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Correlation study for heat tolerance in durum wheat (*Triticum durum* Desf.) under timely and late sowing conditions

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Abstract
Fifty durum wheat genotypes were evaluated in three replicated trials under timely and late sowing conditions during 2015-16. The Experiment was carried out to assess effects of heat tolerant traits on grain yield and their association under late sowing condition in durum wheat. The values of genotypic correlation in both sowing conditions (D_0 & D_1) were higher as compared to the corresponding phenotypic correlation. This indicated that though there was high degree of association between two variables at genotypic level, its phenotypic expression was deflated by the influence of environment. The character, grain yield per plant exhibited highly significant and positive genotypic and phenotypic correlation under D_0 condition with harvest index, biological yield per plant and 100-grain weight, while it also manifested the highly significant positive correlation with length of main spike and plant height at genotypic level. The character, grain yield per plant under D_1 condition exhibited significant and positive genotypic and phenotypic correlation with harvest index, biological yield per plant and plant height, while it also manifested the significant positive correlation with length of main spike and number of grains per main spike at genotypic level. The yield components exhibited varying trends of association among themselves. Thus, revealed that under D_0 condition harvest index, biological yield per plant, 100-grain, length of main spike and plant height and under D_1 condition harvest index, biological yield per plant, plant height length of main spike and number of grains per main spike were the most important traits and may contribute considerably towards higher grain yield.

Keywords: durum wheat, correlation coefficient, heat tolerance

Introduction
Durum wheat (*Triticum durum* Desf.) is a monocotyledonous plant of the Gramineae family. It is the only tetraploid (AABB, 2n=4x=28) species of wheat which has commercially a great importance and is a promising and viable alternative crop for farmers. The cultivation of durum wheat was 10 to 11% of the world wheat areas and accounting for about 8% of the total wheat production. Globally, durum wheat covers total area of 20 million hectares and production of 30 million metric tons (Wolde *et al*., 2017).

Heat stress at later growth stages is a problem in 40 per cent of wheat areas in the temperate environments. A brief period of exposure to high ambient temperature (>35°C) may drastically reduce grain yield in wheat because of induction of early senescence and acceleration of grain filling activities in wheat due to shortening of grain filling duration and constriction of carbon assimilation. Grain weight is affected by high temperatures, especially those above 34°C that reduce the duration of grain filling owing to the limited photosynthesis.

Heat tolerance is a complex phenomenon and difficult to measure. Many selection criteria based on morpho-physiological traits were reported to be associated with performance under heat stress in wheat. Heat tolerant metabolism reported to be indicated by longer leaf chlorophyll retention, canopy temperature depression, photosynthetic rate, leaf senescence (Khan *et al.*, 2013) [6].

Materials and Methods
The experimental material consisted of 50 diverse genotypes of durum wheat (*Triticum durum* Desf.) under timely and late sowing condition for 50 genotypes of durum wheat in a Randomized Block Design with three replications during *rabi* 2015-2016 at Wheat Research Station, Junagadh Agricultural University, Junagadh. Each entry was accommodated in a single row of 2.5 m length with a spacing of 22.5 cm between two rows. The recommended agronomical practices and plant protection measures were followed for the successful raising of the crop. Five competitive plants per genotype in each replication were randomly selected for recording observations on different characters *viz*., Days to 50% flowering,

Days to maturity Grain filling period (Days), Plant height (cm), Number of productive tillers per plant Length of main spike (cm), Number of grains per main spike, Grain weight per main spike (g), Grain yield per plant (g), Biological yield per plant (g), Harvest index (HI) (%), 100-grain weight (g), Chlorophyll content at anthesis (SPAD unit), Chlorophyll content at 21 days after anthesis (SPAD unit), Canopy temperature depression at vegetative stage (°C) and Canopy temperature depression at grain filling stage (°C) (except days to 50% flowering, grain filling period and days to maturity) and their averages were used in the statistical analysis. The analysis of variance for RBD was carried out by linear model suggested by Panse and Sukhatme (1985) [11]. Correlation coefficients measure the relationship between two or more series of variables. The genotypic correlation coefficient provides a measure of genotypic association between different characters, while phenotypic correlation includes both genotypic as well as environmental influences. The phenotypic and genotypic correlation coefficients of all the characters were worked-out as per Al-Jibouri *et al*. (1958) [1].

Results and Discussion

The study of genotypic correlation gives an idea of the extent of inherent relationship between different variables. This relationship among yield contributing characters as well as their association with yield provides information for exercising selection pressure for bringing genetic improvement in grain yield. In general, the values of genotypic correlation were higher than their corresponding phenotypic correlations in the present study. This indicated that though there was high degree of association between two variables at genotypic level, its phenotypic expression was deflated by the influence of environment. The results are in agreement with those obtained by Munir *et al*. (2007), Majumder *et al.* (2008), Malav (2015) and Singh (2016) [10, 7, 8, 12]

D_0: The characters, grain yield per plant under timely sowing condition (D_0) exhibited significant and positive genotypic and phenotypic correlation with harvest index, biological yield per plant and 100-grain weight. It also manifested the highly significant positive correlation with length of main spike and plant height at genotypic level. Grain yield per plant also manifested positive, but non-significant genotypic and phenotypic correlation with number of grains per main spike, grain weight per main spike, days to maturity, chlorophyll content at 21 days after anthesis, days to 50% flowering and chlorophyll content at anthesis. The significant and positive correlation also reported by Chhibber and Jain (2014), Ali *et al.* (2015), Malav (2015), Singh (2016) and Mecha *et al.* (2017) [10, 7, 8, 12].

The plant height exhibited significant and positive correlation at genotypic level with length of main spike, 100-grain weight and biological yield per plant. Number of productive tillers per plant exhibited significant and negative correlation at genotypic level with chlorophyll content at anthesis. The length of main spike exhibited highly significant and positive correlation with 100-grain weight at both the levels. The number of grains per main spike showed significant and positive correlation with grain weight per main spike and 100-grain weight at both the levels. The grain weight per main spike exhibited significant and positive correlation with biological yield per plant at both genotypic and phenotypic levels. Biological yield per plant showed significant and positive correlation with 100 grain weight at both genotypic and phenotypic levels. It also showed significant and negative correlation with harvest index. The chlorophyll content at anthesis possessed positive and highly significant correlation with chlorophyll content at 21 days after anthesis.

Days to 50% flowering exhibited highly significant and positive correlation both at genotypic and phenotypic levels with days to maturity. Days to 50% flowering exhibited significant and negative correlations both at genotypic and phenotypic levels with grain filling period, grain weight per main spike and number of grains per main spike. The days to maturity possessed positive and highly significant genotypic association with plant height and positive and highly significant phenotypic association with grain filling period. Days to maturity exhibited significant and negative correlations at genotypic level with grain weight per main spike. The grain filling period possessed positive and highly significant genotypic association with plant height and positive and significant phenotypic association with 100-grain weight.

D_1: The character, grain yield per plant under late sowing condition (D_1) exhibited significant and positive genotypic and phenotypic correlation with harvest index, biological yield per plant and plant height. It also manifested the significant positive correlation with length of main spike and number of grains per main spike at genotypic level. Grain yield per plant also manifested positive, but non-significant correlation with grain filling period and chlorophyll content at 21 days after anthesis. The significant and positive correlation also reported Gelalcha and Hanchinal (2013), Zeeshan *et al.* (2014), Malav (2015), Singh (2016) and Mecha *et al.* (2017) [10, 7, 8, 12].

The plant height possessed highly significant and positive correlation both at genotypic and phenotypic levels with harvest index. Number of productive tillers per plant exhibited significant and negative correlation both at genotypic and phenotypic levels with chlorophyll content at anthesis and grain weight per main spike, while only at genotypic level with length of main spike and chlorophyll content at 21 days after anthesis. Length of main spike exhibited highly significant and positive correlation with harvest index, grain weight per main spike and number of grains per main spike at genotypic level. The number of grains per main spike showed significant and positive correlation with grain weight per main spike at both the levels. The grain weight per main spike exhibited significant and positive correlation with biological yield per plant at both at genotypic and phenotypic levels. Biological yield per plant showed significant and positive correlation with 100 grain weight, chlorophyll content at anthesis and chlorophyll content at 21 days after anthesis at both genotypic and phenotypic levels. The trait harvest index showed significant and negative correlation with 100-grain weight and chlorophyll content at anthesis at genotypic level. The chlorophyll content at anthesis possessed positive and highly significant with chlorophyll content at 21 days after anthesis.

Days to 50% flowering exhibited highly significant and positive correlation both at genotypic and phenotypic levels with days to maturity. Days to 50% flowering exhibited significant and negative correlations both at genotypic and phenotypic levels with grain filling, grain weight per main spike and number of grains per main spike. The days to maturity possessed positive and highly significant phenotypic association with grain filling period. Days to maturity exhibited significant and negative correlations at genotypic

level with chlorophyll content at 21 days after anthesis, grain weight per main spike, grain filling period and chlorophyll content at anthesis while at phenotypic level length of main spike. The grain filling period possessed highly significant and positive correlation both at genotypic and phenotypic levels with grain weight per main spike and positive and highly significant genotypic association with number of grains per main spike. Grain filling period exhibited significant and negative correlations at phenotypic level with length of main spike. Dwivedi *et al.* (2002) [4] found that days to 50% flowering showed negative and significant association with 1000 grain weight.

The present results on correlation coefficients, revealed that under timely sowing condition (D_0) harvest index, biological yield per plant, 100-grain, length of main spike and plant height, while under late sowing condition (D_1) harvest index, biological yield per plant, plant height length of main spike and number of grains per main spike were the most important traits and may contribute considerably towards higher grain yield. The interrelationship among yield components would help in increasing the yield levels and, therefore, more emphasis should be given to above components, while selecting better types in wheat.

Conclusion

The values of genotypic correlation in both sowing conditions (D_0 & D_1) were higher as compared to the corresponding phenotypic correlation. This indicated that though there was high degree of association between two variables at genotypic level, its phenotypic expression was deflated by the influence of environment. The character, grain yield per plant exhibited highly significant and positive genotypic and phenotypic correlation under D_0 condition with harvest index, biological yield per plant and 100-grain weight, while it also manifested the highly significant positive correlation with length of main spike and plant height at genotypic level. The character, grain yield per plant under D_1 condition exhibited significant and positive genotypic and phenotypic correlation with harvest index, biological yield per plant and plant height, while it also manifested the significant positive correlation with length of main spike and number of grains per main spike at genotypic level. The yield components exhibited varying trends of association among themselves. Thus, revealed that under D_0 condition harvest index, biological yield per plant, 100-grain, length of main spike and plant height and under D_1 condition harvest index, biological yield per plant, plant height length of main spike and number of grains per main spike were the most important traits and may contribute considerably towards higher grain yield.

Table 1: Genotypic (r_g) and phenotypic (r_p) correlation coefficients among 14 characters in 50 genotypes of durum wheat under timely sowing (D_0)

Characters		Days to 50% flowering	Days to maturity	Grain filling period (Days)	Plant height (cm)	Number of productive tillers per plant	Length of main spike (cm)	Number of grains per main spike	Grain weight per main spike (g)	Biological yield per plant (g)	Harvest index (%)	100-grain weight (g)	Chlorophyll content at anthesis (SPAD unit)	Chlorophyll content at 21 days after anthesis (SPAD unit)
Grain yield per plant (g)	r_g	0.0816	0.1259	0.0156	0.408*	-0.2718	0.3759**	0.2027	0.1932	0.5179**	0.6239**	0.4956**	0.0429	0.1004
	r_p	0.0895	0.0649	0.0306	0.2415	-0.2427	0.0908	0.1863	0.1493	0.5258**	0.6335**	0.3995**	0.0389	0.0665
Days to 50% flowering	r_g		0.509*	-0.684*	0.0579	0.2503	0.046	-0.3010*	-.4602**	-0.0704	0.1833	-0.1725	-0.1202	-0.0855
	r_p		0.38**	-.6292**	0.0410	0.2034	-0.0346	-0.2878*	-0.3118*	-0.0579	0.1801	-0.1876	-0.1219	-0.0873
Days to maturity	r_g			0.2787	0.570*	0.0109	0.1215	-0.1937	-0.3149*	-0.0268	0.1783	0.0328	-0.2372	-0.1917
	r_p			0.4764**	0.2422	-.0802	0.1271	-0.1545	-0.2135	-0.0379	0.1184	0.1485	-0.2674	-0.1982
Grain filling period (Days)	r_g				0.5485**	-.2702	0.0517	0.1718	0.2468	0.0558	-0.0535	0.2204	-0.0670	-0.0670
	r_p				0.1648	-.2612	0.1399	0.1440	0.1172	0.0232	-0.0718	0.3036*	-0.1090	-0.0837
Plant height (cm)	r_g					-.1506	0.7479**	-0.2633	-0.2043	0.3358*	0.1252	0.4654**	0.0588	0.1355
	r_p					-.0723	0.1545	-0.1355	0.0034	0.1828	0.0914	0.1541	0.0494	0.1149
Number of productive tillers per plant	r_g						-0.0026	-0.1414	-0.2539	-0.1117	-0.1698	-0.1597	-0.3509*	-0.4200
	r_p						-0.0144	-0.1206	-0.1920	-0.1006	-0.1519	-0.1679	-0.2442	-0.2338
Length of main spike (cm)	r_g							0.0124	0.1632	0.2694	0.1509	0.4534**	-0.0441	-0.0708
	r_p							0.0369	0.1021	0.0967	0.0042	0.3644**	0.0376	0.0446
Number of grains per main spike spike	r_g								0.7762**	0.1828	0.0794	0.3165*	0.0497	0.0620
	r_p								0.5731**	0.1739	0.0727	0.2931*	0.0713	0.1037
Grain weight per main spike (g)	r_g									0.4910**	0.1583	0.216	0.0958	0.1283
	r_p									0.3930**	0.1237	0.1287	0.0843	0.0892
Biological yield per plant (g)	r_g										-0.3372*	0.3587*	0.1443	0.2154
	r_p										-0.3166*	0.3043*	0.1334	0.1563
Harvest index (%)	r_g											0.2089	-0.1112	-0.1197
	r_p											0.1619	-0.1003	-0.0909
100-grain weight (g)	r_g												0.1828	0.2557
	r_p												0.1061	0.1285
Chlorophyll content at anthesis (SPAD unit)	r_g													1.0220**
	r_p													0.8382**

*, ** Significant at 5% and 1% levels, respectively

Table 2: Genotypic (r_g) and phenotypic (r_p) correlation coefficients among 14 characters in 50 genotypes of durum wheat under late sowing (D_1)

Characters		Days to 50% flowering	Days to maturity	Grain filling period (Days)	Plant height (cm)	Number of productive tillers per plant	Length of main spike (cm)	Number of grains per main spike	Grain weight per main spike (g)	Biological yield per plant (g)	Harvest index (%)	100-grain weight (g)	Chlorophyll content at anthesis (SPAD unit)	Chlorophyll content at 21 days after anthesis (SPAD unit)
Grain yield per plant (g)	r_g	-0969	-0.1291	0.0412	0.3830*	-0.0009	0.4704*	0.2869*	0.3224*	0.6858**	0.7243*	-0.0773	-0.0057	0.0208
	r_p	-0692	-0.0117	0.0530	0.3680*	0.0101	0.2701	0.2766	0.2718	0.6875**	0.7430*	0.1488	0.0284	0.0574
Days to 50% flowering	r_g		0.7789*	-0.8539**	-0.0589	0.0407	0.1131	-0.3408*	-.4929**	-0.1561	-0.0154	-0.1901	-0.1100	-0.1669
	r_p		0.3873**	-0.5390**	-0.0576	0.0313	0.0439	-0.3226*	-0.3560*	-0.1395	0.0080	-0.0530	-0.0856	-0.1357
Days to maturity	r_g			-0.3388*	-0.2141	-0.0721	0.1749	-0.1486	-.4206**	-0.0893	-0.0992	-0.0627	-0.3379*	-0.4330**
	r_p			0.5678**	-0.1908	-0.1949	-.3779**	-0.1064	0.0816	0.0284	-0.0506	0.1477	-0.1363	-0.1794
Grain filling period (Days)	r_g				-0.0891	-0.1225	-0.0203	0.3910*	0.3931*	0.1636	-0.0580	-0.2431	-0.1188	-0.1124
	r_p				-0.1219	-0.2065	-0.3842*	0.1916	0.3941*	0.1524	-0.0523	0.1821	-0.0484	-0.0428
Plant height (cm)	r_g					0.1462	0.2720	-0.1636	-0.0530	0.0757	0.4604**	0.0519	-0.0334	0.0768
	r_p					0.1905	0.2848	-0.1508	-0.0886	0.0794	0.4387**	0.0680	-0.0221	0.0858
Number of productive tillers per plant	r_g						-.4466**	-0.1893	-0.3235*	-0.2242	0.2432	-0.1243	-0.3619**	-0.2869*
	r_p						0.0475	-0.1593	-0.3520*	-0.1994	0.2297	0.0134	-0.3179*	-0.2445
Length of main spike (cm)	r_g							0.3656*	0.3861*	0.1903	0.4075*	-0.1069	-0.1398	0.0239
	r_p							0.2455	-0.0295	0.1251	0.2364	0.1662	-0.0221	0.0698
Number of grains per main spike spike	r_g								0.7330*	0.2364	0.1570	0.0367	0.1493	0.0319
	r_p								0.6351*	0.2346	0.1518	0.0340	0.1505	0.0354
Grain weight per main spike (g)	r_g									0.3544**	0.1234	0.0170	0.2308	0.1299
	r_p									0.3234**	0.0850	0.1107	0.2257	0.1398
Biological yield per plant (g)	r_g										0.0071	0.4802*	0.3041*	0.2826*
	r_p										0.0380	0.3770*	0.3163*	0.2970*
Harvest index (%)	r_g											-.5247**	-0.2981*	-0.2597
	r_p											-0.1152	-0.2516	-0.2113
100-grain weight (g)	r_g												0.2432	0.1547
	r_p												0.2523	0.2222
Chlorophyll content at anthesis (SPAD unit)	r_g													0.8174**
	r_p													0.8236**

*, ** Significant at 5% and 1% levels, respectivel

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