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Association analysis among morphological and physiological traits of grain yield in wheat and meteorological parameters

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ABSTRACT

In order to identify potential traits determining yield under terminal heat stress during grain filling stages, correlation and path coefficients analyses were conducted to study character associations among 25 morphological and physiological traits in a set of genetically divergent 36 bread wheat genotypes under normal and late sown conditions. Grain yield depicted positive association with grain weight (GW), grains/spike (G/S), biological yield (BY), harvest index (HI) under normal (NS) and late sown (LS) conditions, GGR-3 (grain growth rate at 28 days after anthesis) in LS and negative association with DM (days to maturity) , HU (heat units) and PTU (photothermal unit) in NS and with ChA-1(CHB "a" at anthesis), CHB "a"-1 (total CHB at anthesis) and CHB "a"-2 (total CHB at 28 days after anthesis) in LS. Path coefficient analysis revealed that out of eight characters significantly related to yield under normal sown conditions, PTU, harvest index, biological yield and grains per spike directly affected the grain yield in positive direction. On the basis of strong association with yield and marked direct influence on yield, the numbers of grains are considered to be first order yield components and ought to have top priority in selection under normal sown conditions. Under late sown conditions BY, harvest index (HI), CHB "a"-1 and grain weight had direct positive effect but the grains per spike exhibited negative direct effect despite of the fact that it possessed a positive significant correlation with grain yield. Based on results, it is suggested that high numbers of grains and high grain weight should be given priority for selection of high yielding genotypes in NS and LS, respectively.

Key words : Wheat, correlation, path coefficient, character association selection criteria, stay green, chlorophyll, grain yield,

Wheat is one of the most important cereal crops of the world. Due to its wide adaptability it can be grown under various agro climatic conditions. The high yielding semi dwarf wheat varieties from CIMMYT brought about a significant increase in wheat production in India and elsewhere in the world. But most of these high yielding varieties are susceptible to high temperature.

The present day rice-wheat and cotton-wheat cropping systems sometimes coupled with untimely rains, pushes the wheat sowing in late December. It coincides with high temperature at grain filling period and adversely affects the grain development, reduces the grain weight and ultimately grain yield. The effects of environmental factors in general and, temperature and photoperiod components in particular are genotypic specific. Thus, genotypes with differential photothermo response are influenced by temperature and photoperiod at different growth stages, i.e. vegetative, spike development and stem elongation phase (Kirby and Appelyard, 1981).

In most of the studies dealing with temperature response, days to ear emergence or anthesis has been regarded as key diagnostic character as it represents liaison between vegetative and reproductive stages. Different wheat genotypes interact differently with prevailing temperatures. This forms the basis for difference in expression of potential traits contributing to high temperature stress tolerance in wheat genotypes. Grain yield is a complex trait made up of sequentially interwoven characters. The relationships among various yield attributing traits change over different environments in terms of magnitude and direction (Kumar *et. al.,* 1986, Paul and Ganguli, 1996). This necessitates identification of environment specific potential target traits to affect crop improvement during selection phases.

Table 1: Meteorological indices for different treatments on the basis of mean of 36 varieties

Phenophases	Sowing Environment	Mean HU (°C day)	HU Range (°C day)	Mean PTU (°C day hrs)	PTU Range (°C day hrs)
50% Flowering (DF)	Normal	726.6	631.3-1146.7	7704.2	6633.3-12670.8
	Late	697.0	583.7-1605.1	7973.0	6613.4-19605.3
50% Anthesis (DA)	Normal	777.4	694.1-1183.6	8274.8	7339.2-13114.2
	Late	752.5	615.4-1466.6	8639.0	6993.8-17778.6
50% Flag Leaf senescence (DFLS)	Normal	1014.8	874.8-1589.6	11088.6	9408.0-18273.3
	Late	1135.7	921.9-1929.7	13504.7	10742.9-23962.7
50% Maturity (DM)	Normal	1146.7	931.8-1659.3	12670.8	10092.6-19173.6
	Late	1206.4	973.8-2046.2	14417.4	11412.7-255526.6
Grain growth rate at 14 days after	Normal	946.6	867.5-1444.8	10270.2	9321.0-16403.4
anthesis (GGR-1)	Late	1013.7	863.6-1784.2	11928.1	9989.1-22010.2
Grain growth rate at 21 days after	Normal	1046.5	931.8-1615.1	11469.0	10092.6-18603.3
anthesis (GGR-2)	Late	1184.0	992.5-1988.2	14128.0	11654.2-24748.0
Grain growth rate at 28 days after	Normal	1165.1	1031.7-1772.7	12892.2	11290.8-20638.5
anthesis (GGR-3)	Late	1341.5	1158.4-2163.0	16163.2	13798.0-27094.5

Keeping these facts in mind, the present study was conducted to know the association among various meteorological, morphological and physiological attributes of grain yield as well as their direct and indirect effects on grain yield to identify potential traits for selection of improved genotypes for normal as well as late sown conditions.

MATERIALS AND METHODS

The material for present investigation consisted of 36 genotypes of wheat differing in yield potential and levels of thermo tolerance. All the genotypes were grown in randomized block design with three replications under two different dates of sowing *viz.,* 23rd Nov. 2004 (normal sown) and 10th Jan 2005 (late sown). Each plot consisted of single row of two meter length spaced with row to row distance of 30 cm and plant to plant distance of 10 cm in each replication. Observations were recorded on 5 randomly selected competitive plants for 25 morpho-physiological traits related to adaptation and yield *viz.,* days to 50% flowering (DF), days to 50% anthesis (DA), days to 50 % maturity (DM), days to 50% flag leaf senescence (DFLS), spike length (SL), peduncle length (PL), plant height (PH) , number of spikelets per spike (S/S), thousand grain weight (GW), number of grains per spike (G/S), leaf area (LA), biological yield (BY), grain yield (GY), harvest index (HI), CHB "a" at anthesis : (CHA-1), CHB 'b' at anthesis (CHB-1), CHB 'a' at 28 DAA (CHA-2), CHB 'b' at 28 DAA (CHB-2), total CHB at anthesis (CHB "a"-1), total CHB at 28 DAA (CHB "a"-2), grain growth rate at 14 days after anthesis (GGR-1), grain growth rate at 21 days after anthesis (GGR-2) and grain growth rate at 28 days after anthesis (GGR-3). The meteorological data were used for computing heat units (HU) (Bauer *et al*., 1984) and photothermal unit (PTU) (Angus *et al*., 1981) for each genotype under normal and late sown environments taking 5^{0}C as base temperature of for wheat (Bishnoi *et al*., 1995).

Using variance covariance matrix obtained from mean data, correlation coefficients at phenotypic as well as genotypic levels were calculated according to Al-Jibouri *et. al.,*(1958). Characters showing significant correlations at genotypic level were used to work out Path Coefficient analysis according to Dewey and Lu (1959).

RESULTS AND DISCUSSION

Heat units (HU) and photothermal unit (PTU)

It is apparent from the Table 1 that for the phenophses days to 50% flowering, days to 50% anthesis and days to 50% flag leaf senescence the mean was high

Table 2: Correlation co-efficient among different characters under normal and late sown conditions

CH	TOC	Environment	
		Normal sown	Late sown
DF	**+ve**	DA,DM,DFLS,CHA-1,CHA-2,CHB "a"-1,CHB "a"-2,HU&PTU	DA,DM,DFLS,CHB-1,CHA-2, HU&PTU
	-ve	PL,G/S,BY,GY,GGR-1,GGR-2 &GGR-3	DM,PL,G/S, GGR-1,GGR-2 &GGR-3
DA	**+ve**	DM,DF,DFLS,CHA-1,CHA-2,CHB "a"-1,CHB "a"-2,HU&PTU	DF,DM,DFLS,CHB-1,CHA-2,HU&PTU
	-ve	PL,SL,GW,G/S,BY,GGR-1,GGR-2 &GGR-3	G/S, GGR-1,GGR-2 &GGR-3
DM	**+ve**	DFLS,CHA-1,CHA-2,CHB "a"-1,CHB "a"-2,HU&PTU,DF,DA	DF,DA,DFLS,CHA-1.CHA-2,HU & PTU
	-ve	PL,G/S,BY,GY,GGR-1,GGR-2 &GGR-3	GW,G/S,BY, GGR-1,GGR-2 &GGR-3
DFLS	**+ve**	CHA-1,CHA-2,CHB "a"-1,CHB "a"-2,HU ,PTU,DF,DA,DM	DF,DA,DM,CHA-2,HU & PTU
	-ve	PL,SL,GW,G/S,BY, GGR-1,GGR-2 &GGR-3	G/S, GGR-1,GGR-2 &GGR-3
PL	**+ve**	PH,GGR-1	PH,GGR-1 &GGR-2
	-ve	DF,DA,DM,DFLS,CHA-1,CHB-1, CHB "a"-1,HU& PTU	DF,DA,G/S,HU & PTU
SL	**+ve**	S/S	S/S
	-ve	DA,DM,DFLS	-
S/S	**+ve**	SL	SL
	-ve	CHA-2	-
GW	**+ve**	G/S,LA,BY & GY	LA,BY,GY &GGR-1,GGR-2 & GGR-3
	-ve	DA,DM,DFLS,CHA-1,CHB "a"-1,HU & PTU	DM,CHA-1,CHB-1,CHA-2,CHB-2,CHB "a"-1,CHB "a"-2
G/S	**+ve**	GW,LA,BY,GY&GGR-2	LA,BY,GY
	-ve	DF,DA,DM,DFLS,CHA-2,CHB "a"-2,HU & PTU	DF,DA,DM,DFLS, PL,PH,HU& PTU
LA	**+ve**	GW,G/S	GW,G/S,GGR-1,GGR-2 & GGR-3
	-ve	CHA-1,CHB "a"-1,	DFLS
BY	**+ve**	GW,G/S,GY	GW,G/S,GY, GGR-1,GGR-2 & GGR-3
	-ve	DF,DA,DM,DFLS,CHA-1,CHA-2,CHB "a"-1,HU & PTU	DM,CHA-1,CHB "a"-1
GY	**+ve**	GW,G/S,BY,HI	GW,G/S,BY,HI& GGR-3
	-ve	DF,DA,DM,DFLS,HU&PTU	CHA-1,CHB "a"-1
HI	**+ve**	GY	GY
PH	**+ve**	PL,HU& PTU PL,GGR-1,GGR-2 & GGR-3	
	-ve	-	G/S,CHA-1,CHA-2
ChA-1	**+ve**	DF,DA,DM,DFLS,HU & PTU DM,HU	
	-ve	PL,GW,LA,BY,GGR-2	GW,BY,GY,GGR-1,GGR-2 & GGR-3
CHB-1	**+ve**	CHA-1 DF,DA,HUCHA-1	
	-ve	PL	GW,PH,GGR-1,GGR-2 & GGR-3
ChA-2	**+ve**	DF,DA,DM,DFLS,HU& PTU	DF,DA,DM,DFLS ,CHA-1,CHB-1,HU&PTU
	-ve	SL,G/S,BY,GGR-1,GGR-2 & GGR-3	GW,PH,GGR-1,GGR-2 & GGR-3

CHB-2	+ve	DM,CHA-2,CHB “a”-2	CHA-1,CHB-1,CHA-2, CHB “a”-1, CHB “a”-2
	-ve	CHB-1,GGR-2 & GGR-3	GW
CHB “a”-1	+ve	DF,DA,DM,DFLS,CHA-1, CHB-1HU & PTU	HU,CHA-1,CHB-1,CHA-2,CHB-2
	-ve	PL,GW,BY,GGR-2	GW,BY,GY,GGR-1 & GGR-3
CHB “a”-2	+ve	DF,DA,DM,DFLS ,CHA-2, CHB-2,HU,PTU	HU CHA-1,CHB-1,CHA-2,CHB-2,CHB “a”-1
	-ve	SL,G/S,GGR-1,GGR-2,GGR-3	GW,PH,GGR-1,GGR-2, GGR-3
HU	+ve	PTU, DF,DA,DM,DFLS,CHA-1,CHA-2, CHB “a”-1,CHB “a”-2	PTU,CHA-1,CHB-1,CHA-2,CHB “a”-1,CHB “a”-2 ,DF,DA,DM,DFLS
	-ve	PL,GW,G/S,BY,GY,GGR-1,GGR-2,GGR-3	PL,G/S,GGR-1,GGR-2, GGR-3
PTU	+ve	DF,DA,DM,DFLS,CHA-1, CHA-2,CHB “a”-1,CHB “a”-2,HU	DF,DA,DM,DFLS,CHA-2,HU
	-ve	PL,GW,G/S,BY,GY GGR-1,GGR-2,GGR-3	PL,G/S.GGR-1,GGR-2, GGR-3
GGR-1	+ve	PL,SL,S/S,GGR-2,GGR-3	PL,GW,LA,BY,PH,GGR-2,GGR-3
	-ve	DF,DA,DM,DFLS,CHA-2, CHB “a”-2,HU,PTU	CHA-1,CHB-1,CHA-2,CHB “a”-1, CHB “a”2, HU, PTU, DF, DA, DM, DFLS
GGR-2	+ve	G/S,GGR-1,GGR-3	PL,GW,LA,BY,PH,GGR-1,GGR-3
	-ve	DF,DA,DM,DFLS,CHA-1,CHA-2,CHB-2,CHB “a”-1,CHB “a”-2,HU,PTU	DF,DA,DM,DFLS,CHB-1,CHA-2,CHB “a”-2,HU,PTU
GGR-3	+ve	GGR-1,GGR-2	GW,LA,BY,GY,PH,GGR-1,GGR-2
	-ve	DF,DA,DM,DFLS,CHA-2, CHB-2,CHB “a”-2,HU,PTU	DF,DA,DM,DFLS,CHA-1,CHB-1,CHA-2, CHB “a”-1,CHB “a”-2,HU,PTU

in normal sown environment whereas the range was higher in late sown environments for heat units (HU). On the other hand mean was low in normal sown environment and range was high in late sown environment for PTU. For 50% days to maturity, GGR1,GGR2 and GGR3 mean for HU and PTU was low in normal sown environment and range was high in late sown environment. This trend is basically conditioned by the HU and PTU requirements of delayed chlorophyll senescence of two stay green genotypes WH147M and MLU2. In normal sown environments most of the genotypes have access to longer photoperiods and due to higher temperature coinciding early plant growth stages the HU is lower in normal sown environment whereas PTU is higher in late sown environment as the temperature shoots up during late Feb and early March.

Correlation coefficients

Correlation coefficients were computed between all possible 300(nxn-1/2) combinations (excluding reciprocals) among 25 morpho physiological traits (data not given for brevity, Table 2). In normal sown conditions, 136 character combinations revealed significant correlations. Among significant correlation coefficients the lowest magnitude was observed between DM and GW (-3.09) followed by between DM and GY (-0.305) and between BY and CHB “a”-1 (-0.30). Likewise, the highest magnitude of correlation coefficient was observed between CHA-1 and CHB “a”-1 (0 .991) followed by between PTU and HU (0.984) and between DFLS and DM (0.983). Under late sown conditions, only 124 character combinations depicted significant correlations. The lowest magnitude of correlation coefficients was observed between GY and CHB “a”-2 (-0.303) followed by between PH and G/S (-0.315). The highest magnitude of correlation coefficient was found between CHA-1 and CHB “a”-1 (0.995) followed by between GGR-1 and GGR-2 (0.987), GGR-1 and GGR-3 (0.971) and GGR-2 and GGR-3(0.971). By and large the direction of significant correlation coefficients remained unchanged over NS and LS conditions. However, magnitude of correlation coefficients changed in several cases making some correlation coefficients non significant to significant ones under late sown conditions as compared to normal sown conditions and vice versa. Maximum frequency of such magnitude changes leading to changes in significance levels of correlation coefficients existed between various character combinations with all the three grain growth stages (GGR-1, GGR-2 and GGR-3). This change might be due to genotypic differences and/or genotype x environment interactions.

An objective analysis of correlation coefficients revealed (Table 2) that the four phenological traits; DF, DA, DM and DFLS exhibited significant positive association with each other in both the environments. These traits in general showed significant positive association with various CHB content at different stages and agro-meteorological parameters like HU and PTU and negative significant association with one or more grain yield components (G/S or GW) at all the grain growth stages (GGR1, GGR-2,GGR-3). Likewise, GGR-1, GGR-2 and GGR-3 were significantly and positively correlated with each other. This indicated that phenological stages were more or less similar and grain growth continued in most of the genotypes, though with magnitude differences, over all the three growth stages under normal and late sown conditions.

Plant canopy determining traits like plant height and peduncle length were positively and significantly correlated with each other and they also exhibited positively significant association with one or more grain growth stages under normal and late sown conditions. However, PL exhibited negative correlation with phenological, CHB and meteorological traits in NS and LS whereas PH exhibited positive association with HU and PTU in NS and G/S and CHA-1 and CHA-2 in LS. Leaf area expressed significant, positive correlation with GW and G/S in NS and LS and also with GGR-1, GGR-2 and GGR-3 in LS. Spike length and spikelets per spike were positively and significantly associated with each other. SL exhibited negative association with DA, DM, DFLS whereas S/S with CHA-2 in NS. Component traits like GW and S/S were positively associated with each other. They also exhibited positive association with LA, BY and GY and negative association with phenological, CHB and meteorological traits in NS and LS. GW exhibited positive association with all the three GGR stages in LS.

Grain yield was positively associated with BY and HI, GW and G/S in NS and LS. Also, BY was positively correlated with GGR-1, GGR-2 and GGR-3 in LS, whereas, GY was correlated with GGR-3 only. Both BY and GY showed negative association with phenological, meteorological and CHB traits in normal and/or late sown conditions.

CHB related traits CHA-1, CHB-1 CHB-2 CHB “a”-1 CHB “a”-2 in general expressed positive association with phenological and meteorological traits in NS and LS and negative association with one or more grain yield components like GW, BY and GGR at different stages. Also, PTU and HU were positively associated with each other and they in turn depicted positive association with phenological parameters and CHB traits and negative association with PL, GW, G/S and GGR-1, GGR-2 and GGR-3 in normal and late sown conditions.

Character associations among different phenological characters thus revealed that increased days to flowering ; anthesis; maturity or days to flag leaf senescence led to a decrease in number of grains per spike, thousand grain weight, grain yield, biological yield and GGR under normal sown condition. With the increased days to flag leaf senescence (WH147 M and MLU-2), were having a comparatively higher yield under late sown condition. Number of grains per ear is decided at GS1 stage of the plant growth (Kirby and Appleyard, 1981). Under late sown condition, duration for GS1 stage is quite less than that under normal sown resulting in to decreased number of grains per spike. However, in stay green genotypes like WH147M and MLU2, number of days to flowering is considerably more than other late sown cultivars, due to which they get ample duration for GS1 stage and hence, they do not bear a loss in number of grains per ear under late sown condition as compared to the normal sown. A significant positive correlation was observed between grain weight and leaf area under normal as well as late sown conditions. This was because the larger surface area for photosynthesis led to more reserves in the sink-resulting in higher grain weight. It was interesting to note that leaf area exhibited a significant positive correlation with GGR under late sown but not under the normal sown condition. Though leaf area is an important parameter to decide various important functions leading to higher yields including higher photosynthetic rates by receiving more sunlight but the comparative importance of leaf area is more in late sown as compared to the normal sown.

Path coefficients

Direct effects **:** A critical perusal of path coefficient analysis exhibited under normal sown conditions (Table 3) high direct and positive effect of PTU (3.981), harvest index (0.8962), biological yield (0.7982) and days to maturity (0.2659) on grain yield while heat units (-3.991) had highest negative direct effect. In late sown condition (Table 3), biological yield (0.7754), harvest index (0.674), CHB ‘a’ at anthesis (0.4464) exhibited high direct and positive effects, while total CHB at 28 DAA (-0.4074) and grains per spike (-0.0326) had highest negative direct effects on grain yield.

Indirect effects**:** Under normal sown condition (Table 3), HU (0.1951), PTU (0.1884), days to flowering (0.1846) had high positive indirect effect while biological yield

Table 3: Direct (diagonal), indirect effects (off diagonal) and genotypic correlations of different characters with grain yield under normal sown condition

Characters	DF	DM	GW	G/S	BY	HI	HU	PTU	'r'
DF	**0.0066**	0.0046	-0.0019	-0.0034	-0.0031	-0.0002	0.0062	0.0062	-0.322
DM	0.1846	**0.2659**	-0.0856	-0.1335	-0.1407	0.0038	0.1951	0.1884	-0.305
GW	-0.0007	-0.0008	**0.0023**	0.001	0.0009	0.0007	-0.0008	-0.0008	0.427
G/S	-0.0628	-0.0604	0.0503	**0.1202**	0.0562	0.0202	-0.0662	-0.0697	0.391
BY	-0.3787	-0.4223	0.3216	0.3731	**0.7982**	0.0261	-0.3843	-0.3967	0.677
HI	-0.0336	0.0127	0.2493	0.1506	0.0293	**0.8962**	-0.0817	-0.1285	0.726
HU	-3.7583	-2.9286	1.3411	2.1963	1.9215	0.364	**-3.991**	-3.9746	-0.348
PTU	3.7146	2.8204	-1.4287	-2.3094	-1.9787	-0.5709	3.9646	**3.981**	-0.377
GY	-0.3283	-0.3083	0.4485	0.3948	0.6837	0.7397	-0.358	-0.3949	-
Partial R^2	-0.0022	-0.082	0.001	0.0475	0.5457	0.663	1.4289	-1.5721	-

Residual effect = 0.0905

Table 4: Direct (diagonal), indirect effects (off diagonal) and genotypic correlations of different characters with grain yield under late sown condition

Characters	GW	G/S	BY	HI	CHA-1	CHB "a"-1	CHB "a"-2	GGR-3	'r'
GW	**0.0292**	0.007	0.0121	0.0053	-0.0114	-0.0121	-0.0138	-0.6488	0.431
G/S	-0.0078	**-0.0326**	-0.013	-0.0003	0.0042	0.0042	0.0011	-1.6521	0.315
BY	0.3212	0.3105	**0.7754**	-0.0747	-0.2988	-0.2953	-0.2307	30.1348	0.714
HI	0.122	0.0068	-0.0649	**0.674**	-0.0081	-0.0309	-0.0769	-17.7495	0.583
CHA-1	-0.174	-0.057	-0.172	-0.0054	**0.4464**	0.4444	0.3909	-13.6014	-0.301
CHB "a"-1	0.1687	0.0524	0.1551	0.0187	-0.4056	**-0.4074**	-0.3635	10.0371	-0.32
CHB "a"-2	0.0045	0.0003	0.0029	0.0011	-0.0084	-0.0086	**-0.0096**	0.1323	-0.303
GGR-3	-0.0153	0.0349	0.0267	-0.0181	-0.021	-0.0169	-0.0095	**0.0007**	0.326
GY	0.4485	0.3223	0.7222	0.6006	-0.3026	-0.3225	-0.312	6.653	-
Partial R^2	0.0131	-0.0105	0.56	0.4048	-0.1351	0.1314	0.003	0.0046	-

Residual effect = 0.1695

(-0.1407) and grains per spike (-0.1335) had high negative direct effect *via* days to maturity on grain yield. Grains per spike (0.371) and 1000-grain weight (0.3216) and high positive indirect effect whereas, days to maturity (-0.4223), PTU (-0.3907), heat units (-0.3843), days to flowering (-0.3787) had high negative indirect effect on grain yield via biological yield. High positive indirect effect on grain yield was observed in grains per spike (2.1963), biological yield (1.9215), 1000-grain weight (1.3411) and harvest index (0.364), while PTU (-3.9740), days to flowering (-3.7583) and days to maturity (-2.9286) had high negative indirect effect via heat units. High positive indirect effect of heat units (3.9646), days to flowering (3.7146) and days to maturity (2.8204),t on grain yield via PTU was recorded, whereas, grain per spike (-2.3094) biological yield (-1.9787) 1000-grain weight (-1.4287) and harvest index (-0.5709) had high negative indirect effects.. Grains per spike (0.1506) and 1000-grain weight (0.2493) had high positive indirect effects while PTU (-0.1285) had high negative indirect effect on grain yield via harvest index.

Under late sown (Table 4) conditions high negative indirect effect was observed in GGR -3 (-1.6521) on grain yield via grains per spike. High positive indirect effect on grain yield was recorded in GGR-3 (30.1348), 1000-grain weight (0.3212), grain per spike (0.3105) via BY, .while such indirect effects were negative in CHA-1 (-0.2988) CHB "a" -1 (-0.2953) and CHB "a"-2. Likewise, 1000-grain weight (0.122) had higher positive indirect effect on grain yield via

HI whereas such effects for GGR-3 (-17.7495) were high and negative. Total CHB at anthesis (0.444), total CHB at 28 DAA (0.3909) had high positive indirect effect while GGR3 (-13.604) and 1000-grain weight (-0.174) had high negative indirect effect on grain yield via CHB 'a' at anthesis. GGR-3 (10.0371), 1000-grain weight (0.1687) and biological yield (0.1551) contributed high positive indirect effect whereas CHB 'a' at anthesis (-0.4056) and total CHB at 28 DAA (-0.3635) contributed high negative indirect effect on grain yield via total CHB at anthesis.

Path coefficient analysis provides additional information about cause and effect relationship and the relative contribution of important characters toward grain yield. Under normal sown condition (Table 3), PTU, harvest index, biological yield and grains per spike directly affected the grain yield in positive direction. Both GW and G/S had high positive indirect effects on GY via HI and BY though their individual indirect effects on GY via each other were low.

Under late sown condition (Table 4), biological yield, harvest index, CHB, 'a' at anthesis and grain weight had direct positive effect but the grains per spike exhibited negative direct effect despite the fact that it possessed a positive significant correlation with grain yield. Grain weight, Grains per spike and GGR-3 had high indirect positive effects on grain yield via BY while HI had positive indirect effect through GW but negative through GGR-3. Also, GGR-3 had high positive indirect effect on yield though CHB "a"-1.

Being photo-thermo insensitive the stay green genotypes WH147M and MLU2 take longer days to flowering and subsequent phenophases both in normal and late sown condition. In both these genotypes photosynthesis also continues till late in April due to delayed chlorophyll senescence (Ahlawat *et al,* 2007). Thus these genotypes are of great interest to plant breeders to incorporate partial green trait for longer phtosynthetically active period for higher grain yield and to agro-meteorologist to draw relationship between photosynthetically active radiation (PAR) and grain yield under terminal heat stress to which the stay green genotypes coincide during grain growth phases.

CONCLUSIONS

On the basis of correlation coefficients, marked direct and indirect influence on yield under normal and late sown conditions observed in present studies and published experimental evidences, it appeared that the higher numbers of grains while maintaining medium to high grain weight and medium maturity could be considered to have top priority for selection of high yielding genotypes for normal sown conditions. Likewise, under late sown conditions, the high grain weight while maintaining high BY, GGR, CHB "a"-1, LA and medium to high grain number/ear should assume priority in selection of high yielding genotypes.

REFERENCES

Ahlawat,S., Chhabra,A.K and Behl, R.K(2007). Delayed leaf senescence, metereological parameters, morphological traits and their association with grain yield in wheat. In: Crop Production in Stress Environments: Genetic and Management Options, Eds. D.P.Singh, V.S.Tomar, R.K.Behl, S.D. Upadhyaya, M.S.Bhale and D.Khare. Agrobios(International) Publshers, Jodhpur, pp 176-181.

Al-Jibouri, H.A., Miller, P.A.,Robinson, H.P. (1958). Genotypic and phenotypic covariance in an upland cotton crosses of interspecific origin. *Agron. J.,* 50: 633-636.

Angus, J.F., Mackenzie, D.H., Morton, R. and Schafer, C.A. (1981). Phasic development in field crops. II. Thermal and photoperiodic responses of spring wheat. *Field Crops Res.,* 4: 269-283.

Bauer, A., Fanning, C., Enz, J.W. and Eberlein, C.V., 1984. Use of growing-degree days to determine spring wheat growth stages, *North Dakota Coop. Ext. Set. 14 AGR-*1, pp. 11.

Bishnoi, O.P., Singh, S. and Niwas, R.1995. Effect of temperature on phonological development of wheat. *Indian J. Agric. Sci*., 63: 211-214.

Dewey, O.P., Lu, K.H. (1959). A correlation and path coefficient analysis of crested wheat grass seed production. *Agron. J.*, 51: 515-518.

Kirby, E.J.M., Appelyard, M. (1981). *Cereal development guide*. Cereat Unit, NRC, Stoneleigh, England.

Kumar,D., Sharma,S.C.,Gupta, S.C. (1986). Correlation and Path studies in wheat under normal and saline conditions. *Wheat Inform Service,* 61/62:64-67.

Paul,A., Ganguli,D.K (1996). Association of grain yield and its component characters over environments in wheat. *J. Res. Birsa Agric. Univ.,* 82(2): 127-129.

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