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Research Article

Heterosis for some physio-morphological plant traits in spring wheat crosses

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Abstract

An experiment was conducted at the experimental site of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan to study heterosis analysis and gene action on seven wheat varieties and their F_1 hybrids in 7×7 diallel fashion. Data for flag leaf area, flag leaf related traits including epidermal cell size, stomatal frequency, leaf venation, stomatal size, hygrophilic colloids and grain yield per plant was collected and analyzed. Higher positive values for flag leaf area (16.53) and leaf venation (9.89) were found in MH-97 × 4072. Negative hygrophilic colloids (-28.00) and stomatal frequency (-13.92), however, positive flag leaf area (9.35) and leaf venation (5.62) were recorded for Uqab-2000 × Punjab-96 with, and. In contrast, 4072 × Punjab-96 produced positive leaf venation (8.36) and epidermal cell size (2.36), but negative stomatal frequency (-8.18), stomatal size (-3.65). Considering genetic behavior of these three crosses, they should be utilized for future wheat breeding program to develop varieties able to survive not only under optimum environmental conditions but also perform better under stressful environment.

Keywords: F_1 hybrids; Flag leaf; Flag leaf related traits; Gene action; Heterosis; Wheat

Introduction

In Pakistan wheat (*Triticum aestivum* L.) is staple food and an important winter cereal crop and its demand is gradually increasing due to increasing population **[1-3]**. In Pakistan wheat was cultivated on an area of 9.26 million hectare (m ha) during 2015-16, producing 25.45 million tons of wheat **[4]**. Leaf is involved in the photosynthetic process in all green plants and it has the main role in the production photosynthates and dry matter of crop plants **[5]**. So increased leaf area increases the rate of photosynthetic process in plants and provides increased translocation of photosynthates in spikes during grain filling stages ultimately, the yield of the plant will increase **[6, 7]**. In wheat, flag leaf area has significant contributions in improving grain yield **[8]**. Consequently, flag leaf and its related traits also contribute to enhance yield of newly developed wheat varieties like less number of stomata and small size of stomata because these traits help the plant to use water efficiently [9, 10]. Geneticists remained fascinated by heterosis even after 100 years [11]. Shull [12] rediscovered heterosis in maize and described it as “heterosis is an increased vigor, growth, size, rate of development and other desirable characteristics of hybrids as compared with related parents”. Hybrid vigor or heterosis is dissimilarity due to cross combinations and the mean of both parents [13]. It is generally termed as mid-parent heterosis. Utilization of heterosis is not only applied for cross-pollinated crops in F_1 hybrids for high yield on large scale but its heterotic effects are also available in self-pollinated crops like wheat as well. In wheat Freeman [14] first time described heterosis when he found taller F_1 than its tall parents. Commercial utilization of heterosis was suggested by Briggle [15]. It is observed by many researchers that positive heterosis is important in some plant traits like grain yield per plant [16, 17] flag leaf area [18, 19]. This study was performed to evaluate F_1 hybrids of seven wheat varieties for flag leaf area and its related traits using various biometrical tools and to explore new genetic potential among available genetic resources in the country. Produced new combinations can further be utilized in the future breeding program to enhance existing yield level.

Materials and methods

An experiment was executed at experimental site of Plant Breeding and Genetics Department, University of Agriculture, Faisalabad, Pakistan. Soil of experimental site had pH 6.5 and EC of 4 dS/m. The complete diallel analysis was adopted in which seven wheat varieties/ lines were sown in the field and were hybridized at anthesis to develop new genetic combinations for hereditary study. At maturity seeds from crosses were collected and were sown next year along with parent varieties under triplicated randomized complete block design in field conditions. Every replication contained thirty plants per genotype having all the parents and F_1 hybrids. Distance for rows and for plants was kept 30 cm and 15 cm. Local recommendations including agronomic practices and crop protection measures were uniformly applied throughout the growing period to avoid any stress. Data for leaf venation, flag leaf area, stomatal size, the number of stomata, epidermal cell size, hygrophillic colloids and grain yield per plant at maturity were recorded and used for analysis. Variances of data collected as per replications for all genotypes and their hybrids were subjected according to statistically analysis using DMRT following Steel *et al.* [20] and then it was further subjected for calculating heterosis and heterobeltiosis as described earlier [21].

Results

Analysis of variance

Data collected for plant characters were subjected to find out significant differences among 49 genotypes through ANOVA as suggested by Steel *et al.* [20]. All genotypes were significantly different for studied traits except stomatal size (Table 1). The significant genotypic differences permitted further genetic analysis following the technique suggested by Hayman [22] Hayman [23] and Jinks [24].

Heterosis analysis

For flag leaf trait, positive heterosis was observed in 11 crosses (Table 2). Significantly higher heterosis and heterobeltosis for flag leaf area was showed by only one hybrid i.e., MH-97 × 4072.

Table 1. Mean squares of various plant traits in 7×7 diallel crosses of *Triticum aestivum* L.

Source	DF	Flag leaf area	Leaf venation	Stomatal frequency	Stomatal size	Epidermal cell size	Hygrophilic colloids	Grain yield per plant
Replication	2	4.21	1.02	2477	7002	1003	0.00017	2.23
Genotypes	48	21.77**	16.59**	5919**	1394ns	5274**	0.0235**	9.12**
Error	96	2.25	4.14	2460	9444	1025	0.0096	3.08
Mean		15.184	36.398	575.710	1782.14	3697.95	0.164	20.043
CV %		9.873	5.589	8.616	5.453	8.659	28.89	8.764

**, Significant at $P \leq 0.01$; *, Significant at $P \leq 0.05$; ns, Non-significant at $P > 0.05$.

Whereas rest of the crosses displayed a reduction in flag leaf area as compared to their mid parents. Majority of crosses i.e., 37 out of 42 crosses exhibited negative heterobeltosis. Heterosis for leaf venation (Table 2) showed that 23 crosses exhibited an increase in leaf venation over mid-parent values whereas only 6 crosses gave significant values. Highest positive heterosis was observed in Iqbal-2000 × Uqab-2000 (10.23) and MH-97 × 4072 (9.89). The maximum positive heterobeltiosis for leaf venation was recorded for 4072 × Parwaz-94 (10.26), similarly other 12 crosses also showed positive heterobeltosis.

Heterosis observed for stomatal frequency revealed that 28 crosses showed decreased stomatal frequency over mid parent value out of which only 6 crosses were significant. Highest level of heterosis was observed in Uqab-2000 × Iqbal- 2000 (-16.78) and Uqab-2000 × Punjab-96 (-13.92). More than 75% of crosses i.e., 34 crosses out of 42 crosses produced negative heterobeltosis, from which heterobeltosis reached significant level in 15 crosses for stomatal frequency. Surprisingly maximum heterobeltosis was found in the crosses with maximum values of negative heterosis.

In case of stomatal size approximately half crosses i.e., 23 crosses displayed increased size of stomata, however stomatal size was decreased in 19 crosses (Table 2). Maximum reduction in stomatal size was recorded in MH-97 × Iqbal-2000 (4.32). Heterobeltosis for stomatal size explained that 30 crosses out of 42 crosses showed a reduction in stomatal size, whereas maximum reduction was found in cross Punjab-96 × Iqbal-2000 (-7.56). Heterosis data for epidermal cell size revealed that 20 crosses showed positive heterosis however, only 5 of these were significantly positive. Highest value of heterosis for epidermal cell size was recorded in MH-97 × Punjab-96 (25.66) followed by Parwaz-94 × Uqab-2000 (15.32). One out of eight crosses showed significant positive heterobeltosis which was observed in the crosses with maximum positive heterosis values. While 34 crosses showed reduced size of epidermal cells. Similarly, 13 crosses displayed decreased hygrophilic colloids value for heterosis. Moreover, 11 out of 28 crosses demonstrated significantly decreased heterosis, while 12 crosses showed positive heterosis for hygrophilic colloids. Maximum decrease in hygrophillic colloids was observed in MH-97 × Uqab-2000 (-81.67) followed by Uqab-2000 × Iqbal-2000 (-75.0) and Iqbal-2000 × Parwaz-94 (-72.85). Similarly, maximum negative heterobeltosis was also found in crosses with positive heterosis for hygrophilic colloids. Considering decreasing hygrophilic colloids of Uqab-2000 and Iqbal -2000, both proved to be best parents. For grain yield parameter, 20 crosses exhibited increased trend for mid-parent value of which only 2 were important. Greatest positive heterosis value was observed in 4072 × Punjab-96 (21.95). However increased heterobeltosis was present in 7 cross combinations in which one hybrid was prominent with the highest heterobeltosis (11.33).

Table 2. Heterosis (%) and heterobeltiosis (%) effects in flag leaf are and its related traits in 7×7 diallel crosses

Crosses	Flag leaf area		Leaf venation		Stomatal frequency		Stomatal size		Epidermal cell size		Hygrophilic colloids		Grain yield per plant	
	Ht	Hb	Ht	Hb	Ht	Hb	Ht	Hb	Ht	Hb	Ht	Hb	Ht	Hb
Shahkar-95 × Parwaz-94	-9.24^{NS}	-15.18^{NS}	-9.27**	-11.19**	4.10	-1.14^{NS}	-2.75^{NS}	-3.91^{NS}	-3.95^{NS}	-4.83^{NS}	-0.99^{NS}	-28.57^{NS}	-1.93^{NS}	-2.60^{NS}
Shahkar-95 × Iqbal-2000	-20.17**	-38.78**	-9.25**	-12.97**	9.62	5.01^{NS}	3.08^{NS}	0.74^{NS}	-9.25^{NS}	-13.94*	-53.85**	-68.42**	0.12^{NS}	-8.91^{NS}
Shahkar-95 × Uqab-2000	2.63^{NS}	-5.49^{NS}	-4.65^{NS}	-5.99^{NS}	3.34	-5.39^{NS}	-1.94^{NS}	-7.43*	3.12^{NS}	-7.10^{NS}	-13.33^{NS}	-25.71^{NS}	1.44^{NS}	-3.61^{NS}
Shahkar-95 × MH-97	-7.81^{NS}	-19.34**	-3.18^{NS}	-8.25*	4.04	2.59^{NS}	0.84^{NS}	0.62^{NS}	4.00^{NS}	1.41^{NS}	33.33^{NS}	14.29^{NS}	-0.93	-4.20^{NS}
Shahkar-95 × 4072	-1.37^{NS}	-17.88*	1.48^{NS}	-2.78^{NS}	-0.51	-2.00^{NS}	0.58^{NS}	0.21^{NS}	-2.30^{NS}	-12.38*	-31.87^{NS}	-55.71^{NS}	1.04^{NS}	2.46^{NS}
Shahkar-95 × Punjab-96	-2.01^{NS}	-24.39**	0.82^{NS}	-1.65^{NS}	1.52	-2.02^{NS}	3.58^{NS}	1.72^{NS}	1.96^{NS}	-0.40^{NS}	0.00^{NS}	-14.29^{NS}	-8.42^{NS}	-19.62**
Parwaz-94 × Shahkar-95	-2.62^{NS}	-9.00^{NS}	-1.90^{NS}	-3.98^{NS}	-9.64	-14.19**	1.02^{NS}	-0.17^{NS}	3.86^{NS}	-2.91^{NS}	18.81^{NS}	-14.29^{NS}	-4.03^{NS}	-4.95^{NS}
Parwaz-94 × Iqbal-2000	-36.08**	-48.41**	-4.50^{NS}	-6.49^{NS}	2.38	-6.63^{NS}	0.33^{NS}	-0.77^{NS}	-0.26^{NS}	-6.23^{NS}	-63.80**	-78.95**	-11.72*	-19.19**
Parwaz-94 × Uqab-2000	2.60^{NS}	0.99^{NS}	-2.35^{NS}	-5.72^{NS}	-1.80	-5.54^{NS}	-0.01^{NS}	-4.53^{NS}	15.32**	4.74	23.46^{NS}	0.00^{NS}	0.09^{NS}	-4.27^{NS}
Parwaz-94 × MH-97	-5.79^{NS}	-12.26^{NS}	-9.48**	-12.42**	1.78	-2.01^{NS}	2.74^{NS}	1.28^{NS}	4.06^{NS}	2.40^{NS}	23.46^{NS}	0.00^{NS}	-9.93^{NS}	-13.47*
Parwaz-94 × 4072	-6.73^{NS}	-17.67**	-6.49^{NS}	-12.24**	1.05	-2.66^{NS}	-4.02^{NS}	-5.51^{NS}	-3.50^{NS}	-14.16*	-19.23^{NS}	-32.26^{NS}	0.57^{NS}	-3.09^{NS}
Parwaz-94 × Punjab-96	-17.05**	-32.61**	-7.06^{NS}	-7.40^{NS}	-3.59	-11.48*	-2.36^{NS}	-5.22^{NS}	11.69*^{NS}	10.09^{NS}	25.93^{NS}	2.00^{NS}	2.36^{NS}	-9.63^{NS}
Iqbal-2000 × Shahkar-95	-18.22**	-37.28**	6.04^{NS}	1.68^{NS}	-7.52	-11.41 NS	-1.34^{NS}	-3.57^{NS}	3.90^{NS}	-1.46^{NS}	-69.23**	-78.95**	-15.67**	-23.28**
Iqbal-2000 × Parwaz-94	-3.49^{NS}	-22.11**	2.47^{NS}	0.34^{NS}	-5.65	-13.97*	-1.25^{NS}	-2.34^{NS}	-7.41	-12.96*	-72.85**	-84.21**	2.43^{NS}	-6.23^{NS}
Iqbal-2000 × Uqab-2000	-17.11**	-32.27**	10.23**	4.29^{NS}	-9.21	-20.06**	3.78^{NS}	0.16^{NS}	9.39^{NS}	-5.99^{NS}	-33.33*	-57.89**	1.35^{NS}	-3.20^{NS}
Iqbal-2000 × MH-97	-12.66**	-25.24**	-3.60^{NS}	-4.78^{NS}	-5.39	-10.58^{NS}	0.16^{NS}	-2.32^{NS}	12.76**	4.41^{NS}	-41.67**	-63.16**	-7.66^{NS}	-18.50**
Iqbal-2000 × 4072	2.07^{NS}	-8.00^{NS}	4.78^{NS}	-3.55^{NS}	1.67	-3.99^{NS}	4.38^{NS}	-6.89^{NS}	-2.41^{NS}	-8.08^{NS}	-14.69^{NS}	-52.63**	-7.17^{NS}	-11.99^{NS}
Iqbal-2000 × Punjab-96	1.45^{NS} NS	0.58^{NS}	2.77^{NS}	0.99^{NS}	4.39	3.59^{NS}	2.79^{NS}	-1.29^{NS}	9.22^{NS}	1.29^{NS}	-41.67^{NS}	-63.16**	0.78^{NS}	-4.66^{NS}
Uqab-2000 × Shahkar-95	9.02^{NS} NS	0.39^{NS}	1.07^{NS}	-0.30^{NS}	-12.46**	-19.86**	-0.81^{NS}	-6.36^{NS}	14.00**	2.68^{NS}	-16.67^{NS}	-28.57^{NS}	-1.03^{NS}	-5.95^{NS}
Uqab-2000 × Parwaz-94	-2.25^{NS}	-3.78^{NS}	-0.25^{NS}	-3.70^{NS}	-11.36*	-14.74**	7.34*	2.49^{NS}	3.04^{NS}	-6.41^{NS}	-1.23^{NS}	-20.00^{NS}	-10.66*	-14.55*
Uqab-2000 × Iqbal-	-7.54^{NS}	-24.46**	-7.09*	-	-	-	2.05^{NS}	-	-6.85^{NS}	-	-75.00**	-84.21**	4.92	0.20

2000				12.10**	16.78**	26.73**		1.50NS		19.96**				
Uqab-2000 × MH-97	-7.35 NS	1.48 NS	-0.18NS	-6.65NS	-2.92	-9.98*	-1.75NS	-7.44*	5.86NS	-2.42NS	20.00NS	20.00NS	1.62	-6.46
Uqab-2000 × 4072	4.79 NS	-6.20 NS	-3.74NS	-6.52NS	-5.65	-12.42*	-0.66NS	-6.55NS	-10.55*	-26.83**	12.68NS	-20.00NS	-8.98	-9.68
Uqab-2000 × Punjab-96	9.35 NS	-10.05* NS	5.62NS	1.61NS	-13.92**	-23.70**	2.25NS	-5.09NS	4.65NS	-3.68NS	-28.00NS	-28.00NS	6.05	-2.50
MH-97 × Shahkar-95	7.42 NS	-6.02 NS	0.79NS	-4.40NS	-4.52	-5.85NS	2.25NS	2.03NS	-6.02NSNS	-8.36NS	-33.33NS	-42.86NS	-17.54**	-20.26**
MH-97 × Parwaz-94	-1.83 NS	-8.56 NS	5.72NS	2.80NS	-3.40NS	-7.02NS	-3.89NS	-5.23NS	-4.70NS	-6.25NS	-25.93NS	-40.00NS	-12.88**	-16.31**
MH-97 × Iqbal-2000	-6.64 NS	-20.09**	-0.76NS	-1.98NS	15.47**	9.15*	-4.32NS	-6.69NS	-16.71**	-22.88**	-81.67**	-88.42**	-0.94	-12.56*
MH-97 × Uqab-2000	-3.88 NS	-9.14 NS	8.05*	1.04NS	-11.56*	-17.99**	-1.22NS	-6.94NS	0.54NS	-7.32NS	-40.00NS	-40.00NS	-7.00	-14.39**
MH-97 × 4072	16.53**	9.95 NS	9.89**	0.01NS	6.14NS	6.02NS	0.73NS	-0.88NS	2.15NS	-10.39*	97.18NS	40.00NS	-3.99	-10.99*
MH-97 × Punjab-96	1.93 NS	-12.12*	2.60NS	-0.37NS	-8.80NS	-13.17*	0.48NS	-1.10NS	25.66**	25.45**	24.00NS	-24.00NS	-17.41**	-29.57**
4072 × Shahkar-95	-1.65 NS	-18.12**	-5.25NS	-9.23**	-0.92NS	2.41NS	-2.20NS	-2.57NS	2.98NS	-7.64NS	-12.09	-42.86NS	-8.10	-12.02*
4072 × Parwaz-94	-6.57 NS	-17.53**	17.47**	10.26**	-9.60NS	-12.90*	5.87NS	4.23NS	-9.36NS	19.38**	-3.85NS	-19.35NS	4.32	0.52
4072 × Iqbal-2000	-15.18**	-23.55**	0.63NS	-7.38*	7.70NS	1.70NS	4.99NS	2.23NS	-1.18NS	-6.85NS	-71.56**	-84.21**	13.01*	7.14
4072 × Uqab-2000	-4.84*	-14.82*	7.58*	4.48NS	-2.42NS	-9.43NS	3.59NS	-2.54NS	-11.97**	-27.99**	43.66NS	2.00NS	9.58	8.74
4072 × MH-97	-15.47**	-20.24**	1.91NS	-7.25*	-6.09NS	-6.19NS	0.61NS	0.46NS	-6.88NS	-18.33**	-38.03NS	-56.00NS	-2.74	-9.83
4072 × Punjab-96	-10.16**	-18.40**	8.36*	1.36NS	-8.18NS	-12.66**	-3.65NS	-5.03NS	2.36NS	-10.08*	40.85NS	0.00NS	21.95**	11.33
Punjab-96 × Shahkar-95	-22.20**	-39.98**	0.05NS	-2.41NS	-6.08NS	-9.36	-1.01NS	-2.79NS	-1.34NS	-3.63NS	-30.00NS	-40.00NS	4.48	-8.31
Punjab-96 × Parwaz-94	-15.88*	-32.66**	3.70NS	3.32NS	-10.18*	-17.53**	0.33NS	-2.60NS	-9.40NS	-10.70NS	-1.23NS	-20.00NS	5.36	-6.98
Punjab-96 × Iqbal-2000	-1.46 NS	-2.30 NS	-8.90*	-10.47**	-3.52NS	-4.25NS	-3.72NS	-7.56*	-6.14*	-12.96**	-66.67**	-78.95**	6.40	2.23
Punjab-96 × Uqab-2000	-5.14 NS	-21.97**	5.08NS	1.09NS	-7.72NS	-18.21**	5.20NS	-2.36NS	-15.97**	-22.66**	-30.00NS	-30.00NS	6.25	-2.32
Punjab-96 × MH-97	-0.32 NS	-14.05**	-7.11*	-9.81**	8.56NS	3.36NS	-2.62NS	-4.16NS	-21.72**	-21.85**	40.00NS	40.00NS	8.90	-7.14
Punjab-96 × 4072	-6.89 NS	-15.44**	3.75NS	-2.95NS	-1.30NS	-6.12NS	1.66NS	0.20NS	7.10NS	-18.40**	-15.49NS	-40.00NS	-5.05	-13.31*

**, Significant at $P \leq 0.01$; *, Significant at $P \leq 0.05$; ns, Non-significant at $P > 0.05$.

Discussion

During this study, a program was initiated to observe genetic differences between wheat varieties and their cross combinations for flag leaf area and its related traits. Through analysis of variance (ANOVA; Table 1), it was found that all genotypes were different significantly for all plant traits except for stomatal size. These results are in agreement with other researchers as they also found dissimilarity between genotypes for plant yield and other traits in wheat varieties **[19, 25-28]**. In crop plants genetic variability is an important source for creating new genetic combinations with maximum ability to produce higher yield **[29-32].** The supremacy of hybrids over better parent is important to find out option for utilization of heterosis on a commercial scale and recognize specific combinations for producing transgressive segregants of premier quality. In this study, as parent wheat varieties are highly adapted varieties so heterosis and heterobeltosis played an important role for improvement in yield. For future wheat breeding programs, study for the extent of heterosis is important. Leaf and its related traits play critical role in survival of the plant both under optimum and deficient moisture levels. The increase in area of flag leaf in wheat is important for high yield production. Several researchers working on wheat concluded that positive heterosis for flag leaf area ultimately can produce higher grain yield, as flag leaves have significant contribution in production of photosynthates, which are ultimately translocated to grain **[18]**. Maximum mid-parent heterosis in hygrophilic colloids was found to be high (-81.67 %) among the plant traits during the study of seven parental complete diallel analysis **[19]** which showed that hygrophilic colloids played an important role in yield contribution and stability of yield. The negative sign showed there would be higher yield with decreasing amount of hygrophilic colloids in cross hybrids **[30]**. Epidermal cell size is also a vital plant trait contributing to high yield and yield stability. Maximum positive flag leaf area (16.53) and leaf venation (9.89) were found in MH-97 × 4072 followed by Uqab-2000 × Punjab-96 with hygrophilic colloids (-28.00) and other traits while other flag leaf related traits like positive leaf venation (8.36), epidermal cell size (2.36) and stomatal frequency (-8.18), stomatal size (-3.65), was found in 4072 × Punjab-96.

Conclusion

The results indicated that the plant traits studied in this experiment were affected on the efficiency of plants to grow well with the limited use of water if a shortage of water occur as these traits enable the plants to make them water use efficient. Crosse MH-97 × 4072 showed best performance followed by Uqab-2000 × Punjab-96 and 4072 × Punjab-96. Considering performance of these crosses, they can be used as promising lines for further breeding program. Due to better characteristics of flag leaf traits these crosses have potential for the development of drought resistant through efficient water utilization which is the key for plant survival under normal as well as under adverse environmental conditions.

Authors' contributions

Envisioned the project, designed and performed the experiment: S Mahpara, S Hussain & J Iqbal. Performed statistical analysis: S Mahpara, MIA Rehmani, JS Dar, M.K. Qureshi & MA Shehzad. Wrote and edited the paper: S. Mahpara, MIA Rehmani, M.K. Qureshi & JS Dar. All authors read the final draft.

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