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GENETIC ANALYSIS IN VARIOUS GENOTYPES OF BREAD WHEAT UNDER NORMAL AND HEAT-STRESS ENVIRONMENTS

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ABSTRACT

Abiotic stresses have brought the crops to a destructive position towards yield production of crops, especially wheat. The present study was investigated to compare the relationship between normal and heat stress conditions under two different sowing dates viz. normal and late sowing dates (25th Nov and 25th Dec). The correlation coefficients varied with both sowing dates (normal and late planting). In normal planting number of grains showed a significant positive correlation with grain weight spike^{-1} (r = 0.618**), grain yield plant^{-1} (r = 0.591**), seed index (r =0 .456**), biological yield plant^{-1} (r = 0.540**) and harvest index (r =0 .667**). Grains spike^{-1} contributed significant positive correlation with grains spike^{-1} (r=0.094**), grain yield plant^{-1} (r=0.844**), biological yield plant^{-1} (r=0.936**), harvest index (r=0.556**), leaf area (r=0.791**), relative water content (r=0.763**), chlorophyll content (r=0.853**), cell membrane stability (r=0.828**) and stomatal conductance (r=0.292**). Grain yield plant^{-1} exhibited a significant positive correlation under normal planting with the number of tillers plant^{-1}, number of spikelets spike^{-1}, grains spike$^{-1,}$ and grain weight spike^{-1} (r=0.695**,0.207*,0.591**and 0.950**), respectively. Whereas, late planting declared grains spike^{-1} revelaed signficant positive correlation with grains spike^{-1} (r=0.094**), grain yield plant^{-1} (r=0.844**), biological yield plant-1 (r=0.936**), harvest index (r=0.556**), leaf area (r=0.791**),relative water content (r=0.763**), chlorophyll content (r=0.853**), cell membrane stability (r=0.828**) and stolatal conductance (r=0.292**). Under late planting, Yield showed a significant positive correlation with spike length, grains spike$^{-1,}$ and grain weight spike^{-1} (r=0.343**,0.844**, and 0.964**), respectively

Keywords: Heat stress, wheat, morphological character, stomatal conductance, grain yield plant^{-1}

Introduction

Wheat is a staple food crop of one-third of the population of world (Abhinandan *et al.,* 2018). Pakistan is one of the major wheat-growing countries and its divergent consumption aptitude in human nutrition leads among the cereals (Farzi and Bigloo, 2010). Plants have altered dynamic responses to defend against abiotic stresses at the morpho-physiological and biochemical levels (Pandiya *et al.,* 2016). Avoidance mechanisms escaping heat stress, counting diffuse roots, reduced stomatal number, reduced leaf area, and leaf rolling, reduce evaporation stimulation (Goufo *et al.,* 2017). Tolerance is characterized by cellular and biochemical modifications that display hydrostatic pressure, mainly through osmotic regulation (Blum, 2017). High temperature plays a crucial role in determining yield in crop growth and development (Gray and Brady, 2016). When temperatures approach high thresholds they may adversely affect plant growth and development of the wheat crop (Farooq *et al.,* 2011). During the anthesis and grain filling period, the wheat crop is extremely affected by high-temperature stress, and seed development is disrupted (Ahmed *et al.,* (2022) High temperatures during flowering and seed formation lead to substantial losses. Therefore, temperature is considered an important variable determinant of agricultural practices worldwide (Yang *et al.,* 2016). Wheat gradually increases stress tolerance through the priming phase (Wang *et al.,* 2011). Meanwhile, the flowering and booting stages of wheat crops were more affected by heat stress (Wang *et al.,* 2011). High temperatures have the potential to disrupt pollen development before flowering, leading to reduced seed setting (Farooq *et al.,* 2011; Mirosavljević *et al.,* 2021). Exposure of wheat crops to high temperatures during reproductive stages may negatively affect grain number and grain filling (Farooq *et al.,* 2011; Xu *et al.,* 2022). Reproductive stages involving pollen, stigma viability, flowering, and stem tube growth are highly sensitive to high temperatures (Giorno *et al.,* 2013; Hedhly, 2011). Grain size is greatly affected by high temperature during grain filling, as higher respiration affects quality characteristics (Ahmed *et al.,* 2022). In wheat crops, high ambient temperature, and drought may reduce photosynthetic activity, cell size, and closure of stomata (Long *et al.,* 2022). Further stated that high temperatures reduced photosynthesis by changing the structural organization of thylakoids

(Khan *et al.,* 2021). In brief, it was evident that high temperature significantly affected anatomical structures not only in the tissues, and cells but also in the sub-cellular. During reproduction, short-term heat stress can lead to significant reductions in spikelets and their abortions despite large differences in susceptibility within and between plant species and cultivars (Sato *et al.,* 2006). Plants may not flower or flower without fruit or seeds, even during high temperatures during reproductive development (Maheswari *et al.,* 2012). Planting crops at different sowing dates can search for heat-tolerant genotypes (Zhang *et al.,* 2020; Long *et al.,* 2022). Heat stress causes multifaceted and often adverse changes in plant growth, development, physiological processes, and yield (Hasanuzzaman *et al.,* 2013). Such disaster was investigated during high temperature (30-35^{0}C) effects. A similar study was carried out by who assessed three genotypes of wheat, one heat tolerant and the other two heat susceptible genotypes. Therefore, the present study was to investigate the relationship between normal and heat stress conditions in various genotypes including parents and hybrids as well as their inheritance pattern.

Material and Methods

The present research was carried-out at the experimental field, the Department of Plant Breeding and Genetics, Sindh Agriculture University, Tandojam, Pakistan. This experiment was conducted in factorial design (RCBD) with three replications during 2019-20. In this context, the experimental materials were evaluated in two sowing dates i.e. normal (25th November) and late planting (25th December). A total of six genotypes namely, T.J-83, NIA-Saarang, Khirman, SKD-1, Sehar-2006, Sarsabaz and three testers such as AS-2002, NIA-Amber, and NIFA-Barsat crossed and 18 F_1 hybrids obtained were: TJ-83 x NIA Sarrang, T.J-83 x Khirman, T.J-83 × SKD-1, Sehar-2006 × NIA-Saarang, Sehar-2006 x Khirman, Sehar-2006×SKD-1, Sarsabaz x NIA-Saarang, Sarsabaz x Khirman, Sarsabaz ×SKD-1, AS-2002 × NIA-Saarang, AS-2002 × Khirman, AS-2002 × SKD-1, NIA-Amber × NIA-Saarang, NIA-Amber×Khirman, NIA-Amber×SKD-1, NIFA-Barsat × NIA Saarang, NIFA-Barsat × Khirman, and NIFA-Barsat × SKD-1. Correlation and heritability estimates were analyzed by the method of Snedecor and Cochran (1980) and Robinson et al. (1949).

Results and Discussion

Correlation analysis: The correlations among lines, testres and F_1 hybrids were obtained for yield and morphological traits of bread wheat grown under normal and heat stress conditions

Days to75% heading: Correlation analysis showed variability among both normal and heat stress conditions. Under normal environment, this character depicted positive and significant association with plant height (r=0.863**), number of tillers plant^{-1} (r=0.564**), spike length (r=0.305**), number of spikelet spike^{-1} (r=0.249**), biological yield plant^{-1} (r=0.872**), harvest index (r=0.811**), leaf area (r=0.786**), relative water content (r=0.438**) and chlorophyll content (r=0.838**). Whereas a negative and significant correlation was observed in the number of grains spike (r=-0.453**), grain weight spike^{-1} (r=-0.825**), grain yield plant^{-1} (r=-0.867**), seed index (r=-0.228*), cell membrane stability (r=-0.825**) and stomatal conductance (r=-0.747**). Similarly, under heat stress conditions days to heading showed a significant and positive association with days to maturity (r=0.915**), plant height (r=0.895**), number of tillers plant^{-1} (r=0.223*), spike length (r=0.369**), biological yield plant^{-1} (r=0.833**), harvest index (r=0.757**), flag leaf area (r=0.715**), relative water content (r=0.541**), chlorophyll content (r=0.787**), cell membrane stability (r=0.652**), while number of spikelets spike^{-1} (r=0.167ns) and seed index (r=0.165ns) revealed non-significant association. The remaining characters exhibited a negative and significant relationship with this trait (Table 1). Our results are in agreement with Khan et al. (2020) who reported significant correlations between the number of tillers plant^{-1}(r=0.256*), number of grain spike^{-1} (r=0.302*), and grain yield plant^{-1}(r=0.259*).

Plant height (cm): For this character various yield traits were observed to have positive association with each other as normal sowing date showed significant and positive correlation with tillers plant-1 (r=0.647**), spike length (r=0.246*), biological yield plant^{-1} (r=0.905**), harvest index (r=0.885**), leaf area (r=0.836**), relative water content (r=0.417**) and chlorophyll content (r=0.833**). This showed that characters had a close relationship for these traits (Figure 1). However, grains spike^{-1}, grain weight spike^{-1}, grain yield plant^{-1} and cell membrane stability showed negative and significant correltion (r=-0.664**, -0.916**,-0.189**, -0.852**& -0.843**), respectively. Accordingly, under heat stress conditions spike length, biological yield plant^{-1}, harvest index, leaf area, relative water content, chlorophyll content, and cell membrane stability were observed to have a significant and positive association with plant height (r=0.241*, 0.787**,0.814**,0.427**,0.796**and 0.730**), respectively. However, negative association was found with grains spike^{-1} (r=-0.790**), grain weight spike^{-1} (r=-0.853**), grain yield plant-1 (r=-0.891**). Whereas, the remaining characters revealed to have a non-significant association with this trait (Table 1; Figure 4). Bhanu et al. (2018) also observed a significant positive correlation between plant height and spike length in their study. Ul-Allah et al. (2021) identified noteworthy associations between the plant height and a number of spikelets.

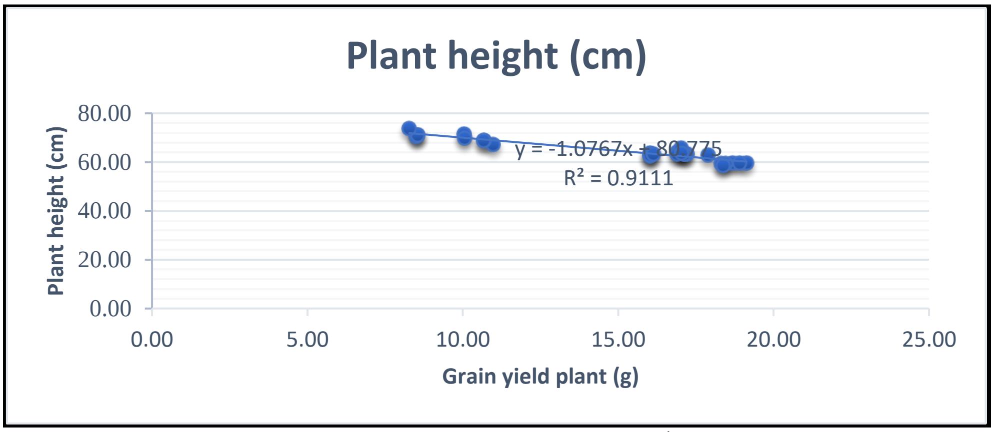

Figure 1. The correlation coefficient of plant height with grain yield plant^{-1} in bread wheat genotypes under normal planting

Number of productive tillers plant^{-1}: This character showed positive significant association with spike length, number of spikeltes plant^{-1}, grains spike$^{-1,}$ grain weight spike^{-1}, 1000 grain weight, biological yield plant^{-1}, harvest index, leaf area, relative water content, chlorophyll content and cell membrane stability (r=0.307**,0.386**,0.677**,0.685**,0.695**,0.638**,0.675**,0.673**,0.783**, 0.364**,0.709**,0.823** and 0.646**), respectively under normal sowing date. In heat stress condition, spike length depicted significant positive relationship with spike length, number of spikelets spike^{-1}, grains spike^{-1}, grain weight spike^{-1}, grain yield plant^{-1}, seed index, biological yield plant^{-1}, leaf area, relative water content, chlorophyll content, cell membrane stability and stomatal conductance (r=0.877**,0.857**,0.244**,0.308**,0.835**,0.401**,0.199*,0.284* and 0.455**), respectively. The remaining traits showed a non-significant association with number of tillers plant^{-1} (Table 1). Yared *et al.*, (2021) also reported a significant association of tillers plant^{-1} with various yield and physiological characteristic

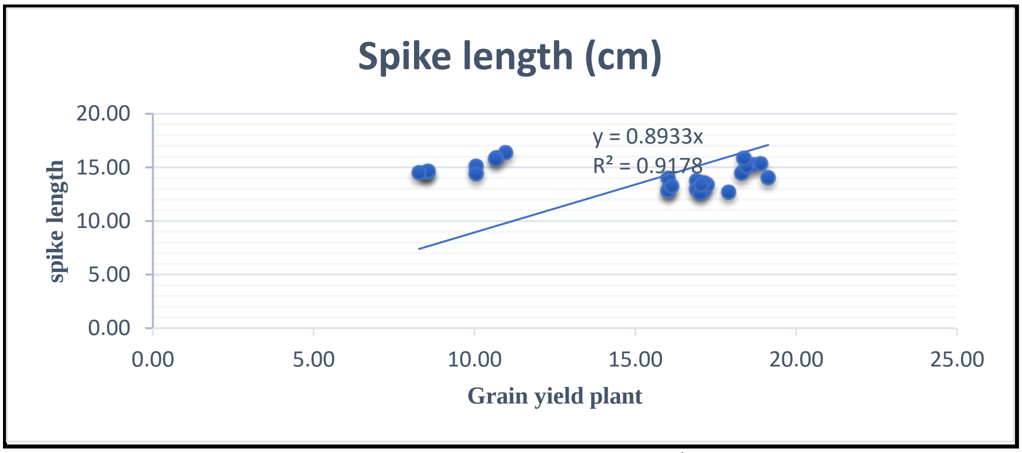

Figure 2. The correlation coefficient of spike length with grain yield plant^{-1} in bread wheat genotypes under normal planting

Spike length (cm): The spike length expressed highly significant positive correlations with number of spikelets spike^{-1} (r =0 .888**), grains spike^{-1} (r = 0.677**), seed index (r =0 .580**), harvest index (r=0.193*),. However, some characters such as grain weight spike^{-1}, grain yield plant^{-1}, biological yield plant$^{-1,}$ and chlorophyll content were observed to have negative and significant associations with this trait (r=-0.207**,-0.285**,-0.325** and -0.225*), respectively. The remaining characters depicted a non-significant association with spike length (Table-1). Whereas, under late planting the correlation varied as it had a significant positive association with the number of spikelets spike^{-1}, grains spike^{-1}, grain weight spike^{-1}, grain yield plant^{-1}, seed index, biological yield plant^{-1}, flag leaf area, relative water content, chlorophyll content, cell membrane stability and stomatal conductance (r=0.815**,0.437**,0.490**,0.343**,0.792**,0.575**,0.192**,0.339**,0.274*0.450** and 0.483**), respectively (Figure 4).These results are in agreement with Getachew *et al.*, (2021), who emphasized that spike length has a relationship with yield traits.

Number of spikelets : Under normal sowing date, significant positive correlation for this trait was observed with grains spike^{-1} (r = 0.398**), grain yield

plant^{-1} (r =0.207*), seed index (r = 0.620**), and biological yield plant^{-1}
(r=0.250*), respectively. While other characters grain weight spike^{-1}, harvest index, and leaf area revealed a non-significant association with this trait. Remaining traits as relative water content, chlorophyll content, cell membrane stability, and stomatal conductance were found to have a negative and non-significant association with this character (r=-0.054ns,-0.168ns.-0.002ns and -0.105ns), respectively. However, under heat stress, grains spike$^{-1,}$ grain weight spike^{-1}, seed index, biological yield plant^{-1}, harvest index, and stomatal conductance exhibited to have a significant association with this trait (r=0.192*,0.201*,0.888**,0.332**0.274*,0.206*and 0.618**), respectively, while other characters showed non-significant association with this trait (Table 1). Kumar *et al.*, (2022) observed significant associations of number spikelets with yield traits.

Number of grain spike^{-1}: Under normal planting this trait showed significantly higher positive correlation with almost all the characters as grain weight spike^{-1} (r = 0.618**), grain yield plant^{-1} (r = 0.591**), seed index (r =0 .456**), biological yield plant^{-1} (r = 0.540**), harvest index (r =0 .667**), leaf area (r=0.702**), relative water content (r=0.328**), chlorophyll content (r=0.504**), cell membrane stability (r=0.618**) and stomatal conductance (r=0.609**), respectively (Table 1;Figure 3). Similarly. Under late planting grains spike^{-1} revealed significant positive correlation with grains spike^{-1} (r=0.094**), grain yield plant^{-1} (r=0.844**), biological yield plant^{-1} (r=0.936**), harvest index (r=0.556**), leaf area (r=0.791**), relative water content (r=0.763**), chlorophyll content (r=0.853**), cell membrane stability (r=0.828**) and stolatal conductance (r=0.292**) (Figure 5) (Table 1). Baye *et al.*, (2020) also found similar results. Number of Grains per ear revealed positive and highly significant correlation with Number of spikelets per ear (rp= 0.8573) at phenotypic leve.

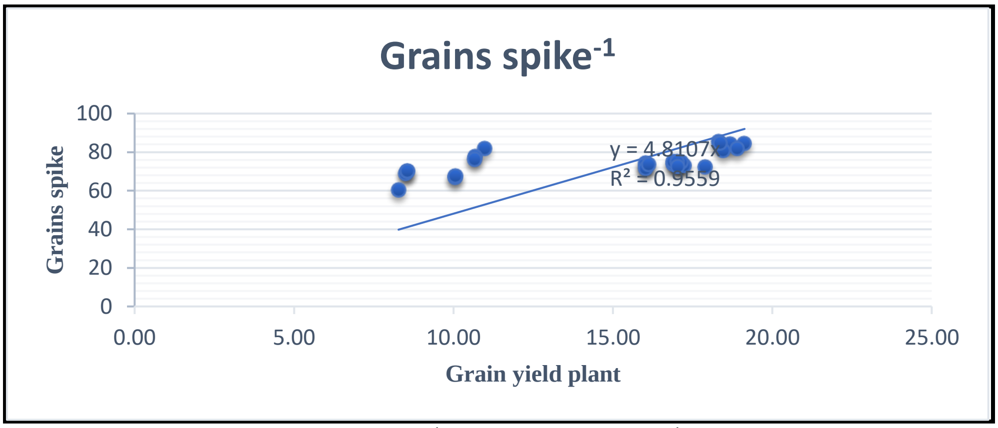

Figure 3. The correlation coefficient of grains spike^{-1} with grain yield plant^{-1} in bread wheat genotypes under normal planting

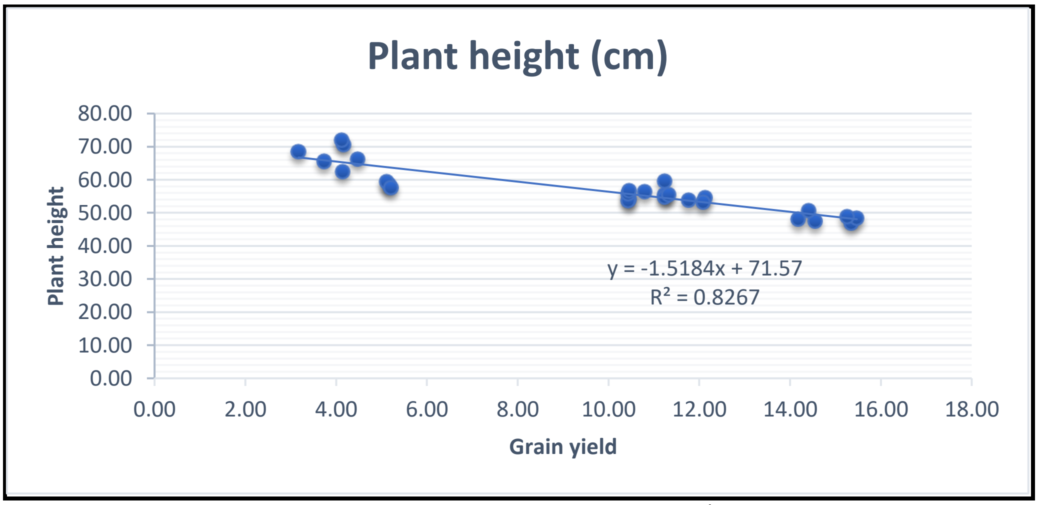

Figure 4. The correlation coefficient of plant height with grain yield plant^{-1} in bread wheat genotypes under late planting

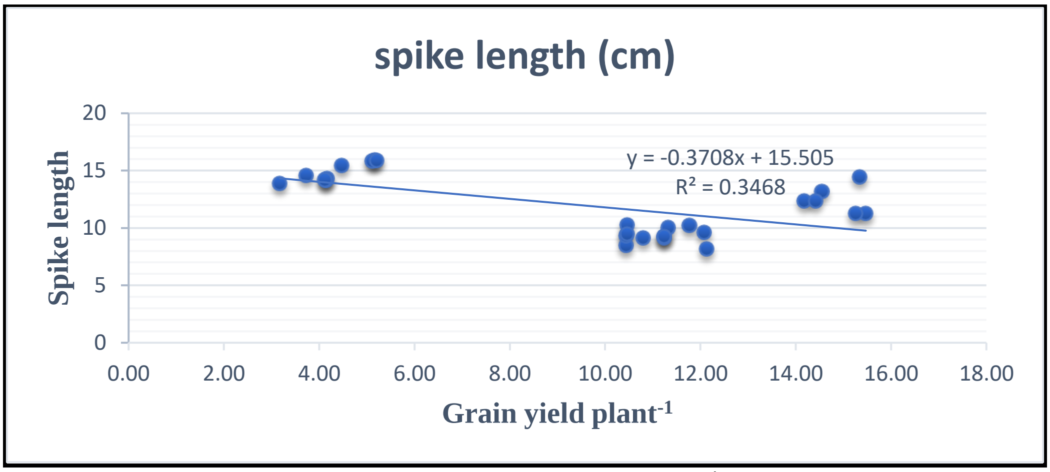

Figure 5. The correlation coefficient of spike length with grain yield plant^{-1} in bread wheat genotypes under late planting

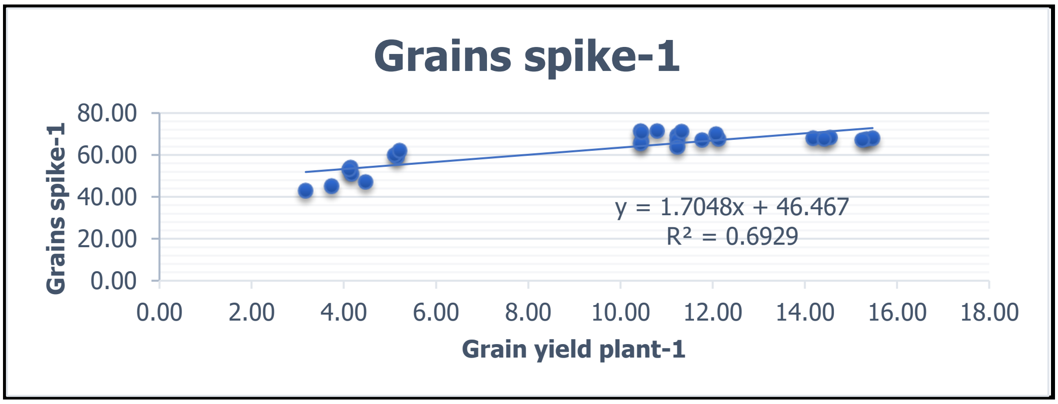

Figure 6 The correlation coefficient of spike length with grain yield plant^{-1} in bread wheat genotypes under late planting

Grain weight spike^{-1} (g): The trait under normal planting exhibited positive and significant correlation with number of tiller plant^{-1} (r=0.685**), grains spike-^{1} (r=0.618**), while depicted negative and significant association with days to 75% heading, days to 75% maturity and plant height (r=-0.825**,-0.952** and -0.916**), respectively. Similarly, for late planting, days to 75% heading, days to 75% maturity and plant height exhibted negative significant association (r=0.864**,-0.968** and -0.853**), respectively. However, tillers plant^{-1}, spike length, grains spike^{-1}, grain weight spike^{-1} and grain yield plant^{-1} depicted significant and positive correlation with each other (r=0.964**,r=0.264**,0.971**,0.746**,0.894**,0.505**,0.846** and 0.920**), respectively (Table 1). These results of number of grains spike^{-1} are with agreement to the reports of Khan et al. (2020).

Grain yield plant^{1} (g): Grain yield is a complex character which influenced by various quantitative traits. Grain yield plant^{-1} exhibited a significant positive correlation under normal planting with number of tillers plant^{-1}, number of spikelets spike^{-1}, grains spike$^{-1,}$ and grain weight spike^{-1} (r=0.695**,0.207*,0.591**and 0.950**), respectively. However, a negative and significant correlation was observed with days to 75% heading, days to 75% maturity and plant height (r=-0.867**,-0.971**, and -0.916**), respectively. Under late planting, days to 75% heading, days to 75% maturity, and plant height depicted a negative signifcant correlations with yield plant^{-1} (-0.896**,-0.968**and -0.891**), respectively. However, a significant positive correlation was depicted with spike length, grains spike$^{-1,}$ and grain weight spike^{-1} (r=0.343**,0.844** and 0.964**), respectively. While the remaining characters showed a non-significant association. Contrary to the present study, Verma *et al.,* (2019) reported a positive correlation between the number of spikelets and tillers per plant with grain yield at both genotypic and phenotypic levels.

Seed index (g): Under normal planting **p**ositive significant correlation was observed with all the characters as biological yield plant^{-1} (r = 0.217**), (r=0.273*), (r=0.485**), (r=0.327**), (r=0.347**), (r=0.437**) and (r=0.312**), respectively. Whereas, under late planting days to 75% maturity, tillers plant^{-1}, spike length, number of spikelets and grain weight spike^{-1} (r=0.275*), (r=0.835), (r=0.792**),(r=0.888**) and (r=0.964**) depicted significant positive association with seed index, respectively. However, a non-significant association was observed with days to 75% heading, plant height, grains spike$^{-1,}$ and grain yield plant^{-1} (Table 1). These results are similar to the findings of Bayisa *et al.,* (2020).

Biological yield plant^{-1}: This character showed a significant positive correlation under normal planting with the days to 75% heading, days to 75% maturity, number of tillers, number of spikelets spike^{-1}, grains spike^{-1}, grain yield plant$^{-1,}$ and seed index (r=0.872**, 0.970**, 0.905**, 0.675**, 0.250*,0.540**,0.94*,0.993** and 0.217*), respectively. However, under late planting, plant height, days to 75% heading, days to 75% maturity, number of tillers plant^{-1}, number of spikelets spike^{-1}, grains spike^{-1}, grain yield plant^{-1} (r=0.833**, 0.939**,0 . 787**, 0.401**, 0.575**, 0.332**,0.971** and 0.911**), respectively (Table 1). Rajput et al. (2019) reported biological yield significantly correlated with harvest index

Flag leaf area (cm^2): Flag leaf area showed significant positive correlations with days to 75% heading, days to 75% maturity, plant height, number of tillers, grains spike^{-1}, grain weight spike^{-1}, grain yield plant^{-1}, seed index, biological yield plant^{-1} and harvest index (r=0.786**, 0.874**, 0.836**, 0.783**,0.702**,0.870**,0.906**,0.958**,0.273**, 0.920**), respectively. Whereas, under late sowing days to 75% heading, days to 75% maturity, plant height, spike length, grains spike^{-1}, grain weight spike$^{-1,}$ and grain yield exhibited a significant association with leaf area. The remaining characters showed a non-significant correlation (Table 1).

Relative water content (g): The physiological trait and relative water content revealed significant positive correlations with days to 75% heading, days to 75% maturity, plant height, number tillers plant^{-1}, grains spike^{-1}, grain weight spike^{-1}, grain yield plant^{-1}, seed index, biological yield plant^{-1}, harvest index, leaf area, relative water content, chlorophyll content and cell membrane stability (r=0.438**,0.533**,0.417**,0.364**, 0.328**,0.468**,0.591**,0.327**,0.572**,0.673**and 0.652**), respectively. Under late sowing date all the characters showed significant and positive correlations with relative water content (Table 1).

Chlorophyll content (RG): This physiological trait exhibited significant positive associations with days to 75% heaidng, days to 75% maturity, plant height, number of tillers plant-1, grains spike-1, grain weight spike^{-1}, grain yield plant$^{-1,}$ seed index, biological yield plant and harvest index. However, under late sowing this character showed a positive significant association with days to 75% heading, days to 75% maturity, plant height, spike length, grains spike, grain weight spike and grain yield plant$^{-1,}$ biological yield plant^{-1} and leaf area.

Cell membrane stability (%): Cell membrane stability in wheat genotypes marked significant positive correlation with number of tillers plant^{-1}, grain weight spike^{-1}, grain yield plant$^{-1,}$ seed index, biological yield plant^{-1}, harvest index, leaf area, relative water content, chlorophyll content, cell membrane stability and stomatal conductance (r = 0.823**, 0.618**, 0.787**, 0.925**,0.437**,0.926**, 0.865**, 0.935**,0.523** and 0.921**), respectively under normal planting. Accordingly, late planting showed a significant relationship with almost all the characters except for number of tillers plant^{-1} and seed index. From the present research work, it is regarded that the cell membrane stability showed a close but very strong positive significant association with stomatal conductance (Table 1). Islam et al. (2017) recorded that cell membranes showed a very strong positive correlation with various characteristics.

Stomatal conductance: This physiological trait also showed a significant positive association with a number of tillers plant^{-1}, grains spike^{-1}, grain weight spike^{-1}, grain yield plant^{-1}, seed index, biological yield plant$^{-1,}$ harvest index, leaf area, chlorophyll content, and cell membrane stability. However, under late planting significant positive associations were depicted with tiller plant^{-1}, spike length, number of spikelets, grains spikelets, seed index, biological yield plant$^{-1,}$ and harvest index, respectively.

Heritability Estimates

The heritability estimates of bread wheat genotypes for morphological traits grown under normal and heat stress conditions: The higher heritability estimates for various quantitative traits of bread wheat genotypes determined during present study with regard days to 75% heading, days to 75% maturity, plant height, number of productive tillers plant^{-1}, spike length spike^{-1}, number of spikelets spike^{-1}, number of grains spike^{-1}, grains weight spike^{-1}, grains yield plant^{-1}, seed index, biological yield plant^{-1} and harvest index perceived with broad sense were: h^2 = 95.84, 99.86, 98.85, 83.55, 89.84, 90.21, 98.47, 99.96, 99.99, 93.99, 99.90 and 99.62% respectively in non-heat stress condition. Wherease the heritability estimates in heat stress conditions for yield morphological traits observed were; h^2 = 94.35, 94.72, 98.45, 82.56, 84.78, 90.06, 97.36, 99.54, 98.38, 92.85, 99.04 and 99.89% respectively (Table-2). These findings are in agreement of Ahmed *et al.,* (202)

Table 1. The correlation coefficient among the lines, testers and F_1 hybrids for quantitative traits in hexaploid bread wheat grown under normal (lower diagonal) and heat stress (upper diagonal) conditions.

Traits	Days to heading 75%	Days to maturity 75%	Plant height (cm)	Number tillers plant-1	Spike length (cm)	Number of spikelets spike-1	Grain spike-1	Grain weight spike-1 (g)	Grain yield plant-1 (g)	Seed index (%)	Biologic. yield plant-1 (g)	Harvest index (%)	Flag Leaf area (cm^2)	Relative water content (%)	Chlorophyll Content (%)	Cell membrane stability (%)	Stomatal conductance
DH 75%	**1**	**0.915****	0.895**	0.223*	0.369**	0.167ns	-0.806**	0.864**	-0.896**	0.165ns	0.833**	0.757**	0.715**	0.541**	0.787**	0.652**	0.008ns
DM 75%	0.886**	**1**	0.864**	0.279*	0.444**	0.218*	-0.857**	-0.968**	-0.968**	0.275*	0.939**	0.797**	0.826**	0.483**	0.833**	0.832**	0.071ns
PH	0.863**	0.945**	**1**	0.088ns	0.241*	-0.043ns	-0.790**	-0.853**	-0.891**	0.004ns	0.787**	0.816**	0.814**	0.427**	0.796**	0.730**	0.168ns
T/P	0.564**	0.634**	0.647**	**1**	0.877**	0.857**	0.244*	0.308**	0.173ns	0.835**	0.401**	0.132`ns	0.013ns	0.199*	0.078ns	0.284*	0.455**
SP/L	0.305**	0.323**	0.246*	0.307**	**1**	0.815**	0.437**	0.490**	0.343**	0.792**	0.575**	0.003ns	0.192*	0.339**	0.274*	0.450**	0.483**
Ns p^{-1}	0.249**	0.287**	0.182ns	0.386**	0.888**	**1**	0.192*	0.201*	0.071ns	0.888**	0.332**	0.274*	0.158ns	0.206*	0.013ns	0.161ns	0.618**
G/sp^{-1}	-0.453**	-0.563**	-0.664**	0.677**	0.344**	0.398**	**1**	0.094**	0.844**	0.164ns	0.936**	0.556**	0.791**	0.763**	0.853**	0.828**	0.292**
G/W/s	-0.825**	-0.952**	-0.922**	0.685**	-0.207*	0.145ns	0.618**	**1**	0.964**	0.264*	0.971**	0.746**	0.894**	0.505**	0.846**	0.920**	0.093ns
GYP	-0.867**	-0.971**	-0.916**	0.695**	-0.285**	0.207*	0.591**	0.950**	1	0.175ns	0.911**	0.872**	0.875**	0.433**	0.852**	0.846**	0.034ns
SI	-0.229*	-0.157ns	-0.189*	0.638**	0.580**	0.620**	0.456**	0.169ns	0.233*	1	-0.346**	0.094ns	0.092ns	-0.081ns	0.026ns	0.026ns	0.573**
BYP	0.872**	0.970**	0.905**	0.675**	-0.325**	0.250*	0.540**	0.940**	0.993**	0.217*	1	0.603**	0.820**	0.616**	0.835**	0.835**	0.259*
Hi	0.811**	0.920**	0.885**	0.673**	0.193*	0.115ns	0.667**	0.906**	0.958**	0.273*	0.920**	**1**	0.767**	0.116ns	0.686**	0.686**	0.417**
F/L/A. cm²	0.786**	0.874**	0.836**	0.783**	0.030ns	0.070ns	0.702**	0.870**	0.906**	0.485**	0.888**	0.910**	1	0.325**	0.794**	0.888**	0.183ns
RWC	0.438**	0.533**	0.417**	0.364**	-0.082ns	-0.054ns	0.328**	0.468**	0.591**	0.327**	0.572**	0.673**	0.652**	**1**	0.575**	0.363**	0.587**
C L. C.	0.838**	0.926**	0.833**	0.709**	-0.225*	-0.168ns	0.504**	0.880**	0.944**	0.347**	0.952**	0.889**	0.917**	0.669**	1	0.759**	0.080ns
CMS	-0.825**	-0.896**	-0.852**	0.823**	-0.064ns	-0.002ns	0.618**	0.878**	0.925**	0.437**	0.926**	0.865**	0.935**	0.523**	0.921**	**1**	0.037ns
SC.	-0.747**	-0.843**	-0.811**	0.646**	-0.154ns	-0.105ns	0.609**	0.817**	0.870**	0.312**	0.861**	0.868**	0.820**	0.642**	0.841**	0.804**	**1**

DH = Days to heading, **DM =** Days to maturity, **PH** = Plant height , **T**/P = Number of tillers $plant^{-1}$, **SP/ L =** Spike length $spike^{-1}$, **Ns/P =** Number of spikelets spike $^{-1}$, **G/sp** = Grains $spike^{-1}$, **G/W/s** = Grain weight $spik^{-1}$, **GYP** = Grain yield $Plant^{-1}$, **SI =** seed index , **BYP** = Biological yield $plant^{-1}$, **H**i = Harvest index, **F/L./A. cm²**. = Flag leaf area square centimeter, **RWC** = Relative water content, **CL. C** = Chlorophyll content, **CMS** = Cell membrane stability and **SC.** = stomatol conductance.

Table 2. Heritability estimates in a broad sense for various quantitative traits of bread wheat genotypes under normal and heat-stress environments

Characters	**Heritability % (Broad sense)**	**Heritability % (Broad sense)**
	Non-heat stress	**Heat stress**
Days to 75% heading	95.84	94.35
Days to 75% maturity	99.86	94.72
Plant height (cm)	98.85	98.45
Number of tillers plant^{-1}	83.55	82.56
Spike length (cm)	89.84	84.78
Number of Spikelets spike^{-1}	90.21	90.06
Number of grain spike^{-1}	98.47	97.36
Grain weight spike^{-1} (g)	99.96	98.87
Grains yield plant^{-1} (g)	99.99	98.38
Seed index (%)	93.99	92.85
Biological yield plant^{-1}	99.90	98.87
Harvest index (%)	99.62	99.24
Flag leaf area (cm^2)	99.01	98.93
Relative water content (%)	99.54	98.09
Chlorophyll content	98.10	97.49
Cell membrane stability (%)	99.42	98.06
Stomatal conductance (%)	98.06	97.84

h^2 = %= Percentage

CONCLUSION:

It is concluded that the lines, testers, and crosses exhibited significant relationship with most of the characters under both normal and heat stress conditions. However, correlation analysis showed significant and positive association with most of the characters including yield. Late and early planting observed to have difference in correlation with yield characters. Though high heritability was influenced by both early and late sowing dates.

AUTHORS' CONTRIBUTION:

Raza Ali Rind analyzed and interpreted the data, Wajid Ali Jatoi designed the experimental design, Shabana Memon helped with the manuscript writeup and Aijaz Ahmed Soomro supported the data interpretation.

ONFLICT OF INTEREST:

Authors have no conflict of interest.

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