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Heterosis, Correlation and Path Analysis of Morphological and Biochemical Characters in Wheat (*Triticum aestivum* L. Emp. Thell)

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Abstract: Genetic studies were conducted on six marketable cultivars of wheat (*Triticum aestivum* L. emp. Thell) viz; Inqilab, Khyber 87, Soghat, Sarsabz, Rohtas 90 and Pak 81 and their three F_1 hybrids; Khyber 87 X Inqilab, Rohtas 90 X Pak 81 and Soghat X Sarsabz in Pakistan. Data for various morphological and biochemical traits were taken and analyzed for heterosis, correlation and path co-efficient. Significant heterosis for grain yield, biomass, plant height, flag leaf area, spike length, spikelets per spike and 1000-seed weight, protein content, gluten, reducing sugars, fats and minerals was recorded in F_1 for all the three crosses. Analysis of variance revealed significant sum of genetic variability for all the characters. Positive and significant correlation of grain yield was recorded with plant height, spike length and biological yield at the genotypic level. There was a positive and significant association between protein content and number of spikelets per spike and protein and gluten content at genotypic level. However, correlation between grain yield and 1000-seed weight was negative and highly significant. In general, more correlation coefficient was recorded at the genetic level as compared to phenotypic level. While improving the yield potential of wheat varieties under investigation, direct simultaneous selection based on plant height, spikelets per spike, biological yield, harvest index and protein content of kernel would be advantageous. This information will ultimately lead to the determination of suitable plant types in wheat (*Triticum aestivum* L. emp. Thell)

Key words: Heterosis, correlation studies, path analysis, morphological characters, biochemical characters, *Triticum aestivum*

INTRODUCTION

Wheat (*Triticum aestivum*) is a staple diet and provides more nourishment for the people of the world than any other crop. There are fifteen recognized species within the genus *Triticum*[1]. About 90% of the world's wheat production consists of three species; *Triticum aestivum* (common wheat), *Triticum compactum* (club wheat) and *Triticum durum* (durum or macaroni wheat). Common wheat is an important winter cereal crop of Pakistan.

Pakistan is one of the top ten wheat-producing countries and wheat is the most important staple food for the people of Pakistan. Due to high demand for wheat, major emphasis has been placed on increasing wheat yield potential, which can be achieved through adopting appropriate production practices. Wheat plays an important role in the Pakistan's economy. During the last few decades, better progress has been made in increasing the per unit area yield of wheat in the country. By comparing the yield of wheat per unit area of Pakistan with the per unit area yield of wheat of the advanced countries, we are still outlying at the rear.

Production of wheat depends on the cultural practices, environment and the most important is the genetic characteristics carried by the seed. Genetic variability is a prerequisite for the improvement of any crop. Wheat possesses abundant genetic variability for qualitative as well as quantitative traits. With this variation, productive genotypes with high quality attributes acceptable to both producers and consumers can be developed.

A great success of developing high yielding wheat genotypes has been achieved through breeding. But before starting any breeding program aimed at increasing the productivity, it is crucial to learn the information regarding the correlation of yield with other yield contributing parameters. Such information has paramount importance in determining suitable selection procedures for maximum genetic gain. However, some breeders have

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expressed apprehension about total reliance on yield component analysis[2]. Path studies provide an opportunity to study the magnitude and direction of association of yield with its direct and indirect components and also among various components.

Aim of the study: The present study was designed to accumulate optimum combination of yield contributing characters and which components are influencing the yield substantially in genetically different commercial genotypes and their F_1 hybrids.

MATERIALS AND METHODS

The present study was conducted in the field conditions at National Seed Registration Department (NSRD), Islamabad, Pakistan. Seeds of pure lines were obtained from National Seed Registration Department. These cultivars are well established varieties that have been tested in different regions of Pakistan. Being naturally self pollinated, these cultivars are homozygous for the characters under study.

Seeds of six commercial varieties viz; Inqilab, Khyber 87, Soghat, Sarsabz, Rohtas 90 and Pak 81 were sown. Three crosses Khyber 87 X Inqilab, Rohtas 90 X Pak 81 and Soghat X Sarsabz were made by keeping the first three varieties as male parents. Fifty single crosses were performed for each pair. The heads were harvested and threshed to get the grains for sowing in next winter. Parental lines along with the three F1 hybrid seeds were planted in randomized complete block design with three replications in winter of next year. Plant to plant and row-to-row distance were kept at 10 cm and 30 cm, respectively.

Experiment was conducted under arid conditions. Following cultural practices were adopted to raise the crop. All the cultivars were employed agronomic practices equally including fertilizers, irrigation and pesticide application. Recommended doze of Nitrogen, Phosphorus and Potassium fertilizer at the rate of 150-90-60 Kg/Hectare, respectively were applied. Half doze of Nitrogen and full doze of potassium and phosphorus were applied before sowing; remaining half doze of Nitrogen was applied two weeks after germination. Seeds were sown in moist soil (60% water holding capacity) and germinated plants were irrigated when required. Manual weed eradication was undertaken in the plots when required through out the experiment.

Plant height (cm), spike length (cm), number of spikelets per spike, flag leaf area (cm^2), biomass (g), grain yield, grain protein percentage, fat percentage, gluten content, reducing sugars and mineral content were recorded on 10 randomly selected plants in each replication. 1000-seed weight (g) was recorded. Harvest index was determined as economical yield expressed as percentage of total biomass. The data recorded was analyzed for heterosis[3], phenotypic (rp) and genotypic (rg) correlation coefficients by Singh and Chaudhry[4]. Direct and indirect path coefficients were determined by Dewey and Lu[5]. To determine biochemical characteristics standard methods[6,7] were used.

RESULTS AND DISCUSSIONS

The availability of genetic variability is essential for the genetic improvement of crop plants. The identification of plants with suitable combination of characters from a population with genetic variability is dependent upon knowledge of breeders on that population. This knowledge is utilized to decide selection criteria, which are expected to prove effective for yield improvement together with improvement in other traits. The parents and F_1 hybrids provided considerable genetic variability for characters under study (Tables 1 and 2). Variability among different yield contributing characters have been documented in various studies[8-10].

Heterosis studies: Highly significant increase in the F_1 hybrids over mid parents has been obtained for all the characters under study except for plant height in Khyber 87 X Inqilab 91 F_1 hybrid where it was significantly higher (9.98%). There was a considerable variability for spike length that ranged from 10.417 cm (Pak81). However, for harvest index in Soghat X Sarsabz cross, nonsignificant increase over mid parent was recorded (Table 2) Highly significant increase in percent of mean values in F_1 for various characters had been recorded over better parent except that a significant increase over better parent was observed for plant height in Rohtas 90 X Pak 81 hybrid. Maximum increase 51.97% of F_1 hybrid was noted for flag leaf area in Soghat X Sarsabz cross over mid parent while, a maximum 45.30% increase of F_1 hybrid in cross Rohtas 90 X Pak 81 was noted for spike length over the better parent. Maximum increase of 35.07 and 29.77% in economic yield over mid and better parent was recorded for F1 hybrid of Rohtas 90 X Pak 81 cross.

The maximum protein content was recorded for the cross between Khyber X Inqilab 91 with average 12.63% protein, which means that F1 hybrid showed 11% increase as compared with mid parent (Tables 1 and 2) The cross Rohtas 90 X Pak 81 had maximum increase i.e. 49.09% over mid parent for reducing sugars. There was highly significant increase ($p<0.05$) over mid parents i.e. 45.5 and 70.04% for crosses Khyber 87X Inqilab 91, respectively.

Table 1: Average performance of different characters in F1and their statistical significance

Characters	Height (cm)	Spike length (cm)	Spikelets per spike	Flag leaf area	Biomass (g)	Economic yield	Harvest index	1000-grain weight (g)	Protein content	Reducing sugar (%)	Gluten	Fat (%)	Mineral content
Rohtas 90× pak 81	118.00a	16.383a	26.83a	53.197a	1446.33a	620.90a	43.167a	44.01a	12.633a	6.210a	10.71a	4.227a	2.612a
Soghat× Sarsabaz	117.70ab	15.85b	25.833b	52.37ab	1429.33b	589.49b	41.00b	40.75b	11.967b	4.923b	10.637b	3.917b	1.74b
Pak 81	109.43c	15.58bc	24.433c	49.74c	1355.66c	548.32c	40.86bc	37.78c	11.20bc	4.633c	10.59c	3.47c	1.71c
Sarsabaz	107.633cd	13.183d	23.567d	39.797d	1323.00d	539.87d	40.73cd	37.71c	11.00c	4.36d	10.57c	3.29d	1.68de
Khyber 81× Inqilab 91	99.36e	12.367d	23.167e	39.76d	1301.00e	513.17e	39.167e	37.09c	10.567cd	4.27de	9.548d	2.96e	1.677 e
Inqilab 91	94.67f	12.20de	21.967f	38.61de	1241.66f	465.82f	38.60f	34.47d	10.33de	4.057ef	7.48e	2.93e	1.664e
Rohats 90	87.70g	11.233ef	21.50fg	36.61e	1207.867g	454.25g	38.50fg	31.21e	9.903ef	3.913f	7.37f	1.843f	1.660f
Soghat	87.26g	10.717g	20.367h	35.21ef	1207.667g	442.63h	37.56g	30.26e	9.52f	3.65g	5.26g	1.75g	1.62g
Khyber 87	86.25g	10.417g	18.367i	33.113f	1149.00h	418.59i	33.50h	28.99e	9.507f	3.32h	5.25g	1.48h	1.20i

The means in each column having the same letters do not differ significantly at 5% level of significance

Table 2: Heterosis over mid and better parent for various characters in F_1 hybrids of *Triticum aestivum*

Crosses		Plant height	Spike length	No. of Spikelets	Flag leaf area	Biomass	Grain yield	Harvest index	1000-seed weight	Protein content	Reducing sugar (%)	Gluten	Fat (%)	Mineral content
Khyber 87 X Inqilab 91	Mid	9.98*	35.28**	20.63**	45.03**	6.71**	14.09**	5.62*	17.67**	30.53**	12.64**	70.04**	7.60*	57.03**
	Better	5.22*	29.91**	15.71**	39.39**	5.43**	13.19**	5.30*	16.70**	28.04**	7.39**	45.59**	5.14*	56.97**
Rohtas 90 X Pak 81	Mid	19.64**	47.53**	18.86**	30.26**	17.62**	35.07**	15.02**	16.72**	21.84**	49.09**	40.50**	40.50**	18.86**
	Better	7.76*	45.30**	17.62**	25.09**	16.48**	29.77**	8.83**	9.60**	17.88*	45.43**	7.84*	7.84*	3.45*
Soghat X Sarsabz	Mid	20.78**	28.26**	12.77**	51.97**	10.41**	12.97**	1.51	35.83**	3.83	12.75**	6.28*	43.53**	2.42*
	Better	9.36**	24.27**	9.82**	31.56**	7.72**	10.16**	1.38	30.55**	1.76	11.73**	1.42	42.56**	1.22*

* = Significant, ** = Highly significant

Impressive significant positive heterosis i.e. 43.53% was observed in hybrids of Soghat X Sarsabz for fat percentage. The cross Khyber87 X Inqilab91 produced the highest mineral percentage (2.612%). These findings suggests that most of the parents carried the same height controlling genetic mechanism and more expression in height among hybrids may be due to the presence of various modifiers in the parental genotypes. Similar heterotic effects for various characters have been documented in different studies[11-15]. It is obvious from the results that hybrid progenies offered a good source material for exploitation of hybrid vigor and selection of genotypes in the succeeding generations.

Correlation studies: The results regarding genotypic and phenotypic correlation coefficients have been presented in Table 3. The results revealed that genotypic correlations were higher than the phenotypic correlations for most of the characters. Plant height was positively and significantly correlated with spike length, number of spikelets per spike while at the genotypic level it was highly significant with harvest index. It reveals that long spikes with greater number of spikelets per spike are likely to be produced on taller plants. These results are in agreement with those of Singh[16]. It is also suggested that harvest index and 1000-seed weight can never be missed while making selection for high yielding varieties of wheat. Flag leaf area and spike length exerted positive and significant correlation at genotypic level. It is therefore suggested that greater flag leaf area is likely to increase the spike length and consequently number of spikelets per spike, as the association between spike length and number of spikelets per spike was positive and significant.

There was positive and significant ($p<0.05$) association between protein content and number of spikelets per spike and protein and gluten content at genotypic level, but non significant ($p<0.05$) at phenotypic level. Further, there was a significant and positive correlation between reducing sugars and fat percentage. A positive and significant association was observed between mineral percentage and gluten content at genotypic level. Association between mineral content and plant height was found positive and significant at genotypic level while it was non significant at phenotypic level.

Similarly higher genetic values as compared to phenotypic correlation coefficients have been reported by Bhagat[17]. The correlation coefficient of economic yield was positive and significant at genotypic level and highly significant at phenotypic level with plant height, spike length, number of spikelets and biomass. Sarkar[18,17,19,10,20,21]; reported positive and significant correlation coefficients of various characters with economic yield in wheat. The strong positive association

Table 3: Genotypic (G) and Phenotypic (P) correlation coefficients among 13 characters of Wheat (*Triticum aestivum)*

Characters		Spike length	Spikelets per spike	Flag leaf area	Biological yield	Economic yield	Harvest index	1000 grain weight	Protein content	Reducing sugar	Gluten content	Fat (%)	Mineral (%)
Plant height	G	0.8231*	0.6231*	-0.028	0.3113	0.7134*	0.873*	0.1562	-0.204	0.302	-0.170	0.183	0.455*
	P	0.7070*	0.5416**	-0.123	0.115	0.5907**	0.174	0.2017	-0.203	0.186	-0.142	0.062	0.056
Spike length	G		0.747*	0.6311	-0.719	0.818*	-0.1671	-0.107	0.996**	0.017	-0.578	0.895**	0.028
	P		0.705**	0.0917	-0.776	0.789	-0.096	-0.045	0.127	-.095	-0.186	0.140	-0.013
Spikelets	G			-0.102	0.146	0.632*	-0.316	-0.532	0.733*	-0.696	-0.998**	0.882**	0.401
per spike	P			0.423	-0.072	0.606**	-0.073	-0.473	0.175	0.181	-0.115	0.154	-0.080
Flag leaf area	G				-0.148	0.243	0.243	-0.068	-0.33	-0.961**	-0.653	0.238	-0.504
	P				0.248	-0.097	-0.861	-0.067	-0.09	-0.117	-0.192	0.181	-0.202
Biological	G					0.559*	0.201	-0.141	-0.172	-0.186	-0.169	-0.103	-0.209
yield	P					0.342	0.070	-0.076	-0.005	-0.028	-0.103	-0.101	-0.082
Economic	G						-0.878**	-0.843	-0.160	-0.261	-0.631	-0.631	-0.905**
yield	P						-0.156	0.206	-0.101	-0.041	-0.150	-0.184	-0.205
Harvest	G							-0.829**	-0.207	-0.938**	-0.403	-0.101	-0.237
index	P							-0.350	-0.121	-0.129	-0.052	-0.112	-0.892
1000grain	G								-0.896**	-0.4711*	-0.254	0.247	-0.165
weight	P								-0.0221	-0.154	-0.134	0.127	-0.142
Protein	G									-0.833**	0.313*	-0.142	0.185
content	P									-0.346	0.212	-0.121	0.054
Reducing	G										-0.124	0.504*	0.197
sugar	P										-0.213	0.092	-0.131
Gluten	G											-0.762*	0.698*
content	P											-0.229	0.132
Fat	G												-0.108
(%)	P												-0.013

* = Significant, ** = Highly significant, G = genotypic and P = phenotypic

Table 4: Path coefficient analysis for direct (parenthesis) and indirect effects on yield in *Triticum aestivum*

Characters	Plant height	Spike length	No. of Spikelets	Flag leaf area	Biomass	Harvest index	1000-seed weight	Protein content
Plant height	0.848	0.084	-0.002	-1.408	0.188	0.539	0.103	-0.231
Spike length	-0.075	-0.949	-0.092	-0.495	4.718	-0.103	0.273	-1.123
No, of spikelets	0.097	-0.023	0.080	0.888	-0.196	0.349	0.825	0.825
Flag leaf area	-0.788	1.516	-0.099	-0.900	1.507	-0.024	-0.371	-0.372
Biomass	0.606	0.264	-0.588	0.142	1.170	0.124	0.525	-1.964
Harvest index	0.617	0.740	0.012	-0.030	-1.923	0.122	0.302	-0.234
1000-seed weight	0.242	0.056	0.093	-0.054	-0.875	-0.512	(0.364	-1.010
Protein content	-0.174	0.075	0.071	0.260	-1.057	-0.128	0.326	1.127

between yield and these parameters revealed that any increase in the height, spike length, number of spikelets per spike and biological yield would have direct and proportionate impact on grain yield. The correlation of yield with harvest index and 1000-seed weight was negative and highly significant at the genotypic level. These results are confirmatory to those of Akhtar[22].

Path coefficient analyses: Path analysis provides an effective way to find out direct and indirect sources of correlation using genotypic correlation of different characters. Examination of the data (Table 4) revealed that plant height had positive direct contribution to grain yield and it mainly contribute to economic yield via harvest index, spike length and biological yield. Kashif and Khaliq[19]; Asif[10] also reported positive direct effects of plant height on grain yield. However, plant height exerted negative indirect effects through number of spikelets per spike and flag leaf area and protein content. Direct effect of spike length on grain yield was negative but its indirect effects via biological yield and 1000-seed weight were positive. However, Singh[16] reported positive direct effects of spike length on grain yield. This discrepancy in results could be due to the difference in genotypes and environment in which the studies were carried out. Number of spikelets per spike positively contributed to grain yield via direct effects while indirectly through flag leaf area and biological yield. Ugowska[23,24] recorded positive direct effects of number of spikelets per spike over economic yield. Direct effects of flag leaf area on grain yield were negative while it positively contributed indirectly to grain yield through plant height and harvest index. Biomass had maximum positive direct effect on grain yield and it also contributed positively and indirectly via all characters except number of spikelets per spike. Singh[25,16] reported similar positive direct effect of biomass on economic yield. Direct effects of harvest index and 1000-seed weight on economic yield were positive and they also contributed indirectly and positively via plant height, spike length and number of spikelets per spike. Their indirect contribution to grain yields via flag leaf area and biomass were negative. Singh and Diwivedi[20,18,16] also reported positive direct effect of harvest index and 1000-seed weight on economic yield.

Results revealed a positive and significant association between protein content and spikelets per spike at genotypic level but non significant at phenotypic level. It can be concluded that with the increase in spike length and spikelets number, the protein content also increases. Significant positive association between protein content and spike length was reported by Mahmood and Shahid[26]. Protein content showed negative but non-significant correlation with plant height both at genotypic and phenotypic levels. A negative and non-significant correlation was found between protein content and grain yield at phenotypic and genotypic levels. Thus the protein content of the high yielding varieties will be low since protein content had negative correlation with yield. Association between mineral content and plant height was found positive and significant at genotypic level but it was non significant at phenotypic level. An increase in the mineral content of grains can be expected with the increase in plant height.

CONCLUSION

The genetic variability is present in the commercial genotypes of wheat, which can be utilized through appropriate crossing and suitable selection indices for better genotypes in the segregating populations. While improving the yield potential of wheat varieties under investigation, direct simultaneous selection based on plant height, spikelets per spike, biological yield, harvest index and protein content of kernel would be advantageous. These information will ultimately lead to the determination of suitable plant types in wheat (*Triticum aestivum* L. emp. Thell)

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