Response of Bread Wheat Genotypes to Heat Stress

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ABSTRACT

Fifty-eight spring wheat genotypes were evaluated for yield and yield component traits. These traits are Flag leaf area, plant height, heading to date, spikes per plant, 1000-kernel weight, and grain yield. This study evaluated wheat genotypes of diverse origins for three sowing date treatments during three seasons, to assess the heat stress tolerance of these genotypes under nine environmental conditions. Genotypes were sown on first November (early), middle November (medium) and middle December (late) during the winter seasons of 2009/2010, 2010/2011 and 2011/2012 at Sohag University experimental farm, Egypt. Analysis of variance revealed that all of these traits were significantly affected by genotypes, heat stress treatments, and years. The results of this study indicated that six wheat genotypes could be selected to grow under heat stress conditions. Optimum sowing in the middle of November resulted in a better performance of genotypes than early and late sowing. Grain yield was reduced under heat stress, therefore highlighting the importance of breeding for genotypes with good adaptation in order to respond to future high temperature.

Keywords: Spring Wheat, *Triticum aestivum* L., Heat Stress, High Temperature.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important staple crop around the world. Its importance has risen even more due to the frequently experienced food shortages and its role in world trade. Terminal heat is a major abiotic stress affecting yield in wheat. Yates and Strzepek (1998) assessed the integrated impacts of climatic change on the agricultural economy of Egypt in 2060. Using outputs from three general circulation models (GFDL, UKMO, and GISS A1) the researchers found a decrease in yields from −5 to −51% for wheat, −5 to −27% for rice, and −2 to −21% for other cereals. CIMMYT-ICARDA (2011) estimated that 20-30% of wheat yield losses will occur by 2050 in developing countries as a result of an assumed temperature increase of 2-3°C on a global scale, but these yield losses will not be fully compensated by yield gains in high latitude regions, estimated at 10-15% (OECD-FAO, 2009). Several research findings noticed that temperature below (<10°C) or above (>25°C) the optimum (12 to 25°C) alters phenology, growth and development and finally reduce the yield of existing Bangladeshi wheat varieties (Hakim *et al.*, 2012; Hossain *et al.*, 2009, 2011, 2012a, 2012b, 2012c; Nahar *et al.*, 2010; Rahman *et al.*, 2009). The IPCC (2007), CIMMYT-ICARDA (2011), CGIAR (2009) and OECD (2003) reported that world wheat production will decrease due to global warming and developing countries, will be highly affected by the

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negative effects on wheat and other crops production. These factors of stress have a negative influences on the movement of photosynthetic products to the developing grains and inhibited starch synthesis; thus, it causes lower grain weight which might result in lower grain yields (Bhullar and Jenner, 1985). For healthy wheat growth and a good yield, the range of the optimum temperatures was 18 to 24◦C. Temperatures above 28 to 32◦C for short periods (e.g., 5 to 6 days) caused about 20% or more wheat yield losses (Stone and Nicolas, 1994). Substantial losses in rain-fed wheat are also anticipated: studies in India suggest that a 0.5°C rise in winter temperature would reduce wheat yield by 0.45 tones/ha while a similar rise in temperature of > 2.5°C would reduce non-irrigated wheat and rice farm revenue by 9-25% (Anonymous, 2012). The rise in daily average temperature, up to about 30 ºC, increased dough strength, while temperatures above this threshold value (35 - 40 ºC), even for periods of only few days, tended to decrease dough strength (Randall and Moss, 1990; Borghi *et al*., 1995 and Corbellini *et al*., 1997).

Under heat stress, the photosynthetic process is affected especially during grain filling stage when demand for assimilates is the greatest (Savin *et al*., 1997, Garc´ıa del Moral *et al*. 2003, Kumari *et al*. 2007). Terminal heat stress can be a problem in 40% of the irrigated wheat growing areas of the world (Fischer and Byerlee, 1991). Yield reduction in wheat under heat stress could be caused by accelerated phasic development (Frank and Bauer, 1997), accelerated senescence (Kuroyanagi and Paulsen, 1985), increased respiration (Berry and Bjorkman, 1980), reduced photosynthesis (Conroy *et al*., 1994) and inhibition of starch synthesis in developing kernels (Jenner, 1994). High temperatures during early crop development and particularly after anthesis may limit yield (Hunt *et al*., 1991). Temperature fluctuations during grain filling were caused deviations from expected dough properties (Blumenthal *et al*., 1991). Genotype-environment (GE) interactions are extremely important in the development and evaluation of plant varieties because they reduce the genotypic stability values under diverse environments (Hebert *et al*., 1995). Heading time is affected by complex interactions of temperature and photoperiod (Masle *et al*., 1989). Musich and Dusek (1980) found a decrease in grain yield by delaying sowing date. Different responses of wheat genotypes to dates were reported by (Ismail, 1995). Seeding wheat on first November gave the lowest numbers of tillers and spikes/m, plant height, kernels/spike and grain yield/fed when compared with the favorable and late planting dates. The crop sown in mid-November produced 7.76 and 2.22 % more grain yield than that sown in early and late November during first season, in which10.59 and 4.52 % in the second season as fund by (El-Gizawy, 2009). Mahfouz (1992) and Hamam and Khaled (2009) reported the highest production for all traits were studied at optimum date of wheat sowing in mid-November in Upper Egypt. The objectives of this study were to evaluate the grain yield of fifty-eight bread wheat genotypes of diverse origins at three sowing dates and to select the genotypes widely adapted to climate change (high-temperature) in Sohag in South Egypt.

METHODOLOGY

Planting and treatments: Fifty eight bread wheat genotypes of diverse origin were evaluated for heat stress tolerance under normal irrigated field conditions. (Table 1).

Table 1. Fifty-eight bread wheat genotypes were collected from different origins (Afghanistan, China, ICARDA, India, Iran, Germany, Germany, Spain, Russia, USA and Egypt.

Ent. No.	Origin	Genotype Name	Ent. No.	Origin	Genotype Name	Ent. No.	Origin	Genotype Name
1	Afghanistan	TRI 2794	21	India	TRI 2514	41	Russia	TRI 12737
2	Afghanistan	TRI 2814	22	India	TRI 2592	42	Russia	TRI 12738
3	Afghanistan	TRI 2843	23	Iran	TRI 5580	43	Turkey	TRI 19821
4	Afghanistan	TRI 2846	24	Iran	TRI 5625	44	Turkey	TRI 19837
5	Afghanistan	TRI 2858	25	Iran	TRI 5631	54	USA	TRI 17189
6	China	TRI 2420	26	Iran	TRI 5635	45	Egypt	Local line 1
7	China	TRI 2444	27	Iran	TRI 5646	46	Egypt	Local line 2
8	China	TRI 2446	28	Germany	TRI 25286	47	Egypt	Local line 11
9	China	TRI 2447	29	Germany	Devon	48	Egypt	Local line 3
10	China	TRI 2492	30	Germany	TRI 7794	49	Egypt	Local line 4
11	ICARDA	CHAM-4	31	Mongolia	TRI 7790	50	Egypt	Local line 5
12	ICARDA	KATILA-13	32	Mongolia	TRI 8149	51	Egypt	Sedes 1
13	ICARDA	QIMMA-12	33	Mongolia	TRI 8394	52	Egypt	Giza 168
14	ICARDA	HAMAM-1	34	Mongolia	TRI 17629	53	Egypt	Local line 6
15	ICARDA	HUD-10	35	Spain	TRI 12856	55	Egypt	Local line 7
16	ICARDA	HAMAM-14	36	Spain	TRI 12866	56	Egypt	Local line 8
17	ICARDA	ASHOSHA-1	37	Spain	TRI 12874	57	Egypt	Local line 9
18	India	TRI 2474	38	Spain	TRI 12887	58	Egypt	Local line 10
19	India	TRI 2477	39	Spain	TRI 18675			
20	India	TRI 2485	40	Russia	TRI 12736			

The seed material was obtained from Egypt, ICARDA-Aleppo, Syria and IPK-gatersleben Genebank-Germany. The experiments were conducted at the experimental farm of the Faculty of Agriculture, Sohag University, Sohag, Egypt during 2009/2010, 2010/2011 and 2011/2012 seasons, in a split-split plot arrangement of treatments with three replicates. The three sowing dates were assigned to the main plot and genotypes were assigned randomly to the sub-plot. Each genotype was sown in three rows with 3 meters long and 30 cm apart (sub plot size = 3.0 x 3.0 x 0.30 = 2.7 m^2). The first sowing date was on first November as early sowing date (D1), while the second date was in middle November as favourable sowing date (D2) and the third date was planted in middle December as late sowing (heat stress, D3). Data were recorded on plot basis for each genotype and each replicate and included the following traits: - (1) Flag leaf area: leaf length (cm) x width (cm) x 0.75 was measured according to (Jatimliansky *et al*., 1984); (2) Plant height (cm): The distance from the base of the culm to the tip of the spike of the main culm; (3) Days to heading: number of days from sowing until the upper most spikes appeared beyond the auricles of the flag leaf sheath (50% heading on plants basis). (4) Number of spikes / plant: Tiller with fertile spike; (5) 1000-kernel weight: It was obtained as the weight of 1000-kernel, which were chosen randomly; (6) Yield: It was determined as the weight of grains of each experimental plot and attributed it to hectare. Heat tolerant data of relative performance (%) and heat susceptibility index were calculated by following equations: RP%= Stress performance / Optimum performance. Relative performance (RP%) for yield was calculated as described by (Asana and Williams, 1965) and was expressed as a percentage. Heat susceptibility index (HSI) was calculated for each genotype according to the formula of (Fischer and Maurer, 1978): HIS= 1- (Y/ Yp)/1-(X/ Xp). Where ,Y = mean grain yield of a genotype under a stress environment. Yp = mean yield of the same genotype under a stress-free environment, X = mean Y of all genotypes, Xp = mean Yp of all genotypes, If HSI < 0.5, the crop is highly tolerant to high temperature stress, if HSI > 0.5 < l.0, it is moderately tolerant, and if HSI > 1.0, it is susceptible to high temperature stress.

Environment: The monthly temperatures varied from year to year (Table 2). The mean daily maximum and minimum air temperatures from the time of sowing to first booting stage (SBS1), first booting stage to heading date (BHS2) and heading date to maturity (HMS3) of early, medium and late sown crops are given in Table 2. The difference in the maximum temperatures at Sohag between the early and favorable then sowing dates were 2.26 ºC, 1.75 ºC and -0.85 ºC in SBS1, BHS2 and HMS3, respectively, while the difference in the maximum temperatures at Sohag between late and favorable sowing dates was -2.55 ºC, -1.27 ºC and 1.42 ºC in SBS1, BHS2 and HMS3, respectively.

Table 2. Mean maximum and minimum air temperatures (ºC) in Sohag during wheat growth stages in early, medium and late sowing.

Months	Years					
	2009/2010		2010/2011		2011/2012	
	Max.	Min.	Max.	Min.	Max.	Min.
November	26.16	13.43	29.23	13.52	22.03	8.57
December	22.54	8.67	24.41	10.18	21.37	7.55
January	23.29	8.03	19.05	7.51	18.93	4.22
February	26.51	8.03	27.64	9.42	20.81	7.09
Mars	28.76	13.35	28.02	10.83	23.20	8.00
April	33.81	12.00	33.49	20.53	31.58	15.75
May	36.81	22.96	36.00	25.6	39.55	26.41
Sowing dates	Sowing to booting stage (SBS1)		Sowing to heading date (SBS1)		Sowing to maturity (SBS1)	
	Max.	Min.	Max.	Min.	Max.	Min.
Early	24.32	10.4	23.47	10.16	23.03	8.91
Medium	22.06	8.43	21.72	8.31	23.87	6.64
Late	19.51	7.24	20.45	7.08	25.29	8.65

Statistical analysis: The significance of differences between genotypic means, heat stresses treatments and years were calculated by LSD and Revised LSD method according to (Waller and Duncan, 1969). The data of 2009/2010, 2010/2011 and 2011/2012 seasons were subjected to statistical analysis using the SAS software (SAS Institute, 1999).

RESULTS

Analysis of variance revealed mean squares of genotypes, sowing date and years were highly significant for flag leaf area, plant height, date to heading, spikes per plant, 1000-kernel weight, and grain yield (Table 3). However, the interaction between sowing dates * genotypes and sowing dates * years were showed highly significant for all traits studied. Moreover, genotypes * years interaction was highly significant for flag leaf area, days to heading, 1000-kernel weight and grain yield. The genotypes * sowing dates * years interaction was not significant for the studied traits. These results indicated that studied genotypes responded differently to the different environmental conditions suggesting the importance of the assessment of genotypes under different environments in order to identify the best genetic make up for a particular environment. Similar results were obtained by (El-Morshidy *et al*., 2001), (Abd-El-majeed *et al*., 2005), (Tawfelis, 2006), (Menshawy, 2007) and (Hamam and Khaled, 2009).

Table 3. Mean squares (MS) of the analysis of variance of all studied traits under sowing dates treatments over three years.

Source of variance	d.f.	Mean squares (MS)					
		Flag leaf area	Plant Height	Heading to date	Spikes per plant	1000-kernel Wight	Grain yield
Years (Y)	2	503.91**	2801.92**	1283.22**	3.64**	189.82**	28.71**
Sowing date (D)	2	397.87**	36062.17**	20173.38**	357.17**	18892.61**	592.99**
Y x D	4	6.43**	464.23**	903.07**	4.78**	405.97**	17.82**
Genotypes (G)	57	671.80**	1712.45**	1404.01**	56.44**	844.82**	68.81**
G x Y	114	1.61**	4.39	40.51**	0.07	5.87*	0.53**
G x D	114	2.15**	307.21**	78.39**	0.34**	51.28**	2.38**
G x Y x D	228	0.69	6.18	5.53	0.08	3.14	0.14
Error	1042	0.90	10.26	18.44	0.13	4.69	0.21

Flag leaf area (cm): The averages flag leaf area under D_1, D_2 and D_3 were 15.37, 16.17 and 14.23 cm^2 over three years. The data in Table (4) showed that, genotypes over the three sowing dates during the three years ranged from 8.31 cm^2 for genotype no. 31 to 27.13 cm^2 for genotype no. 34 with an average of 15.26 cm^2 over all genotypes. Reduction average in flag leaf area under D1 and D3 treatments was low for genotypes no. 8,10, 14, 23, 32, 34, 38, 47, 55 and 57 as compared with favourable sowing date (Table 4). Growth resources are limited by effect of heat stress, the size of plant organs such as leaves, tillers, and spikes were reduced (Fischer, 1984).

Table 4. Mean of flag leaf area for 58 bread wheat genotypes under sowing dates treatments and over three seasons.

Flag leaf area(cm)									
Genotype	**D_1**	**D_2**	**D_3**	**mean**	**Genotype**	**D_1**	**D_2**	**D_3**	**mean**
1	12.19	13.13	11.29	12.11	30	15.8	16.89	14.63	15.69
2	11.41	11.76	10.57	11.33	31	8.37	8.54	7.76	8.31
3	11.99	12.82	11.11	11.91	32	19.33	20.6	17.91	19.2
4	8.72	8.91	8.07	8.65	33	18.64	19.38	17.27	18.51
5	9.27	10.06	8.59	9.21	34	27.32	28.93	25.3	27.13
6	15.73	16.36	14.57	15.62	35	18.67	19.46	17.29	18.54
7	8.5	9.24	7.87	8.44	36	17.65	18.79	16.35	17.53
8	20.05	20.92	18.57	19.91	37	8.68	8.88	8.04	8.62
9	18.91	20.21	17.52	18.78	38	25.65	27.27	23.76	25.47
10	27.22	28.36	25.22	27.03	39	14.19	14.64	13.14	14.09
11	18.19	19.54	16.85	18.06	40	16.16	17.19	14.97	16.05
12	17.56	18.18	16.26	17.44	41	11.02	11.44	10.21	10.94
13	8.81	9.06	8.16	8.75	42	18.57	19.3	17.2	18.44
14	26.17	27.8	24.24	25.99	43	15.11	16.16	14	15.01
15	14.57	15.51	13.49	14.46	44	16.83	17.56	15.59	16.71
16	16.63	17.31	15.4	16.51	45	18.24	19.39	16.9	18.11
17	11.16	11.96	10.34	11.08	46	13.24	13.7	12.26	13.15
18	14.79	15.39	13.7	14.68	47	20.08	21.32	18.6	19.94
19	15.51	16.47	14.37	15.4	48	12.19	12.55	11.29	12.11
20	17.2	17.85	15.93	17.08	49	11.41	12.23	10.57	11.33
21	18.3	19.42	16.95	18.17	50	11.99	12.39	11.11	11.91
22	13.47	14.3	12.48	13.38	51	8.72	9.44	8.07	8.65
23	20.16	21.11	18.68	20.02	52	9.27	9.57	8.59	9.21
24	16.2	17.18	15.01	16.09	53	15.73	16.71	14.57	15.62
25	12.01	12.48	11.13	11.93	54	8.5	8.77	7.87	8.44
26	11.28	12.07	10.45	11.2	55	20.05	21.24	18.57	19.91
27	11.73	12.17	10.87	11.65	56	18.91	19.73	17.52	18.78
28	8.68	9.35	8.04	8.62	57	27.22	28.9	25.22	27.03
29	9.08	9.34	8.41	9.02	58	18.19	18.85	16.85	18.06
					Mean	15.37	16.17	14.23	15.26

LSD	0.05	0.01
LSD: Sowing dates (D)	0.12	0.15
Revised LSD: Genotypes (G)	1.35	1.75

Plant Height (cm): The averages plant height under D_1, D_2 and D_3 were 89.04, 95.47 and 77.31 cm over three years. Plant height average of fifty-eight genotypes over the three dates during three years ranged from 64.66 cm for genotype no. 28 to 107.10 cm for genotype no. 37 with an average of 87.28 cm over all genotypes. The averages of genotypes no. 3, 4, 8, 9, 23, 36, 37, 49, 57 and 58 revealed the lowest reduction in plant height under D_1 treatment as compared to the height under the favourable sowing date. The genotypes no. 4, 5, 6, 8, 9, 10, 36, 37, 39, 55 and 58 showed the lowest reduction in plant height under D_3 treatment (Table 5). Moreover, genotypes no. 4, 8, 9, 36, 37 and 58 gave the least reduction under D1 and D3 as compared to favourable sowing date (D2). The obtained results are on line with those obtained by (Nachit and Ketata, 1987) and (Ismail, 1995) and (Hamam and Khaled, 2009).

Table 5. Mean of plant height for 58 bread wheat genotypes under sowing dates treatments and over three seasons.

Plant height(cm)									
Genotype	**D_1**	**D_2**	**D_3**	**mean**	**Genotype**	**D_1**	**D_2**	**D_3**	**mean**
1	91.46	96.92	85.29	91.23	30	95.26	100.87	84.11	93.41
2	83.7	84.11	75.13	80.98	31	88.2	103.82	65.62	85.88
3	100.7	103.82	84.23	96.25	32	89.96	93.97	69.06	84.33
4	107.2	102.84	88.19	99.39	33	81.95	93.97	59.63	78.51
5	87.84	93.97	88.32	90.04	34	73.48	85.1	54.6	71.06
6	89.41	98.9	93.24	93.85	35	86.05	89.67	88.01	87.91
7	86.43	87.07	74.6	82.7	36	105.35	108.75	92	102.04
8	99.38	100.87	91.73	97.33	37	108.22	111.71	101.38	107.1
9	98.71	113.68	93.41	101.9	38	95.62	101.85	85.99	94.49
10	95.03	99.38	90.83	95.08	39	94.69	100.87	89.36	94.97
11	77.64	82.14	70.68	76.82	40	88.57	94.95	80.57	88.03
12	82.64	89.04	67.21	79.63	41	92.58	94.95	83.57	90.37
13	91.9	97.91	80.78	90.2	42	91.16	92.98	81.85	88.66
14	85.08	95.94	70.12	83.71	43	91.43	97.91	88.08	92.48
15	81.34	85.1	72.15	79.53	44	92.55	94.95	81.7	89.73
16	79.52	88.05	80.08	82.55	45	83.02	85.1	74.06	80.73
17	79.38	82.14	71.48	77.67	46	85.91	88.05	80.08	84.68
18	74.9	84.11	71.76	76.92	47	78.69	89.04	80.11	82.61
19	85.06	92	78.07	85.04	48	90.13	95.54	73.03	86.24
20	88.82	93.97	80.3	87.69	49	103.79	112.69	67.51	94.66
21	92.92	93.97	67.51	84.8	50	89.23	104.81	67.22	87.09
22	87.19	95.94	87.25	90.13	51	86.93	95.94	87.11	89.99
23	98.76	113.68	69.1	93.85	52	92.63	101.85	67.81	87.43
24	83.01	94.95	52.85	76.94	53	81.46	94.95	66.87	81.1
25	89.01	98.9	55.34	81.08	54	92.9	103.82	67.91	88.21

Plant height(cm)									
Genotype	**D_1**	**D_2**	**D_3**	**mean**	**Genotype**	**D_1**	**D_2**	**D_3**	**mean**
26	83.16	92.98	82.28	86.14	55	91.46	96.92	96.47	94.95
27	78.92	89.04	68.51	78.83	56	81.9	84.11	75.13	80.38
28	66.95	76.23	50.79	64.66	57	100.69	103.82	84.23	96.25
29	81.43	84.11	61.4	75.64	58	103.34	102.84	88.19	98.12
					Mean	89.04	95.47	77.31	87.28

LSD	0.05	0.01
LSD: Sowing dates (D)	0.39	0.51
Revised LSD: Genotypes (G)	4.55	5.88

Heading to date: The averages days to heading under D_1, D_2 and D_3 treatments were 69.59, 79.65 and 65.77 days over the three years. The average days to heading of fifty-eight genotypes over the three sowing dates during three years ranged from 53.31 days for genotype no. 4 to 96.31 days for genotype no. 51 with an average of 71.67 days over all genotypes (Table 6). The earliest genotypes were no. 4, 23, 24, 25, 31, 33, 34, 42, 47 and 58 revealed the highest decrease in days to heading under D1 treatment as compared with favourable sowing date treatment (Table 6). The earliest genotypes were no. 4, 23, 24, 25, 27, 31, 32, 34, 54 and 58 under D3 treatment for days to heading. Sivori (1975) reported a delay of 3 days in flowering of wheat by a delay of 15 days in sowing date. Also, Nachit and Ketata (1987) and Hamam and Khaled (2009) stated that the number of days to heading tended to decrease by delaying sowing date. Furthermore, the earliest genotypes were no. 4, 23, 24, 25, 31, 34 and 58 under D1 and D3 for days to heading as compared to favourable sowing date treatment. Similar results were found by (Abdel-Karim, 1991), (Ismail, 1995) and (Hamam and Khaled, 2009).

Table 6: Mean of days to heading for 58 bread wheat genotypes under sowing dates treatments and over three seasons.

Days to heading (day)									
Genotype	**D_1**	**D_2**	**D_3**	**mean**	**Genotype**	**D_1**	**D_2**	**D_3**	**mean**
1	77.85	86.35	74.77	79.65	30	75.96	85.86	72.53	78.12
2	70.45	77.03	73.03	73.5	31	54.97	72.61	53.66	60.41
3	69.41	78.5	62.5	70.14	32	65.92	77.52	54.92	66.12
4	53.86	56.91	49.17	53.31	33	63.85	79.97	57.19	67
5	66.19	72.12	67.11	68.47	34	58.94	70.16	51.85	60.32
6	68.94	77.03	72.61	72.86	35	64.03	73.59	67.27	68.3
7	70.22	72.61	60.18	67.67	36	70.35	78.01	63.26	70.54
8	81.97	86.84	75.58	81.46	37	74.36	84.88	73.51	77.58
9	68.08	80.46	68.53	72.36	38	70.3	80.46	65.8	72.19
10	69.08	77.03	66.73	70.95	39	71.97	80.46	70.48	74.3

Days to heading (day)									
Genotype	**D_1**	**D_2**	**D_3**	**mean**	**Genotype**	**D_1**	**D_2**	**D_3**	**mean**
11	77.75	87.33	75.17	80.09	40	73.44	82.43	68.07	74.64
12	69.2	81.93	66.76	72.63	41	64.92	71.63	60.15	65.57
13	67.13	76.54	65.66	69.78	42	62.05	70.65	63.57	65.42
14	69.49	80.46	66.95	72.3	43	65.04	72.61	63.13	66.93
15	71.12	80.46	72.47	74.68	44	70.88	77.52	65.19	71.2
16	68.8	78.01	67.5	71.44	45	65.12	71.14	60.08	65.45
17	70.48	77.03	65.58	71.03	46	71.21	76.54	65.8	71.18
18	67.16	77.03	69.88	71.36	47	63.18	73.59	63.62	66.8
19	76.87	87.82	75.53	80.08	48	70.19	79.38	64.41	71.33
20	78.32	87.82	72.75	79.63	49	73.36	84.39	60.49	72.75
21	79.05	86.35	66.81	77.4	50	66.31	82.43	65.56	71.43
22	75.26	84.88	78.11	79.42	51	87.89	105.48	95.54	96.31
23	58.94	72.61	53.86	61.8	52	83.34	104.5	78.16	88.67
24	57.96	71.63	50.9	60.17	53	65.51	80.95	64.03	70.16
25	62.41	72.61	55.06	63.36	54	64.58	76.04	56.57	65.73
26	66.7	78.01	64.69	69.8	55	75.7	84.89	69.87	76.82
27	68.09	79.48	56.54	68.04	56	82.03	90.92	76.84	83.26
28	64.04	77.52	59.38	66.98	57	79.9	90.93	68.05	79.63
29	75.95	89.29	67.4	77.55	58	59.94	68.61	54	60.85
					Mean	69.59	79.65	65.77	71.67

LSD	0.05	0.01
LSD: Sowing dates (D)	0.52	0.69
Revised LSD: Genotypes (G)	6.10	7.89

Spikes per plant: The averages spikes per plant under D_1, D_2 and D_3 were 8.5, 9.0 and 7.2 over three years. The averages spikes per plant of fifty-eight genotypes over the three sowing dates during three years ranged from 5.6 for genotypes no. 7, 18, 29, 40 and 51 to 10.2 for genotypes no. 9, 20, 31, 42 and 53 with an average of 8.2 over all genotypes (Table 7). The averages of genotypes no. 2, 9, 13, 20, 24, 31, 35, 42, 46, 53 and 56 gave the least reduction under D1 and D3 as compared to favorable sowing date treatment. These results are in harmony with those obtained by (Witt, 1996).

Table 7 Mean of number of spikes for 58 bread wheat genotypes under sowing dates treatments and over three seasons.

Number of spikes									
Genotype	**D_1**	**D_2**	**D_3**	**mean**	**Genotype**	**D_1**	**D_2**	**D_3**	**mean**
1	8.08	9	6.88	7.85	30	6.14	6.7	5.23	5.97
2	9.96	10	8.48	9.68	31	10.5	11	8.96	10.23
3	6.95	7.6	5.92	6.76	32	9.02	9.8	7.68	8.77
4	9.74	10	8.29	9.47	33	8.09	8.4	6.88	7.86
5	8.93	9.3	7.6	8.68	34	8.08	8.8	6.88	7.85
6	9.56	10	8.14	9.29	35	9.96	10	8.48	9.68
7	5.73	5.8	4.88	5.57	36	6.95	7.6	5.92	6.76
8	6.14	6.8	5.23	5.97	37	9.74	10	8.29	9.47
9	10.52	11	8.96	10.2	38	8.93	9.9	7.6	8.68
10	9.02	9.8	7.68	8.77	39	9.56	10	8.14	9.29
11	8.09	9	6.88	7.86	40	5.73	6.2	4.88	5.57
12	8.08	8.5	6.88	7.85	41	6.14	6.1	5.23	5.97
13	9.96	11	8.48	9.68	42	10.5	11	8.96	10.23
14	6.95	7.1	5.92	6.76	43	9.02	9.2	7.68	8.77
15	9.74	10	8.29	9.47	44	8.09	8.8	6.88	7.86
16	8.93	9.7	7.6	8.68	45	8.08	8.1	6.88	7.85
17	9.56	9.8	8.14	9.29	46	9.96	11	8.48	9.68
18	5.73	6.4	4.88	5.57	47	6.95	7.3	5.92	6.76
19	6.14	6.3	5.23	5.97	48	9.74	11	8.29	9.47
20	10.52	11	8.96	10.2	49	8.93	9.3	7.6	8.68
21	9.02	9.3	7.68	8.77	50	9.56	10	8.14	9.29
22	8.09	8.1	6.88	7.86	51	5.73	6.5	4.88	5.57
23	8.08	8.8	6.88	7.85	52	6.14	6.3	5.23	5.97
24	9.96	10	8.48	9.68	53	10.5	11	8.96	10.23
25	6.95	7.6	5.92	6.76	54	9.02	9.7	7.68	8.77
26	9.74	10	8.29	9.47	55	8.08	8.4	6.88	7.85
27	8.93	9.6	7.6	8.68	56	9.96	11	8.48	9.68
28	9.56	11	8.14	9.29	57	6.95	7.7	5.92	6.76
29	5.73	5.8	4.88	5.57	58	9.74	10	8.29	9.47
					Mean	8.45	9	7.19	8.21

LSD	0.05	0.01
LSD: Sowing dates (D)	0.04	0.06
Revised LSD: Genotypes (G)	0.51	0.66

1000-kernel Weight: The average 1000-kernel weight under D_1, D_2 and D_3 were 40.89, 44.80 and 31.37 g. over the three years. The average of 1000-kernel weight of the fifty-eight genotypes over the three sowing dates during three years (Table 8) ranged from 21.63 g. for genotype no. 30 to 51.69 g. for genotype no. 19 with an average of 39.15 g. over all genotypes. Table 8 showed the average reduction in 1000-kernel weight under D1 treatment was low for genotypes no. 2, 8, 17, 19, 21, 24, 32, 34, 47 and 53 as compared with favorable sowing date treatment. The genotypes no. 2, 8, 17, 19, 23, 24, 32, 34, 37 and 53 indicated the lowest reduce in 1000-kernel weight under D3 treatment. It is clear that genotype no. 2, 8, 17, 19, 24, 32, 34 and 53 gave the lowest decrease under D1 and D3 treatments as compared to their performance under the favorable sowing date treatment (Table 8). The results have the same trend to that obtained by (Tawfelis 2006, Menshawy 2007 and Hamam and Khaled 2009).

Table 8. Mean of 1000-kernel weight for 58 bread wheat genotypes under sowing dates treatments and over three seasons.

1000-kernel weight (g)									
Genotype	**D_1**	**D_2**	**D_3**	**mean**	**Genotype**	**D_1**	**D_2**	**D_3**	**mean**
1	36.83	39.14	29.80	35.26	30	22.50	23.54	18.84	21.63
2	48.93	52.68	38.06	46.56	31	42.52	47.79	33.18	41.16
3	36.88	38.21	31.62	35.57	32	47.92	49.18	41.58	46.23
4	45.32	50.42	32.28	42.67	33	34.91	38.32	27.99	33.74
5	39.49	44.86	26.48	36.94	34	49.36	49.54	45.14	48.01
6	43.14	47.43	31.31	40.63	35	43.43	47.07	32.85	41.12
7	41.79	44.44	33.30	39.84	36	38.82	41.20	33.10	37.71
8	46.87	48.46	40.06	45.13	37	42.64	45.11	36.53	41.43
9	41.55	45.94	30.21	39.23	38	40.63	46.09	26.81	37.84
10	36.89	42.49	23.94	34.44	39	29.20	34.09	20.00	27.77
11	24.58	27.91	18.50	23.66	40	40.42	44.86	31.39	38.89
12	39.56	47.90	26.71	38.06	41	33.11	39.35	21.98	31.48
13	24.37	25.96	21.27	23.87	42	40.37	43.88	32.34	38.86
14	42.68	45.37	35.75	41.27	43	43.23	48.51	31.65	41.13
15	38.41	43.11	27.80	36.44	44	39.33	46.92	24.09	36.78
16	39.22	47.48	26.40	37.70	45	41.51	43.57	35.47	40.18
17	51.32	55.72	40.50	49.18	46	40.57	43.47	34.02	39.35
18	40.20	45.58	30.16	38.65	47	48.52	54.18	34.80	45.83
19	53.09	56.65	45.32	51.69	48	41.20	44.83	31.85	39.29
20	40.86	47.28	30.94	39.69	49	39.88	42.90	32.79	38.52
21	46.62	52.53	34.94	44.69	50	40.42	43.88	32.63	38.98
22	41.79	48.10	28.71	39.53	51	39.57	42.08	34.92	38.85

1000-kernel weight (g)									
Genotype	**D_1**	**D_2**	**D_3**	**mean**	**Genotype**	**D_1**	**D_2**	**D_3**	**mean**
23	41.70	44.24	36.42	40.78	52	44.68	49.29	32.96	42.31
24	47.82	48.26	42.92	46.33	53	46.83	48.62	39.96	45.13
25	37.12	39.66	32.13	36.30	54	40.91	47.17	26.68	38.26
26	45.03	50.21	32.71	42.65	55	38.71	41.51	30.86	37.02
27	40.97	46.87	30.84	39.56	56	45.12	47.43	36.20	42.91
28	38.48	45.42	22.55	35.49	57	40.16	43.75	32.11	38.67
29	37.16	38.57	31.59	35.78	58	46.57	49.53	35.91	44.01
					Mean	40.89	44.80	31.76	39.15

LSD	0.05	0.01
LSD: Sowing dates (D)	0.26	0.35
Revised LSD: Genotypes (G)	3.08	3.98

Grain Yield, ton/ha: The averages of grain yield under D_1, D_2 and D_3 were 4.57, 5.97 and 3.55 ton/ha.over three years. The averages of grain yield is presented in (Table 9) of the fifty-eight genotypes over treatments during three years ranged from 1.34 ton/ha for genotype no. 7 to 7.32 ton/ha for genotype no. 47 with an average of 4.69 ton/ha over all genotypes. Table 9 showed the average reduction in grain yield under D1 treatment was low for genotypes no. 4, 6, 9, 14, 18, 22, 35, 37 and 47 as compared with favorable sowing date treatment. The genotypes no. 2, 4, 9, 14, 15, 22, 35, 47, 50 and 58 indicated the lowest reduction in grain yield under D3 treatment. It is clear that genotypes no. 2, 4, 9, 14, 22, 35 and 47 gave the lowest yield decrease under D1 and D3 compared to with favorable sowing date treatment. The local line 11 from Egypt produced the highest grain yield (9.37 ton/ha.) during the favorable condition under Sohag condition (Table 9). The grain yield was greatly affected by yield components like kernel weight. The delay in heading date under late sowing was attributed to grains could be affected by the high temperature specially during this period. Tawfelis (2006) found significant variation in yield and yield components among wheat genotypes under favorable and late planting. Seeding earlier and later reduces yield potential. A 34% decrease in grain yield occurred when planting was delayed from 22 September to 19 October in Nebraska USA, (Blue *et al*., 1990). Wheat yield declined by 30 to 40% when seeding was delayed from early September to late October in SW Saskatchewan obtained by (McLeod *et al*., 1992) Delayed planting of wheat from first October to first December in Kansas (USA) decreased grain yield by 18% per month reported by (Witt, 1996).

Table 9. Mean of grain yield for 58 bread wheat genotypes under sowing dates treatments and over three seasons.

Grain yield(ton/h)									
Genotype	D_1	D_2	D_3	mean	Genotype	D_1	D_2	D_3	mean
1	4.27	5.12	3.77	4.39	30	3.58	5.15	2.38	3.71
2	6.89	8.72	5.70	7.10	31	3.16	4.64	2.03	3.27
3	2.91	3.30	2.71	2.97	32	4.23	5.82	2.94	4.33
4	6.70	8.05	5.78	6.85	33	3.78	4.80	3.03	3.87
5	4.93	5.76	3.79	4.83	34	4.47	6.92	2.58	4.66
6	6.33	7.92	4.54	6.26	35	6.55	9.02	5.21	6.93
7	1.30	1.71	1.02	1.34	36	2.64	3.41	2.06	2.71
8	1.63	2.19	1.26	1.70	37	6.31	8.21	4.91	6.48
9	6.52	8.79	5.01	6.77	38	4.58	5.57	3.90	4.68
10	4.52	5.93	3.47	4.64	39	4.33	5.54	3.48	4.45
11	4.12	5.06	3.47	4.21	40	3.95	5.31	3.01	4.09
12	5.86	8.24	4.20	6.10	41	3.21	4.38	2.27	3.29
13	4.05	5.51	3.00	4.19	42	5.84	8.04	4.05	5.98
14	7.03	9.18	5.28	7.16	43	4.41	5.87	3.34	4.54
15	6.14	7.73	5.49	6.45	44	2.48	2.99	2.14	2.54
16	5.37	8.05	3.43	5.62	45	2.16	2.96	1.58	2.23
17	2.62	3.51	2.02	2.71	46	2.22	2.96	1.64	2.28
18	6.80	8.92	4.68	6.80	47	7.40	9.37	5.20	7.32
19	5.13	6.54	4.08	5.25	48	4.81	5.95	3.76	4.84
20	4.04	5.06	3.40	4.17	49	2.39	3.51	1.56	2.49
21	5.68	6.99	4.70	5.79	50	6.00	7.89	5.33	6.41
22	6.49	7.63	5.87	6.66	51	5.62	7.89	3.93	5.81
23	4.69	5.41	3.71	4.60	52	4.47	5.65	3.65	4.59
24	4.94	6.02	4.20	5.05	53	5.56	7.40	4.29	5.75
25	1.48	1.77	1.27	1.51	54	3.17	4.36	2.24	3.26
26	6.17	8.60	4.81	6.53	55	5.17	5.80	4.88	5.28
27	1.95	2.64	1.45	2.01	56	6.15	8.29	4.79	6.41
28	3.70	5.12	2.66	3.83	57	3.56	4.43	3.12	3.70
29	4.52	6.28	3.16	4.65	58	6.06	7.68	5.03	6.26
					Mean	4.57	5.97	3.55	4.69

	0.05	0.01
LSD	0.05	0.01
LSD: Sowing dates (D)	0.06	0.07
Revised LSD: Genotypes (G)	0.65	0.84

Relative yield performance and heat susceptibility index: The performance of different genotypes under stress could be observed by calculating relative performance% (Asana and Williams, 1965) and Heat susceptibility index (Fischer and Maurer, 1978). Rahman *et al.* (2009) and Hossain *et al. (2012)* also reported genotypic variation in relative performance % of sensitive and tolerant genotypes, and a higher relative performance% indicated that the genotype was tolerant to stress. Al-Karaki (2012) found cultivars Waha-1, Omrabi-5, and Massara-1 genotypes performed better in Mediterranean climate among genotypes studied. The results showed that the late sowing date, the RP% of all genotype ranged from 37.30 to 82.33%. The highest relative performance % was found among the fifty-eight genotypes, 'genotype no. 3' (82.33%), lowest in 'genotype no. 34' (37.30%). Considering the HSI value, thirty-one genotypes (> 1 up to 1.55) was higher than 1.0 in late sowing date, indicating that this genotype had no tolerance to high temperature. The HSI of twenty-five genotypes (> 0.5 < l.0) showed the moderate heat stress tolerance. Among the fifty-eight genotypes, 'TRI2843' from Afghanistan and 'local line 7' from Egypt (RP% = 82.33 and 84.14; HSI = 0.44 and 0.39 respectively) were found highly tolerant to high temperature stress.

DISCUSSION

Wheat production is often limited by terminal heat stress. Temperatures through growing seasons are shown in (Table 2). The data showed wide fluctuations of the temperature over the growing seasons. Temperatures at different growing stages of the same sowing date were not fixed in the three seasons of the study. Moreover, the temperature of growing months fluctuated from season to season. The investigated genotypes were grown under different climatic conditions namely; sowing date (heat stress) and years. The results showed that grain yield was decreased about 23.34 and 40.23 % under early and late sowing dates (Table 9). Rosenzweig and Tubiello (1996) and Hamam and Khaled (2009) reported that consistent decreases in wheat yield due to daily temperature rise. **Flag leaf area (cm):** Flag leaf area reduction was avoidance strategy in some genotypes to tolerance the heat stress under late sowing date. The averages of flag leaf area at early and late sowing date were reduced by 4.9 and 11.91% respectively (Table 4). Under early sowing date and late sowing (heat stress), loss of leaves and reduced expansion of younger leaves caused a decrease in the leaf area ratio in the stressed plants. As different environmental factors may affect leaf morphology in the same direction and act simultaneously (Fonseca *et al*. 2000). Reducing caused a great reduction in grain yield. The present results are similar to those obtained by (Saadalla, 1993), (Abd-Elmajed *et al*., 2005) and (Hamam and Khaled, 2009).

Plant Height (cm): Sowing dates caused a significant reduction of the plant height and a remarkable decrease of plant dry matter accumulation. Sowing dates caused reduction in the plant height during early sowing date and late sowing (heat stress), for the same treatment which had the highest leaf area under favourable sowing date. The genotypic and sowing date induced variability in plant height in the present study was interrelated. The averages of plant height at early and late sowing date were reduced by 6.70 and 25.83% respectively (Table 5)

Date to heading: High temperature stress in late sowing, duration of life cycle stages of wheat varieties was reduced. Optimum sowing on November 15 resulted in better performance of all varieties than late sowing on December 27 (Hossain and Teixeira da Silva 2012). However, with a delay in sowing, crop yield potential is decreased (Keatinge *et al*., 1986). In addition, the time had taken for the spike to emergence from the enclosing sheath is entirely dependent on growth conditions. In our study, the genotypes evaluated needed most time for heading in optimum sowing and less time in heat stress early and late sowing. Among fifty- eight genotypes, 'genotypes no. 8, 22, 51, 52 are statistically similar and the longest time for heading, while 'genotypes no. 4, 23, 24, 31 and 34' required the least time to reach heading due to heat stress in D3 (Table 6). Due to heat stress in D3, the reduction in required heading to date was the highest in 'genotype no. 32' (22.58 days) and the lowest in 'genotype no. 2' (4 days). The averages of number of days to heading at early and late sowing date were reduced by 10.1 and 13.9 days (Table 6). Hossain *et al.* (2011, 2012, 2012b, 2012c), Nahar *et al.* (2010), Rahman *et al.* (2009) Hamam and Khaled (2009) and Ubaidullah et a*l* (2006) also observed that delayed sowing in wheat shortened the duration of each developmental phase due to a rise in temperature. They also reported up to 13.88 days difference between optimum sowing and late sowing for heading. Al-Karaki (2012), investigating 16 wheat cultivars in a Mediterranean climate, showed long pre-heading periods, followed by short periods and high rates of grain filling to avoid terminal drought and high temperature stress (18.93 - 39.55°C). Among fifty- eight genotypes, 'genotypes no. 4 and 58' was tolerant to heat stress and early for heading date with high yielding. **Spikes per plant:** The averages of spikes per plant at early and late sowing date were reduced by 5.92 and 19.94% days (Table 7). Reducing number of spikes/plant caused a great reduction in grain yield. Late sowing wheat decreases number of spikes per plant and causes tillers that develop during spring to be small with a low grain yield. The results found by (Thiry *et al.*, 2002) were in the harmony. The present results are similar to those obtained by (Saadalla, 1993), (Abd-Elmajed *et al.*,2005) and (Hamam and Khaled, 2009). **1000-kernel Weight:** High temperature affected grain maturity which resulted in shrinked kernels and reduced kernel weight. The average 1000-kernel weight at early and late sowing dates was reduced by 8.69 and 28.94% days (Table 8). The results have smilar trend with what was obtained by (Tawfelis 2006, Menshawy 2007 and Hamam and Khaled 2009) who reported that high reduction in kernel weight was found under late planting; it could be fully accounted by the reduction in grain filling period. Reducing 1000 kernel weight caused a great reduction in grain yield. The present results are in harmony with those obtained by (Saadalla, 1993), (Abd-Elmajed *et al.*, 2005) and (Hamam and Khaled, 2009). **Grain yield:** Sowing date is the most important factor for temperature-sensitive cereals such as wheat, but the time of planting and its effect on plant varies from region to region. In Sohag, Egypt, planting during optimum sowing encourages more number of spikes per plant and promotes high grain yield. Early planting causes excessive tillering, increases competition, and leads to a low grain yield. In this study planting early lead to early maturity, and resulted in partial loss of the grain yield because of birds" attacking and feeding crop leads to the lack of cultivated area at that time. Early sowing growing season was unfavorable for seedling establishment and yield was well above the average 2.5 t (Acevedo and Naji, 1989). The earliest sowing resulted in yield reduction, and the penalty for late sowing was severe, loosing about 37 kg ha^{-1} of grain yield per day, or 5% per week (Mahdi *et al.*, 1998). In Sohag, Egypt, early wheat faces high temperature stress at the germination stage whereas late sown wheat is affected by high temperature at two stages: reproductive stage and grain filling stage (>21.37 until 39.55 °C), which ultimately affects grain yield. Our results were similar to those obtained by (Hossain *et al.*, 2011; 2012c). For each degree rises in temperature above the optimum (15°C) a yield reduction of 3-4% per spike (Wardlaw *et* *al.*, 1989a, 1989b). Mahdi *et al*. (1998) reported that delay sowing led to a significant decrease in yield. In our study, some genotypes were highly affected by heat stress in D1 and D3 these effects were more than those observed in D2, resulted eventually in a drastic reduction in grain yield. Among the fifty- eight genotypes, 'Local line 2 from Egypt' produced statistically the highest grain yield both in D1, D2 and D3, followed by 'HAMAM-1 from ICARDA' while 'TRI 2444 from China' produced least grain yield. However, the rate of reduction varied from genotype to another. Among the fifty- eight genotypes, the average yield reduction was 23.34 and 40.23% in early and late sowing date, respectively, was a result of high temperature stress in early and late sowing date. In our research, fluctuations in weather conditions (Table 2) were reflected in number of spikes per plant, 1000-kernel weight and ultimately grain yield, which is common to several crops (Martiniello and Teixeira da Silva, 2011). Previous research findings also indicated that high temperature significantly decreased all traits, especially 1000-kernel weight (by 20.61%) and grain yield (by 46.63%) under high temperature stress (>25 to 30°C) (Modarresi *et al.*, 2010).

RECOMMENDATIONS

From the above results and discussion, the high temperature stress in late sowing, resulted in the reduction of crop life cycle of the tested wheat genotypes. Optimum sowing on the middle of November resulted in a better performance than early and late sowing. The results of this study indicated that wheat genotypes no. 4 (TRI 2846) from Afghanistan, 15 (HUD-10) from ICARDA, 18 (TRI 2474) from India, 22 (TRI 2592) from India, 35 (TRI 12856) from Spain and 47 (Local line 11) from Egypt could be selected to be grown under heat stress conditions. Large scale trait evaluations may enhance utilization of plant genetic resources collections by increasing genetic variability for economically significant traits into wheat breeding programs. A wide genetic base is useful for breeding purposes found in this study for plant height, days to heading, 1000-kernel weight and grain yield. Moreover, selection based on the tolerance indices which calculated from the yield under different conditions, we are breeding for the genotypes that adapted to a wide range of high temperature.

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استجابة التراكيب الوراثية لقمح الخبز لإجهاد الحرارة

خلف على همام*

ملخـص

تم تقييم ثمانية وخمسين تركيبا وراثيا للقمح الربيعي لصفات المحصول ومكوناته. وهذه الصفات، هي: مساحة ورقة العلم ، طول النبات ، عدد الأيام حتى طرد السنابل ، عدد السنابل لكل نبات، وزن الألف حبة ومحصول الحبوب. هدفت هذه الدراسة إلى تقييم التراكيب الوراثية للقمح مختلفة المنشأ، وتم تقييمها تحت ثلاث معاملات مواعيد زراعة خلال ثلاثة مواسم زراعية ، إلى تقييم تحمل الإجهاد الحراري من هذه التراكيب الوراثية تحت تسعة ظروف بيئية. زرعت التراكيب الوراثية للقمح في ثلاثة مواعيد: أول نوفمبر (المبكر)، منتصف نوفمبر(متوسط) ومنتصف ديسمبر (الإجهاد الحراري) خلال مواسم شتاء 2010/2009، 2010/ 2011 و 2012/2011م بالمزرعة التجريبية - جامعة سوهاج – مصر. كشف تحليل التباين أن جميع الصفات تحت الدارسة عالية المعنوية تحت تأثير التراكيب الوراثية، معاملات مواعيد زراعة، والسنوات. وأشارت نتائج هذه الدراسة إلى أنه تم انتخاب ستة تراكيب وراثية من القمح للنمو تحت ظروف الإجهاد الحراري، وكان أفضل موعد للزراعة هو منتصف نوفمبر؛ حيث أداء أفضل للتراكيب الوراثية بالمقارنة بمواعيد الزراعة المبكرة والمتأخرة. انخفاض محصول الحبوب تحت الإجهاد الحراري، وتوضيح أهمية تربية تراكيب الوراثية مع الأقلمة الجيدة من أجل الاستجابة لتغير المناخ في المستقبل.

الكلمات الدالة: القمح الربيعي، الإجهاد الحراري، الحرارة المرتفعة.

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