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Screening and Selection of Spring Bread Wheat (*Triticum aestivum* L.) Genotypes for Adaptation to High-temperature Areas of Sudan

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Introduction

Traditionally, wheat is the main cereal crop grown on the fertile soils of the banks of the River Nile in the Northern states of Sudan, where there is relatively cooler and longer winter. However, recently due to the urbanization and changes in food habits, wheat became the second most important crop in Sudan after sorghum. To meet the ever-increasing demand for wheat the strategy and national policies adopted in Sudan aim at expanding wheat production to the south into the non-traditional warmer areas, in the east (New Halfa area) and south of Khartoum (Gezira area). The growing season of wheat in the Gezira is from mid-October to mid-April. Only in December and January are the Gezira's mean daily temperatures below the tolerance limit for wheat of 25 ^{0}C. In northern Sudan, north of Latitude 18.5 ^{0} N, mean daily temperatures stay below this limit from November to March but exceed it in October and April. The climate is therefore only moderately suitable for irrigated wheat in the north, and only marginally suitable in central Sudan. In these non-traditional areas, the high temperatures prevail during the beginning and end of the cropping cycle leading to reduced crop productivity, and considerable variability in bread wheat performance over years was observed (Ageeb, 1994). Also Ishag (1990) stated that heat stress influences productivity of wheat specially when temperature higher than 30 ^{0} C coincides with initial stage development and generally hot environment reduces the duration of all developmental stage of the crop. Therefore, expanding wheat production south to these non-traditional areas necessitates development of adapted and heat tolerant cultivars. The main objective of this investigation was to evaluate the performance of different wheat genotypes and to identify the most heat tolerant adapted genotype.

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Material and Methods

Twelve different bread wheat genotypes (Table 1), out of more than 80 field-screened breeding lines obtained from ICARDA, were selected and field tested for performance under terminal heat stress during winter season of 2008 at Shambat (central of Sudan, Lat.: 15^0 40’N, Long.: 30^0 32’ E, and Altit. of 380 m above sea level). The locality is in the semi-arid zone with hot summer, a mild winter and short rainy season during the summer (July-September). Two sowing dates were used: 1) optimum, and 2) late sowing, to induce terminal heat stress. The experimental design used was split plot design with three replications. Each genotype was grown in a sub-plot consisted of four rows, each 2.5 m long and 20 cm apart. The sowing dates were assigned to the main plots. The seed rate used was 120 Kg/ha. Irrigation was applied at interval of every seven days up to crop maturity. All experimental plots were hand weeded after three weeks and then whenever it was necessary. Fertilizer was applied in form of urea (46% N) at the sixth irrigation. Different agronomical characters were measured and used for evaluation. These included grain yield (t/ha), grain yield/plant (g), 100-grains weight (g), number of spikes/plant, number of grains/spike, days to booting, days to anthesis and days to maturity, and only results for yield (t/ha), 100-grain weight and maturity is presented here. For estimating heat tolerance of genotypes the relative performance is calculated as a percentage of yield (t/ha) under terminal heat stress to that under optimum sowing condition (SD1).

Table 1: Names, Pedigree and mean yield of the 12 wheat genotypes field-tested under optimum sowing date (SD1) and terminal heat stress (SD2) in Sudan

No.	Code No.	Name/Pedigree	Mean yield (t/ha)
1	1	TEVEE-1/SHUHA-6	2.20
2	14	MAZRAA-2 (Chil)	1.65
3	16	MARSAA-2 (Kar)	1.60
4	33	JAWAHIR-1 (Shuha)	1.55
5	41	KAUZ/KAPSW (Kauz)	1.85
6	53	ADEL-3 (Samr/Pastor)	2.05
7	56	ZAIEM-4 (Henne)	2.00
8	63	CHAM-4/GRU90-202579	1.35
9	67	Qimma2	1.65
10	83	Hudieba1	1.90
11	86	Hudieba2	2.10
12	95	Imam (check cultivar)	1.90

Results and Discussion

The results revealed that the adverse effect of terminal heat (late sowing) was more significant and pronounced on yield, yield components and other traits, it reduced yield (t/ha) up to 20%. Significant genotype x sowing date interaction effect was observed for grain yield (t/ha), grain yield/plant (g), 100-grain weight, days to booting, days to anthesis and days to maturity, indicating the differential response of genotypes to the sowing dates. Generally, high variability and low yields relative to the potential yield characterized wheat yields in all producing areas. Similar yield variation of wheat productivity in Sudan over years was reported (FAO, 2000), which is usually attributed to the variation of the prevailing environmental factors and lack of adaptation.

Under optimum sowing date (SD1), the genotypes TEVEE-1/SHUHA-6 and Hudieba2 gave the highest yield (2.8 t/ha). While the genotype ADEL-3 gave the highest yield (2.1 t/ha) under late sowing date (terminal heat stress) and out-yielded the most widely grown check variety Imam (Fig. 1), which produced 1.8 t/ha.

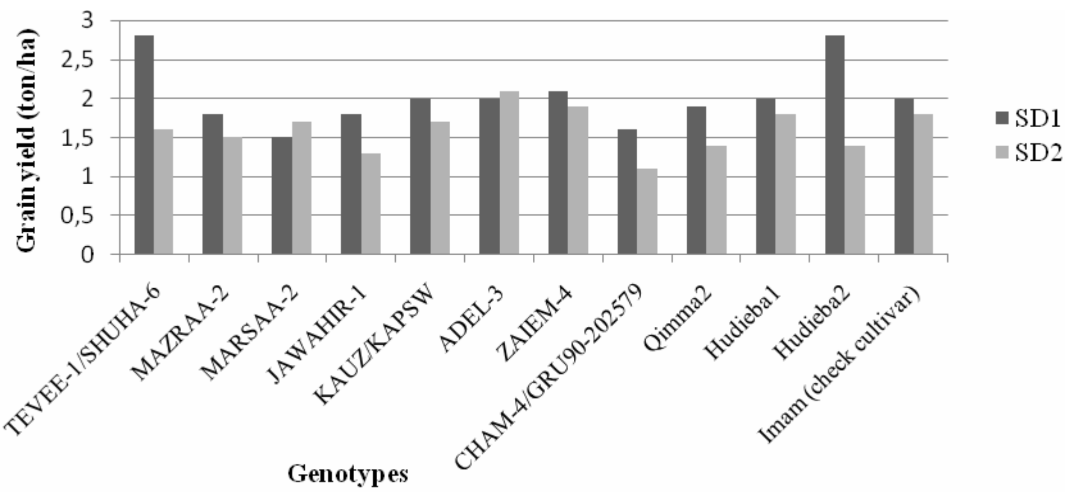

Figure 1: Grain yield (t/ha) of 12 different wheat genotypes grown under two sowing dates (SD1=optimum and SD2=heat stress)

In addition, the genotype ADEL-3 and MARSAA-2 showed the highest relative performance (Fig. 2). However, ADEL-3 has the advantage over MARSAA-2 by its relatively higher and similar yield (t/ha) performances under both sowing dates (Fig. 1), indicating its stability across environments and wide adaptation to the extreme environments. Other genotypes that exhibited adequate yields under optimum as well as under terminal heat stress were ZAIEM-4 and Hudieba1, which both have a relative performance of 90% (Fig. 2). On the other hand, genotypes TEVEE-1/SHUHA-6 and Hudieba2 although exhibited the highest yields (t/ha) under favorable conditions (SD1), they have the lowest relative performance (Fig. 2), indicating their high sensitivity to the terminal heat stress (late sowing) and adaptability only to the optimum sowing date. Several studies in Sudan have shown that wheat yields are influenced and very sensitive to planting dates, and irrespective of the varieties used, the largest yields were obtained from sowings dates from mid-October to mid-November, and sowing wheat after 20 November significantly decreases yield (Ishag, 1992).

Generally, mean 100-grain weight was significantly higher in the optimum sowing (3.3 g) as compared to the late sowing (2.5 g). The genotypes Qimma2 and Hudieba1 produced the highest 100-grain weight under optimum sowing condition (Fig. 3), while genotype TEVEE-1/SHUHA-6 produced the highest 100-grain weight (3.0 g) under terminal heat stress condition. Similar to this genotype, other genotypes exhibited low reduction in 100-grain weight due to terminal heat stress, e.g., ZAIEM-4, indicating variation in magnitude of differential response exhibited by genotypes. This trait is genetically controlled, however, it is greatly influenced by environment during the process of grain filling, and the high temperatures during most of grain filling period are very common in the arid and semi-arid areas, such as Sudan. Similar to these results, Tahir et al., (2006) found that high temperatures significantly decreased grain yield by decreasing grain weight, although genotypes showed variable responses.

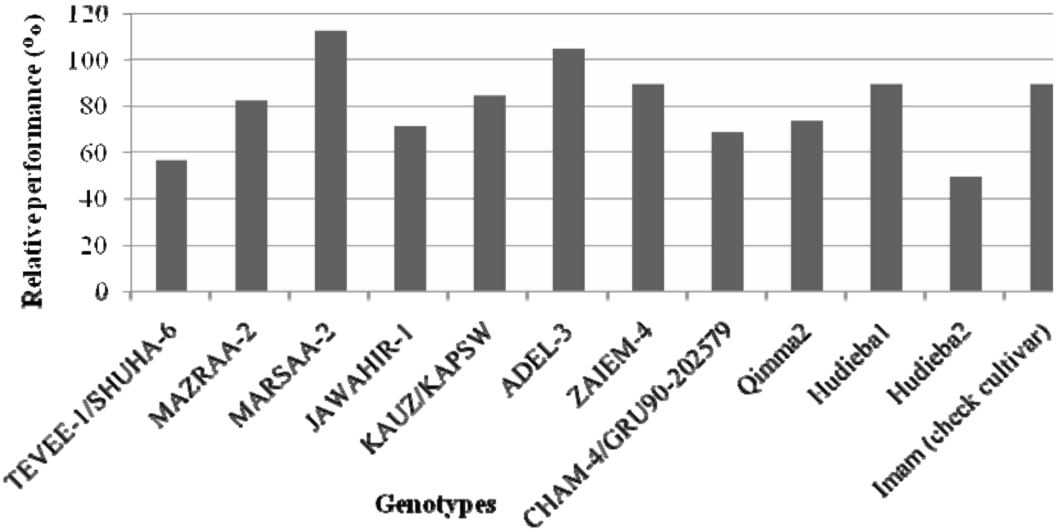

Figure 2: Relative performance (%) of 12 genotypes of wheat for yield (t/ha) under terminal heat stress (SD2) to that under optimum sowing date (SD1)

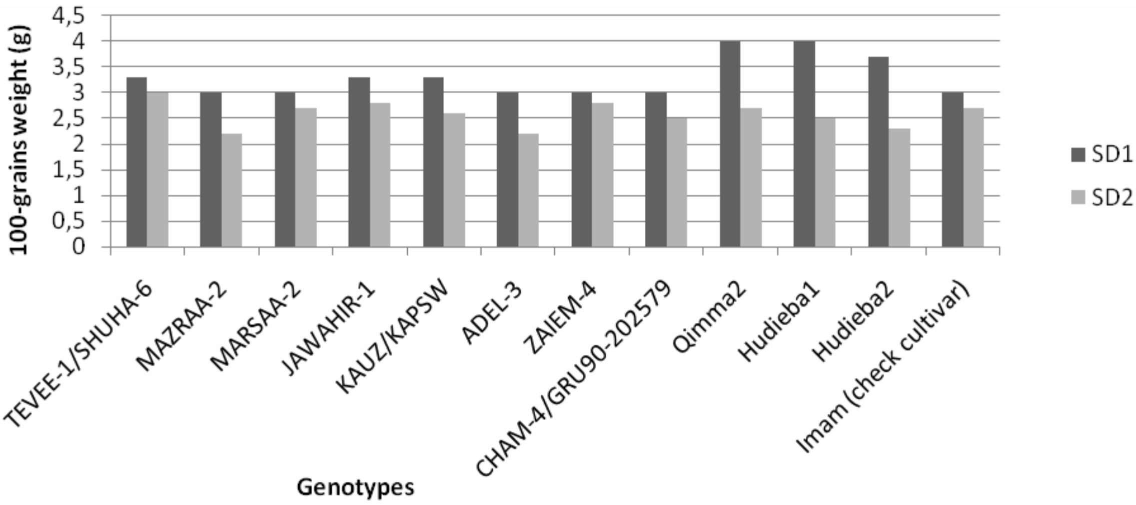

Figure 3: Mean of 100-grain weight of 12 different genotypes of wheat grown under two sowing dates (SD1=optimum and SD2=heat stress)

On the average, the genotypes exhibited shorter period for maturity under the stress conditions than under optimum sowing conditions (Table 2). The genotypes KAUZ/KAPSW and ZAIEM-4 were the most early-maturing genotypes under the optimum sowing date (SD1), and Hudieba 1 and Hudieba2 were the most late-maturing genotypes. While under the stress conditions (SD2), the genotypes CHAM-4/GRU90-202579 and ZAIEM-4 were earlier than others (Table 2). This early maturity under terminal heat stress (late sowing) could be one of the advantages that enable these two genotypes to escape the adverse effect of terminal heat stress, which indicated by their relatively higher relative performance (Fig. 2) of grain yield (> 80%), compared to the late maturing genotype Hudieba2, which showed large reduction in grain weight (Fig. 3) and accordingly in grain yield (Fig. 1).

Table (2): Means of maturity (day) of 12 genotypes of wheat grown under two sowing dates (SD1 and SD2) during 2008-09, at Sudan

Genotype	Sowing dates SD1	Sowing dates SD2	mean
TEVEE-1/SHUHA-6	91.0 b	88.3 cd	89.7 cd
MAZRAA-2	91.3 b	88.7 c	90.0 c
MARSAA-2	88.3 cd	86.7 cdef	87.5 e
JAWAHIR-1	86.3 cdef	87.7 cde	87.0 e
KAUZ/KAPSW	84.0 g	85.7 efg	84.8 f
ADEL-3	92.0 b	87.7 cde	89.8 cd
ZAIEM-4	84.0 g	85.3 fg	84.7 f
CHAM-4/GRU90-202579	86.0 defg	85.0 fg	85.5 f
Qimma2	88.3 cd	88.3 cd	88.3 de
Hudieba1	97.7 a	92.3 b	95.0 a
Hudieba2	96.3 a	91.3 b	93.8 a
Imam (check cultivar)	92.0 b	91.3 b	91.7 b
Mean	**89.8**	**88.2**	**89.0**
C.V%		**1.39%**	
SE±			
Genotype		**0.50**	
Sowing date		**0.33**	
Interaction G x S		**0.71**	

Means within the same columns followed by the same letter (s) are not significantly different at 0.05% according to DMRT. **SD1 and SD2** represent sowing dates at 4th and 29th of Dec. 2008, respectively.

Conclusions and Outlook

The screened genotypes used in this study exhibited great variability to the terminal heat stress under Sudan conditions. This has been indicated by the significant reduction and genotype x environment interaction for yield, yield components, as well as for other measured traits. Among the twelve screened genotypes, the genotypes ADEL-3 and ZAIEM-4 could be selected as the most potential heat-tolerant, stable across contrasting environments (optimum vs. late sowing) and with adequate yield potential under optimum sowing conditions compared to the check varieties. These characteristics gave them the advantage to be useful in the breeding programs for development of adapted heat tolerant cultivars suitable for expanding wheat into the central warmer non-traditional wheat areas of Sudan. However, further investigation, under a range of environments, is needed for studying the role and contribution of the different plant morpho-physiological traits to heat tolerance.

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