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Relationship Between Some Morphological and Physiological Traits with Grain Yield in Bread Wheat (*Triticum aestivum* L.em.Thell.)

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ABSTRACT
The better way of exploiting genetic association with several traits having high heritability is to construct a selection index that combines information on all the characters which are having decisive role in influencing the yield. Therefore, an experiment consisting thirty wheat genotypes was grown in a randomized block design with three replications during Rabi 2007-08 to determine mutual relationship between various yield components in bread wheat. The mean performance of individual genotypes was employed for analysis of variance to test the significance for each character. The higher genotypic and phenotypic coefficients of variation were exhibited by harvest index, biological yield per plant, number of productive tillers per plant, test weight and grain yield per plant. The role of additive gene action was observed in the expression of the character like plant height, grain yield per plant, biological yield, harvest index and test weight. The correlation coefficient between grain yield per plant and other quantitative attributing to yield showed that grain yield was positively associated with plant height, spike length, number of grains per spike and test weight and biological yield. Path coefficient at genotypic level revealed biological yield had the highest direct positive effect on seed yield per plant followed by harvest index, days to maturity, test weight, spike length and number of productive tillers per plant, indicating these are the main contributors to yield.

Key words: Wheat, correlation, path association, genetic parameters, quantitative traits

INTRODUCTION
Wheat (*Triticum aestivum* L.) is considered as king of cereals as it provides foods to 36% of the global population contributing 20% of the food calories (CIMMYT, 2000). It is an important staple food of many countries in the world and occupies a unique position as it is used for the preparation of a wide range of food stuffs. The attainment of maximum crop yield is an important objective in most breeding programmes and the major emphasis in wheat breeding is on the development of improved varieties. Over the past century selection of desirable parents for hybridization programme has been found as an effective operating implement in developing high yielding crop varieties upon which the modern agriculture can rely. Efficient and economic crop improvement scheme refers to the collection of superior alleles into a single population. Many earlier researchers studied genotypic correlation coefficients of various yield components with grain yield for its genotypic improvement in wheat (Chowdhry *et al*., 2000; Shahid *et al*., 2002; Khaliq *et al*., 2004;

Burio *et al*., 2004; Aycecik and Yildirim, 2006; Akram *et al*., 2008; Anwar *et al*., 2009; Khan and Dar, 2010; Khokhar *et al*., 2010). Selection for grain yield improvement can only be effective if sufficient genetic variability is present in the genetic material (Ali *et al*., 2008). Genetic variability in a population can be partitioned into heritable and non heritable variation with the aid of genetic parameters such as variance, genotypic coefficient of variation, heritability and genetic advance which serve as a basis for selection of some outstanding genotypes from existing ones. Choice of parents is not only based on desirable agronomic traits, components of yield and extent of variability but also on heritability of yield contributing traits. The environment, in which selection is made, is also important because heritability and genetic advance vary with change in environment. Direct selection based on crop yields is often a paradox in breeding programmes because yield is influenced by its component traits (Mustafa and Elsheikh, 2007). Therefore, it is essential to have knowledge of interrelationship between existing genotypes among yield components. The availability of the above information greatly aids in the formulation of breeding scheme as well as in the choice of appropriate selection method. Keeping this view in mind an attempt was made in the present studies to estimate the extent of variability and character association for wheat improvement and to assess their suitability in a breeding plan.

MATERIALS AND METHODS

Experimental design: The experimental material consisting thirty diverse wheat genotypes (Table 1) was grown in a randomized block design with three replications during Rabi 2007-08 at the Field experimentation centre of Department of Genetics and Plant Breeding, Allahabad Agricultural Institute-Deemed University, Allahabad. This experimental site is situated at 25.87°N latitude and 81.5°E latitude and 98 m above the sea level. Each genotype was grown in a single row plot of 2.5 m length with 25 cm with an approximate plant to plant distance of 5 cm in each replication and recommended package of practices were followed to raise the crop. First irrigation was applied the crop after 35 days and subsequent irrigations were applied at the start of flowering, anthesis and filling stages. At maturity the observations were recorded on various quantitative characters viz., days to 50% flowering, days to maturity, plant height (cm), spike length (cm), number of productive tillers per plant, number of grains per spike, biological yield per plant (g),

Table 1: List of genotypes and their source used in present investigation

Name of genotypes	Source	Name of genotypes	Source
RAJ-1972	RAU, Rajasthan	RAJ-3779	RAU, Rajasthan
HD-2236	IARI, New Delhi	HD-2687	IARI, New Delhi
RAJ-1482	RAU, Rajasthan	HD-1982	IARI, New Delhi
VEERI	CIMMYT, Mexico	RAJ-4037	RAU, Rajasthan
HD-2501	IARI, New Delhi	K-9423	CSA, Kanpur
PBW-524	PAU, Punjab	HD-2789	IARI, New Delhi
HD-2385	IARI, New Delhi	HUW-12	BHU, Varansi
HD-2881	IARI, New Delhi	HUW-468	BHU, Varansi
RAJ-6560	RAU, Rajasthan	HD-2428	IARI, New Delhi
UP-2594	G.B. Pantnagar	HD-2009	IARI, New Delhi
HUW-510	BHU, Varansi	RAJ-3077	RAU, Rajasthan
SONALIKA	IARI, New Delhi	HUW 533	BHU, Varansi
HUW-318	BHU, Varansi	HUW-234	BHU, Varansi
PBW-373	PAU, Punjab	K-8962	CSA, Kanpur
KALYANSONA	PAU/IARI	K-8020	CSA, Kanpur

harvest index (g), test weight (g) and grain yield per plant (g). The observations were recorded on ten randomly selected competitive plants in each entry of each replication for all the characters except for days to 50% flowering and days to maturity which were recorded on plot basis. Further, the value of harvest index was calculated as per the formula given by Donald and Humblin (1976).

Statistical analysis: The mean performance of individual genotypes was employed for statistical analysis. Analysis of variance to test the significance for each character was carried out as per methodology advocated by Panse and Sukhatme (1967). PCV and GCV were calculated by the formula given by Burton (1952), heritability in broad sense (h^2) by Burton and de Vane (1953) and genetic advance i.e., the expected genetic gain were calculated by using the procedure given by Johnson *et al.* (1955). Correlation coefficient and path coefficient was worked out as method suggested by Al-Jibouri *et al.* (1958) and Dewey and Lu (1959), respectively.

RESULTS AND DISCUSSION

The analysis of variance (Table 2) revealed that the sum of square due to treatments was highest in biological yield followed by harvest index, plant height and days to 50% flowering while spike length has lowest estimate. This suggested that the genotypes selected were genetically variable and considerable amount of variability existed among them. Thus, indicates ample scope for selection for different quantitative characters for wheat improvement. Bergale *et al.* (2001), Dwivedi *et al.* (2002) and Asif *et al.* (2004) also reported considerable genetic variability for grain yield and its component characters in wheat.

The development of an effective plant breeding programme depends on the existence of genetic variability. Wide range of Phenotypic (VP) and Genotypic Variance (VG) were observed in the experimental material for all the traits studied (Table 3). The higher phenotypic and genotypic variances were recorded for biological yield followed by harvest index, plant height and days to 50% flowering while moderate values were observed for days to maturity and grain yield per plant. However, number of productive tillers per plant and spike length showed low estimate. Less difference in the estimates of genotypic and phenotypic variance and higher genotypic values compared to environmental variances for all the characters suggested that the variability present among the genotypes were mainly due to genetic reason with minimum influence of environment

Table 2: Analysis of variance for different quantitative characters in wheat

	Source of variation		
Characters	Replications (d.f = 02)	Treatments (d.f = 29)	Error (d.f = 58)
Days to 50 % flowering	11.677	136.355**	1.632
Plant height	0.854	354.725**	1.471
Spike length	0.917	3.292**	0.456
Number of productive tillers/plant	1.835	7.542**	0.722
Days to maturity	1.211	14.812**	1.108
Number of grains/spike	5.036	60.283**	1.729
Biological yield/plant	0.933	2301.457**	1.991
Harvest index	0.447	659.129**	2.152
Test weight	0.008	60.330**	0.038
Grain yield/plant	0.677	34.838**	1.448

**Significant at 1% level of significance

Table 3: Estimation of components of variance and genetic parameters for different characters in wheat

Characters	VG	VP	GCV	PCV	h^2	GA	GG
Days to 50% flowering	44.91	46.54	8.63	8.78	96.49	13.56	17.46
Plant height	117.75	119.22	10.99	11.05	98.77	22.22	22.49
Spike length	0.94	1.40	10.10	12.30	67.43	1.64	17.08
Number of productive tillers/plant	2.27	2.99	12.57	14.43	75.90	2.71	22.56
Days to maturity	4.57	5.68	1.68	1.87	80.48	3.95	3.10
Number of grains/spike	19.52	21.25	8.94	9.33	91.86	8.72	17.65
Biological yield per plant	766.49	768.48	35.37	35.42	99.74	56.96	72.77
Harvest index	218.99	221.14	36.71	36.89	99.03	30.34	75.25
Test weight	20.09	20.13	11.77	11.78	99.81	9.23	24.23
Grain yield/plant	11.13	12.58	11.86	12.61	88.49	6.46	22.99

VG: Genotypic variance, VP: Phenotypic variance, GCV: Genotypic coefficient of variation, PCV: Phenotypic coefficient of variation, h^2 (bs): Heritability broad sense, GA: Genetic advance and GG: Genetic gain

and hence heritable. These findings of genotypic and phenotypic variance for different quantitative characters in wheat are in accordance with the findings of Singh *et al.* (2001), Sharma and Garg (2002) and Chandrashekhar and Kerketta (2004). However, these findings were in disagreement with the results of Kumar *et al.* (2009) who observed low variability for days to 50% flowering and days to maturity in wheat.

A Perusal of Genotypic (GCV) and Phenotypic Coefficients of Variation (PCV) revealed that higher magnitudes of GCV and PCV were recorded for harvest index followed by biological yield, number of productive tillers per plant, grain yield per plant, test weight and plant height. While characters like; spike length, number of grains per spike and days to 50% flowering exhibited moderate estimates and days to maturity exhibited least genotypic coefficient of variation. On an average, the higher magnitude of GCV and PCV were recorded for harvest index (36.71 and 36.89), biological yield (35.37 and 35.42), number of productive tillers per plant (12.57 and 14.43), grain yield per plant (11.86 and 12.61), test weight (11.77 and 11.78), plant height (10.99 and 11.05) and spike length (10.10 and 12.30) suggesting sufficient variability and thus exhibited scope for genetic improvement through selection for these traits. Relatively low magnitudinal difference was observed between GCV and PCV for all the traits studied (Table 3). This indicated less environmental influence on the expression of all the attributes. These findings were in agreement with those of Dwivedi *et al.* (2002).

These values alone are not helpful in determining the heritable portion of variation. The proportion of genetic variability which is transmitted from parents to offspring is reflected by heritability (Lush, 1949). All the characters showed high estimates of heritability in broad sense except spike length which had moderate estimate. Among them test weight recorded highest estimates followed by biological yield, harvest index, plant height, days to 50% flowering, number of grains per spike, grain yield per plant, days to maturity and number of productive tillers per plant (Table 3). High values indicate that heritability may be due to higher contribution of genotypic component. High heritability estimates were also reported by Amin *et al.* (1990) and Phadnawis *et al.* (2002) for test weight, Panwar and Singh (2000) and Asif *et al.* (2004) for plant height, Nimbalkar *et al.* (2002), Joshi and Mahal (2004), Ribadia *et al.* (2007) and Rasal *et al.* (2008) for grain yield and its components in wheat.

The estimates of heritability are more advantageous when expressed in terms of genetic advance. Johnson *et al.* (1955) suggested that without genetic advance the estimates of heritability will not be of practical value and emphasized the concurrent use of genetic advance along with heritability. Hanson (1963) stated that heritability and genetic advance are two complementary concepts. Based on this consideration high heritability coupled with high genetic advance as percent of mean was registered biological yield, harvest index and plant height suggesting predominance of additive gene action in the expression of these traits. High heritability along with moderate genetic advance was registered for days to 50% flowering suggesting predominance of additive and non additive gene action in the expression of these traits therefore, these characters can be improved by mass selection and other breeding methods based on progeny testing (Table 3). Similar results in wheat have been also reported by Pawar *et al.* (2002), Kamboj (2007) and Sen and Toms (2007).

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 breeder is always concerned for the selection of superior genotypes on the basis of phenotypic expression. However, for the quantitative characters, genotypes are influenced by environment, thereby affecting the phenotypic expression. Information regarding the nature and extent of association of morphological characters would be helpful in developing suitable plant type, in addition to the improvement of yield a complex character for which direct selection is not effective.

The estimates of correlation coefficients (Table 4) revealed that highest direct genotypic and phenotypic correlation was observed in biological yield (0.40*, 0.38*) followed by plant height (0.21, 0.21), tiller number (0.20, 0.19), spike length (0.17, 0.08) and test weight (0.15, 0.14) while days to maturity has lowest estimate. However, days to 50% flowering (0.19, 0.17) and harvest index (0.03, 0.04) has direct negative correlation with grain yield. Further, genotypic correlation coefficients were higher in magnitude than the corresponding phenotypic correlation coefficients

Table 4: Genotypic (rg) and phenotypic (rp) correlation coefficient for different quantitative characters in wheat

Characters	r	Plant height	Spike length	No. of productive tillers/plant	Days to maturity	No. of grains per spike	Biological yield per plant	Harvest index	Test weight	Grain yield/ plant
Days to 50%	rg	0.15	-0.18	-0.38*	0.55**	0.28	-0.05	0.07	-0.18	-0.19
flowering	rp	0.15	-0.15	-0.32	0.46**	0.24	-0.05	0.07	-0.18	-0.17
Plant height	rg		-0.08	0.22	-0.15	0.54**	0.62**	-0.46*	0.01	0.21
	rp		-0.06	0.17	-0.12	0.51**	0.62**	-0.45*	0.01	0.21
Spike length	rg			0.44*	-0.04	0.25	0.08	-0.06	-0.27	0.17
	rp			0.31	-0.01	0.21	0.07	-0.06	-0.22	0.08
No. of productive	rg				-0.33	0.07	0.20	-0.17	-0.11	0.20
tillers/plant	rp				-0.26	0.04	0.17	-0.14	-0.10	0.19
Days to maturity	rg					0.06	-0.16	0.20	-0.07	0.05
	rp					0.02	-0.14	0.17	0.06	0.02
Number of grains	rg						0.32	-0.18	-0.34	0.07
per spike							0.31	-0.18	-0.33	0.06
Biological yield	rg							-0.87**	0.08	0.40*
per plant	rp							-0.87**	0.08	0.38*
Harvest index	rg								-0.10	-0.03
	rp								-0.10	-0.04
Test weight	rg									0.15
	rp									0.14

*Significant at 5%, ** Significant at 1% level of significance, rg and rp = Genotypic and phenotypic correlation, respectively residual value = 0.5593 which might be due to masking or modifying effect of environment. High genotypic correlations also suggest that there is inherent relationship between the characters studied. Very close values of genotypic and phenotypic correlations were also observed between some character combinations, such as plant height with grain yield, days to 50% flowering, biological yield and test weight; harvest index with days to 50% flowering, spike length and number of grains per spike which might be due to reduction in error (environmental) variance to minor proportions. The correlation coefficient between seed yield per plant and other quantitative attributing to yield showed seed yield was significantly and positively associated with biological yield per plant at both genotypic and phenotypic level. Direct non significant positive correlation was observed for traits like; plant height, days to maturity, spike length, number of productive tillers per plant, number of grains per spike, biological yield per plant and test weight. Thus selection for higher yield on the basis of above characters would be reliable. Days to 50% flowering and harvest index showed negative non significant correlation with grain yield. Similar findings were also reported by, Dwivedi *et al.* (2002), Gupta *et al.* (2004), Shukla *et al.* (2005) and Khan *et al.* (2005). However, Akram *et al.* (2008) observed number of tillers and spike length had negative effects towards grain yield which is in contradiction with present findings. When two characters show negative phenotypic and genotypic correlation it would be difficult to exercise simultaneous selection for these characters in the development of a variety.

When characters having direct bearing on yield are selected, their associations with other characters are to be considered simultaneously as this will indirectly affect yield. The results of correlation coefficients implied that significant positive correlations at both the levels were recorded for plant height with number of grains per spike and biological yield; days to 50% flowering with days to maturity. However, spike length showed positive estimates with number of productive tillers per plant length but significant at genotypic level. Significant indirect negative correlations at both the levels were recorded for harvest index with plant height and biological yield while days to 50% flowering had negative estimate with number of productive tillers per plant but significant at only genotypic level. These findings were in agreement with results of Ashfaq *et al.* (2003), Shukla *et al.* (2005), Khan *et al.* (2005) and Sherif *et al.* (2005). However, these results were in disagreement with the findings of Burio *et al.* (2004) who observed that harvest index had positive effects with plant height.

If relationship is due to manifold effect of gene (s) it is difficult to separate these effects by selecting particular character so related. Information obtained from correlation study does not give a complete idea about the contributions of each component character. Therefore, it is important to establish the genetic basis of correlation before launching any breeding programme. Path coefficient analysis is useful for partially direct and indirect causes of correlation and also enables us to compare the causal factors on the basis of their relative contributions. Shrivastava and Sharma (1976) suggested that only direct yield components should be used for path analysis. Path coefficient at genotypic level (Table 5) revealed that biological yield (1.65) had highest direct positive effect on seed yield per plant followed by harvest index (1.36), days to maturity (0.19), test weight (0.14), spike length (0.10) and number of productive tillers per plant (0.09) indicating these are the main contributors to yield. Gupta *et al.* (2007) also observed the highest contribution towards grain yield with biological yield, harvest index, test weight and spikelets per spike. However, plant height, number of grains per spike and days to 50% flowering had direct negative effect on grain yield. These negative effects were in agreement with results of Bhutta *et al.* (2005) for number of spikelets per spike but disagree with the findings of

Table 5: Direct and indirect effect of component traits attributing to grain yield in wheat at genotypic level

Characters	Days to 50% flowering	Plant height	Spike length	No. of productive tillers/plant	Days to maturity	No. of grains /spike	Biological Yield/ plant	Harvest index	Test weight	Genotypic correlation
Days to 50% flowering	-0.18	-0.01	-0.02	-0.04	0.11	-0.03	-0.09	0.09	-0.02	-0.19
Plant height	-0.03	-0.08	-0.01	0.02	-0.03	-0.06	1.03	-0.63	0.07	0.21
Spike Length	0.03	0.01	0.10	0.04	-0.01	-0.03	0.14	-0.08	-0.04	0.17
Number of productive tillers/plant	0.07	-0.02	0.04	0.09	-0.06	-0.01	0.33	-0.24	-0.02	0.20
Days to maturity	-0.10	0.01	0.00	-0.03	0.19	-0.01	-0.26	0.27	-0.01	0.05
Number of grains/spike	-0.05	-0.04	0.03	0.01	0.01	-0.12	0.53	-0.25	-0.05	0.07
Biological Yield per plant	0.01	-0.05	0.01	0.02	-0.03	-0.04	1.65	-1.18	0.01	0.40
Harvest Index	-0.01	0.04	-0.01	-0.02	0.04	0.02	-1.44	1.36	-0.01	-0.03
Test Weight	0.03	-0.02	-0.03	-0.01	-0.01	0.04	0.13	-0.14	0.14	0.15

Gupta *et al.* (2004) who observed that number of spikelets per spike showed positive direct effect on seed yield. However, Chowdhry *et al.* (2000) and Khaliq *et al.* (2004) observed that plant height, tillers per plant and spike length had direct positive effects on yield and disagreement with these finding.

CONCLUSION

The present study indicated that the character like; harvest index, biological yield, number of productive tillers per plant, grain yield per plant, test weight, plant height and spike length should be given to top priorities during selection for genetic improvement. Further, the character association analysis revealed that biological yield per plant, spike length, number of productive tillers per plant, number of grains per spike, test weight and days to maturity are the most important characters that contributed directly to yield. Thus a genotype with higher magnitude of these traits could be selected for improvement in wheat yield.

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