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Estimation of Degree and Direction of Relationship of the Yield Contributing Characters with Yield in Bread Wheat under Terminal Heat Stress

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A B S T R A C T

A study was conducted at Wheat Breeding section, RPCAU, Pusa, Samastipur, Bihar during *rabi* 2016-17 to evaluate the genotypes of bread wheat (*Triticum aestivum* L.) for terminal heat tolerance. Observations were recorded on plant height, number of tillers per plant, flag leaf area, days to fifty per cent flowering, canopy temperature, relative water content, spike length, number of grains per spike, spike fertility, chlorophyll content, days to maturity, thousand grain weight, harvest index, yield per plant, thousand grain weight susceptibility index and heat susceptibility index. 24 genotypes were grown under two environments *i.e.* timely sown (non-stressed) and late sown (stressed). The experiment in each environment was laid out in Randomized Block Design with three replications. In order to find out the degree and direction of relationship of the yield contributing characters with yield and inter relationship between them, correlation (phenotypic and genotypic) coefficient analysis was carried out for all traits under investigation. Correlation analysis showed that phenotypic and genotypic correlation for most of the character pairs were in same direction and genotypic estimates were higher than the phenotypic one, indicating inherent association between the characters. Hence, selection based on these characters would be more effective for yield improvement in bread wheat under heat stress condition. Grain yield showed highest positive genotypic correlation with relative water content (0.9029) and lowest with days to maturity (0.0019) under timely sown condition. Under late sown condition grain yield showed highest positive genotypic correlation with relative water content (0.9428) and lowest with days to fifty percent flowering (0.0919). The traits *viz*., harvest index and spike fertility have to be given importance in selection process for improvement in yield, since they had positive correlation with grain yield. The path coefficient analysis facilitates the partitioning of the correlation coefficients into different components of direct and indirect effects. Days to maturity has high positive direct effect on grain yield (2.0544) whereas plant height showed low direct effect on grain yield (0.3679) under timely sown condition. Harvest index has high direct effect on grain yield (0.6822) and low direct effect of canopy temperature on grain yield (0.0147) under late sown condition and also all other characters contributed indirectly towards grain yield via these characters. Hence, selection based on these characters would be more effective for yield improvement in bread wheat under heat stress condition. It could be concluded from correlation and path analysis under timely sown condition that the traits like relative water content, spike fertility, chlorophyll content, harvest index, flag leaf area would be effective and reliable, since they had high positive correlation with grain yield, positive inter correlation among themselves and high indirect effect of most of the characters via these traits on grain yield.

Introduction

Wheat (*Triticum aestivum* L., 2n = 6x =42) is a one of the most widely grown food grain crop in the world. It is self-pollinated crop belonging to the most diverse and important family 'Poaceae' of the plant kingdom. Most widely grown wheat is a hexaploid species

(Triticum aestivum L.) contains three genome ABD, source of A genome was *Triticum monococcum*, B genome taken from unknown species, source of D genome was *Triticum tauschii.* Wheat is one of the most important staple food crops of the world, occupying 17 per cent of crop acreage worldwide, feeding about 40 per cent of the world population and providing 20 per cent of total food calories and protein in human nutrition (Gupta *et al.*, 2008). It is considered to be the second most important food crop in India only after rice and providing foods for about 2 billion people which is about 36 per cent of the total world population. Wheat is cultivated over a wide area all over the world and is grown on an area of about 224.82 million hectare and production of about 732.98 million tons with productivity of 3.26 tons per hectare (Anonymous, 2015). In India, wheat is grown on an area of about 30.93 million hectare which produces 93.50 million tons of wheat with a productivity of 30.34 quintal per hectare (Director's report 2017). The crop is best suited to temperate climate, however, it is mainly produced and consumed in the tropical and sub-tropical regions of developing world. Therefore, its cultivation in warmer climates is restricted to cooler months of the year (*i.e.*, winter season). During the last decade there was globally decline in annual growth rate in wheat production associated with an unprecedented increase in the price of food grains. It was partially attributed the impact of variety of abiotic stresses including heat and drought due to increasingly variable climate.

Unfortunately, heat stress is a major environmental factor that substantially reduces wheat grain yield globally especially in arid, semi-arid, tropical, and sub-tropical regions that are associated with higher temperature. Wahid *et al.*, 2007 defined heat stress as the rise in temperature beyond a threshold level for a period of time sufficient to cause irreversible damage to plant growth and development. Heat stress can cause partial or total breakdown of anatomy, morphology, biochemistry and physiology of the crop. It is function of the magnitude and rate of temperature increase, as well as the duration of exposure to the raised temperature (Wahid *et al.*, 2007). End-of-season or 'terminal' heat stress is also likely to increase for wheat in the near future (Semenov, 2009) due to increase in global warming. Therefore, breeding for heat tolerance in wheat is a major global concern (Paliwal *et al.*, 2012). Consequently, development of heat-tolerant cultivars is of importance in wheat breeding programs (Sikder and Paul, 2010). Wheat exposes to heat stress to varying degrees at different phenological stages, but the exposure of the reproductive phase to heat stress is more harmful than exposure during vegetative stages due to its direct effect on grain number and dry weight (Wollenweber *et al.*, 2003). It has been observed that each degree rise in ambient temperature reduces the yield by 3-4 per cent (Mishra 2007). Wheat breeders are seeking to incorporate late heat tolerance in the wheat germplasm and to develop genotypes that are early in maturity in order to escape the terminal heat stress and, thus suit well in the rice-wheat cropping system. Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement in yield. The knowledge about the extent and nature of interrelationship among yield components provide a better understanding in improving yield through selection. Grain yield, being a complex character, is highly influenced by environment therefore, direct selection for yield would not give better results. Indirect selection in such a situation is more effective. The path coefficient analysis facilitates the partitioning of the correlation coefficients into different components of direct and indirect effects. Thus, study on association among different character is very essential for developing effective selection criteria (Singh *et al.,* 2009). In order to find out the degree and direction of relationship of the yield contributing characters with yield and inter relationship among them under terminal heat stress condition, the present investigation was carried out.

Materials and Methods

A study was conducted at Wheat Breeding section, RPCAU, Pusa, Samastipur, Bihar during *rabi* 2016-17 to evaluate the genotypes of bread wheat (*Triticum aestivum* L.) for terminal heat tolerance. Observation were recorded on plant height, number of tillers per plant, flag leaf area, days to fifty per cent flowering, canopy temperature, relative water content, spike length, number of grains per spike, spike fertility, chlorophyll content, days to maturity, thousand grain weight, harvest index, yield per plant, thousand grain weight susceptibility index and heat susceptibility index. 24 genotypes were grown under two environments namely non stressed (timely sown) and stressed (late sown). The experiment in each environment was laid out in Randomized Block Design with three replications. In each replication each genotype was grown in a plot of 5 rows of 3 meter length each with a spacing of 23 cm (Timely sown) and 18 cm (Late sown).

Results and Discussion

Grain yield is the end product of interaction of many factors known as contributing components hence it is complex trait. Understanding of the interaction of characters among themselves and with the environment has been of great use in the plant breeding. The aim of correlation studies is primarily to know the suitability of various characters for indirect selection because selection for one or more traits resulted in correlated response for several other traits (Scarle, 1965), and the pattern of variation will also be changed (Weddington and Robertson, 1966). This is due to correlation between different characters of plant could arise because of linkage, pleiotrophy or developmentally influenced functional relationship (Giriyappanawar, 2007). Thus correlation studies provide information on the nature and extent of association between any two pairs of metric characters. From this it could be possible to bring about genetic upgradation in one character by selection of other pair. In present study, in general, the genotypic correlation coefficient values were higher than the phenotypic values. This indicated that strong intrinsic associations were somewhat masked at phenotypic level due to environmental effect similar findings were also reported by Singh *et al.,* (2002), Muhammad *et al.,* (2007) and El- Mohsen *et al.,* (2012) and Rajshree and Singh (2016). Under timely sown condition (Table 1), the genotypic correlation data showed that grain yield per plant having strong positive correlation with relative water content (0.9029), harvest index (0.8801), spike fertility (0.6839), number of grain per spike (0.5694), flag leaf area (0.5284) and chlorophyll content (0.4730), while total number of tillers per plant (0.1936), canopy temperature (0.1884), thousand grain weight (0.1812), plant height (0.1193) and days to maturity (0.0019) showed weak positive agreement with grain yield per plant. However, it was negatively correlated with spike length (-0.0818) and days to fifty per cent flowering (-0.2484) at genotypic level. Grain yield per plant exhibited significant positive correlation with flag leaf area, relative water content, number of grain per spike, spike fertility, chlorophyll content and harvest index at both phenotypic and genotypic levels, positive correlation was observed for grain yield with plant height, total number of tillers per plant, canopy temperature, days to maturity, thousand grain weight whereas it showed negative correlation with days to fifty per cent flowering. Similar results were found by Sinha and Sharma (1980) who observed positive correlation of grain yield with thousand grain weight, number of grains per spike, plant height, total number of tillers per plant and days to maturity. Sindhu *et al.*, (1976) reported positive and high correlation of grain yield with harvest index. Srivastava *et al.,* (1988) reported significant and positive correlation of grain yield with flag leaf area, harvest index. Ibrahim (1994) reported significant positive correlation of grain yield with number of grains per spike. Esmail *et al.*, (2001) reported positive correlation of grain yield with plant height, Merah (2001) observed significant positive correlation of grain yield with relative water content and harvest index Tirkey *et al.,* (2008), Talebi (2011) and Okuyama (2012) observed positive correlation of grain yield with chlorophyll content, Singh *et al.*, (2014) reported positive correlation of grain yield with total number of tillers per plant, thousand grain weight, harvest index, number of grains per spike, flag leaf area, chlorophyll content and relative water content. Therefore from the above discussion it may be concluded that grain yield is positively correlated with flag leaf area, relative water content, number of grain per spike, spike fertility, chlorophyll content and harvest index so direct selection of the these traits can be done to improve grain yield. Under late sown condition (Table 2), the high and positive genotypic correlation of grain yield per plant was exhibited by the traits like relative water content (0.9428), harvest index (0.8842), spike fertility (0.7852), thousand grain weight (0.6693), flag leaf area (0.6685), chlorophyll content (0.5856), number of grain per spike (0.5785), days to maturity (0.3810) and total number of tillers per plant (0.2619) whereas spike length (0.1350), days to fifty per cent flowering (0.0919) showed low positive correlation. Whereas, it showed negative genotypic correlation with canopy temperature (-0.1690), plant height (-0.2488), thousand grain weight susceptibility index (-0.4813), heat susceptibility index (-0.8568).

Grain yield per plant exhibited significant positive association with flag leaf area, relative water content, spike length, number of grain per spike, spike fertility, chlorophyll content, days to maturity, thousand grain weight, and harvest index. However, it was significant negatively associated with thousand grain weight susceptibility index, heat susceptibility index. These results was in accordance with the findings of Singh *et al.*, (2014) for relative water content, thousand grain weight, harvest index, number of grain per spike, chlorophyll content and flag leaf area showed significant positive correlation with grain yield, Sethi and Singh (1972) for thousand grain weight, days to maturity, Marakby *et al.*, (2007) for days to maturity, number of grain per spike, Singh *et al.*, (2009) for number of grains per spike, Talebi (2011) for chlorophyll content, Gupta *et al.*, (1997) for harvest index, Merah (2001) for relative water content and harvest index. From the above discussion, it may be concluded that direct selection of flag leaf area, relative water content, spike length, number of grains per spike, spike fertility, chlorophyll content can be done for the improvement of grain yield under terminal heat stress condition.

Days to maturity recorded for weak positive association with grain yield (0.0019) under timely sown condition (Table 3), although it showed high positive direct effect on grain yield (2.0544). The positive correlation was build-up by the contribution of its indirect effect via days to fifty per cent flowering (0.8316), chlorophyll content (0.2620), plant height (0.0412), numbers of tillers per plant (0.0570) and, canopy temperature (0.0429) on grain yield. However indirect effect of days to maturity via remaining characters was negligible on grain yield.

Table.1 Genotypic and phenotypic correlation coefficient for sixteen characters in bread wheat under timely sown condition

Characters		PH	TPP	FLA	DFF	CT	RWC	SL	GPS	SF	CHL	DM	TGW	HI
PH														
TPP	P	0.1158												
	G	0.5123												
FLA	P	0.0054	0.3955**											
	G	-0.2189	0.5128											
DFF	P	0.0724	-0.1354	-0.2204										
	G	0.1791	-0.1451	-0.2821										
CT	P	0.1728	0.0137	-0.0461	0.1020									
	G	0.1809	-0.0321	-0.0373	0.1614									
RWC	P	-0.0272	0.2949*	0.3913**	-0.0356	0.2196								
	G	0.1433	0.3863	0.4893	-0.0875	0.5902								
SL	P	-0.1411	-0.2150	-0.1478	-0.1088	-0.1037	-0.1244							
	G	-0.2038	-0.2532	-0.2506	-0.1384	-0.0199	-0.2226							
GPS	P	0.2054	0.1205	0.0476	0.0826	0.0603	0.0942	0.0725						
	G	0.4019	0.2298	0.0055	0.1036	0.1588	0.5576	0.0140						
SF	P	-0.0631	0.1653	0.0888	-0.3660**	0.0609	0.2826*	-0.1681	0.1280					
	G	0.1282	0.2480	0.2333	-0.5410	-0.0480	0.7077	-0.1288	0.5004					
CHL	P	-0.1843	0.2105	0.4807**	-0.0054	-0.0515	0.2306	-0.1728	0.1095	0.2661*				
	G	-0.5880	0.3839	0.5933	-0.0462	-0.0783	0.0584	-0.1993	0.2632	0.4286				
DM	P	-0.0944	0.0795	0.0196	0.6743**	0.0251	0.2304	-0.2497*	0.1040	-0.0453	0.2045			
	G	0.0412	0.0570	0.0082	0.8316	0.0429	0.2194	-0.2598	0.2453	-0.1460	0.2620			
TGW	P	0.1284	0.2486*	0.1270	-0.2523*	-0.0131	0.0890	0.0205	0.0864	0.3058**	0.1544	-0.1303		
	G	0.2555	0.3262	0.1287	-0.3653	-0.1476	-0.0610	0.0544	0.2214	0.4634	0.1781	-0.3430		
HI	P	-0.0633	0.1765	0.4573**	-0.1739	0.1447	0.3618**	-0.1017	0.1855	0.2695*	0.4380**	-0.0504	0.1818	
	G	-0.1054	0.1772	0.6017	-0.1990	0.2549	0.7292	0.0757	0.2065	0.7523	0.7114	-0.1400	0.2500	
GY	P	0.0315	0.1906	0.3660**	-0.2103	0.0718	0.5356**	0.0888	0.2696*	0.5314**	0.3041**	0.0558	0.1396	0.5059**
	G	0.1193	0.1936	0.5284	-0.2484	0.1884	0.9029	-0.0818	0.5694	0.6839	0.4730	0.0019	0.1812	0.8801

* * Significant at 1% level = 0.301

* Significant at 5% = 0.231

Table.2 Genotypic and phenotypic correlation coefficient for sixteen characters in bread wheat under late sown condition

Characters		PH	TPP	FLA	DFF	CT	RWC	SL	GPS	SF	CHL	DM	TGW	HI	TSI	HSI
PH																
TPP	P	0.0939														
	G	0.1579														
FLA	P	-0.2000	0.3301**													
	G	-0.2780	0.3906													
DFF	P	0.0593	0.1623	0.0432												
	G	0.1032	0.2023	0.0503												
CT	P	-0.0130	-0.1082	-0.1842	0.1138											
	G	0.0682	-0.0197	-0.3724	0.2079											
RWC	P	-0.1273	0.2225	0.5884**	0.0128	-0.0781										
	G	-0.3911	0.1931	0.8718	0.0087	-0.1386										
SL	P	0.0309	0.0531	0.0417	-0.1867	0.0539	0.0042									
	G	-0.3816	0.2654	0.0917	-0.5040	0.1058	-0.0599									
GPS	P	0.1459	0.1593	0.2751*	0.1263	-0.0513	0.2707*	0.0613								
	G	0.1101	0.2892	0.3723	0.1954	-0.1254	0.5801	-0.0137								
SF	P	0.0421	0.2514*	0.5111**	0.0350	-0.1802	0.4251**	0.0431	0.4197**							
	G	0.0327	0.3770	0.6263	0.0418	-0.4083	0.5905	0.1354	0.5378							
CHL	P	-0.0056	0.2950*	0.4849**	0.0886	-0.3611**	0.4410**	0.0802	0.3742**	0.5284**						
	G	0.0177	0.2996	0.6112	0.1052	-0.4747	0.5712	0.1741	0.5414	0.6550						
DM	P	-0.0378	0.1258	0.0694	0.2869*	-0.0980	0.2355*	0.0708	0.1377	0.0960	0.2068					
	G	-0.4419	0.1411	0.0871	0.4443	-0.2182	0.6170	-0.0587	0.1562	0.2109	0.3998					
TGW	P	-0.1461	0.2055	0.3687**	0.2459*	-0.1627	0.3862**	0.0973	0.4096**	0.5573**	0.5607**	0.3116**				
	G	-0.3082	0.2462	0.4824	0.2621	-0.1871	0.5880	0.1774	0.5012	0.6583	0.6803	0.4966				
HI	P	-0.0632	0.2220	0.6480**	0.1150	-0.1859	0.6273**	0.0977	0.4063**	0.5700**	0.5260**	0.1335	0.5567**			
	G	-0.3405	0.3191	0.8379	0.1504	-0.2179	0.9991	0.2663	0.5502	0.7206	0.6241	0.2924	0.6456			
TSI	P	0.1159	-0.0206	-0.2929*	-0.2693*	0.0858	-0.3123**	-0.0433	-0.2773*	-0.3917**	-0.4051**	-0.3462**	-0.7614**	-0.4003**		
	G	0.2654	-0.0148	-0.3511	-0.2810	0.0777	-0.5078	-0.0106	-0.3578	-0.4478	-0.4584	- 0.5028	-0.8060	0.4169		
HIS	P	0.1190	-0.1765	-0.6003**	-0.0946	0.1346	-0.5084**	-0.0666	-0.4494**	-0.7057**	-0.5893**	-0.2858*	-0.7208**	-0.6201**	0.6727**	
	G	0.2935	-0.2296	-0.6800	-0.0839	0.2698	-0.7573	-0.1489	-0.5356	-0.8130	-0.6875	-0.3885	-0.8208	-0.7496	0.7393	
GY	P	0.0241	0.1962	0.5107**	0.0630	-0.1159	0.5910**	0.2332*	0.4332**	0.6074**	0.5088**	0.2962*	0.5528**	0.7631**	-0.4284**	-0.7214**
	G	-0.2488	0.2619	0.6685	0.0919	-0.1690	0.9428	0.1350	0.5785	0.7852	0.5856	0.3810	0.6693	0.8842	-0.4813	-0.8568

* * Significant at 1% level = 0.301

* Significant at 5% = 0.231

Table.3 Genotypic path coefficient analysis of thirteen characters on grain yield in bread wheat under timely sown condition

Characters	PH	TPP	FLA	DFF	CT	RWC	SL	GPS	SF	CHL	DM	TGW	HI
PH	**0.3679**	0.1885	-0.0805	0.0659	0.0666	0.0527	-0.0750	0.1479	0.0472	-0.2163	0.0152	0.0940	-0.0388
TPP	-0.5272	**-1.0290**	-0.5277	0.1493	0.0330	-0.3975	0.2605	-0.2365	-0.2552	-0.3950	-0.0586	-0.3357	-0.1824
FLA	-0.3064	0.7178	**1.3997**	-0.3949	-0.0523	0.6848	-0.3507	0.0077	0.3265	0.8304	0.0114	0.1802	0.8422
DFF	-0.3087	0.2503	0.4865	**-1.7243**	-0.2783	0.1508	0.2386	-0.1786	0.9328	0.0796	-1.4341	0.6299	0.3431
CT	0.1830	-0.0324	-0.0378	0.1632	**1.0115**	0.5970	-0.0201	0.1607	-0.0485	-0.0792	0.0434	-0.1493	0.2579
RWC	-0.0466	-0.1257	-0.1592	0.0285	-0.1921	**-0.3255**	0.0724	-0.1815	-0.2304	-0.0190	-0.0714	0.0198	-0.2373
SL	0.0150	0.0186	0.0184	0.0102	0.0015	0.0164	**-0.0735**	-0.0010	0.0095	0.0147	0.0191	-0.0040	-0.0056
GPS	-0.0350	-0.0200	-0.0005	-0.0090	-0.0138	-0.0485	-0.0012	**-0.0870**	-0.0435	-0.0229	-0.0213	-0.0193	-0.0180
SF	0.1496	0.2894	0.2722	-0.6313	-0.0560	0.8259	-0.1503	0.5840	**1.1670**	0.5001	-0.1704	0.5408	0.8780
CHL	0.0216	-0.0141	-0.0217	0.0017	0.0029	-0.0021	0.0073	-0.0096	-0.0157	**-0.0367**	-0.0096	-0.0065	-0.0261
DM	0.0847	0.1170	0.0167	1.7086	0.0881	0.4508	-0.5337	0.5039	-0.3000	0.5383	**2.0544**	-0.7047	-0.2876
TGW	-0.1656	-0.2115	-0.0835	0.2368	0.0957	0.0395	-0.0353	-0.1436	-0.3005	-0.1155	0.2224	**-0.6484**	-0.1621
HI	0.0248	-0.0417	-0.1417	0.0469	-0.0600	-0.1717	-0.0178	-0.0486	-0.1772	-0.1675	0.0330	-0.0589	**-0.2355**
GY	**0.1193**	**0.1936**	**0.5284**	**-0.2484**	**0.1884**	**0.9029**	**-0.0818**	**0.5694**	**0.6839**	**0.4730**	**0.0019**	**0.1812**	**0.8801**

Residual effect = 0.5240

Table.4 Genotypic path coefficient analysis of fifteen characters on grain yield in bread wheat under late sown condition

Characters	PH	TPP	FLA	DFF	CT	RWC	SL	GPS	SF	CHL	DM	TGW	HI	TSI	HIS
PH	**0.2507**	0.0396	-0.0697	0.0259	0.0171	-0.0980	-0.0957	0.0276	0.0082	0.0044	-0.1108	-0.0773	-0.0853	0.0665	0.0736
TPP	-0.0035	**-0.0220**	-0.0086	-0.0045	0.0004	-0.0043	-0.0058	-0.0064	-0.0083	-0.0066	-0.0031	-0.0054	-0.0070	0.0003	0.0051
FLA	0.0695	-0.0976	**-0.2499**	-0.0126	0.0930	-0.2179	-0.0229	-0.0930	-0.1565	-0.1527	-0.0218	-0.1206	-0.2094	0.0877	0.1699
DFF	-0.0092	-0.0180	-0.0045	**-0.0889**	-0.0185	-0.0008	0.0448	-0.0174	-0.0037	-0.0094	-0.0395	-0.0233	-0.0134	0.0250	0.0075
CT	0.0010	-0.0003	-0.0055	0.0031	**0.0147**	-0.0020	0.0016	-0.0018	-0.0060	-0.0070	-0.0032	-0.0028	-0.0032	0.0011	0.0040
RWC	-0.0580	0.0286	0.1293	0.0013	-0.0206	**0.1483**	-0.0089	0.0860	0.0876	0.0847	0.0915	0.0872	0.1482	-0.0753	-0.1123
SL	0.0137	-0.0096	-0.0033	0.0181	-0.0038	0.0022	**-0.0360**	0.0005	-0.0049	-0.0063	0.0021	-0.0064	-0.0096	0.0004	0.0054
GPS	-0.0026	-0.0069	-0.0089	-0.0047	0.0030	-0.0138	0.0003	**-0.0239**	-0.0128	-0.0129	-0.0037	-0.0120	-0.0131	0.0085	0.0128
SF	-0.0033	-0.0383	-0.0635	-0.0042	0.0414	-0.0599	-0.0137	-0.0546	**-0.1015**	-0.0665	-0.0214	-0.0668	-0.0731	0.0454	0.0825
CHL	-0.0043	-0.0725	-0.1478	-0.0255	0.1148	-0.1382	-0.0421	-0.1310	-0.1584	**-0.2419**	-0.0967	-0.1646	-0.1510	0.1109	0.1663
DM	-0.0766	0.0245	0.0151	0.0770	-0.0378	0.1070	-0.0102	0.0271	0.0366	0.0693	**0.1734**	0.0861	0.0507	-0.0872	-0.0674
TGW	-0.0310	0.0247	0.0485	0.0263	-0.0188	0.0591	0.0178	0.0504	0.0661	0.0684	0.0499	**0.1005**	0.0649	-0.0810	-0.0825
HI	-0.2323	0.2177	0.5716	0.1026	-0.1487	0.6816	0.1817	0.3754	0.4916	0.4257	0.1995	0.4404	**0.6822**	-0.2844	-0.5114
TSI	0.0888	-0.0050	-0.1175	-0.0940	0.0260	-0.1700	-0.0036	-0.1197	-0.1498	-0.1534	-0.1683	-0.2697	-0.1395	**0.3346**	0.2474
HSI	-0.2517	0.1969	0.5832	0.0719	-0.2314	0.6495	0.1277	0.4593	0.6972	0.5896	0.3332	0.7039	0.6429	-0.6340	**-0.8576**
GY	**-0.2488**	**0.2619**	**0.6685**	**0.0919**	**-0.1690**	**0.9428**	**0.1350**	**0.5785**	**0.7852**	**0.5856**	**0.3810**	**0.6693**	**0.8842**	**-0.4813**	**-0.8568**

Residual effect = 0.1894

Under timely sown condition days to maturity and flag leaf area had high and positive direct effect, whereas total number of tillers per plant, days to fifty per cent flowering had high and negative direct effect on grain yield at genotypic level. However, spike fertility showed moderate and positive direct effect at both genotypic and phenotypic level; and number of grain per spike and relative water content and harvest index showed moderate and positive direct effect on grain yield at phenotypic level. Therefore, number of grains per spike, relative water content, spike fertility should give due weightage to increase the grain yield in bread wheat, since correlation coefficient of these traits were also high and in same direction as of direct effect with grain yield indicating their true relationship with grain yield. However, canopy temperature may also be used for screening genotypes in timely sown condition as its negative direct effect towards grain yield. These findings were in accordance of Singh (1983), Sharma and Singh (1991), Ibrahim (1994) observed direct effect of number of grains per spike on grain yield, Singh *et al.*, (2003) recorded positive direct effect of number of grains per spike on grain yield, Kumar *et al.*, (2005) reported positive direct effect of harvest index and days to maturity on grain yield, Bhutta (2006) observed positive direct effect of flag leaf area on grain yield, Sen *et al.*, (2007) reported positive direct effect of days to maturity and number of grains per spike on grain yield, Ali *et al.*, (2008) observed positive direct effect of number of grains per spike on grain yield. Hence, from above discussion it could be concluded that selection based on these traits like total number of tillers per plant, harvest index, spike length, relative water content, chlorophyll content would be effective and reliable, since they had positive correlation with grain yield, positive inter correlation among themselves and positive indirect effect of most of the characters via these traits on grain yield. Canopy temperature had high negative association with grain yield per plant due to its negative indirect effect with most of the character on grain yield, suggesting importance of this trait during selection of breeding programme for improvement of bread wheat genotypes.

Harvest index recorded positive association with grain yield (0.8842) under late sown condition (Table 4), although it showed high positive direct effect on grain yield (0.6822). The positive correlation was build-up by the contribution of its indirect effect via days to maturity (0.0507), thousand grain weight (0.0649), heat susceptibility index (0.6429), and relative water content (0.1482) on grain yield per plant. Whereas indirect effect of harvest index via remaining character was negligible on grain yield. High positive direct effect at genotypic level was exhibited by the characters harvest index, thousand grain susceptibility index, plant height whereas moderate positive direct effect was recorded by days to maturity, relative water content, thousand grain weight. At phenotypic level harvest index showed highest positive direct effect on grain yield per plant, whereas days to maturity, spike length, thousand grain susceptibility index and plant height depicted moderate positive direct effect Rangare *et al.*, (2010) reported positive direct effect of plant height, thousand grain weight, days to maturity on grain yield per plant, Mohammadi *et al.*, (2012) reported positive direct effect of plant height on grain yield, Sharma and Singh (1991) reported positive direct effect of harvest index on grain yield. These results were in accordance of Sarkar (2002) who found high positive direct effect of harvest index on grain yield. Kumar *et al.,* (2005) found positive direct effect of days to maturity, harvest index, thousand grain weight, and plant height on grain yield. Sen *et al.*, (2009) reported positive direct effect of thousand grain weight, number of grains per spike, and days to maturity on grain yield per plant. Therefore, it implicated from above discussion that the traits like harvest index and days to maturity have to be given importance in selection process for improvement in yield, since they had positive correlation with grain yield, positive inter correlation among themselves, high direct effect towards grain yield and also all other characters contributed indirectly towards grain yield via these characters. Hence, selection based on these characters would be more effective for yield improvement in bread wheat under terminal heat stress condition.

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