت تاثير العديد من الجينات.

أظهر تحليل التباين تاثيرا عالى المعنوية للتفاعل بين التراكيب الوراثية والبيئة كما هو متعارف عليه فى الصفات الكمية. هذا وقد ادى التحليل العنقودى للتراكيب الوراثية إلى تقسيم هذه التراكيب إلى مجموعتان منفصلتان احداهما تضم التراكيب المقاومة والاخرى حوت التراكيب الغير متحملة للحرارة. وقد ارتبط الشكل الظاهرى للتراكيب مع مصفوفة التشابه تحت مستوى معنوية اقل من ١٪ بارتباط قدره ٠,٧٦ مما يرجح ان التحليل العنقودى نجح بقوة فى تقسيم التراكيب والتمييز بينها.