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Differential Response of Some Bread Wheat (*Triticum aestivum* L.) Genotypes for Yield and Yield components to Terminal Heat Stress under Sudan Conditions

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Introduction

In the hot countries of subtropics and warm regions of the temperate zones, the distribution of wheat is determined by temperature and water supply. In Sudan, wheat is exclusively produced under irrigation in winter during the period from November to March (Ishag, 1992). This period is shorter and with relatively higher temperature than those of traditional wheat producing regions of the world. The northern region, which is characterized by a relatively longer and cooler season, is considered more suitable for wheat production compared to the central part of the country. However, due to the high costs and limited area in the northern region, the crop was introduced into the central areas of Sudan, such as Gezira and New Halfa schemes, which are known by relatively higher temperatures during the beginning and end of growing season. The effect of these high temperatures on wheat results usually in serious reduction of yield and its components, e. g., kernel weight (Wiegand and Cuellar, 1981). Acevedo *et al.*, (1991) reported that an increase by one degree of mean temperature during grain filling resulted in a reduction of 4 percent in grain weight. The influence of high temperature stress on yield and its components depends usually on the growth stage during which the high temperature commences (Vos 1981). In recent years, because of the increasing demand to fill the gap and to have a very effective food security, wheat has acquired great attention from the government as a strategic food crop and became one of the main priorities of the national agricultural policy. Where, the government of Sudan has aimed towards greater self-sufficiency and has taken measures aimed to boost domestic production of wheat (Faki *et al.*, 1998). This fact imposes breeding programs for developing more locally-adapted, heat tolerant and high-yielding cultivars, capable of surviving and producing high yields under these heat-stress conditions which characterizing the central non-traditional areas of wheat production. Therefore, the objectives of this study were: 1) to estimate the effect of high temperature on wheat. 2) to determine the genetic variability and differential response of wheat genotypes to terminal heat stress for yield and its components.

Material and Methods

The experiment was conducted over two consecutive winter seasons (2005/06-2006/07), at Shambat (Khartoum North) in the Experimental Farm of Faculty of Agriculture-University of Khartoum (Lat: 15’ 40” N. and Long: 32’ 32” E., 380 m above sea level). The climate was described differently by Oliver (1965), Whiteman (1971) and Adam (1971). The soil consists of Nile alluvium and sandy clay soil. The genetic material used in this study composed of a total of 15 genotypes of bread wheat (*Triticum aestivum* L.), eleven of them were locally-developed advanced breeding lines and four were commercial released varieties, used as checks. The heat stress was simulated by using three dates of sowing: S1, S2 and S3, with interval of 15 days. In the first season (2005/06), the sowing dates, S1, S2 and S3 were on the 13th of November, 28th of November and 12th of December, respectively. While in the second season (2006/07), they were on the 15th of November, 30th of November, and 14th of December, respectively. The first sowing date (S1) was considered as non-stress environment (NSE) and the last two were considered as heat stress environments (HS2E and HS3E), with terminal heat stress. The experiment was laid out in the field in a split plot design with three replications, each replication was divided into three main plots, and each main plot was divided into subplots. Sowing dates were randomly assigned as main plots and genotypes were randomized as subplots within main plots. After well land preparation including plowing, harrowing and leveling, each genotype was grown in a sub-plot, which consisted of four rows, each 2.5 m in length. Seeds were drilled in lines, each 20 cm apart at a seed rate of 120 kg/ha. Irrigation was on every 10-14 days, and the crop received a total of 13 irrigations, during the growing season. After crop emergence, weeding was done every three weeks until grain filling, using hand hoeing. Data was collected on ten randomly chosen plants, and was recorded on both vegetative and reproductive traits. However, in this manuscript only data on reproductive traits (yield and yield components) is presented. The proper statistical procedure was carried out to analyze the collected data.

Results and Discussion

The combined analysis revealed that the effect of years was significant for all of the studied traits and the effect of sowing date was significant only for the characters grain yield, 100-kernels weight and dry weight (Table 1). The interaction between years and sowing dates was significant for all of the studied traits, except number of kernels/spike and number of kernels/plant. These results indicate the great role of variation imposed by years and their interaction with sowing date on growth and yield of bread wheat grown in the central areas of Sudan. Similar considerable variability in crop performance due to changes in climatic conditions over years in the non-traditional areas of central Sudan was reported by Ageeb (1994). The genotypes exhibited significant variation for the traits: number of spikes/plant, 100-kernels weight, and dry weight, and non-significant variation for the others. This indicates the importance of these traits as selection criteria for wheat improvement. However, significant genotypic differential response to the different sowing dates (terminal heat stress) was observed for the traits grain yield (kg/ha), number of spikes/plant, 100-kernels weight, and dry weight (Table 1). This observed differential response and stability performance of some genotypes to terminal heat stress was also reported by Lin *et al*., (1984) and Abdelmula *et al*., (2010), which could be of great importance in identification and selection of most adapted heat tolerant genotypes.

Table 1: Mean Squares from combined analysis due to Years (Y), Sowing dates (SD), Genotypes (G), and their interaction (Y x SD and G x SD) for some traits of 15 genotypes of wheat, evaluated for two years (2005/06 and 2006/07) at Shambat (Sudan)

Characters	Y	SD	Y x SD	G	G x SD
	df =1	df =2	df =2	df =14	Df =28
Grain yield (kg/ha)	135440.5*	4111767.3*	29292.7*	741033.1 NS	518214.7*
Number of spikes/plant	755.4**	0.4 NS	11.7*	3.3*	3.0*
Number of kernels/spike	1120.4**	10.5 NS	27.2 NS	71.8 NS	42.1 NS
Number of kernels/plant	651312.0**	1688.0 NS	3634.0 NS	3860.0 NS	2832.0 NS
100-kernels weight (g)	2.5*	4.9**	0.9*	0.9**	0.2**
Dry weight (g)	8296.7**	1037.0**	2012.6**	183.9**	89.2*

*, ** = significant at 5% and 1% probability level of significance, respectively.
NS = non – significant different at 5% probability level of significance.

Under the most delayed sowing date (S3), i.e., the terminal heat stress, the traits grain yield (kg/ha), 100-kernels weight and dry weight were significantly reduced compared to the optimum (S1) sowing date (Table 2). Nevertheless, the reduction in yield under slight delay (S2) was not significant; indicating that this slight delay in sowing date was not severe enough to cause injury to the genotypes under study. This would confirm the fact that the optimum sowing date of wheat at Shambat (Central Sudan) depends mainly on the onset of winter, which fluctuates from year to another and even within the season from month to another. However, some traits, such as number of spikes/plant and number of kernels/spike, were not significantly reduced under slight and severe heat stress (S2 and S3), which indicates that these traits could be highly-genetic controlled and less influenced by the environmental factors. Similar results were reported by Tahir *et al*., (2006). The decrease in grain yield could be attributed mainly to the reduction of yield components, such as 100- kernel weight, which are strongly correlated with yield. Similar results were observed by O'Toole and Stockle (1991).

Table 2: Means of yield, yield components and dry weight of 15 genotypes of wheat, evaluated at Shambat (Sudan), under three sowing dates (S1, S2 and S3) averaged over two years (2005/06 and 2006/07)

Characters	Sowing date			Means	C.V%
	S1	S2	S3		
Grain yield (kg/ha)	* 1945 a	1362 a	761 b	1356	17.4
Number of spikes/plant	5.8	5.8	5.7	5.76	6.4
Number of kernels/spike	21.1	21.3	21.7	21.4	7.9
Number of kernels/plant	118	126	125	123	7.3
100-kernels weight (g)	* 3.65 a	3.35 b	3.30 b	3.43	3.3
Dry weight (g)	* 40.1 a	34.8 b	33.7 b	36.2	4.3

* Means followed by the same letter(s) are not significantly different

Great variation was observed, when the performance of genotypes across the different sowing dates was concerned (Figure 1). It was found that under optimum sowing date (S1), genotypes OASIS/ KAUZ//3*BCN and TAGANA produced the highest and lowest grain yield (kg/ha), respectively. Moreover, under both optimum (S1) and slight delayed sowing (S2) dates, the genotype OASIS/KAUZ/3*BCN out-yielded all of the four check varieties (Figure 1). Whereas, under both delayed sowing dates (S2 and S3) the most sensitive genotype to heat stress was CONDOR"S" 14PYT//DWR39. The highest value of grain yield (kg/ha) under the severe heat stress (S3) was produced by the check variety EL-Nelain, followed by KAUZ"S"657C1-3-6-2-2-1-2 and EL-Nelain/SASARAIB. However, the genotype OASIS/ KAUZ//3*BCN exhibited relatively higher performance across the three sowing dates. Similar results were also observed by Abdelmula *et al*., (2010) in other screened group of genotypes of bread wheat. The variation in the response of the genotypes to a range of different environment (sowing dates) could be attributed to the variable adaptation genes possessed by these tested genotypes. Based on results of this study, the genotype OASIS/ KAUZ//3*BCN could be identified as the most suitable genotype to be grown at both sowing dates (S1 and S2). Moreover, the same genotype demonstrated relatively a higher performance under S3, comparable to the check varieties. This higher yield obtained under favorable (S1) as well as under stress environments (terminal heat stress, S2 and S3) indicate a characteristic of wide adaption exhibited by this genotype, which will be very useful in breeding programs for wide adaptation. For the very late sowing date (S3), the most suitable genotype to be identified was KAUZ"S"657C1-3-6-2-2-1-2, although exhibited less yield under favorable conditions (S1) compared to the check varieties. Therefore this genotype has better performance only under specific environment (S3) and could be included in programs for improving specific adaptation to high temperatures.

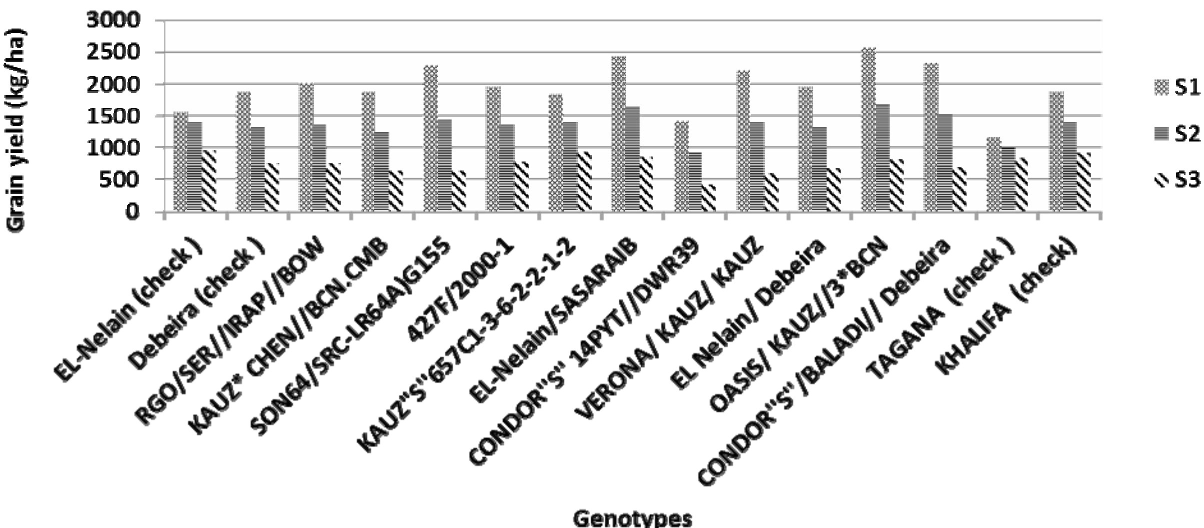

Fig. 1: Grain yield (kg/ha) of 15 genotypes of wheat under three sowing dates (S1, S2 and S3), averaged over two years (2005/06 and 2006/07) at Shambat (Sudan)

Grain yield (kg/ha) was positively correlated with some of its components (Table 3), where it has a positive and significant association with number of kernels/spike, number of kernels/plant, and 100-kernels weight. Significant positive and negative correlations among yield components were observed (Table 3). This strong correlation between yield and its components was reported also by O’Toole and Stockle (1991). This result of correlation showed that 100-kernel weight was the most important yield component that has significant contribution in grain yield, especially under terminal heat stress environment, indicating the importance of the period of grain filling. This could be confirmed by the higher kernel weight exhibited by the genotypes OASIS/ KAUZ//3*BCN and KAUZ"S"657C1-3-6-2-2-1-2 (data not shown) under very late sowing date (S3), when exposed to severe terminal heat stress. These results are in accordance with those found by Tahir *et al*., (2006) and Abdelmula *et al*., (2010). Moreover, care and attention should be given to the negative associations between yield components when used for selection to improve grain yield.

Table 3: Phenotypic correlation coefficients between grain yield and its components of 15 genotypes of wheat evaluated at Shambat (Sudan), averaged over two years (2005/06 and 2006/07)

Characters	Grain yield (kg/ha)	Number of spikes/plant	Number of kernels/spike	Number of kernels/plant
Number of spikes/plant	0.14			
Number of kernels/spike	0.20	- 0.04		
Number of kernels/plant	0.24	- 0.29 *	0.45 **	
100-kernels weight (g)	**0.38 ***	**0.03**	**- 0.09**	**- 0.01**

Conclusions and Outlook

It could be concluded that the induced terminal heat stress during both years was severe enough to cause a reduction in yield of the tested genotypes. The observed significant effect of sowing date and its interaction with years on yield entails the crucial impact of the onset and duration of winter season on wheat productivity in the non-traditional central areas of Sudan. The determined differential genotypic variability to terminal heat stress and the estimated correlation between yield and its components could be exploited in breeding programs to identify and develop new heat tolerant widely adapted cultivars. Such cultivars could be suitable for optimum sowing date as well as for terminal heat stress, e. g., genotype OASIS/ KAUZ//3*BCN. Moreover, the genotype KAUZ''S''657C1-3-6-2-2-1-2, which exhibited a specific adaption and high yielding only under late sowing, could be identified and selected for improving tolerance to terminal heat stress prevailing in the central areas of Sudan.

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