Estimation of Heterosis, Heterobeltiosis and Potence Ratio Over Environments Among Pre and Post Green Revolution Spring wheat in Pakistan

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Abstract: Globally wheat trade has a major and impacting role in political and economic relationships between nations. Twelve pre-green revolution and post green revolution wheat genotypes viz., Sehr-06, Pasban-90, C-273, Pari-73, SA-42, Fsd-08, Chenab-70, Blue Silver, Lasani-08, Pak-81, Uqab-2000, and Pothowar-73 and their direct and reciprocal crosses were evaluated. The study concluded significant differences and highest values in heterosis, heterobeltiosis and potence ratio were found among genotypes and their cross combinations for pollen viability (Sehr-06 × Blue Silver), flag leaf area (SA-42 × Fsd-08), number of grains per spike (Pak-81× Lasani-08) and grain yield plant^{-1} (Chenab-70 × Fsd-08). Under changing climatic condition and limited water provision an amalgamation of pre-green revolution and post green revolution may provide a genetic diversity to break the stagnant yield barrier to ensure food security.

Keywords: Genetic diversity, pollen viability, grain yield, direct, reciprocal.

INTRODUCTION

Wheat (*Triticum aestivum* L)) is grown almost all over the world; from Russian Federation, China, the U.S., India, Australia, and Turkey, Pakistan, North Africa, the Near and Middle East, Italy, France and some areas of Canada it is grown successfully [1]. However in developing countries it is considered as the cheapest source of daily diet. Wheat is a staple food item of Pakistani people; therefore, it is grown in almost every part of the country. It contributes 13.1 percent to the value added in agriculture and 2.8 percent to GDP [2]. Historically it is grown in different parts of geographical centers nearly 10,000 years [3]. Wheat the primarily used for making chapatti, and lot of other fast food items which are more commonly liked to eat by Pakistani community, usually three times a day especially in rural areas. Its multidimensional uses, height of nutrition, efficient storage qualities and easy asses to poor and rural communities have made it an eternal food world's burgeoning population [4]. Wheat is a rich source of essential human diet ingredients like 70% carbohydrates, 12% protein, 22% crude fibers, 2% fat, 12% water and 1.8% minerals. The estimated quantum of wheat production is 23864 million tons which shows 0.7 % decline than last year [5]. Wheat is also used as multiple food and nonfood raw material in some industries such as stiffening or surface coating agent in paper industry, as an adhesive in the manufacturing of corrugated boxes, as fermentation substrate, in the production of vitamins, antibodies, etc. [6, 7].

Pakistan is almost self-sufficient in wheat production but unluckily per acre yield is still less than neighboring and other wheat producing countries, having lot of reasons, one of which is poor water management [8]. Rapidly increasing population of Pakistan is also a serious threat towards our wheat breeding programs to amplify per acre yield. The quantum jump in research and development and evolution of new wheat genotypes decorated with high yield potential, early maturity and stress tolerance, which can plug our prospect need gaps [9]. The major limiting factors in food production throughout the world as well as in Pakistan are environmental stresses. No part of world is fully protected against environmental stresses which shared as (71%) of yields reductions [10]. Heterosis is considered as the best tool to increase or break the yield barriers [11]. This strategy was common in cross pollinated crops but it can also be a beneficial approach for self-pollinated crops like wheat [12]. Under the changing climatic conditions, water will be the most important factor in our crop production system [13, 14]. Plant breeders will have to evolve such type of varieties which can bear water stress condition without losing its yield potential [15, 16] because the growth and development of wheat grain merely reliant on its assimilates [17-19]. The pre-green revolution wheat varieties are considered a broad based genetic architecture and full of resistance against

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environmental stresses [20, 21]. Keeping in view this study was initiated to estimate the hidden level of heterosis, heterobeltiosis and potence ratio of some representative genotypes and their further crosses to assess their level of water stress tolerance.

MATERIALS AND METHODS

The study comprising both field as well as pot experiment was conducted at the research area of University College of Agriculture, University of Sargodha during the crop season 2009-2011.Twelve wheat genotypes (is these genotypes or cultivars?) comprising pre-green revolution and post green revolution were collected from Ayub Agricultural Research Institute (AARI), Faisalabad, Pakistan namely, C-273, Chenab-70, Pothowar-73, Pasban-90, Pari-73, Blue Silver, Pak-81, Sehr-06, SA-42, Fsd-08, Uqab-2000 andLasani-08. The pedigree is given in (Table **1**). All genotypes were sown by adopting recommended production package (plant to plant and row to row distance 15cm and 30 cm) respectively [22, 23] on 15th of October, 2010. After 110 days after sowing (DAS) the direct crosses and their reciprocal crosses were made to get F_1 hybrids like, Sehr-06 × Pasban-90,Pasban-90 × Sehr-06, C-273 × Pari-73, Pari-73 × C-273, SA-42 × Fsd-08, Faisalbad-2008 × SA-42, FS-08 × Chenab-70, Chenab-70 × FS-08, Sehr-06 × Blue Silver, Blue Silver × Sehr-06, Lasani-08 × Pak-81, Pak-81 × Lasani-08, Uqab-2000 × Pothowar-73, Pothowar-73 × Uqab-2000, Pak-81 × Pasban-90, Pasban-90 × Pak-81. In next crop season (2010-11) the parents and F_1 hybrid crosses were sown in pots with two treatments (Normal irrigation and water stress) and three replications using completely randomized design. To save from animal and rain water the pots were placed under net, easy to cover with water proof polythene sheet. After 163 DAS, at maturity the data was recorded.

1. Gametophytic Resistance Against Water Stress

Pollen viability or fertility was used as an index of drought resistance. Pollen from parental and hybrids were collected to ascertain pollen fertility at flowering stage (110 DAS). Pollens from water stress treatment each selected plant were collected and placed on glass slide and stained with aceto-carmine 1%. These pollens were kept under examination at 10x microscope. Fertile pollen grains were turned into black colour, while sterile pollen grain remained colorless. Number of sterile pollens was counted to determine the sterility due to stress.

2. Flag Leaf Area (cm^2)

When the leaves were fully turgid at booting stage in the morning hours, the mother shoot leaves were collected from selected plants. Maximum length and width was recorded. Then flag leaf area was measured by using the formula given by [24].

Flag leaf area = Maximum width × length × 0.74

3. Number of Grains Per Spike

The spike of the selected plants was harvested and threshed manually to get the grains. These grains were then counted for further analysis.

4. Grain Yield Per Plant (g)

Each selected plant was harvested manually, threshed and grains obtained were kept separate in bags which were labeled to avoid mixing of the grains of different plants. The grains were weighed by the help of an electronic balance.

5. Harvest Index %

Harvest index is the ratio of economic yield to total biomass of the crop plant. Harvest index for each of the genotype was computed using the following formula:

Harvest index=,grain yield per plant-biomass of the plant. x 100

Analysis of Variance

Statistical analysis was done by using the analysis of variance technique in completely randomized design with two factors i.e., genotypes and water regimes [25]. Significant differences were further subjected to least significance difference test (LSD). The percent increase or decrease of F_1 hybrids over mid parent as well as better parent value was calculated to estimate possible heterotic effects following [24].

%age Ht=F-1.−M.P-M.P. × 100

%age Hbt=F-1.−B.P-B.P.×100

Where, Ht = Heterosis, Hbt = Heterobeltiosis, M.P = Mid Parent Value, B.P= Better parent Value,

Potence Ratio

To estimate the dominance behavior, the potence ratio was determined by the formulae: Potence ratio=,,F-1.–M.P-B.P–M.P.‘ and t’ Test, was manifested to determine whether F_1 hybrid means were

Table 1: Pre-Green Revolution and Post Green Revolution Selected Wheat Varieties Pedigree

Wheat varieties	Parentage	Research Institute/Station	Year of Release
C273	C209/C591	Punjab.Agri.C.Res.Inst.Lyallpur	1957
Chenab 70	C271-WT(E)//SON 64	AARI.Faisalabad	1970
SA 42	C271-LR64/SON 64	-do-	1971
Blue Silver	II-54-388-AN(YT.54-N 10B/LR 64)	RARI, Bahawalpur	1971
Pothowar	114B-35/NAD 63	-do-	1973
Pari 73	CNO'S'//SON/KL.REND/M.PAK	-do-	1973
Pak-81	KVZ/BUHO//KAL/BB	-do-	1981
Pasban-90	INIA66/A.DISTT//INIA66/3/GEN81	WRI, Faisalabad	1990
Uqab-2000	CROW'S'/NAC//BOW'S'	WRI, Faisalabad	2000
Lasani-08	LUAN/KOH-97	WRI, Faisalabad	2008
Faisalabad-08	PBW62/2*PASTOR	WRI, Faisalabad	2008
Sehr-06	CHILL/2*STAR/4/BOW/CROW//BUC/PVN/3/	WRI, Faisalabad	2006

Source. CIMMYAT.

statistically different from mid parent and better parent value. The t-value for heterosis was calculated following the formula: tij = F1ij – M.P ij (3/8 EMS)1/2While The t-value for heterobeltiosis was calculated following the formula: tij = F1ij – B.P ij (1/2 EMS)1/2

Where F1 ij = The Mean of the ij^{th} F_1 cross, M.P ij = The mid parent for the ij^{th} cross

B.P ij = The better parent values for ij^{th} cross, EMS = Error mean square

RESULTS AND DISCUSSIONS

The analysis of variance for pollen viability is shown in Table **2** which indicated highly significant (P≤0.01) differences among the genotypes and due to parents, crosses and parents vs. crosses. The individual comparisons of means of all the genotypes indicated that among the parents the genotype SA-42 has the highest percentage for pollen sterility and the parent the genotype Lasani-08 showed the lowest percentage for pollen sterility. Among the F_1 hybrids the cross SA-42 × Fsd-08 has shown the highest percentage for pollen sterility and cross Sehr-06 × Pasban-90 has shown the lowest percentage for pollen sterility. Heterosis for pollen sterility of the crosses showed (Table **3**) the significant increase over their mid parents and thus showed significant heterosis (P≤0.05).

Better parents were considered having lower mean value for pollen sterility. Negative heterosis was considered to be superior. The highest negative heterosis and heterobeltiosis for pollen sterility was shown bySehr-06 × Blue Silver. Therefore, this cross has shown the highest tolerance against water stress. The potency ratios of all the crosses are explained in Table **6**. Eleven crosses showed heterosis due to over dominance effect. Other crosses showed partial or no dominance effect. Gametophytes are known to be highly sensitive to the water stress in wheat and other crop species [27]. Therefore they may be considered as marker of drought tolerance or water stress

Table 2: Analyses of Variance for Pollen Viability

SOV	df	SS	MS	F-Cal
Genotypes	27	5219.48	193.31	25.38**
Parents	11	1938.02	176.18	23.13**
Crosses	15	3183.12	212.21	27.86**
P vs. C	1	98.34	98.34	12.91**
Error	56	426.54	7.62	

Where **= (P≤0.01) Highly significant.

Table 3: Estimation of Percent Heterosis and Heterobeltiosis for Pollen Viability in Wheat Under Water Stress Condition

Crosses	Maternal	Paternal	M.P	B.P	F_1	Heterosis	Heterobeltiosis
Sehr-06 × Pasban-90	35.37	26.00	30.69	35.37	38.83	26.52*	9.78NS
Pasban-90 × Sehr-06	26.00	35.37	30.69	35.37	39.60	29.03*	11.95*
C-273 × Pari-73	38.03	41.85	39.94	41.85	48.78	22.14*	16.56*
Pari-73 × C-273	41.85	38.03	39.94	41.85	49.03	22.76*	17.16*
SA-42 × Fsd-08	50.59	36.92	43.75	50.59	52.42	15.24*	3.61*
Fsd-08 × SA-42	36.92	50.59	43.75	50.59	45.56	4.13NS	-9.94*
Fsd-08 × Chenab-70	36.92	40.77	38.84	40.77	49.75	28.08*	22.02*
Chenab-70 × Fsd-08	40.77	36.92	38.84	40.77	42.53	9.49*	4.31*
Sehr-06 × Blue Silver	35.37	45.40	40.38	45.40	23.73	-41.23*	-47.73*
Blue Silver × Sehr-06	45.40	35.37	40.38	45.40	32.68	-19.07*	-28.01*
Lasani-08 × Pak-81	22.27	35.47	28.87	35.47	38.44	33.14*	8.37*
Pak-81 × Lasani-08	35.47	22.27	28.87	35.47	42.24	46.31*	19.08*
Uqab-2000 × Pothowar-73	38.09	40.51	39.30	40.51	42.93	9.22*	5.97*
Pothowar-73 × Uqab-2000	40.51	38.09	39.30	40.51	42.74	8.74*	5.50*
Pasban-90 × Pak-81	26.00	35.47	30.74	35.47	28.41	-7.55*	-19.90*
Pak-81 × Pasban-90	35.47	26.00	30.74	35.47	37.00	20.37*	4.31*

*Significant, NS=Non-significant; M.P=Mid Parent, B.P=Better Parent; Least significant differences among the mean value of parents and F_1 4.52.

sensitivity [28]. Results of the present study showed significant differences among the wheat parents for pollen sterility indicating differential tolerance role for water stress. Previous studies have also shown significant differences among the genotype for pollen sterility [29]. When parents were mated they produced a few hybrids with significant low mean value for pollen sterility which was also indicated from significant negative heterosis manifested by the crosses showing feasibility for the development of drought tolerant hybrids. When the pollen sterility % and yield per plants of hybrids was regressed, it gave significant negative relationship (R^2=0.34) among the two traits showing that selection for the lower pollen sterility would also enhance yield and high yielding genotypes may be selected through lower pollen sterility under water stress conditions.

Flag Leaf Area

Flag leaf area has a major role in the nourishment of the spike as it carries out the highest photosynthetic activity. Plant breeders generally prefer for the

Table 4: Analyses of Variance for Flag Leaf Area (FLA), Grains Per Spike (GS), Grain Yield Per Plant (GYP) and Harvest Index (HI)

SOV	df	FLA	GS	GYP	HI
Genotypes (G)	27	45.96**	110.69**	0.10**	435.02*
Parents (P)	11	37.64**	144.15**	0.11**	287.08NS
Crosses (Cr)	15	27.79**	89.24**	0.09**	321.12 NS
P vs. Cr	1	410.06**	64.29NS	0.04NS	3770.74*
Water Regimes(W)	1	2446.03**	7072.02**	17.53**	49646.78**
G × W	27	23.30*	166.90**	0.11**	343.79 NS
P × W	11	12.24NS	113.48**	0.09**	176.15 NS
Cr × W	15	20.29NS	192.74**	0.13**	402.21 NS
P vs. Cr × W	1	190.07**	366.87**	0.08*	1311.64 *
Error	112	11.98	22.29	0.02	272.94
Total missing					

Genotypic differences were highly significant (P≤0.01).

ideotypes, having higher flag leaf area. The analysis of variance for flag leaf area (Table **4**) showed highly significant (P≤0.01) differences among the genotypes and due to its components i.e., parents, their hybrids and the contrast between parents and crosses. Highly significant differences were shown (P≤0.01) between water regimes and interaction between genotype × water regimes. However there were non-significant variation (P≥0.05) due to parents × water regimes and crosses × water regimes. Individual comparisons (Table **5**) showed that the parent genotype Pak-81 showed the highest mean value for flag leaf area, while the parent genotype Lasani-08 showed the lowest mean value for this trait. Among the crosses, Pasban-90 × Pak-81 showed the highest flag leaf area while the lowest value was shown by Sehr-06× Blue Silver for this trait. Five crosses showed an increase over mid parental values with significant (P≤0.01) positive heterosis (Table **5**).

The potency ratios are depicted in Table **7**. Eleven crosses showed over dominance effect and the range of over dominance is from -1.14 (Pothowar-73 × Uqab-2000) to -9 (Blue Silver × Sehr-06). Blue Silver × Sehr-06 and SA-42 × Fsd-08 have great potential to be used in breeding for flag leaf area as it showed the highest values of heterosis and heterobeltiosis [30, 31]. Despite significant variation among the parents and hybrids, performance of the genotypes was not significantly affected by the contrasting water regimes as indicated from non-significant (P ≥ 0.05) genotypes × water regimes, parents × water regimes and crosses × water regimes [32] also found non-significant ranking among the wheat genotypes for yield components such as flag leaf area due to treatments. This showed that parents and crosses ranking was not changed significantly over the contrasting water regimes indicating that genotypes may have buffering capacity that resist the change in the mean value over various water regimes for this trait [32, 33].

Grains Per Spike

It is also a very important trait that affects the grain yield of any genotype. The analysis of variance for number of grains per spike (Table **4**) showed that overall genotypes are highly significant (P≤0.01) due to its components parents and crosses but the contrast between parents vs. crosses gave non-significant (P≥0.05) results. Highly significant variation (P≤0.01) was found between the water regimes due to contrast × genotype, parents, crosses and crosses × water regimes. Among the F_1 hybrids Sehr-06 × Blue Silver has the highest value for this trait and SA-42× Fsd-08

Table 5: Mean Performance of Parental Lines, Hybrids and Estimation of Percent Heterosis, Heterobeltiosis and Potency Ratio for Flag Leaf Area in Wheat

Crosses	MAT	PAT	F_1	HT	HB	PR
Sehr-06 × Pasban-90	10.50	12.16	12.72	27.54 ^{NS}	16.63 ^{NS}	1.67
Pasban-90 × Sehr-06	12.16	10.50	12.32	50.69 ^{NS}	37.79 ^{NS}	-1.17
C-273 × Pari-73	13.50	11.50	12.20	13.95 ^{NS}	-0.78 ^{NS}	0.29
Pari-73 × C-273	11.50	13.49	14.33	10.19 ^{NS}	-4.06 ^{NS}	1.83
SA-42 × Fsd-08	10.16	11.50	13.67	57.05*	41.43*	4.26
Fsd-08 × SA-42	11.50	10.16	11.28	11.88 ^{NS}	0.76 ^{NS}	-0.67
Fsd-08 × Chenab-70	11.50	13.00	14.63	47.72 ^{NS}	17.52 ^{NS}	3.17
Chenab-70 × Fsd-08	13.00	11.50	14.27	35.21 ^{NS}	7.57 ^{NS}	-2.68
Sehr-06 × Blue Silver	10.50	11.00	11.19	46.06 ^{NS}	16.25 ^{NS}	1.76
Blue Silver × Sehr-06	11.00	10.50	13.00	60.98*	28.12 ^{NS}	-9.0
Lasani-08 × Pak-81	8.66	15.16	14.14	45.82*	23.01 ^{NS}	0.68
Pak-81 × Lasani-08	15.17	8.66	15.16	28.97 ^{NS}	8.80 ^{NS}	-0.99
Uqab-2000 × Pothowar-73	11.66	13.99	12.57	21.86 ^{NS}	1.09 ^{NS}	-0.22
Pothowar-73 × Uqab-2000	14.00	11.66	14.17	32.68 ^{NS}	10.06 ^{NS}	-1.14
Pasban-90 × Pak-81	12.17	15.16	16.10	42.75*	17.50 ^{NS}	1.62
Pak-81 × Pasban-90	15.17	12.16	15.49	41.04*	16.10 ^{NS}	-1.21

MAT= Maternal, PAT= Paternal, F_1= First generation, HT= Heterosis, HB= Heterobeltiosis, PR=Potence Ratio, *=Significant, NS=Non-significant, M.P=Mid Parent, B.P=Better Parent, Least significant differences among the mean value of parents and F_1 ±(3.60).

Table 6: Mean Parental and Hybrid Performance Under Normal Irrigation and Water Stressed Conditions

Crosses	Parent	Parent	F_1	F_1	HTR	HTR	HBR	HBR
	N	WS	N	WS	N	WS	N	WS
Grains per spike (GS)	28.21	16.60	36.46	15.78	2.28-62.30	0.00--66.69	-10.20--16.87	-20.69--58.64
Grain yield per plant (GYP)	0.88	0.21	1.11	0.36	4.81-56.76	-15.15-246.67	-9.17-44.12	-40.43-76.92

Least significant differences among the mean value of parents and hybrids ± 2.72.
F_1= First generation, HTR= Heterosis range, HBR= Heterobeltiosis range, PR=Potence Ratio, N=Normal, WS= Water stress.

showed the lowest mean value for number of grains per spike in water stress condition. For heterosis over the mid parent under normal condition (Table **6**) seven crosses showed an increase over their respective mid parents. And all of them showed significant heterosis (P≤0.05). The heterosis value ranged from 18.13% (Sehr-06 × Pasban-90) to 62.30% (Pak-81× Lasani-08-08). As far as heterosis over better parent is concerned all the crosses showed non-significant results (P≥0.05) for this trait.

The potence ratio table for grains per spike (Table **7**) showed that almost all hybrids except two crosses showed heterosis due to over dominance effect. In water stress condition three crosses showed an increase over their mid parental values and the range of heterosis was from 41.24% (Pothowar-73 × Uqab-2000) to 66.69% (Sehr-06 × Blue Silver). Two crosses showed an increase over their respective better parents and significant positive heterobeltiosis (P≤0.05) over their respective better parents. The highest heterobeltiosis was shown by the cross Sehr-06 × Blue Silver. In water stress twelve crosses showed heterosis due to over dominance effect, other crosses showed no dominance effect. The highest value for over dominance effect was shown by Sehr-06 × Blue Silver. Number of grains per spike is the most important yield contributor in wheat. Studies have indicated the highest direct effect of this trait on grain yield per plant [34]. The highest heterosis and heterobeltiosis magnitude was available under water stress as compared to non-stress condition indicating the potential of hybrid wheat breeding for drought proned environment. Previous finding have shown the potential for wheat hybrids

Table 7: Potence Ratio for Pollen Viability (PV), Flag Leaf Area (FLA), Grains Per Spike (GS) and Grain Yield Per Plant in Wheat

Crosses	PV	FLA	GS	GS	GYP	GYP
	PR	PR	PRN	PRWS	PRN	PRWS
Sehr-06 × Pasban-90	0.60	1.67	1.19	4.25	0.85	1.22
Pasban-90 × Sehr-06	-0.83	-1.17	1.38	1.75	1.62	1.83
C-273 × Pari-73	-4.62	0.29	1.23	1.40	0.52	5.33
Pari-73 × C-273	-4.75	1.83	0.16	1.01	0.33	4.56
SA-42 × Fsd-08	-0.97	4.26	1.16	2.43	31.00	6.00
Fsd-08 × SA-42	-0.26	-0.67	1.68	4.51	26.67	3.17
Fsd-08 × Chenab-70	-5.68	3.17	1.15	1.44	1.62	7.00
Chenab-70 × Fsd-08	-1.92	-2.68	2.07	1.80	1.33	1.16
Sehr-06 × Blue Silver	3.32	1.76	0.78	13.04	1.67	1.83
Blue Silver × Sehr-06	1.53	-9.0	2.11	4.52	2.05	-0.31
Lasani-08 × Pak-81	-1.45	0.68	1.14	0.00	1.22	1.77
Pak-81 × Lasani-08	-2.02	-0.99	1.59	0.16	1.57	1.15
Uqab-2000 × Pothowar-73	-3.00	-0.22	1.07	6.35	0.85	5.00
Pothowar-73 × Uqab-2000	-2.84	-1.14	1.06	11.68	1.21	10.67
Pasban-90 × Pak-81	0.49	1.62	1.61	0.17	7.67	1.35
Pak-81 × Pasban-90	-1.32	-1.21	4.58	0.24	18.11	2.29

under water stress conditions [35]. Hybrids may be more suitable for stress environment because of their broad genetic base helping them to cope up the vagaries of the environment. Significant heterotic effects have been identified in crosses Sehr-06 × Blue Silver and Sehr-06 × Pasban-90. These crosses may be exploited for hybrid seed production on commercial scale basis for wheat cultivating areas under water shortage conditions.

For the trait grain yield per plant nine crosses showed an increase over their respective mid parents under normal condition. Theses crosses showed significant heterosis ($P \leq 0.05$) and three crosses showed an increase over the better parent. Whereas under water stress conditions the cross Chenab-70 × Fsd-08 has great potential to be used further because of its highest value for heterosis. Similar results have been revealed by earlier researcher [36,37,38]. For harvest index difference among the genotype may arouse from the contrast between parents × crosses, indicating that overall parental mean was significantly different from crosses. Overall parental mean averaged over water regimes was 37.53, while crosses mean was 48.78. Thus, of mid parental heterosis of 30% was obtained for harvest index.

CONCLUSIONS

The study concluded that a genotype arose from the best combination (Sehr-06 × Blue Silver) have best pollen viability may be used for water stress tolerance. The flag leaf area, (SA-42 × Fsd-08) number of grains (Pak-81× Lasani-08) tends to be the yield contributing traits by (Chenab-70 × Fsd-08) striking the heterotic exhibition. The highest heterosis and heterobeltiosis shown genotypes can be exploited in future breeding programs to attain self-sufficiency in food grains

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REFERENCES

[1] Stubbs RW, Prescot JM, Saari EE, Dubi HJ. Cereal Disease Methodology Manual.Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), Mexico 1986.

[2] Anonymous. Agriculture: Economic Survey of Pakistan (2008-09). Ministry of Pakistan, Finance Division Economic Advisor's Wing, Islamabad 2009.

[3] Sleper DA, Poehlman JM. Breeding Field Crops. 5th ed. Iowa State University Pres. USA 2006.

[4] Noorka IR, Khaliq I. An efficient techniquefor screening wheat (*Triticum aestivum* L.) Germplasm for drought tolerance. Pak J Bot 2007; 39(5): 1539-46.

[5] Government of Pakistan. Economic Survey of Pakistan. Finance Division, Economic Advisory Wing, Islamabad 2011.

[6] Jones RG. Quality requirements for wheat starch and gluten extraction. In: Aspects of Applied Biology 15-Cereal Quality. Association of Applied Biologists, Warwick 1987.

[7] Noorka IR, Shahid SA. Use of conservation tillage system in semiarid region to ensure wheat food security in Pakistan. Development in Soil Salinity Assessment and Reclamation ISBN 978-94-007-5683-0. Springer Book 2013. http//www.springer.com/environmrnt/soil+science/book/978978-94-007-5683-0

[8] Noorka IR. Sustainable rural development and participatory approach by on-farm water management techniques. Sustainable Agricultural Development, Springer Dordrecht Heidelberg London New York. Part 2, 2011; pp. 139-146. ISBN 978-94-007-0518-0

[9] Noorka IR, Teixeira da Silva JA. Mechanistic Insight of Water Stress Induced Aggregation in Wheat (*Triticum aestivum* L.) Quality: The Protein Paradigm Shift. Notulae Scientia Biologicae 2012; 4(4): 32-38.

[10] Boyer JS, Plant productivity and environment. Science 1982; 218: 443-48. http://dx.doi.org/10.1126/science.218.4571.443

[11] Rauf S, Shahzad M, Teixeira da Silva JA, Noorka IR. Biomass partitioning in sunflower (Helianthus annuus L.) inbred lines and hybrids under contrasting saline regimes. J Crop Sci Biotech 2011; 15(3): 53-57.

[12] Kumar A, Mishra VK, Vyas RP, Singh V. Heterosis and combining ability analysis in bread wheat (*Triticum aestivum* L.). J P Breed Crop Sci 2011; 3(10): 209-17.

[13] Chowdhry MA, Rasool I, Khaliq I, Mehmood T, Gilliani MM. Genetics of some metric traits in spring wheat under normal and drought environments. Rachis 1999; 18(1): 34-39.

[14] Reynolds MP, Skovamand B, Trethowan R, Pfeiffer W. Evaluating a conceptual model for drought tolerance. In: Using molecular markers to improve drought tolerance. (Ed.): Ribaut JM, CIMMYT, Mexico 1999.

[15] Noorka IR, Rehman S, Haidry JR, Khaliq I, Tabassam S, Din M. Effect of water stress on physico-chemical properties of wheat (*Triticum aestivum* L.). Pak J Bot 2009; 41(6): 2917-24.

[16] Hameed A, Bibi N, Akhter J, Iqbal N. Differential changes in antioxidants, proteases, and lipid peroxidation in flag leaves of wheat genotypes under different levels of water deficit conditions. Plant Physiol Biochem 2011; 49: 178-85. http://dx.doi.org/10.1016/j.plaphy.2010.11.009

[17] Yang J, Sears RG, Gil BS, Paulsen GM. Genotypic differences in utilization of assimilate sources during maturation of wheat under chronic heat and heat shock stresses. Euphytica 2002; 125: 179-88. http://dx.doi.org/10.1023/A:1015882825112

[18] Ehdaie B, Alloush GA, Madore MA, Waines JG. Genotypic variation for stem reserves and mobilization in wheat: I. Post anthesis changes in inter node dry matter. Crop Sci 2006; 46: 735-46. http://dx.doi.org/10.2135/cropsci2005.04-0033

[19] Noorka IR, EL-Bramawy MAS, Tabasum S, Saljooqi AR. Consumptive use of water and genetical assessment of wheat genotypes to defy worrisome prevalence of water stress. Sarhad J Agric 2012; 28(4): 559-64.

[20] Jain N, Yadav R. Genetic diversity analysis among pre-green revolution, post-green revolution era cultivars, and wheat

landraces as revealed by microsatellite markers. Crop Pasture Sci 2008; 60(4): 373-81.
http://dx.doi.org/10.1071/CP08310

[21] Akhtar LH, Hussain M, Tariq AH, Nasim M. A review of hundred years of wheat research and development in Punjab (1911-2010). Pak J Sci 2010; 62(2): 128-34.

[22] Khan A, Arif M, Shah A, Ali S, Hussain Z, Khan S. Evaluation of planting methods for grain yield and yield components of wheat. Sarhad J Agric 2007; 23(3): 561-63.

[23] Xianshan W, Zhenghang W, Xiaoping C, Ruilian J, Genetic dissection of the developmental behaviours of plant height in wheat under diverse water regimes. J Exp Bot 2010; 61(11): 2923-37.
http://dx.doi.org/10.1093/jxb/erq117

[24] Muller J. Determining leaf surface area by mean of linear measurements in wheat and triticale (brief report). Archiv Fuchtungsforschung 1991; 21(2): 121-23.

[25] Steel RGD, Torrie JH, Dickey DA. Principles and Procedures of Statistics: A biometrical approach. 3rd ed. McGraw Hill Co., Inc., NewYork, USA 1997*.*

[26] Fonseca S, Patterson FL. Hybrid vigour in seven parent diallel crosses in common wheat (*Triticum aestivum* L.). Crop Sci 1968; 8: 85-89.
http://dx.doi.org/10.2135/cropsci1968.0011183X000800010025x

[27] Saini HS. Effects of water stress on male gametophyte development in plants. Sexual Plant Reproduction 1997; 10(2): 67-73.
http://dx.doi.org/10.1007/s004970050069

[28] Ravikumar RL, Patil BS, Salimath PM. Drought tolerance in sorghum by pollen selection using osmotic stress. Euphytica 2003; 133(3): 371-76.
http://dx.doi.org/10.1023/A:1025702709095

[29] Jager K, Fabian A, Barnabas B. Effect of water deficit and elevated temperature on pollen development of drought sensitive and tolerant winter wheat (*Triticum aestivum* L.) genotypes. Acta Biologica Szegediensis 2008; 52(1): 67-71.

[30] Inamullah, Ahmed H, Mohammad F, Hassan G, Gul R. Evaluation of the heterotic and heterobeltiotic potential of wheat genotypes for improved yield. Pak J Bot 2006; 38(4): 1159-67.

[31] Mahmood Q, Lei WD, Qureshi AS, Khan MR, Hayat W, Jillani G, *et al*. Heterosis, correlation, and path analysis of morphological and biochemical characters in wheat. Agric J 2006; 1(3): 180-85.

[32] Duwayri M. Effect of flag leaf and awn removal on grain yield and yield components of wheat grown under dryland conditions. Field Crops Res 1984; 8: 307-13.
http://dx.doi.org/10.1016/0378-4290(84)90077-7

[33] Kazmi RH, Khan MQ, Abbasi MK. Yield and yield components of wheat subjected to water stress under rainfed conditions in Pakistan. Acta Agronomica Hungarica 2003*;* 51(3): 315-23.
http://dx.doi.org/10.1556/AAgr.51.2003.3.9

[34] Shamsi K, Petrosyan M, Noor-Mohammadi G, Haghparast A, Kobraee S, Rasekhi B. Differential agronomic responses of bread wheatcultivars to drought stress in the west of Iran. Afr J Biotechnol 2011; 10(14): 2708-15.

[35] Abdel-Moneam MA. Heterosis in some crosses of bread wheat under irrigation and drought conditions. Pak J Biol Sci 2009; 12(6): 486-91.
http://dx.doi.org/10.3923/pjbs.2009.486.491

[36] Akbar M, Khan MA, Rehman AU, Ahmad N. Heterosis and heterobeltiosis for improvement of wheat grain yield. J Agric Res 2007; 45(2): 87-94.

[37] Noorka IR, Batool A, Rauf S, Teixeira da Silva JA, Ashraf E. Estimation of heterosis in Wheat (*Triticum aestivum* L.) under contrasting water regimes. Int J Plant Breed 2013; 7(1): 55-60.

[38] Noorka IR, Batool A. Water stress tolerance, its relationship to assimilate partitioning and potence ratio in spring wheat. Am J Plant Sci 2013; In press.

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http://dx.doi.org/10.6000/1927-5129.2013.09.07