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Genetic Studies in Bread Wheat Under irrigated and Drought Stress Conditions

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Abstract: A 6 × 6 diallel cross consisting of six wheat varieties/lines namely Pak 81, LU26S, Inqlab 91, Rohtas 90, 4072 and 4943 was analyzed to determine the nature of genetic mechanisms controlling some Morpho- physiological traits, like stomatal frequency, leaf venation, flag leaf area, specific flag leaf weight, days to heading, tillers per plant, plant height, spike length, grains per spike, 1000-grain weight, biomass per plant and grain yield per plant under irrigated and drought stress conditions. Adequacy test satisfied the simple additive dominance model. High estimates of narrow sense heritability were found for stomata! frequency, specific flag leaf weight, days to heading, plant height, spike length and 1000-grain weight, also observed lower average degree of dominance under both environments. In the present study additive genetic effects were found to be more important than nonadditive effects with the exception of yield per plant which appeared to be more closely linked to nonadditive genetic effects. Since the yield components like grains per spike, 1000-grain weight, tillers per plant were found to be significantly influenced by additive gene action, further progress in genetic improvement of the yielding ability of wheat varieties may be attempted through such yield-related characters, with much better prospects of fixing desirable genes in a single homozygote.

Key words: Diallel, gene action, combining ability, drought stress, morpho-physiological traits, bread wheat

Introduction

Cereal breeders are largely concerned with gaining information regarding the genetic systems controlling morpho-physiological traits using statistical analysis techniques which enable them to test for epistasis and to obtain precise and unbiased estimates of the additive and dominance components of genetic variation. However, some earlier researchers (Lonts and Lone, 1984; Alam *et al*., 1991; Iqbal *et al*., 1991; Chowdhry *et al*., 1992) reported the over dominance type of gene action for tillers per plant, spike length, flag leaf area, grains per spike, 1000-grain weight and grain yield per plant. While additive type of gene action along with partial dominance were observed for plant height, spike length, grains per spike, 1000-grain weight and grain yield per plant by Alam *et al*. (1991), Iqbal *et al*. (1991) and Chowdhry *et al*. (1992). Whereas Prodanovic (1993) showed that tiller number, grain number per spike, 1000-grain weight and grain yield were conditioned mainly by dominance gene effects. Over dominance was found for some traits, such as grain number per spike and grain yield. High narrow sense heritability estimates were noted for spike length (94.7%) and plant height (82.26%).

General combining ability mean squares were higher than the specific combining ability mean squares for plant height, spike length, tillers per plant, grains per spike, 1000-grain weight, days to heading and grain yield per plant indicating that these characters were controlled by additive type of gene action (Khan and Bajwa, 1990; Li *et al*., 1991; Chaudhry *et al*., 1992, 1994). Whereas specific combining ability mean squares for tiller per plant and grain yield per plant were greater than those of their general combining ability mean squares suggesting that these traits were mainly controlled by non-additive type of gene action (Li *et al*., 1991). However, Chaudhry *et al*. (1994) reported that general combining ability mean squares were highly significant for all traits. Specific combining ability mean squares were non significant for days to heading, flag leaf area, tillers per plant and grain yield per plant, significant for spike length and highly significant for plant height and 1000-grain weight.

The present study was under taken to determine the genetic systems affecting morpho-physiological traits and also to assess the relative performance of some bread wheat (*Triticum aestivum* L. em. Thell.) varieties for general and specific combining ability under irrigated and drought stress conditions.

Materials and Methods

Study was conducted at University of Agriculture, Faisalabad, during the year 1994-96. Six varieties/lines of bread wheat viz., Pak 81, LU26S, Inglab 91, Rohtas 90, 4072 and 4943 were crossed in a diallel fashion. The thirty F_1's including reciprocals and their parents were space planted in randomized complete block design with three replications. A single row of 3.75 meter served as an experimental plot. Two seeds per hill were sown with the help of a dibble and later thinned to one seedling per site with a distance of 15 centimeters within rows and 30 centimeters between rows.

For two sets of experiments, one under regular irrigation and the other under non-irrigation (drought stress), the fields were irrigated for seed bed preparation. After planting of experimental population, four canal irrigations were applied to normal experiment during the active growing period. Whereas the other experiment entirely depends on natural precipitation and no surface irrigation was applied to drought experiment for maintaining moisture stress conditions. Normal agronomic practices like fertilizer application and weed control were applied to both experiments.

Measurements were made on only competitive plants under both environments for morpho-physiological traits like stomatal frequency, leaf venation, flag leaf area (cm^2), specific flag leaf weight (mg/cm^2), days to heading, tillers per plant, plant height (cm), spike length (cm), grains per spike, 1000-grain weight (g), biomass per plant (g) and grain yield per plant (g). The data were subjected to analysis of variance for all the characters for individual environments (irrigated and drought stress conditions) according to the method of Steel and Torrie (1980). The diallel cross method developed by Hayman (1954) and applied by Mather and Jinks (1982) was used for genetic analysis of the data. Further analysis for combining ability effects was performed by using Griffing (1956) Method I, Model II.

Results and Discussion

Gene action: Highly significant mean squares among parents and crosses were obtained for all traits under irrigated as well as drought stress conditions. This confirmed the presence of genetic variability in the material grown under both environments and suggested that detailed analysis of gene action was warranted. The analysis of variance for the diallel cross (Table 1) shows that the mean squares of component, a, were highly significant for all the traits except biomass per plant and grain yield per plant under irrigated conditions. But under drought stress conditions mean squares of component, a, were significant for all traits except tillers per plant. This indicates that there was a wide variation caused by the additive genetic effects in all these traits under both environments. The significant mean squares of item, b_l indicated the directional dominance for the expression of stomatal frequency, flag leaf area, spike length and 1000-grain weight under irrigated conditions whereas for tillers per plant, plant height, spike length, grains per spike and 1000-grain weight under drought stress conditions. The mean squares due to item, b_2, significant for flag leaf area, days to heading, plant height, grains per spike and 1000-grain weight indicating asymmetrical gene distribution among the parents under irrigated conditions. Similarly, asymmetrical gene distribution was observed for days to heading, biomass per plant and grain yield per plant under drought stress conditions, The significant mean squares due to item, b_3, for days to heading, tillers per plant, grains per spike, 1000-grain weight, biomass per plant and grain yield per plant suggested the importance of specific gene effects controlling these traits under both conditions. Different levels of dominance were observed for most of the traits under drought stress conditions.

Tests of assumption for the additive dominance model: The regression analysis for stomatal frequency, leaf venation, flag leaf area, specific flag leaf weight, days to heading, plant height, spike length, and 1000-grain weight under irrigated conditions and for leaf venation, flag leaf area, days to heading, plant height, spike length, grains per spike, 1000-grain weight and biomass per plant under drought stress conditions confirmed the validity of the additive dominance model.

The regression and array variance analysis depicted the partial adequacy of the model for tiller per plant, grains per spike, biomass per plant and grain yield per plant under drought stress conditions and tillers per plant under irrigated conditions. Partial failure of the assumptions indicated a more complex genetic system than that described by theoretical model (Hayman, 1954). However, Hayman (1954) stated that it is possible to make estimates of the population parameters and genetic components of such traits. Therefore, Wilson *et al*. (1978) computed the genetic components for partially adequate traits. Still it must be realized that such estimates were less reliable than they would have been had all the assumptions been satisfied.

Genetic components: fkifi estimated components of genetic variance, D, H_1, H_2, h^2, F and some parameters derived from these estimates are presented in Table 2. The narrow sense heritability for stomatal frequency, specific flag leaf weight, days to heading, plant height, spike length, and 1000-grain weight were higher than that of leaf venation, flag leaf area, tillers per plant, grains per spike, biomass per plant and grain yield per plant. These results were confirmed by the findings of Prodanovic (1993) who reported the high narrow sense heritability for plant height and spike length. These traits with higher narrow sense heritability also showed lower average degree of dominance $((H_1/D)^{½})$, ranging from 0.15 to 0.84 than the other traits. Under drought stress conditions, narrow sense heritability for flag leaf area, specific flag leaf weight, days to heading, plant height, spike length and 1000-grain weight were higher than other traits. The traits with higher narrow sense heritability also showed lower average degree of dominance ranging from 0.24 to 0.35.

The D and H_1 components were significant in irrigated conditions revealing that both additive and non-additive type of gene action were involved in the inheritance of leaf venation, flag leaf area, days to heading, spike length and grains per spike. The significant estimates of D indicated that there were additive genetic differences among the parents for stomatal frequency, plant height. The H_1 was positive and significant for tillers per plant, biomass per plant and grain yield per plant under irrigated conditions revealed that only non-additive type of gene effects were involved for the expression of these traits. Positive and significant values of F indicated that dominant genes (alleles) were important for the expression of stomata! frequency, flag leaf area, days to heading, spike length, grains per spike and 1000-grain weight. The significant value of E showed important share of environmental effects in the expression of all traits except tillers per plant and 1000-grain weight under irrigated conditions. The significant value of h^2 revealed a substantial contribution of dominant genes in controlling stomatal frequency, flag leaf area, days to heading, spike length, grains per spike and 1000-grain weight due probably to the loci marked by heterogeneity.

The significant and positive values of D revealed that additive type of gene effects were important for leaf venation, flag, leaf area, specific flag leaf weight, days to heading and plant height whereas significant H_1 revealed the non-additive effects for tillers per plant under drought stress conditions (Table 2). The significant values of D and H_1 exhibited that both additive and non-additive effects were involved for the inheritance of grains per spike, biomass per plant and grain yield per plant. The negative and significant values of F showed the presence of recessive alleles for stomatal frequency, flag leaf area and days to heading. The significant values of h^2 revealed a substantial contribution of dominant genes in controlling flag leaf area, days to heading, tillers per plant, plant height, spike length, grains per spike and 1000 grain weight. Environment played an important role for the expression of all traits under drought stress conditions (Table 2). High narrow sense heritability estimates were

Table 1: Analysis of variance for diallel cross, variance components and other parameters of morpho-physiological traits of wheat under irrigated and dought stress conditions

Traits	Mean Squares							Variance components and other parameters							
	a (df = 5)	b (df = 15)	b1 (df = 1)	b2 (df = 5)	b3 (df = 9)	c (df = 5)	d (df-10)	D	H_1	H_2	F	h^2	E	(H_1/D) ½	HT-NS
Irrigated conditions															
Stomatal frequency	281.68**	25.14	133.11*	14.15	19.25	29.89	18.07	33.47**	3.65NS	4.57NS	3.28NS	21.23*	6.09*	0.33	0.669
Leaf venation	1.96**	0.56**	0.016	1.03	0.35	0.44	0.30	0.47*	0.34**	0.18NS	0.44*	-0.03NS	0.10*	0.85	0.396
Flag leaf area	65.50*	30.72**	167.09**	23.41*	19.63	3.39	5.28	16.95*	21.97**	14.12*	19.64**	13.03*	3.92*	1.08	0.325
Specific F.L. weight	25.36**	0.81	0.10	0.48	1.08	3.02	1.24	2.34*	-0.49	-0.30NS	-0.49*	-0.24*	0.45*	-	0.782
Days to heading	149.53**	7.93**	8.82	0.78**	6-80**	3.81*	2.79	12.87*	6.04*	4.22**	1.75NS	1.33*	0.53**	0.59	0.838
Tillers/plant	15.63**	5.35**	13.73	3.70	5.33**	5.46**	1.99	0.38NS	3.24**	2.70NS	-0.67NS	2.30NS	0.43NS	-	0.418
Plant height	372.55**	12.16*	21.80	10.35**	12.12	21.75	8.64	46.73*	1.12445	1.16NS	6.49*	2.12NS	3.52*	0.15	0.841
Spike length	9.68**	1.21**	10.01*	0.24	0.77	0.70	0.18	0.932*	0.66**	0 66**	-0.11NS	1.82*	0.08*	0.84	0.685
Grains/spike	127.61*	87.91**	521.56	67.94*	50.82	93.65	57.97	19.49**	38.70**	32.36**	16.03NS	89.39*	13.14*	1.41	0.188
1000-grain weight	187.53**	24.65**	142.041*	10.02*	19.73**	1.56	8.99**	25.44*	17.41*	15.50*	6.67NS	26.06*	0.47NS	0.83	0.704
Biomass/plant	287.82	265.51	315.10	159.71	318.77*	261.18	134.90	2.34145	110.56**	100.80*	-6.94NS	37.32NS	38.42*	6.88	0.130
Grain yield/plant	46.96	96.66**	139.48	67.16	108.29**	46.24	42.52	0.21416	49.51**	42.05*	-18NS	19.63NS	11.19*	15.45	0.033
Drought stress conditions															
Stomatal frequency	228.59**	29.82	41.23	23.93	31.80*	29.39	20.73	2.59NS	10.65NS	8.96NS	19.30*	4.61NS	5.46*	2.03	0.605
Leaf venation	2.23**	0.33	0.17	0 25	0.39	0.51	0.20	0.23*	0.04NS	0.04NS	0.01NS	-0.02NS	0.09*	0.43	0.529
Flag leaf area	33.52**	1.87	10.24	1.25	1.29	4.44	1.68	3.60*	-1.31*	-0.84*	-0.54*	0.73*	0.89*	-	0.731
Specific F.L. weight	17.01**	1.35**	0.96	0.52	1.86	1.06	0.74	1.48*	0.38NS	0.42*	-0.38NS	0.04NS	0.24*	0.50	0.724
Days to heading	391.79**	7.74**	11.85*	2.43*	10.23*	6.16	3.77	50.29*	2.92NS	3.07NS	6.97*	1.61*	1.04*	0.24	0.923
Tillers/plant	3.47	2.92**	20.69*	2.51	1.18	1.48	0.73	-0.06NS	1.67*	1.24*	0.11NS	3.21*	0.36*	-	0.159
Plant height	270.46*	25.91**	207.7*	7.70	15.83	34.26	10.38	31.34*	4.95NS	6.75*	1.14NS	36.07*	5.33*	0.40	0.669
Spike length	11.23**	0.733*	6.56*	0.05	0.47	0.57	0.15	1.27*	0.32*	0.36*	0.01NS	1.17*	0.07*	0.50	0.799
Grains/spike	162.67*	66.60**	565.70*	9.33	42.96*	29.47	22.09	20.82*	33.63*	34 77*	3.19NS	102.11*	4.81*	1.27	0.379
1000-grain weight	245.79**	16.10**	79.91*	7.92	13.55*	5.58	2.70*	33.85*	9.66*	8.61*	7.94*	14.23*	1.06*	0.53	0.808
Biomass/plant	145.93**	29.09**	2.67	34.69**	28.92**	29.48	10.91*	17.18*	20.98*	14.80	7.91NS	-0.789NS	2.31*	1.11	0.562
Grain yield/plant	19.81*	6.26**	0.46	6.81*	6.60**	4.22	1.67*	3.31*	4.47*	3.26*	2.47*	-0.17NS	0.46*	1.160**	0.446*

**=Significant at 5 and 1 percent probability levels, respectively *=The value of variance is significant when it exceeds 1.96 after dividing it with in standard error. HT-NS = Heritability (Narrow sense)

Table 2: Analysis of variance (mean squares) for morpho-physiological characters in bread wheat under irrigated and dought stress conditions

Characters	Mean Squares				Variances		
	Gca (df = 5)	sca (df = 15)	Reciprocal (df = 15)	Error (df = 70)	s^2 gca	s^2 sca	s^2 r
Irrigated conditions							
Stomatal frequency	93.910**	8.376	7.338	5.951	7.134	1.408	0.693
Leaf venation	0.654*	0.187*	0.116	0.100	0.039	0.050	0.008
Flag leaf area	21.820	10.238**	1.549	3.939	0.982	3.657	-1.20
Specific flag leaf weight	a 462**	0.271	0.615*	0.373	0.682	0.059	0.121
Days to heading	49.857**	2.640**	0.972**	0.482	3.941	1.253	0.245
Tillers/plant	5.209*	1.782**	1.047	0.442	0.289	0.778	0.303
Plant height	124.181**	4.068*	4.335**	2.148	10.015	1.115	1.093
Spike length	3.219**	0.403**	0.117*	0.065	0.236	0.196	0.026
Grains/spike	42.554	29.304**	23.289*	11.647	1.152	10.252	5.821
1000-grain weight	62.494**	8.220**	1.990*	0.471	4.544	4.500	0.759
Biomass/plant	95.934	88.499**	59.006	36.472	0.751	28.467	9.767
Grain yield/plant	15.655	32.209**	14.582	11.343	1.324	12.116	1.621
Drought stress conditions							
Stomatal frequency	76.180**	9.941*	7.880	4.942	5.533	2.903	1.469
Leaf venation	0.746**	0.109	0.101	0.087	0.053	0.013	0.007
Flag leaf area	11.165**	0.625	0.668	0.882	0.878	-0.149	0.007
Specific flag leaf weight	5.606**	0.448*	0.282*	0.204	0.430	0.142	0.039
Days to heeding	135.768**	2.639**	1.032	0.912	11.099	1.003	0.060
Tillers/plant	1.112	0.976**	0.326	0.343	0.013	0.368	-0.009
Plant height	90.197**	8.637	6.116	5.296	6.889	1.942	0.412
Spike length	3.747**	0.243**	0.097	0.063	0.292	0.105	0.017
Grains/spike	54.230	22.190**	8.186*	4.334	2.718	10.368	1.926
1000-grain weight	81.935**	5.364**	1.220	0.998	6.393	2.535	0.111
Biomass/plant	48.640**	9.702**	5.701**	2.332	3.265	4.279	1.684
Grain yield/plant	6.601**	2.085**	0.839*	0.466	0.381	0.940	0.186

*,**: Significant at 5 and 1 percent probability levels, respectively

Table 3: Mean periormamces (in parentheses) and osurnotes of (Ica effects for morpna morpho-physiological characters in bread wheat under irrigated and dought stress conditions

Traits	Irrigated conditions							Dought stress conditions						
	Pak 81	LU265	Inqlab 91	Rohtas 90	4072	4943	SE/g (LSD)	Pak-81	LU265	Inqlab 91	Rohtas 90	4072	4943	SE/g (LSD)
Stomal frequency	4.07	-0.755	2.248	3.596	1.581	1.118	0.543	2.0'5	9.515	2.175	-3.520	0.042	3.209	0.585
	(92.53)	(80.13)	(77.47)	(77.00)	(88.67)	(83.60)	(5.88)	(103.22)	(101.82)	(99.53)	(97.42)	(100.52)	(05.50)	(6.27)
Leaf venation	0.217	0.331	0.02	-0.044	0.258	7.159	0.083	0.195	0.485	0.077	0.014	0.176	0.023	7.078
	(12.83)	(11.03)	(11.87)	(2.93)	(12.57)	(12.13)	(0.89)	(15.33)	(14.05)	(75.20)	(15.50)	(15.49)	(15.01)	(0.083)
Flag leaf area	-0.414	0.799	0.24	2.236	1.765	0.327	0.423	0.397	0.897	-0.292	1.667	0 694	0 241	0 248
	(40.75)	(38.52)	(38.73)	(37.57)	(39.37)	(47.52)	(5.60)	(15.23)	(77.76)	(15.55)	(13.15)	(15.63)	(16.58)	(2.65)
Specfic flag leaf weight	(19.40)	0.797	1.308	-0.423	-0.443	-0.750	0.151	0.559	0.860	0.384	-7.618	0.736	0.301	0.119
	(19.40)	(22.3)	(22.44)	(19.49)	(19.02)	(8.79)	(1.72)	(18.00)	(15.50)	(17.40)	(15.40)	(18.10)	(15.55)	(1.27)
Days to heading	1.749	3.539	0.558	0.916	1.779	0.139	0.183	2.059	5.191	0.595	1.511	3.194	0.176	0.252
	(14.33)	(106.33)	(109.00)	(112.57)	(116.00)	(109.33)	(1.95)	(110.00)	(92.57)	(103.67)	(109.00)	(113.00)	(105.33)	(2.69)
Tillers/plant	-0.714	0.217	0.645	0.978	0.306	0.335	0.175	0.115	0.279	0.001	0.504	-0.327	0.006	0.154
	(13.00)	(12.93)	(15.20)	(13.57)	(12.80)	(13.47)	(1.45)	(7.73)	(8.80)	(7.97)	(8.67)	(8.07)	(8.47)	(1.65)
Plant height	0.727	0.541	0.673	-5.023	2.549	2.317	0.386	2.169	0.595	0.541	5.474	0.983	1.083	0.606
	(108.47)	(106.13)	(105.33)	(94.33)	(114.27)	(112.73)	(4.13)	(79.77)	(76.53)	(75.73)	(63.33)	(79.80)	(77.27)	(6.49)
Spike length	0.268	0.208	0.764	-0.741	-0.197	0.234	0.059	0.168	-7.788	0.905	0.762	0.086	0.299	0.086
	(12.87)	(13.53)	(14.33)	(11.47)	(12.40)	(13.53)	(0.72)	(11.33)	(11.47)	(11.67)	(10.07)	(11.67)	(12.27)	(0.71)
Grains/spike	1.506	2.379	0.192	2.531	0.336	1.802	0.899	1.090	3.755	1.771	-7.273	0.861	1.315	0.549
	(83.40)	(66.00)	(71.40)	(75.80)	(74.60)	(73.33)	(9.63)	(55.27)	(44.80)	(59.80)	(53.13)	(57.47)	(56.50)	(5.87)
1000-grain weight	0.541	3.114	0.538	3.847	-0.080	0.915	0.191	0.124	3.400	0.925	4.586	7.742	-0.358	0.253
	(42.51)	(52.25)	(43.55)	(37.27)	(42.82)	(47.77)	(1.94)	(34.78)	(43.74)	(34.56)	(25.23)	(35.71)	(33.22)	(2.82)
Biomass/plant	-1.523	0.274	5.589	-0.894	0.587	2.211	1 656	1.990	0.554	2.575	-2.926	0.204	0.859	0.402
	(84.13)	(79.77)	(87.30)	(65.47)	(79.53)	(79.17)	(17.72)	(36.00)	(36.67)	(38.00)	(26.00)	(37.00)	(34.57)	(4.31)
Grain yeild/plant	-1.19	0.441	1.929	0.213	-0.402	0.991	0 588	0.523	0.278	0.828	1.279	-0.085	0.255	0.180
	(39.41)	(37.08)	(39.50)	(30.30)	(34.43)	(35.50)	(9.50)	(12.37)	(14.15)	(12.55)	(8.50)	(13.29)	(12.24)	(1.93)

Table 4: Promising parents and crosser with significant sea effects for gram veld and other morpho-physiolomcal traits in bread wheat under irrigated and drought stress conditions

Traits	Irrigated conditions					Drought stress conditions				
	Best parent based on		Crosses	Sea	F_1 mean	Best parent based on		Crosses	sca	F_1 mean
	gca	Per se performance				gca	Per se performance			
Stomatal frequency	Rohtas 90	Rohtas 90	LU26sxIng. 91	2.188	77.60	Rohtas 90	Rohtas 90	LU26sxIng	2.992	95.61
	Inqlab 91	Inqlab 91	Pak81x4943	1.579	83.00	Inqlab 91	Inqlab 91	Pak81x4943	2.011	102.61
	LU26s	LU26s	Pak81xRoh90	1.535	81.13	1072	4943	Pak81xRoh90	1.222	95.85
Leaf venation	4072	Rohlas 90	1.13265x4072	0.407	72.53	Pak.91	Rohlas 90	Pak 81xLU255	0.457	15.44
	Pak.81	4072	Pak 81xtnq 91	0.242	12.47	4072	4072	Rob 90x4943	0.271	96.45
	Inqlab 91	Pak. 81	Inq 91x4943	0.213	12.10	Inqlab 91	Pak.81	4072x4943	0.139	15.27
Fag leaf area	4072	Pak 81	4072X4943	2.559	47.47	LU26s	4072	LU255xlna 91	0.880	18.25
	LU25s	4943	Inq 91X4972	2.546	45.87	4072	Pak 51	LU26SxRon 90	0.670	113.61
	4943	4072	Ron 90x4072	2.327	43.62	Pak.51	LU255	Pak 81xRah 90	0.520	77.12
Specific flag leaf weight	Inqlab 91	Inglats 91	Pak 81X139 91	0.551	21.37	4072	4072	Pak 51X4943	0.701	17.77
	LU26s	LU26s	Inq 91xRah 90	0.444	20.98	Pak.91	Pak.81	Roh 90X4072	0.526	18.15
	Rohlas 90	Rohtas 90	Inq 91X4072	0434.00	22.46	Inqlab 91	Inqlab 91	Inc 91X4943	0.521	16.80
Days to heading	LU26s	LU26s	LU26sxRoh 90	-1.748	106.57	LU26s	LU26s	4072x4943	2.488	114.57
	4943	4943	Pak 81xImo 91	1.054	110.33	4943	4943	LU26sX4072	1.297	109.00
Tillers/plant	Rohlas 90	Inqlab 91	LU26SxRon 90	1.542	15.43	Rohtas 90	LU26s	Pak 81xRoh 90	0.555	8.20
	Inqlab 90	Rohtas 91	Pak 81xlna 91	1.072	14.20	Pak.81	Rohtas 90	4072x4943	0.393	7.50
	LU26s	Pak.81	LU26Sx4072	0.459	11.57	4943	4043	Inq 91xRoh 90	0.285	8.20
Plant height	Rohlas 95	Rohtas 90	LU26sx4943	2.075	103.90	Rohlas 90	Rahtas 90	Roh 90x4072	1.233	70.93
	LU26s	Inqlab 91	Pak 81x4072	2.062	108.93	LU26s	Inqlab 91	Inq91X4072	0.744	51.07
	Inqlab 91	LU266	Pak 81xLU255	0.751	108.57	Inolab 91	LU26s	LU26sx4943	0.441	82.87
Spike length	Inqab 91	Inqlab 91	Pak 81xLU26s	0.521	14.57	Inqlab 91	Inqlab 91	Pak 81xlnq 91	0.547	12.80
	4943	4943	LU26sxRoh 90	0.500	14.07	4072	4072	Ing.51xRah 90	0.343	13.00
	LU26s	LU26S	Inq 91x4072	0.405	74.57	4943	4943	4072x4943	0.338	12.93
Grains/spike	Rohtas 90	Pak.81	Inq 91xRoh 90	4.309	81.43	Inqlab 91	Inqlab 91	Pak 81xLU26s	5.794	51.93
	Pak.81	Rohlas 90	LU26sx4072	3.704	83.80	4943	Rahtas 90	4072x4943	3.826	51.87
	4072	4072	LU26sxOnq 91	3.315	52.97	Pak.81	4072	Inq 91XRoh 90	3.739	63.07
1000-grain weight	LU26s	LU26s	Inq 91x4072	3.350	51.08	LU26s	LU26s	Inq 91X4072	3.100	42.55
	4943	4943	Pak 81xlng 91	2.566	48.43	Inqlab 91	4072	Pak 81XInq 91	1.886	35.46
	Inqlab 91	4072	Pak 81x4943	1.719	50.26	4072	Inqlab 91	Roh 90X4943	1.661	33.50
Biomass/plant	Inqlab 91	Inqlab 91	Pak.81xInq 91	9.787	99.29	Inqlab 91	Inqlab 91	Pak 81xLU26s	3.359	40.30
	LU2136	Pak.81	LU26sxRah 90	8.256	90.70	Pak.81	4072	Inq 91xRon 90	2.651	37.67
	4072	LU26s	LU26sx4072	7.314	86.97	4072	LU255	Inq 91x4072	1.589	41.33
Grain yield/plant	Inqlab 91	Pak.81	LU26sxRoh 90	5.429	45.95	Inqlab 91	LU26s	Pak 81xLU26s	1.551	15.29
	LU255	Inqlab 91	Pak 81xlnq 91	5.905	45.74	Pak 81	4072	Inq 91xRoh 90	1.516	13.51
	Rohtas 90	LU255	4072x4943	5.047	46.57	1o295	Inqlab 91	4072X4943	1.172	13.94

observed for specific flag leaf weight, days to heading, plant height, spike length and 1000-grain weight under both environments. These traits also showed the partial dominance type of gene action under both environments (Iqbal *et al*., 1991; Chowdhry *et al*., 1992; Khan *et al*., 1992). Flag leaf area, tillers per plant, grains per spike, biomass per plant and grain yield per plant were controlled by over dominance. Similar finding were reported by Lonts and Lone (1984), Alam *et al*. (1991), Iqbal *et al*. (1991) and Prodanovic (1993) who also reported the over dominance for these traits.

Combining ability analysis: The general combining ability (gee) mean squares were significant ($p<0.05$) for all traits except flag leaf area, grains per spike, biomass per plant and grain yield per plant (Table 3). Whereas specific combining ability (sca) mean squares was significant for all traits except stomata! frequency and specific flag leaf weight. The mean squares due to general combining ability were higher than the mean squares for specific combining ability for all traits, indicating the prevalence of additive gene action for these characters with the exception of grain yield per plant under irrigated conditions where non-additive effects appeared more important. Similar results were also reported by Khan and Bajwa (1990), Li *et al*. (1991) and Chaudhry *et al*. (1992, 1994). General combining ability variance was higher than specific combining ability variance for stomatal frequency, specific flag leaf weight, days to heading, plant height, spike length, and grains per spike under irrigated conditions (Table 3). The separation of general combining ability effects by the standard error (g,) are given in Table 4, Inglab 91 had consistently the highest general combining ability effects for specific flag leaf weight, spike length, biomass per plant and grain yield per plant. Variety LU26S had also highest values for 1000-grain weight and specific flag leaf weight. Whereas Rohtas 90 showed maximum general combining ability for tillers per plant and grains per spike under irrigated conditions (Table 4). These varieties were good general combiner for those traits which show maximum general combining ability effects. Promising parents and sca effects of the crosses for grain yield and other morpho-physiological traits under irrigated conditions are presented in Table 4. Crosses LU26S × Roh 90 and Pak81 × Inq; 91 had high and significant sca effects for grain yield per plant, 1000-grain weight, spike length, tillers per plant and days to heading under irrigated conditions. Although the cross 4072 × 4943 with highest sca effects for grain yield per plant and high grain yield per plant also had high sca effects for flag leaf area. Most of the crosses with high sca had at least one high sca parent. However, some of the crosses with high sca had one or both parent with average gca (Singh and Chatrath, 1997).

Significant general combining ability mean squares (Table 3) were obtained for all characters revealed a greater involvement of additive effects in their inheritance except in the case of tillers per plant, grains per spike that produced insignificant results. Khan and Bajwa (1990), Li *et al*. (1991) and Chaudhry *et al*. (1992, 1994) reported similar results, as were found in the present study under drought stress conditions.

General combining ability variance was higher than specific combining ability variance for all the traits except tillers per plant, grains per spike, biomass per plant and grain yield per plant (Table 3), indicating the additive gene action for these traits under drought stress conditions. All varieties/genotypes had high mean values for these traits, indicating that selection among progeny should produce good responses. In case of drought stress conditions variety Pak 81 was good general combiner only for plant height (Table 3). Whereas variety LU26S was good general combiner for 1000-grain weight and grain yield per plant. Variety Inqlab 91 was good general combiner for spike length, grains per spike and biomass per plant. Variety Rohtas 90 was only good combiner for tillers per plant. Genotype 4072 was good general combiner for flag leaf area, specific flag leaf weight and days to heading. In contrast to irrigated conditions genotype 4943 was good general combiner for stomatal frequency under drought stress conditions. Crosses Pak 81 × LU26S, Inq 91 × Roh 90 and 4072 × 4943 had high sca effects for grain yield per plant, biomass per plant, grains per spike, spike length and tillers per plant under drought stress conditions (Table 4). Most of the crosses with high sca effects for grain yield and other morpho-physiological traits had at least one high gca parent. However, some of the crosses with high sca had one or both parent with average gca (Singh and Chatrath, 1997).

It is obvious from the present results that the cross Pak. 81 × LU26S showed specific combination for leave venation, spike per length, grains per spike, biomass per plant and grain yield per plant under drought stress conditions. Whereas under irrigated conditions Pak. 81 × Inqlab 91, LU265 x Rohtas 90 and LU26S × 4072 were specific crosses for most of the traits. The cross Inglab 91 × 4072 had maximum specific combining ability effects for 1000-grain weight under both environments.

The best performing cross may be produced by crossing the two parents showing the highest general combining ability. For example under irrigated conditions, LU26S and Inglab 91 had the lowest general combining ability estimates for days to heading and plant height and highest estimates for spike length, and grain yield. Their cross is expected to produce a population with less days to heading, dwarf plants and with improved grain yieid. Populations that reveal high general combining ability estimates are good candidates to be used as parents in a population improvement programme (Baker, 1978). Under drought stress conditions Pak. 81 × Inqlab 91 cross is expected to produced a population with improved biomass and grain yield.

General combining ability was found to be more important than specific combining ability for most of the traits except grain yield per plant under both environments. The presence of predominantly large amount of non-additive gene action for grain yield would necessitate the maintenance of heterozygosity in the population. Such genetic variability is non-fixable, The superior parents with high combining abilities have been used extensively in a breeding programme for widening the genetic base of the breeding material.

In conclusion, it may be stated that the diallel cross evaluated by different methods including the analysis of variance and genetic components analysis has yielded identical or comparable information on genetic structure of the characters studied. Adequacy test satisfied the additive dominance model. Genetic components were also computed for those traits who were partially fulfilled the assumptions for the validity of the additive dominance model. Invariably, in the present study additive genetic effects were found to be more important than nonadditive effects with the exception of grain yield per plant which appeared to be more closely linked to nonadditive genetic effects. Since the yield components like grains per spike, 1000-grain weight, tillers per plant were found to be significantly influenced by additive gene action, further progress in genetic improvement of. the yielding ability of wheat varieties may be attempted through such yield-related characters, with much better prospects of fixing desirable genes in a single homozygote.

References

Alam, K., M.A. Chowdhry and M.M. Asad, 1991. The inheritance of protein content, grain yield and its components in bread wheat (*Triticum aestivum* L. em. Thell.). Gomal Univ. J. Res., 11: 45-52.

Baker, R.J., 1978. Issues in diallel analysis. Crop Sci., 18: 533-536.

Chaudhry, M.H., A. Sattar, G.M. Subhani and G.S. Khan, 1992. Combining ability estimates in spring wheat (*Triticum aestivum* L.). J. Agric. Res., 30: 153-160.

Chaudhry, M.H., G.M. Subhani, F.A. Khan, M.A. Ali, N. Khan and A. Sattar, 1994. Combining ability analysis of physiological and agronomic traits of wheat. J. Agric. Res., 32: 227-233.

Chowdhry, M.A., M. Rafiq and K. Alam, 1992. Genetic architecture of grain yield and certain other traits in bread wheat. Pak. J. Agric. Res., 13: 216-220.

Griffing, B., 1956. Concept of general and specific combining ability in relation to diallel crossing systems. Aust. J. Biol. Sci., 9: 463-493.

Hayman, B.I., 1954. The theory and analysis of diallel crosses. Genetics, 39: 789-809.

Iqbal, M., K. Alam and M.A. Chowdhry, 1991. Genetic analysis of plant height and the traits above flag leaf node in bread wheat. Sarhad J. Agric., 7: 131-134.

Khan, M.Q., K. Alam and M.A. Chowdhry, 1992. Diallel cross analysis of some morphological traits in spring wheat. Pak. J. Agric. Res., 13: 211-215.

Khan, N.I. and M.A. Bajwa, 1990. Evaluation of potentialities of spring wheat parents and crosses for important agronomic and pathological traits. Pak. J. Agric. Res., 11: 147-153.

Li, L.Z., D.B. Lu and D.Q. Cui, 1991. Study on the combining ability for yield and quality characters in winter wheat. Acta Agric. Univ. Henanensis, 25: 372-378.

Lonts, V. and W. Lone, 1984. Modes of action of genes for agronomically important characters in winter wheat. Acta Univ. Agric. Brno A (Fac. Agron.), 32: 369-374.

Mather, K. and J.L. Jinks, 1982. Introduction to Biometrical Genetics. Chapman and Hall Ltd., London.

Prodanovic, S., 1993. Genetic values of F_1 wheat hybrids obtained in diallel crosses. Rev. Res. Work Fac. Agric., 38: 25-37.

Singh, K. and R. Chatrath, 1997. Combining ability studies in bread wheat (*Triticum aestivum* L. Theil.) under salt stress conditions. Indian J. Genet. Plant Breed., 57: 127-132.

Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics: A Biometrical Approach. 2nd Edn., McGraw Hill Book Co., New York, USA., ISBN-13: 9780070609266, Pages: 633.

Wilson, N.D., D.E. Weibel and R.W. McNew, 1978. Diallel analyses of grain yield, percent protein and protein yield in grain sorghum. Crop Sci., 18: 491-495.