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Exotic Wheat (*Triticum aestivum* L.) Germplasm Evaluated for High Temperature Tolerance

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Abstract

In current scenario, climate is rapidly changing environment and studies have confirmed that Pakistan is largely vulnerable to environment change. So as face this newly emerged challenge, plant material in bulk is imported every year and tested under different agro-ecological conditions. The prime aim of the present study was to assess of 10 exotic wheat germplasm based on their potentiality against high temperature. Heat stress (HS) was noticed by interval of one month (T_2,19th of December 2017) under field condition in comparison with normal sowing (T_1,18th of November 2017) and 02 checks (Kiran-95 and TJ-83) at the experimental area of Nuclear Institute of Agriculture (NIA), Tandojam during Rabi 2017-2018. In addition, morphological traits like days to 75% maturity, plant height (cm), spike length (cm), number of grains spike^{-1}, tillers plant^{-1}, number of spikelets spike^{-1}, peduncle length (cm), 1000-grain weight (g), grain yield plot^{-1} (g), biological yield plot^{-1} (g) and harvest index (%) were studies and recorded. Predominantly the lines HT_{14} and HT_{19} performed well in field and are suggested to be subjected to further evaluation in all possible cross combinations so that more fruitful results may be achieved.

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Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in the world in terms of area harvested. Wheat is a self-pollinated crop known as "king of cereal" after rice and maize around the world. Worldwide, wheat provides 20% of the total dietary calories and proteins (Narayanan, 2018). In addition, wheat is the leading source of vegetable protein in human food internationally. It consists the most staple food of about two billion people of world (Dwivedi *et al.*, 2017).

Particularly, wheat yields are sensitive to heat stress from the stage of flowering to seed maturing in Pakistan (Khan *et al.*, 2015). Optimum sowing constantly gives high yield production in comparison to late sowing. Unfavorable influence of high temperature could be reduced through adjustment of sowing time to an optimal date and to notice heat tolerant genotypes, which could be appropriate for normal and very early sowing settings to ensure high grain yield (Hossain *et al.*, 2011). Throughout lifecycle of *Triticum aestivum*, for the trait of yield and its quality the grain filling phase is a serious period, nonetheless this period is mainly susceptible to heat stress that can lead to higher deleterious objects in wheat quality and production than numerous other developmental stages (Pradhan and Prasad, 2015). Global, high temperature is a foremost problem in field cropping systems with unpredicted dimensional and temporal differences causing reduction in plant growth and productivity (Parent *et al.*, 2010).Today, wheat faces one of the central abiotic stresses that is heat stress. Results of November sown crop, heat stress at sowing time, reliefs wheat crop to increase its growth and thus shortens the tillering stage by inducing the crop to enter the elongation stage more rapidly and this result in poor tillering of the crop. Late seeding of wheat is the key reason of low yield (Tiwari *et al.*, 2017). In wheat, delayed planting tolerates terminal heat stress during grain improvement and maturation (Hussain *et al.*, 2013).The main objectives of the present study were: to investigate the effect on yield and yield contributing traits under high temperature environments and identification of tolerant wheat genotypes suitable for this environment that the yield target can be met out under changing conditions.

Materials and methods

The current research was carried out at the experimental field of Nuclear Institute of Agriculture (NIA), Tandojam, during Rabi season 2017-2018. Twelve wheat genotypes alongwith two local check varieties were examined to determine the effect of normal and high temperature.

The wheat coded genotypes were planted in randomized completely block design (RCBD) with factorial arrangement with three replications on two different sowing dates through drilling method. First was sown on 18^{th} of November 2017 with interval of one month on 19^{th} of December 2017. The plot size was $4.8m^2$, row length 4 rows $plant^{-1}$, one plant to next plant distance 10cm, as well as distance from row to row as 30cm. The coded wheat genotypes were sown respectively in four rows with 4m long in length. Randomly five plants were selected and tagged for collecting data from each plot. Source of irrigation was canal and tube water was applied to the crop.

Treatments = Two factors (A and B)
Factor- A: Sowing dates (D) = 2
D_1 = Normal sowing (18^{th} November)
D_2 = Late sowing (19^{th} December)

Factor-B: Genotypes = 12
Genotypes= 12: HT_2 , HT_6, HT_9 , HT_{10} ,HT_{11} , HT_{14} , HT_{15} , HT_{17} , HT_{19} , HT_{27} , and two check verities namely T.J-83 and Kiran-95.

Statistical analysis

The data for all the traits were subjected to analysis of variance (ANOVA) according to Gomez and Gomez (1984) by using statistical analysis software Statistix (ver. 8.1).

Estimation of relative decrease (%)

Relative decrease (%) was measured by the subtraction of mean value of stress (T_2) from the mean value of non-stress (T_1), divided by mean value of non-stress and multiplied by 100 as the formula given below:

Relative decrease (R.D %) =

$$\frac{\text{Non} - \text{stress} - \text{heat stress}}{\text{non} - \text{stress}} \text{X } 100$$

Results and discussion

Analysis of variance

The significance of mean squares from analysis of variance for two factors T_1 (optimal sowing) and T_2 (late sowing) for twelve exotic wheat genotypes is represented in Table 1 and 2.

The mean squares from ANOVA for yield and its contributing characters indicated that wheat lines were showed significant differences ($P \leq 0.05$) for plant maturity, plant height, length of spike, number of spikelets per spike, number of grains spike^{-1}, 1000 grain weight in grams and grain yield per plot whereas, the rest of the traits like peduncle length, tillers plant^{-1}, biological yield plot^{-1}, and HS % remained non-significant.

Table 1. Mean squares for various quantitative traits of exotic wheat genotypes grown in two different dates.

Source of variance	D.F	Days to maturity	Plant height (cm)	Spike length (cm)	Spikelets spike^{-1}	Peduncle length	Tillers plant^{-1}
Replication	2	14.68	297.54	1.50	31.56	31.93	1.22
Treatment	1	4065.01**	2449.53**	13.10**	39.60**	940.91**	13.52*
Genotype	11	10.41**	63.45**	1.66**	4.97**	7.04 N.S	2.78 N.S
(T × G)	11	7.35**	22.69 N.S	0.31 N.S	1.23 N.S	6.29 N.S	1.50 N.S
Error	22	2.16	22.45	0.17	1.07	8.20	2.008
Total	47						

**,* = significant at P 0.01 and 0.05% of probability levels, respectively. NS= non-significant.

In addition, treatments association were highly significant differed at ($P \leq 0.01$) for majority of the traits except harvest index (HI) % that persisted non-significant for treatments. The significance interaction between treatments × genotype showed that genotypes carried out variability over the heat stress conditions.

Tharwat El Ameen (2012) reported that combined ANOVA exhibited that variances between genotypes in addition; G x E were highly significant for grain yield, 1000 grain weight, number of kernel/spike and spike length. Our studied consequences are in conformity with previously obtained by (Soleman Mohamed Al-Otayk, 2010) who noticed the characters including plant height, spike length, number of kernels per spike, harvest index and grain yield those were significantly affected by years, sowing dates, and genotypes and in findings of Khalaf Ali Hamam (2013) that each of alike traits associated with recently study were significantly influenced by genotypes, heat stress treatments.

Table 2. Mean squares for various quantitative traits of exotic wheat genotypes grown under two different dates.

Source of variance	D.F	Grains spike^{-1}	1000grain weight	Grain yield plot^{-1}	Biological yield plot^{-1}	HI %
Replication	2	263.10	0.64	1208	10995	43.04
Treatment	1	1413.35**	751.10**	1993006**	7397781**	65.31N.S
Genotype	11	133.16**	67.48**	19672**	77723 N.S	26.69 N.S
(T x G)	11	59.87 N.S	18.33**	16669**	64987 N.S	71.26**
Error	22	35.18	5.63	379	45755	24.18
Total	47					

**,* = significant at P 0.01 and 0.05% of probability levels, respectively. NS= non-significant.

Characters studied

Days to 75% maturity

Data in regard to mean showing for days to maturity for exotic wheat alongwith two commercial checks grown under two treatments is presented in (Fig. 1), minimum days to 75% was observed in the genotype HT_6 (118.00), while maximum days was recorded by the genotypes HT_{14} (124.01) andHT_{15}(124.00) in normal sowing. Whereas, in heat-stress condition, HT_{17} took maximum days (107.33) in maturity and minimum days were recorded by the genotype HT_6 (103.33).

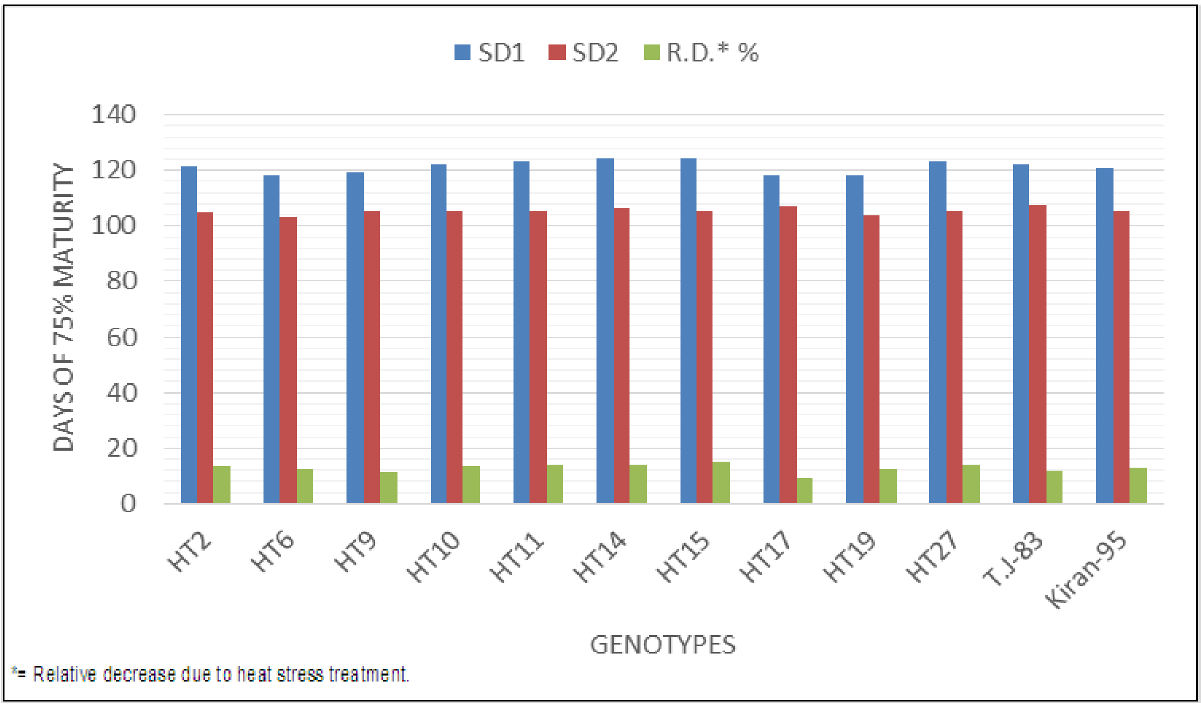

Fig. 1. Effect of high temperature in exotic wheat genotypes at days to 75% maturity under normal and late sowing dates.

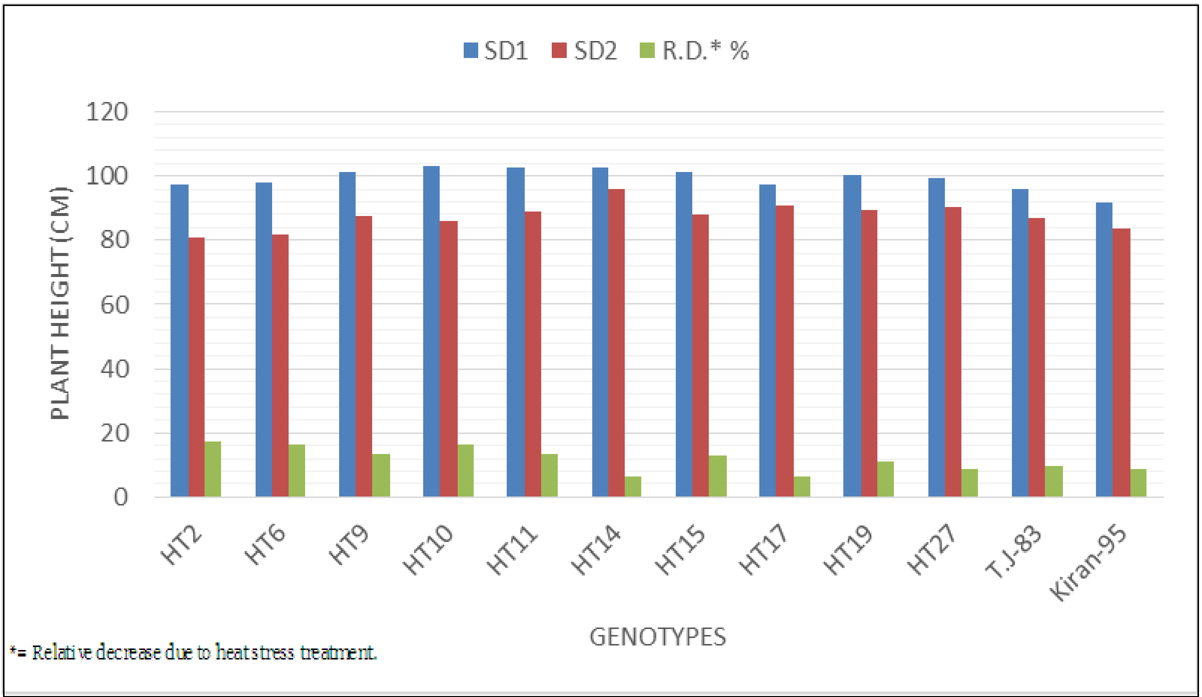

Fig. 2. Effect of heat stresson plant height (cm) of exotic wheat genotypes under normal and late sowing dates.

The overall average was 121.19 of all the genotypes in normal condition however in HS 105.55. The reduction of 12.87% averagely was observed among the genotypes causing by (HS). The smallest reduction was declined in HT_{17} (9.05%), under late sowing, however, the highest was recorded 15.05% by the genotype HT_{15} at heat stress condition. Kumar *et al.* (2016) reported that the duration of planting to maturity in diverse wheat cultivars was also strongly affected by weather parameters (Baloch *et al.,* 2015) also worked on the same trait.

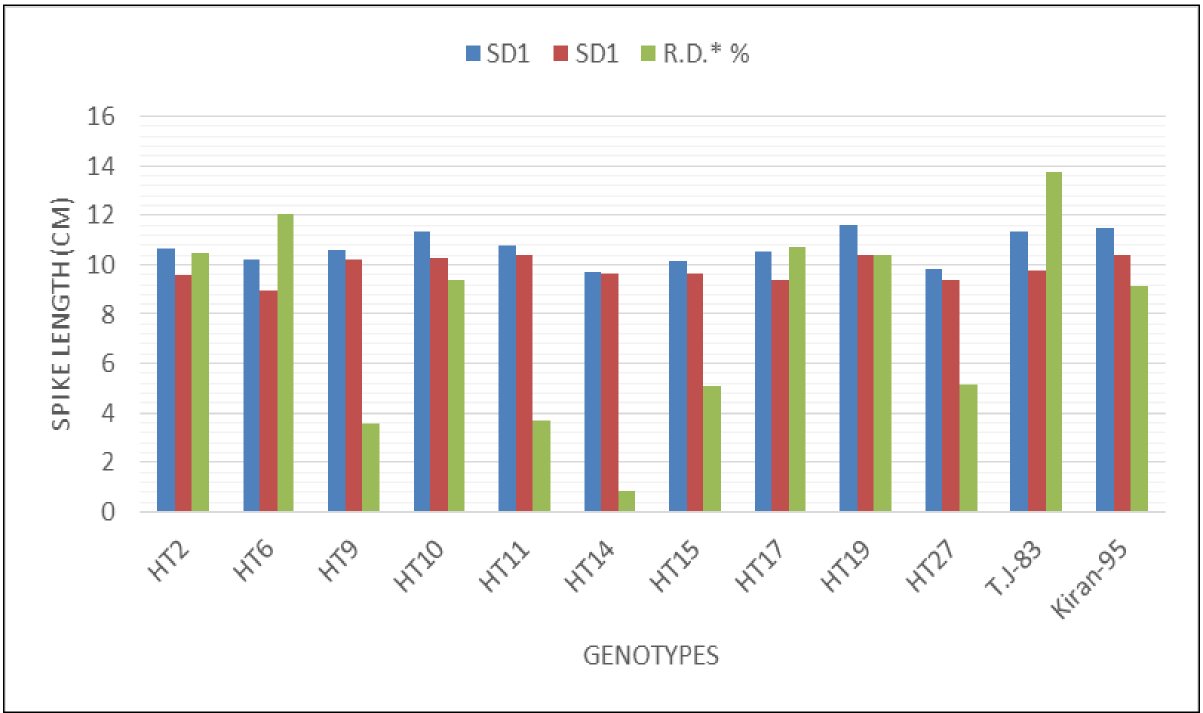

Fig. 3. Effect of heat stress on spike length (cm) of exotic wheat genotypes under normal and late sowing dates.

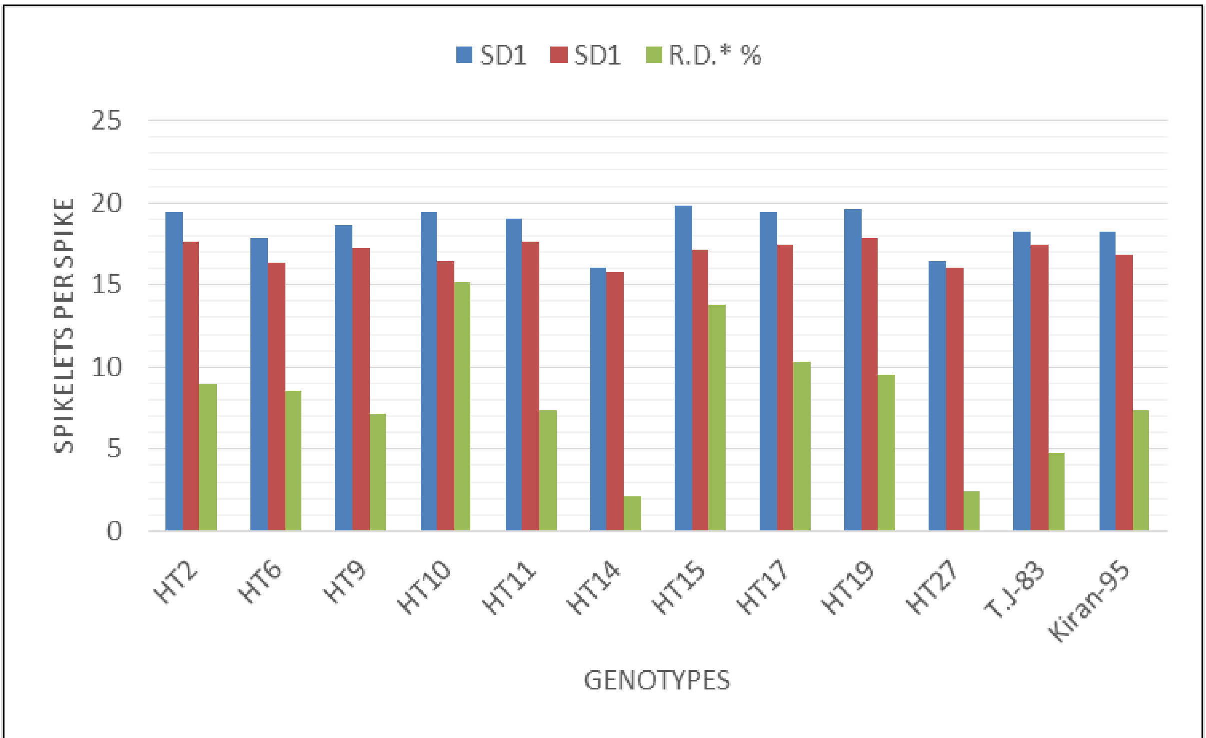

Fig. 4. Effect of heat stress on spikelets spike-1 of exotic wheat genotypes under normal and late sowing dates.

Plant height (cm)

At normal sowing date, lowest plant height was recorded in check variety T.J-83 (96.20) and highest was found in the genotype HT_{10} (103.02).The average decline due to heat stress condition was 11.70%. Maximum plant height was recorded by HT_{14} (96.20) and minimum (80.93) observed by the genotype HT_2 in heat stress condition. The reduction of 11.70% averagely was recorded among all the genotypes, moreover, lowest reduction 6.30% and highest 17.13% was observed by the genotypes HT_{14} and HT_2 respectively.

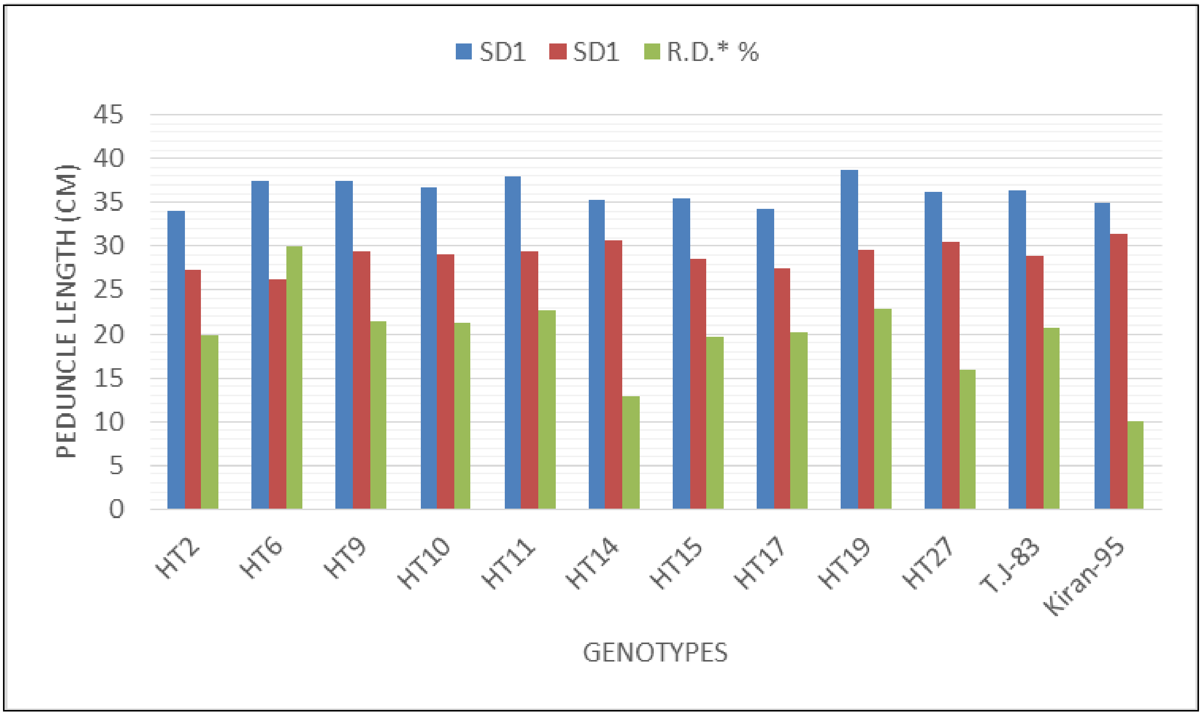

Fig. 5. Effect of heat stress on peduncle length (cm) of exotic wheat genotypes under normal and late sowing dates.

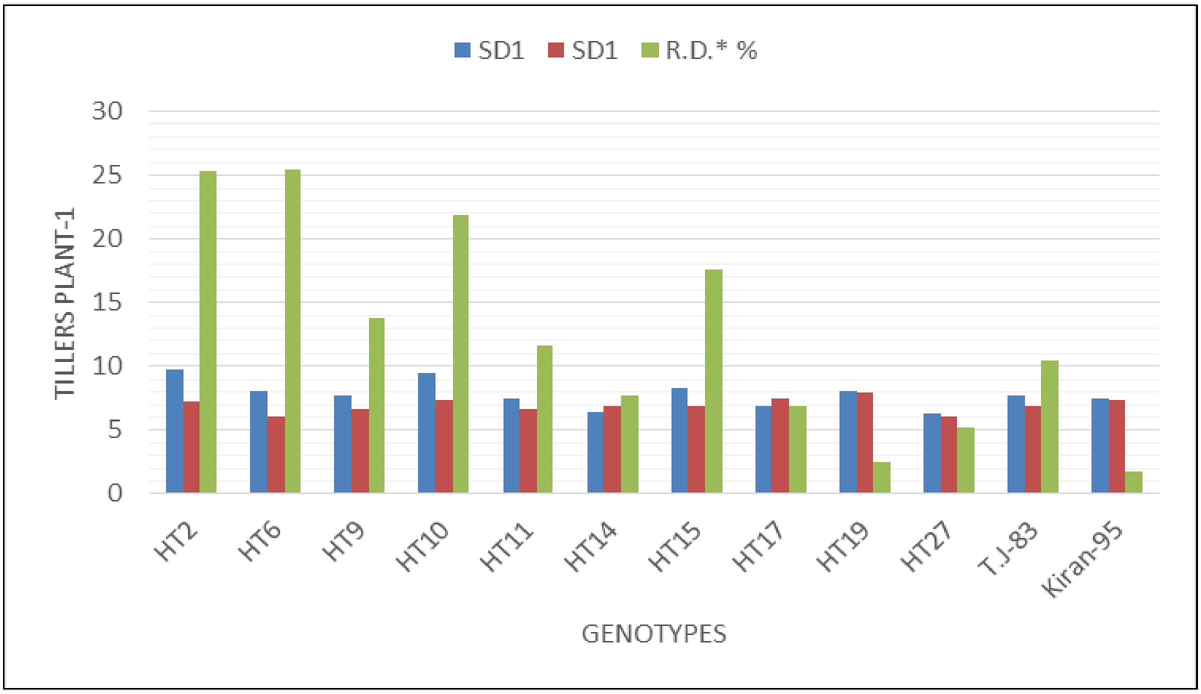

Fig. 6. Effect of heat stress on tillers plant-1 of exotic wheat genotypes under normal and late sowing dates.

The overall mean 99.29 of all the genotypes under normal sowing, while in late sowing, mean was 87.62 (Fig. 2). Tiwari *et al.* (2017) found out less reduction for the character plant height in results of wheat varieties. The same trait was studies in wheat varieties (Halna and Raj 3765) regarding the screening of wheat lines was done in response to plant height (Jaiswal *et al.*, 2018).

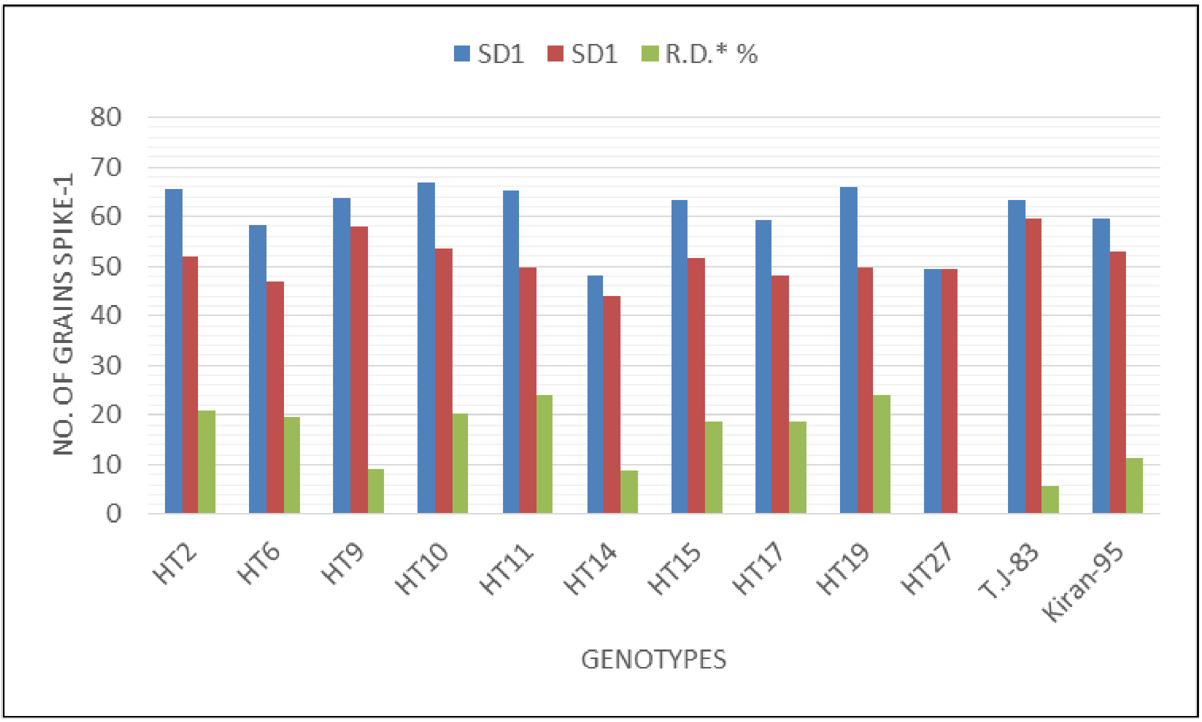

Fig. 7. Effect of heat stress on number of grains spike-1 of exotic wheat genotypes under normal and late sowing dates.

Spike length (cm)

The range of spike length from 9.70 cm to 11.60 cm under non-stress conditions and 8.96 to 10.42 cm in heat stress conditions (Fig. 3). Under the non-stress condition, maximum spike length was measured by the genotype HT_{19} (11.60) whereas minimum (9.70) was recorded by the HT_{14} genotype. In heat stress condition the maximum spike length 10.42 and minimum 8.96 was recorded by the check varietyKiran-95 and HT_6, respectively.

The mean of all the genotypes was 10.69 under non-stress condition while 9.83 in heat stress. The maximum reduction was recorded by the genotype T.J-83 (13.78%**)** while the minimum reduction was observed 0.82% by the genotype $HT_{14..}$ moreover the reduction of 7.85% on average was observed due to heat stress. Soleman Mohamed Al-Otayk (2010) observed that spike length was significantly affected by various sowing dates.

Spikelets spike^{-1}

In normal condition (T_1), range of spikelets spike^{-1} was calculated as 16.06 to 19.86, while in heat stress genotypes was recorded 15.73 to 17.80 (Fig. 4).. On an average, among the genotypes produced 17.68 spikelets spike^{-1} in stress free condition whereas in heat stress condition 16.97.

The lowest decline in spikelets spike^{-1} was observed by the genotype HT_{14} (2.07%) followed by HT_{27} (2.42%), under HS condition. The maximum reduction was observed in HT_{10} (15.18%) due to effect of heat stress. Number of spikelets per spike from highest to lowest were calculated for the genotypes HT_{15} (19.86) and HT_{14} (16.06) in normal sowing date, while in heat stress maximum no. of spikelets spike-^{1}was computed forHT_{19} (17.80), and minimum numbers of spikelets spike-^{1} 15.73 was estimated for HT_{14}. Pimentel *et al.*(2015) declared such the heat stress decreased the no. of spikelets spike^{-1}.

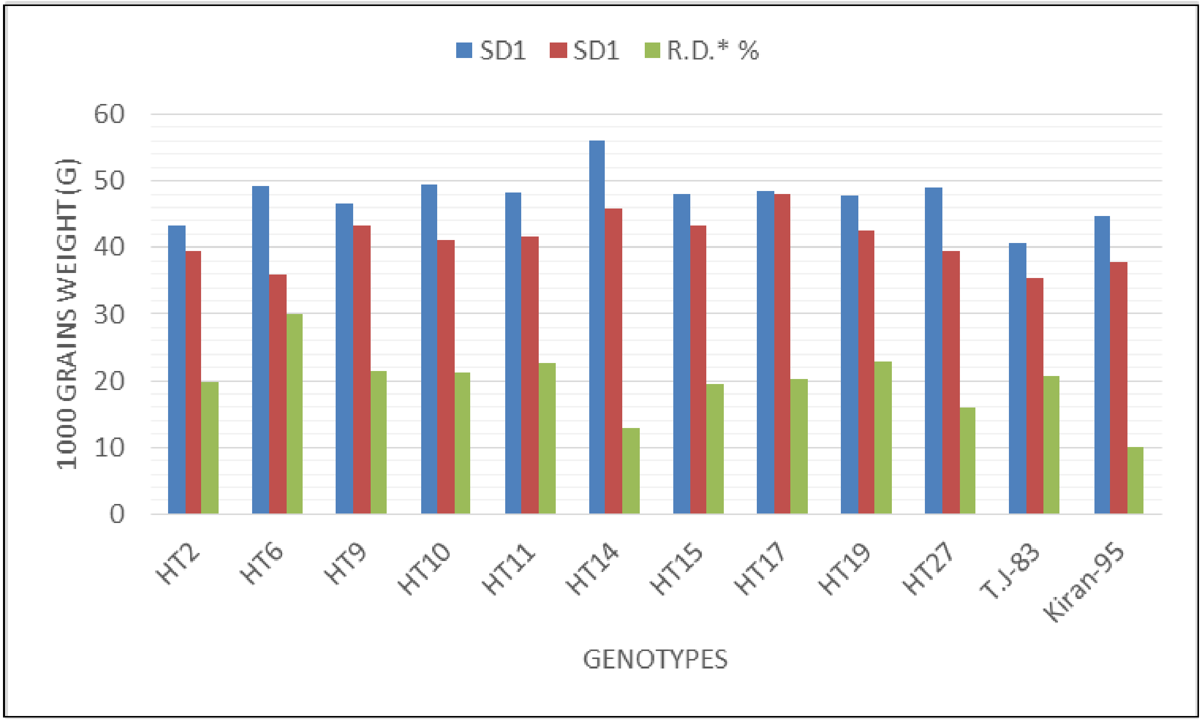

Fig. 8. Effect on 1000 grains weight (g) due to high temperature on exotic wheat genotypes under normal and late sowing dates.

Peduncle length (cm)

Influence of temperature on present trait for various genotypes was seen (Fig.5). Among the genotypes, HT_{19} showed the maximum peduncle length of 38.73 and minimum was observed by the genotype HT_2 (34.06) under normal condition while maximum and minimum peduncle length in heat stress condition was recorded for genotypes Kiran-95 (31.37) and HT_6 (26.26) respectively. However, overall mean performance 36.25 of all genotypes under normal sowing while in case of heat stress condition recorded as 29.02 for the character peduncle length. Minimum reduction percent for the trait peduncle length was observed by check variety Kiran-95 (10.5%), while highest reduction was recorded (29.89%) in the genotype HT_2. Overall averagely reduction (19.76%) because of heat stress. Omidi *et al.* (2014) also noticed in the results of his experiment indicated that the terminal heat stress given rise to significant reduction in peduncle length (27%).

Tillers plant^{-1}

Under stress free condition, among the genotypes HT_2 recorded highest in numbers of tillers andHT_{27} counted lesser amount of tillers per plant (9.73 and 6.33) respectively. The overall mean of all the genotypes as 7.90 in normal sowing. In treatment 2, greater number of tillers was counted by the genotype HT_{19} (7.93) followed by the genotypes HT_{17} (7.46), HT_{10} (7.40) and Kiran-95 check (7.33), while minimum was counted (6.00) in the genotype HT_{27}. Whereas Kiran-95 (check variety) showed minimum relative decrease 1.78% and HT_6 recorded maximum 25.40%. Din *et al.* (2010) reported that tillers in m^{-2} revealed less reduction (15.38%) under late planting conditions. However, in my study heat stress caused averagely 12.50% no. of tillers per plant owing to maximum temperature impact throughout fully maturity (Fig. 6). Farooq *et al.* (2008) recorded that in results of poor formation of crop in form of few tillers and to end with grain yield reduced.

Number of grains spike^{-1}

Among coded genotypes, digit for this character was counted as 48.26 to 67.00 kernels in normal sowing, while under heat stress, was counted as 46.80 to 59.60 grains spike^{-1} (Fig. 7). On an average, the genotypes produced 60.74 grains spike^{-1} in treatment-1 and 51.24 grains in treatment two, the reduction of 15.14% averagely was noticed among the genotypes due to pressure temperature. The lowest decline in no. of grains per spike viewed in HT_{27} (0.40%) under the condition of T_2. The highest decline nonetheless was noted for HT_{19} (24.21%). The highest grain number was counted in HT_{10} (67.00) and the lowest grain was counted in HT_{14} (48.26) under non-stress condition. The maximal grains spike^{-1} was noted in check variety T.J-83 (59.60) and minimum number of grains in HT_6. Omidi *et al* (2014) noticed in his research the morphophonemics qualities were discovered as significant traits in studies of heat stress but number of grains spike^{-1} as the best trait for screening the heat tolerant lines. As stated by Liu *et al.*(2016) that for the trait of grains number per unit area in which reduction was observed at anthesis ascribed to heat stress.

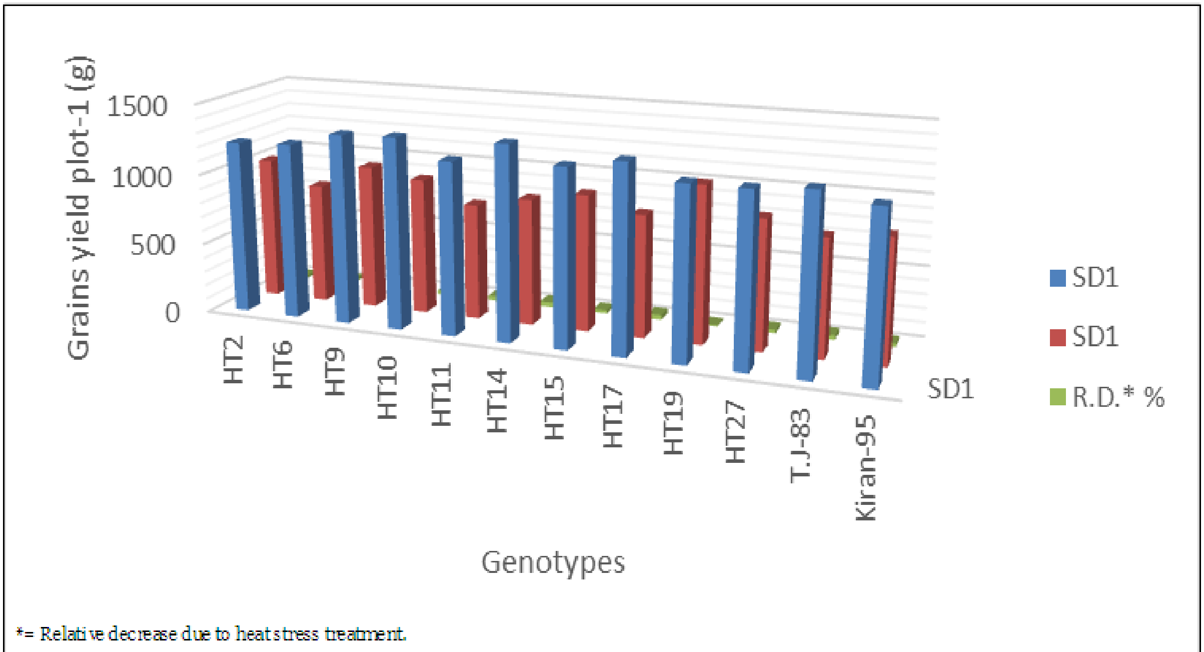

Fig. 9. Effect of high temperature grain yield plot-1 (g) on exotic wheat genotypes under normal and late sowing dates.

1000 Grains weight (g)

1000 maximum grain weight was weighed in genotype HT_{14} (56.20) and the lowest in genotype T.J-83 (40.75) under non-stress conditions, while in heat stress condition, the 1000 highest grain weight was observed in HT_{17} (48.03) and lowest grain weight was recorded as (35.50g) by the genotype T.J-83 (Fig. 8). However the average1000 grain weight of all the genotypes grown under non-stress was 47.65g, while in heat stress condition the average 1000 grains weight showed the mean value as 45.69g. The lowest relative decrease of 10.5% was declared by the genotype Kiran-95, while under heat stress condition, yet the maximum reduction 29.89% for the character of 1000 grains weight was recorded for the genotype HT_6. Mohammadi (2012) explained his experimental results revealed the reduction of 1000 grain weight (23.7%) under heat stress condition.

Grain yield plot^{-1} (g)

Yield has always been the chief objective in plant breeding. All associated traits almost related with it to achieve the major goal of plant breeders. Regarding the present experiment, impact of high temperature on grain yield per plot was ranged from 816.7 to 1100g, in heat stress, while in non-heat condition grain yield ranged from 1220.7 to 1362.3g (Fig. 9). The mean act for each genotype in Treatment~1 was 1255.05g, whereas in heat stress was as 922.30. On an average, 316.26 loss in grain yield plot^{-1} occurred due to terminal heat stress. HT_{14} showed highest reduction decrease 34.52% comes after the genotype HT_{17} (34.46%), while least reduction observed in the genotype HT_{19} 8.38%.

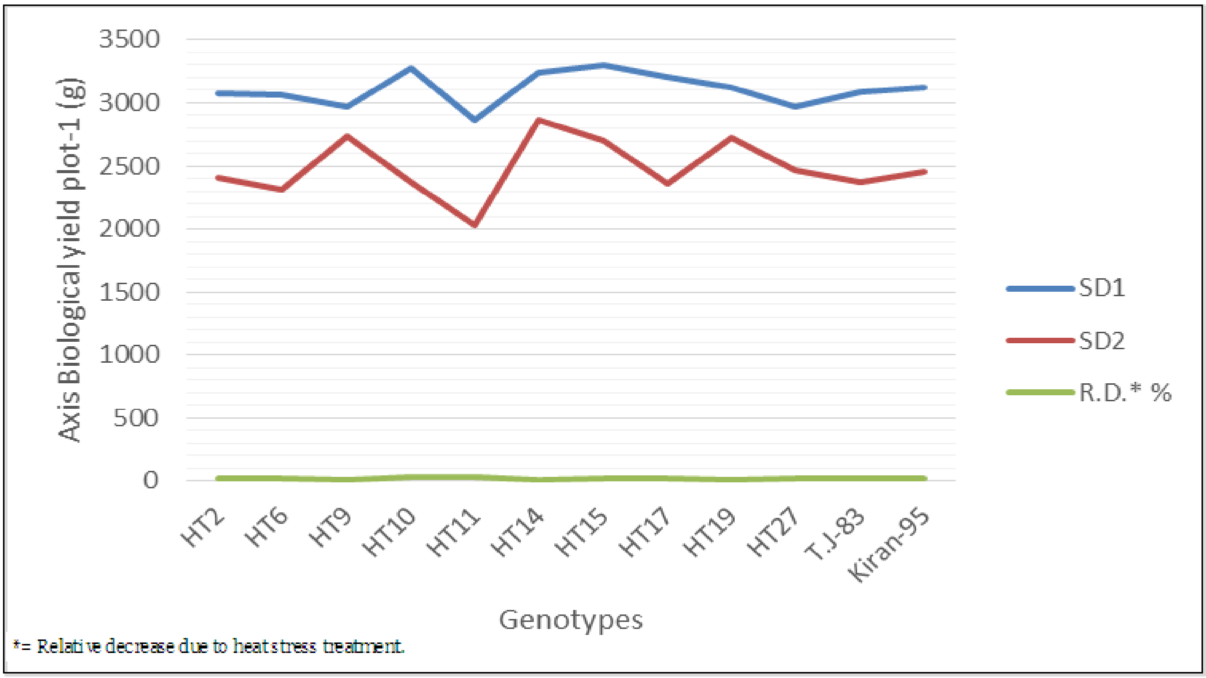

Fig. 10. Effect of heat stress on biological yield plot-1 (g) on exotic wheat genotypes under normal and late sowing dates.

The maximum grain yield was obtained by HT_{14} (1362g) while minimum grain yield HT_2 (1220.7g) in normal sowing, while in treatment-2 the elevated yield of grain was noted down by HT_{19} (1100g), besides lowest grain yield by the genotype HT_{16} (816.7g). Khan *et al.* (2014) found out that as a result of late sowing condition biomass production were harshly influenced by heat stress leading to low grain yield. Pimentel *et al.* (2015) proclaimed that high temperature decreased the grain yield and yield associated characters. Liu *et al.*(2016) observed that whole aboveground biomass was condensed as 0.37 to 0.43 percentage as well as grain yield was reduced by 1.0 to 1.6 in %.

Biological yield plot^{-1}

In non-stress, the highlighted trait had ranged from 2866.3 – 3244.3g, while under heat stress condition, it ranged from 2025.0 to 2730.7g. The average biological yield for each genotype in non-stress form was 3108.44g, besides under the heat stress condition was 2418.74g, thus, averagely (20.44%) reduction was caused by terminal heat stress.

The lowest decrease was exhibited by HT_9 (8.10%) and highest loss by the genotype HT_{11} (29.35%), due to the effect of heat stress. The higher biological weight exhibited by genotype HT_{14} was 3244.3g and lowest by HT_{11} 2866.3g in non-stress condition, however, in heat stress condition, HT_9 performed good and obtained greater biological yield plot^{-1} while less biological yield was taken as 2025.0g by HT_{11} (Fig. 10). Das and Mitra (2013), they revealed their experimental results that all wheat genotypes exhibited higher biological yield in usual situation in comparison with heat stress (HS) condition. Balochet *al.* (2015) similarly stated that less reduction % in performance of biological yield at high temperature.

Harvest Index %

Peak HI % was detected in genotype HT_9 (45.02%) and the lowest in Kiran-95 (36.26%) closely followed by HT_{15} (37.74%) in stress free condition, although under the stress condition (T_2), high harvest index recorded by HT_{10} (40.72%) and minimum (31.73%) by HT_{14} (Fig. 11.).

The whole average was as 40.38% among genotypes in optimal and in temperature condition, it was as 36.30. Heat stress caused the decrement of 9.48% averagely in all the genotypes grown under late sowing condition.

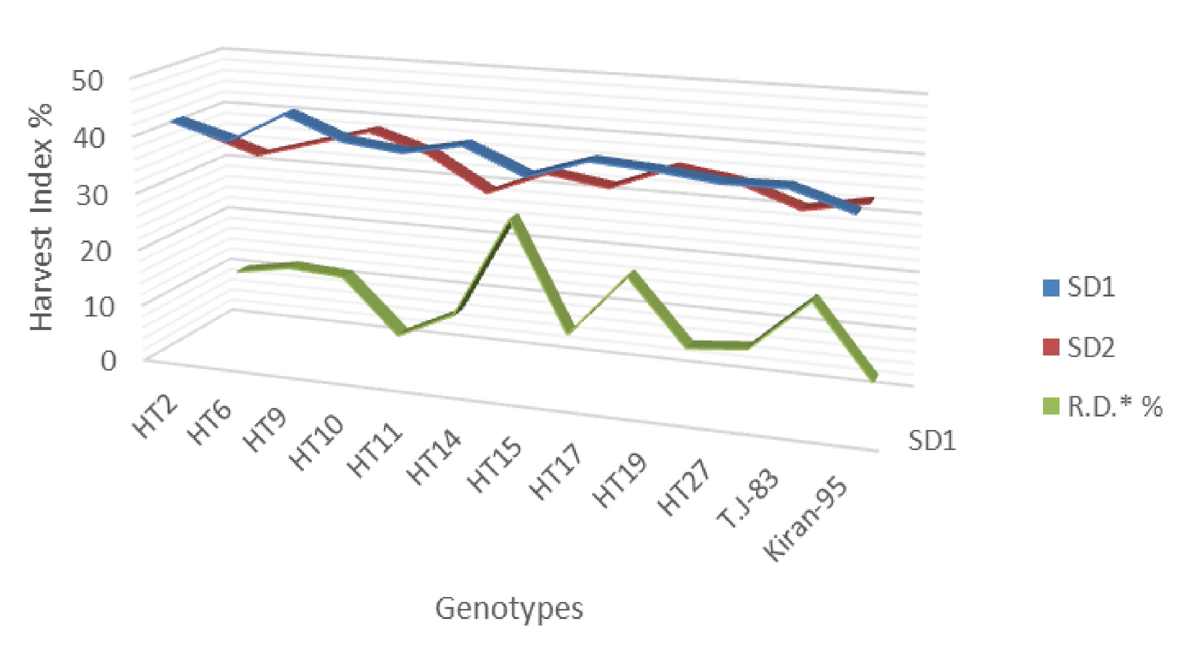

Fig. 11. Effect of heat stress for harvest index % of exotic wheat genotypes under normal and late sowing dates.

The greatest performance was shown by HT_{10} with the relative decrement of 1.12%, in heat stress condition yet the worst was measured in HT_{14} with a decrease of 24.62%. Soleman Mohamed Al-Otayk (2010) reported that HS % was significantly influenced by different sowing times, years and wheat lines as well as planting at the first date is greater than before harvest index. Haman and Khaled (2009) observed that the harvest index (HI) as well as length of spike are individually reduced which differ genotype to genotype.

Conclusion

Our results from the recent study revealed that under the heat stress (HS) condition the coded genotypes predominantly $HT_{14}$and HT_{19} of exotic wheat exhibited better per se performance for yield and its attributing traits. Both of the heat tolerant genotypes can be exploited in further breeding programs for stressed environments Overall, it is suggested that both heat tolerant genotypes of wheat, HT_{14} and HT_{19}can be exploited for further generations in breeding programme in cope of climatic challenges.

References

Al-Otayk SM. 2010. Performance of yield and stability of wheat genotypes under high stress environments of the central region of Saudi Arabia. Journal of King Abdulaziz University: Metrology, Environment and Arid Land Agricultural Sciences, **142(574),** 1-24.

Baloch M, Baloch A, SHAIKH M, Baloch M, Asad M, Depar M, Baloch A. 2015. Evaluation of wheat genotypes for earliness and growth traits exposed to high temperature through delayed planting. Sindh University Research Journal-SURJ (Science Series) **47(3).**

Dwivedi R, Prasad S, Jaiswal B, Kumar A, Tiwari A, Patel S, Pandey G. 2017. Evaluation of wheat genotypes (*Triticum aestivum* L.) at grain filling stage for heat tolerance. International Journal of Pure & Applied Bioscience **5(2),** 971-975. http://dx.doi.org/10.18782/2320-7051.2614

El Ameen T. 2012. Stability analysis of selected wheat genotypes under different environment conditions in Upper Egypt. African Journal Agriculture Research **7(34),** 4838-4844.

Farooq M, Basra S, Rehman H, Saleem B. 2008. Seed priming enhances the performance of late sown wheat (*Triticum aestivum* L.) by improving chilling tolerance. Journal of Agronomy and Crop Science **194(1),** 55-60. http://dx.doi.org/10.1111/j.1439-037X.2007.00287.x

Gomez KA, Gomez AA. 1984. Statistical procedures for agricultural research: John Wiley & Sons.

Hamam K, Khaled A. 2009. Stability of wheat genotypes under different environments and their evaluation under sowing dates and nitrogen fertilizer levels. Australian Journal of Basic and Applied Sciences **3(1),** 206-217.

Hamam KA. 2013. Response of bread wheat genotypes to heat stress. Jordan Journal of Agricultural Sciences **9(4).**

Hossain A, Sarker M, Hakim M, Lozovskaya M, Zvolinsky V. 2011. Effect of temperature on yield and some agronomic characters of spring wheat (*Triticum aestivum* L.) genotypes. International Journal of Agricultural Research, innovation and technology **1(1-2),** 44-54.

Hussian I, Riaz A, Farooq M, Wahid A. 2013. Seed priming improves the performance of poor quality wheat seed. International Journal of Agriculture and Biology **15(6).** http://dx.doi.org/10.3329/ijarit.v1i1-2.13932

Jaiswal B, Prasad S, Rani R, Singh S, Kumar A, Kumar A, Yadav RK. 2018. Evaluation of wheat (*Triticum aestivum* L.) lines at reproductive stage for heat stress tolerance. International Journal of Current Microbiology Applied Science **7,** 1350-1357.

Khan A, Kabir M. 2014. Evaluation of spring wheat genotypes (*Triticum aestivum* L.) for heat stress tolerance using different stress tolerance indices. Cercetari Agronomiceîn Moldova **47(4),** 49-63. http://dx.doi.org/10.1515/cerce-2015-0004

Khan SU, Din JU, Qayyum A, Jaan NE, Jenks MA. 2015. Heat tolerance indicators in Pakistani wheat (*Triticum aestivum* L.) genotypes.Acta Botanica Croatica **74(1),** 109-121. http://dx.doi.org/10.1515/botcro-2015-0002

Kumar S, Prasad R, Rana M. 2013.Effect of weather parameters on growth, development and yield of wheat (*Triticum aestivum* L.) varieties under mid hill conditions of Himachal Pradesh. Education, 2016.

Liu B, Asseng S, Liu L, Tang L, Cao W, Zhu Y. 2016. Testing the responses of four wheat crop models to heat stress at anthesis and grain filling. Global change biology **22(5),** 1890-1903. http://dx.doi.org/10.1111/gcb.13212

Mitra B. 2013.Performance of wheat genotypes under late and very late sowing in sub-Himalayan plains of West Bengal. Crop Research **46(1to3),** 32-35.

Mohammadi M. 2012. Effects of kernel weight and source-limitation on wheat grain yield under heat stress. African Journal of Biotechnology **11(12),** 2931-2937.

Narayanan S. 2018. Effects of high temperature stress and traits associated with tolerance in wheat. Open Access Journal Science **2(3),** 177-186. http://dx.doi.org10.15406/oajs.2018.02.00067

Omidi M, Siahpoosh M, Mamghani R, Modarresi M. 2014. The effects of terminal heat stress on yield, yield components and some morpho-phenological traits of wheat genotypes in Ahwaz weather conditions. Electronic Journal of Crop Production **6**(4).

Parent B, Turc O, Gibon Y, Stitt M, Tardieu F. 2010. Modelling temperature-compensated physiological rates, based on the co-ordination of responses to temperature of developmental processes. Journal of Experimental Botany **61(8),** 2057-2069. http://dx.doi.org/10.1093/jxb/erq003

Pimentel AJB, Rocha JR, Souza MAD, Ribeiro G, Silva CR, Oliveira ICM. 2015. Characterization of heat tolerance in wheat cultivars and effects on production components. Revista Ceres **62(2),** 191-198.
https://doi.org/10.1590/0034-737X201562020009.

Pradhan GP, Prasad PV. 2015. Evaluation of wheat chromosome translocation lines for high temperature stress tolerance at grain filling stage. PLoS One **10(2).**
http://dx.doi.org/10.1371/journal.pone.0116620

Riaz-ud-Din M, Ahmad N, Hussain M, Rehman AU. 2010. Effect of temperature on development and grain formation in spring wheat. Pakistan Journal of Botany **42(2),** 899-906.

Singh K, Sharma S, Sharma Y. 2011. Effect of high temperature on yield attributing traits in bread wheat. Bangladesh Journal of Agricultural Research, **36(3),** 415-426.

Tiwari A, Prasad S, Jaiswal B, Gyanendra K, Singh S, Singh K. 2017. Effect of heat stress on yield attributing traits in wheat (*Triticum aestivum* L.).International Journal of Current Microbiology and Applied Sciences **6,** 2738-2744.
https://doi.org/10.20546/ijcmas.2017.612.317