# Multiple synthetic derivatives population: a new source to identify heat stress tolerance traits in bread wheat

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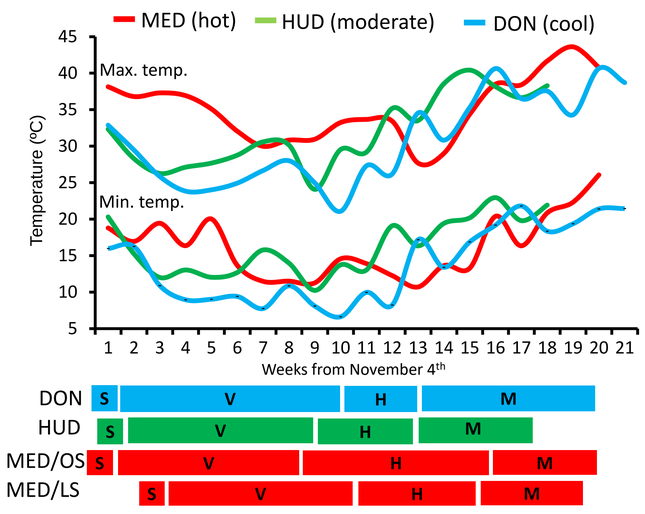
## Introduction:

High temperature (≥30°C) in wheat (*Triticum aestivum* L.) is one of the main factors of yield reduction. Although the genetic variation available for heat stress tolerance is limited in elite wheat germplasm, considerable genetic variation are present in wild relatives (Elbashir *et al*. 2017). Many scientists are using a limited number of *Ae. tauschii* lines in their breeding programs. In other words, only small or limited portion of the huge diversity of *Ae. tauschii* has been utilized. For the breeding program to overcome this problem and insure proper and extensive utilization of this tremendous diversity, a multiple synthetic derivatives (MSD) population has been developed (Tsujimoto *et al* 2015, Gorafi *et al*. unpublished). We used this population to identify the genetic variation for heat stress adaptive traits in order to identify new genetic resource of heat tolerance to be utilized to develop new well-adapted, heat tolerant and high-yielding wheat varieties.

## Materials & Methods:

We examined 400 $BC_1F_4$ derivatives lines randomly selected from MSD population developed by crosses between 'Norin 61' (N61, Japanese spring wheat variety) and 43 synthetic wheat lines, plus three cultivars N61 as control to show the effect of the wild genes on the improvement of N61 heat stress adaptability, and two heat tolerant Sudanese varieties ('Imam' and 'Goumria') as checks to evaluate the heat stress adaptability of the MSD lines. These lines were evaluated in four different environments in Sudan (Dongola (DON), Hudeiba (HUD), Wad Medani optimum sowing (MED/OS) and Wad Medani late sowing (MED/LS)) using Augmented Randomized Complete Block Design. In Gezira Research Farm we used two sowing dates; optimum and late sowing (4th week of November and 2nd week of December, respectively). We collected morphological, phenological yield and yield components traits. Analysis of variance was carried out using Plant Breeding Tools software (PBTools, version 1.4. 2014). To determine the heat tolerant lines, high yield lines and heat tolerant and high yield lines, we performed regression analysis using the data of grain yield (GY) of DON as optimum condition and HTE (DON with MED/LS), and the data of GY of MED/OS as optimum condition and HTE (MED/OS with MED/LS).

## Results & discussion:



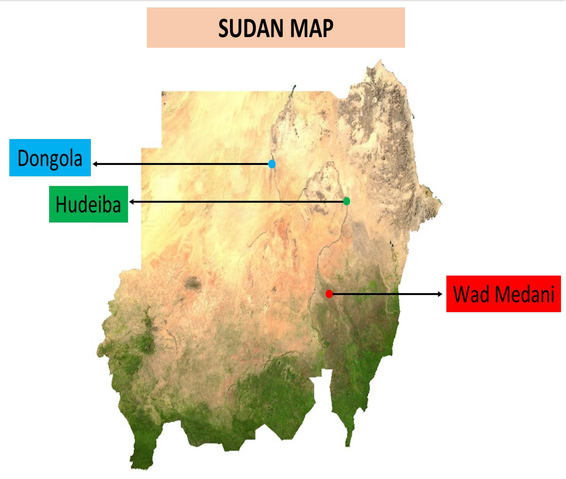




**Fig. 1** Maximum and minimum temperature at Dongola (DON), Hudeiba (HUD) and Wad Medani (MED). DON was the coolest environment during Sowing (S), vegetative growth (V) heading (H) up to the 12th week whereas MED/OS and MED/LS were the hottest and HUD was intermediate. From the 12th week (late heading to the 16th week (early maturity), HUD was the hottest followed by DON, and MED/OS and MED/LS were the coolest environments. From the 16th week (late maturity) MED/OS and MED/LS were the hottest, HUD was intermediate and DON was the coolest.

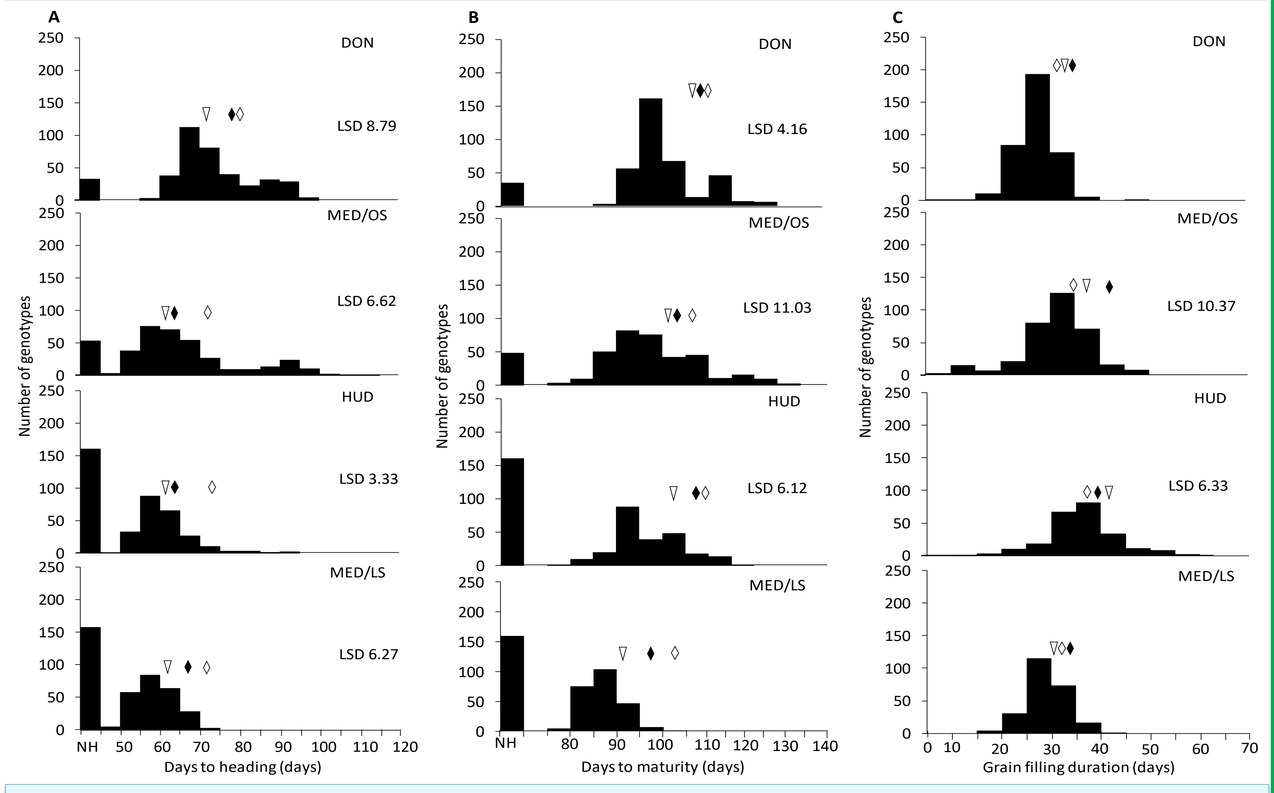
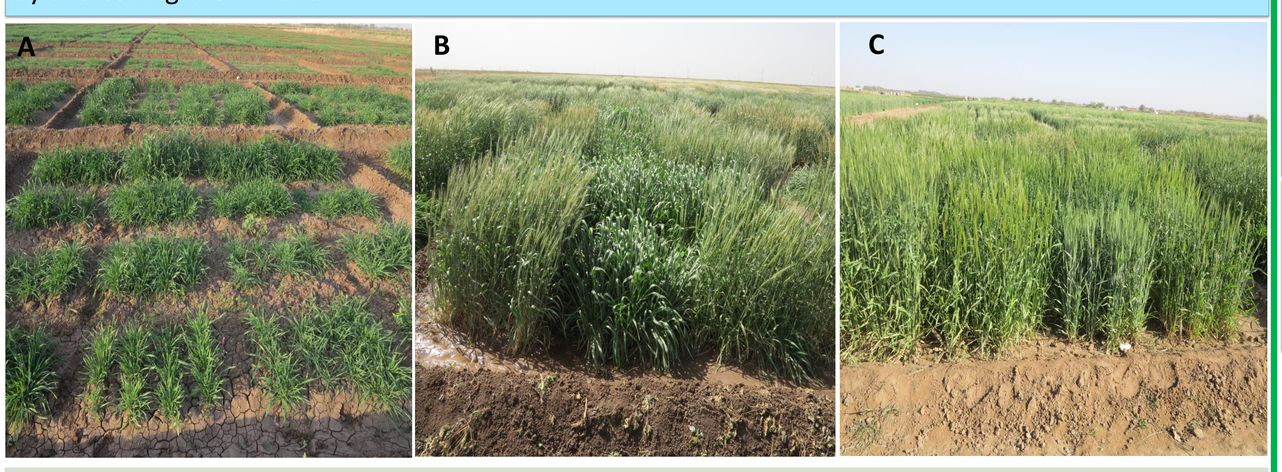



**Fig. 2** Frequency distribution of days to heading (DH) (A), maturity (DM) (B) and grain filling duration (C) at Dongola, Wad Medani optimum sowing (MED/OS), Hudeiba (HUD), and Wad Medani late sowing (MED/LS). Norin 61 (triangle), Goumria and Imam (black and white rhombus, respectively). NH denote no heading and maturity. The MSD lines showed larger variation beyond the variation among N61 and the adapted two Sudanese cultivars in DH, DM and GFD. 8%, 5%, 39% and 38% of the 400 lines did not head in DON, MED/OS, HUD and MED/LS, respectively (Fig 2A), these lines might need vernalization treatment. At cool environments, DON and MED/OS, 0.3% and 5% of the MSD line had significantly earlier DH than N61. At the hot environments, HUD and MED/LS, 3% and 4% of the MSD lines had significantly earlier DH than N61. As for DM, only 1% of the MSD lines had significantly earlier DM than N61 each in DON and MED/OS, whereas, 5% of the MSD lines had significantly earlier DM than N61 at HUD. (Fig. 2B). 5% of the MSD lines showed significantly longer GFD than N61 at MED/OS, whereas 11% of the MSD lines had significantly longer GFD than N61 at HUD (Fig. 2C). Comparing to the adapted Sudanese cultivars the MSD lines that were earlier than N61 and had longer GFD than N61, were also earlier than the adapted Sudanese cultivars and had longer GFD than the adapted Sudanese cultivars. These results indicate that early MSD lines could escape the impact of the high temperature by shortening the DH and DM.




MSD population at vegetative (A), heading time (B) and grain filling stage (C)

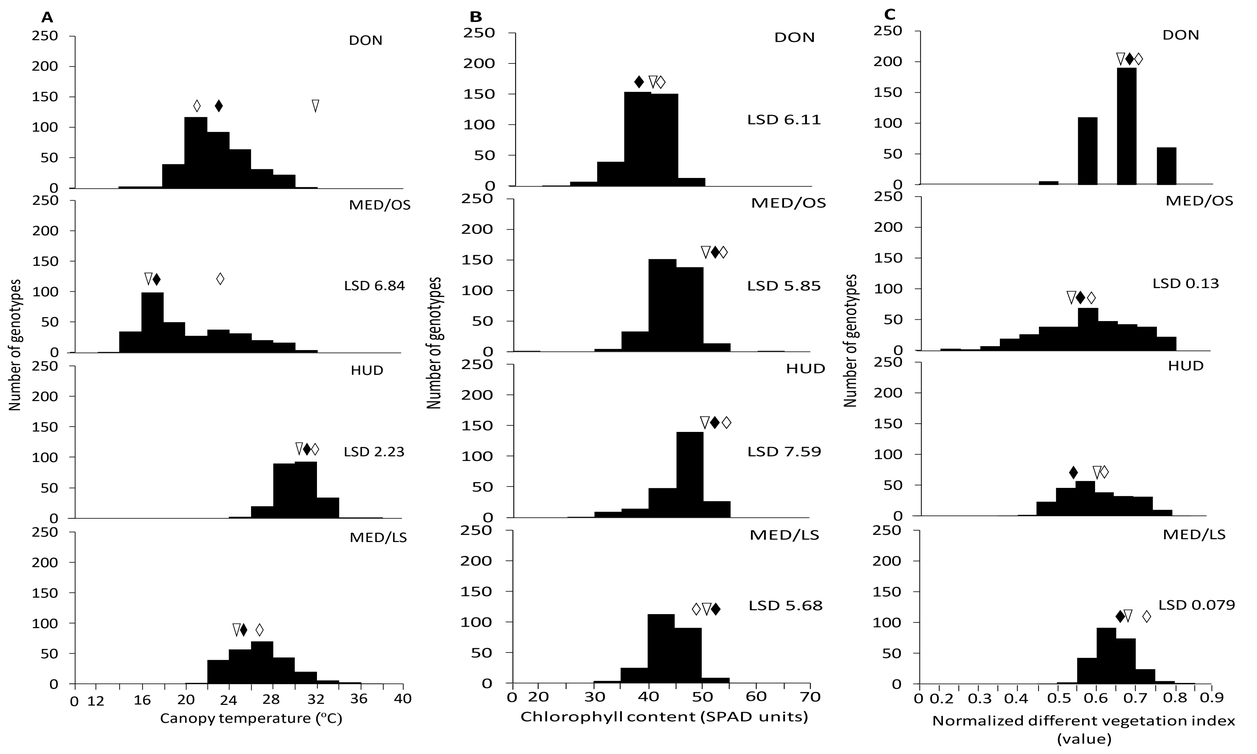



**Fig. 3** Frequency distribution of canopy temperature (CT) (A), chlorophyll content (SPAD) and normalized different vegetation index (NDVI) at grain filling duration in Dongola, Wad Medani optimum sowing (MED/OS), Hudeiba (HUD), and Wad Medani late sowing (MED/LS). Norin 61 (triangle), Goumria and Imam (black and white rhombus, respectively). The CT was lower at MED/OS followed by DON, MED/LS and higher at HUD. This result indicates the high temperature during the time of grain filling in MED/LS and HUD (Fig. 1). 10% of the MSD lines had significantly lower CT than N61 at HUD (Fig. 3A). In SPAD, 7%, 3% and 2% of the MSD lines had significantly higher SPAD than N61, at DON, MED/OS and MED/LS, respectively (Fig. 3B). In NDVI, 30% and 6% of the MSD lines had significantly higher NDVI than N61, at MED/OS and MED/LS, respectively (Fig. 3C). The CT, SPAD and NDVI showed a wide range of variation in MSD lines and some MSD lines showed better values than N61 and the adapted Sudanese cultivars. Low CT, high concentration of SPAD and high value of NDVI are indicators of heat tolerance and high yielding genotypes in wheat (Olivares- Villegas *et al*., 2007, lopes *et al*., 2012, Shahnoza *et al*., 2012).

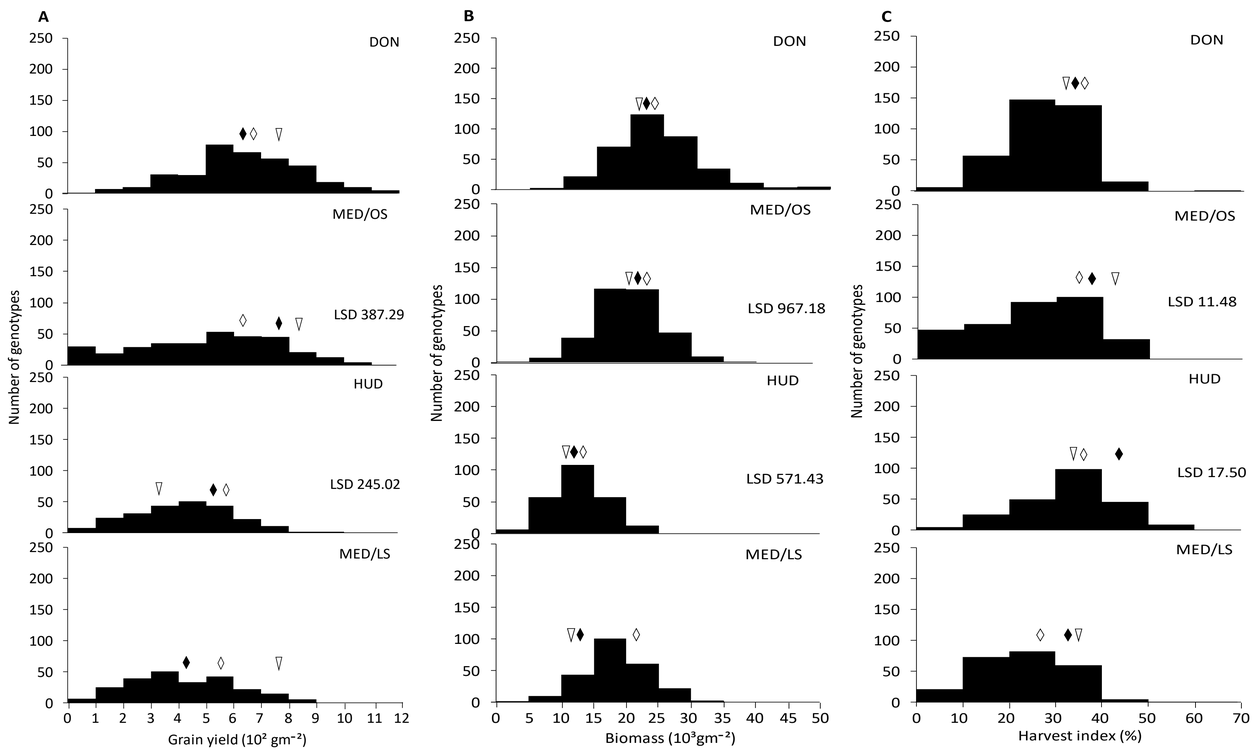



**Fig. 4** Frequency distribution of biomass (A), grain yield (B) and harvest index (C) at Dongola (DON), Wad Medani optimum sowing (MED/OS), Hudeiba (HUD), and Wad Medani late sowing (MED/LS). The MSD lines showed a wide range of variation in BIO, GY and HI than N61 and the adapted Sudanese cultivars. At HUD, 10% of the MSD lines had significantly higher GY than N61 (Fig. 4B). In BIO, 3% and 10% of the MSD lines had significantly higher BIO than N61 at MED/OS and HUD, respectively (Fig. 4A). Comparing to the adapted Sudanese cultivars, 3% of the MSD lines had significantly higher GY than Goumria and Imam at HUD, whereas, 3% and 4% of the MSD lines had significantly higher BIO than Goumria and Imam at MED/OS and HUD, respectively. This result indicates the impact of different parent of synthetic wheat in this population.

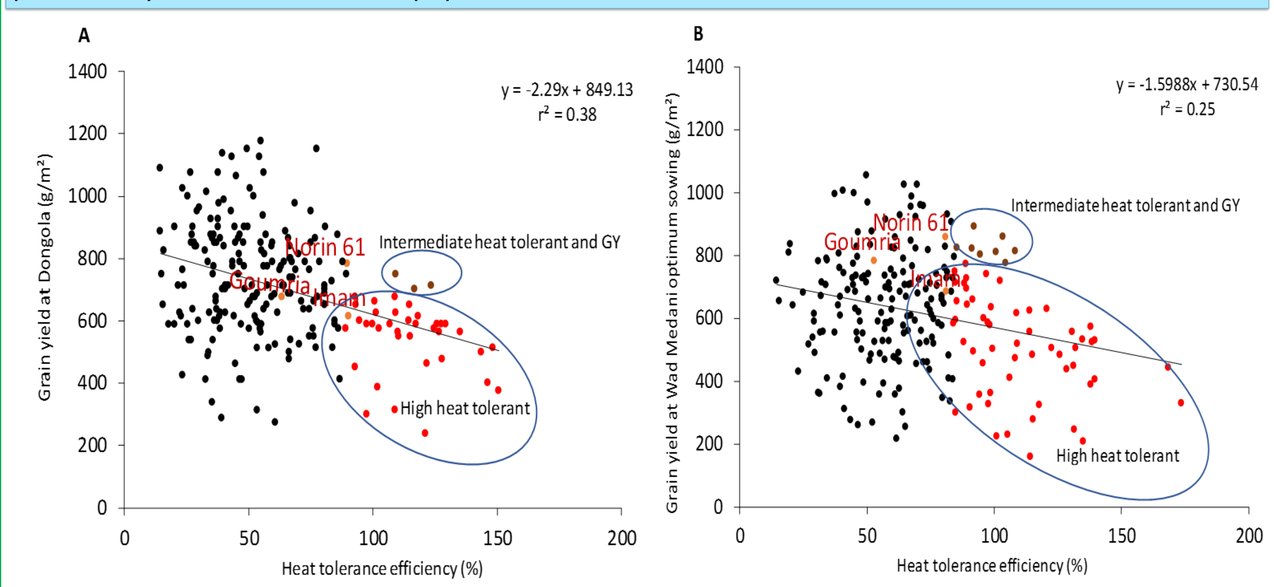



**Fig. 5** Relationship between grain yield and the heat tolerance efficiency (HTE) (measure of heat tolerance) calculated based on (A) grain yield of Dongola (DON, control) and Wad Medani late sowing (MED/LS, stress), and (B) grain yield of Wad Medani optimum sowing (MED/OS, control) and Wad Medani late sowing (MED/LS, stress). We found 16% of the MSD lines showed better HTE than N61 in the range from 93-151% (Fig. 5A),whereas, 24% lines showed better HTE than N61 in the range from 88-173% (Fig. 5B). Also, we found these lines had higher HTE than the adapted Sudanese cultivars. Although we found 13 lines had consistence higher value than N61 (Fig. 5A and 5B). Interestingly, we found lines have intermediate HTE between N61 and the highly tolerant lines with good yield potential. These lines represent good source to improve both GY and heat tolerance.

## Conclusion:

MSD population lines had a wide genetic variation in heat tolerance related traits. The production of the MSD population is very effective and could be the best way to explore the rare variation of heat tolerance in *Ae. tauschii* in short time and more practical less expensive way. The MSD lines identified in this study are very promising and an excellent source to breed new wheat cultivars for heat stress environments.

## References:

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