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Genetic mechanisms of yield related morphological markers response to increase grain yield in different environment of hexaploid wheat

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Abstract

Wheat is an imperative cereal of the world that plays a remarkable role in meeting the food requirements of human population. Improvement in yield relies upon the identification of genetically superior and suitable genotypes and their exploitation. A 5 × 5 diallel cross using five wheat varieties/lines namely Aas-11, Millat-11, SH-95, 9272 and 9276 was carried out to examine the genetics of yield and yield related morphological traits. All traits shown high level of significance after analysis of variance. Variety SH-95 proved to be the best general combiner for plant height, spike length, spike density, number of grains per spike. Cross 9272 x Milla-11 was the best combiner for number of grains per spike and 1000-grain weight. SH-95 x 9272 proved to be best specific combiner for flag leaf area, 1000-grain weight and grain yield per plant. The partitioning of variance into its components exhibited that the magnitude of GCA variance was greater than SCA variance for plant height, flag leaf area, spike length, spike density and number of grains per spike displayed additive type of gene action so improvement and selection will be possible in early generation. Early selection would be difficult for 1000-grain weight and grain yield per plant because SCA variance was greater than GCA variances showed dominance effects.

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Introduction

Wheat being the leading food grain crop and staple diet for more than one third of world population is regarded as the King of Cereals. Overall the Population of world has increased rapidly during the last few decades. With the introduction of high yielding wheat varieties production was increased many folds but this increase in wheat production is not sufficient to meet the future needs of continuously increasing population. To fulfill this demand there is a need to raise the production by galvanizing the pace of research is developing new wheat genotypes resistant against various biotic and abiotic stresses, and with high yielding potential. So a precise understanding of genetic mechanisms underlying the control and expression of various characters in focus is therefore, of obvious importance, however, selection of suitable parents is also equally important (Saeed *et al.* 2001). The magnitude of combining ability and type of gene action in a particular population serves as criteria for selection of parents, which after hybridization are likely to produce the best recombinants for desirable traits. Hassan *et al.* (2004) observed that plant height was controlled by additive genes while over dominance predominated for number of grains per spike, and grain yield per plant. Farooq *et al.*, (2010) reported that yield related traits were controlled by additive effects. However, over dominance type of gene action controlled grain yield per plant. Such information is of great importance in executing an efficient breeding program in order to achieve maximum genetic gain with the minimum resources and less time. To assess the relative magnitude of general combining ability (GCA) and specific combining ability (SCA) for morphological traits to select the best combiner and suitable cross combinations for successful wheat hybridization. The objective of present study was under taken to estimate the general combining ability and specific combining ability for yield and yield contributing traits in some wheat crosses and will be used for a successful wheat breeding program to develop high yielding wheat genotypes.

Materials and methods

Experimental Area

The experiment was performed in the trial zone of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan during crop season 2012-13. Six varieties/genotypes viz., Sehar-2006, Lasani-2008, 6500, 9242 and 9444 were planted in the field during the first year of experiment and were crossed in all possible combinations using diallel mating design.

Sowing plan of parents and their hybrids

Seeds of all crosses alongside their parents were planted in a randomized complete block design with three repeats during (2013-14) the second year of experiment. Inter plant and inter row distance was kept 15 and 25 cm, respectively. Two seeds were planted per hole with the help of dibble and after germination; these were thinned to single seedling per hole.

Data collection

After maturity, the data was recorded for the characters like plant height, flag leaf area, spike length, spike density, number of grains per spike, 1000-grain weight and grain yield per plant.

Statistical Analysis

The figures obtained were subjected to analysis of variance technique (Steel *et al.,* 1997). The traits which showed significant difference among genotypes were further subjected to combining ability analysis using diallel Method-I Model-II (Griffing, 1956).

Results and discussion

The analyses of variance for yield and yield related morphological markers or traits (Table 1) showed that mean squares of F_1's for all the traits were highly significant. These significant results indicated the significant genetic differences in the genetic material. Combining ability analysis (Table 2) showed that mean squares due to general combining were highly significant for all studied traits except 1000-grain weight and grain yield per plant had significant effects. Specific combining ability effects were highly significant for plant height, spike density, 1000-grain and grain yield per plant while non-significant for flag leaf area, spike length and number of grains per spike. However, the reciprocal effects were non significant for all traits except 1000-grain weight and grain yield per plant which had highly significant effects.

Table 1. Analyses of variance for yield related morphological markers in diallel cross of wheat.

Source of Variation	d.f	Plant Height	Flag Leaf Area	Spike Length	Spike Density	No. of Grains/ spike	1000-Grain Weight	Grain yield/ Plant
Replications	2	18.58^{NS}	$3.15^{N.S}$	$0.39^{N.S}$	$0.96^{N.S}$	$58.48^{N.S}$	$11.8^{N.S}$	$8.55^{N.S}$
Genotype/	24	118.18^{**}	96.66^{**}	2.17^{**}	29.29^{**}	223.73^{**}	26.11^{**}	69.07^{**}
Error	48	17.92	24.25	0.59	2.1	117.7	9.18	20.87
Total	74							

*** = Highly Significant P ≤ 0.01,* *N.S = Non significant*

Table 2. Combining ability analysis for yield related morphological markers in diallel cross.

Mean Squares	df	Plant Height	Flag Leaf Area	Spike Length	Spike Density	No. of Grains/ spike	1000-Grain Weight	Grain Yield/ Plant
GCA effects	4	162.09^{**}	136.50^{**}	3.99^{**}	0.048^{**}	259.50^{**}	10.86^{*}	19.18^{*}
SCA effects	10	25.02^{**}	$14.32^{N.S}$	$0.073^{N.S}$	0.0038^{**}	$53.05^{N.S}$	11.74^{**}	31.15^{**}
Rec effects	10	$4.62^{N.S}$	$8.31^{N.S}$	$0.072^{N.S}$	0.004^{NS}	$21.84^{N.S}$	4.86^{**}	16.39^{**}
Error	48	5.97	8.06	0.19	0.0007	39.02	3.05	6.91

*** = Highly Significant P ≤ 0.01,* *N.S = Non significant*

Plant Height (cm)

Tall cultivars are more susceptible to lodging than medium or short stature cultivars. So in breeding program of wheat, plant height should also be considered as an important trait. In Table-2 Mean square due to GCA (162.09) was greater than SCA mean square (25.02) that indicated this trait was controlled by additive type of gene action as already reported by Javaid *et al.* (2001); Chowdhry *et al.* (2007). Ullah *et al.* (2010). Table 3 indicated that highest positive GCA effects was showed by the parent SH-95 (7.06) while the rest of parents showed negative general combining ability effects. Negative general combining ability indicated that parents were short stature and in wheat it is desirable because short stature plants never lodged and are more responsive to fertilizers. The highest negative general combining ability effects were exhibited by the genotype Aas-11 (-2.77). The negative GCA values are preferred further for introducing dwarfing genes in the high yielding varieties. Maximum positive SCA effects (Table 3) were found in the cross combination Aas-11 x 9276 (5.16). The lowest SCA effects was shown by the Millat-11 x SH-95 (-4.004). The highest positive reciprocal effects (Table 3) were found in SH-95 x Millat-11 (2.31) while the lowest reciprocal effects were shown by the SH-95 x Aas-11 (-2.83). Due to the absences of epistasis and the presence of additive type of gene action selection will be possible in early generation.

Flag Leaf Area (cm^2)

The analysis of variance for combining ability (Table 2) indicated that mean square due to general combining ability was higher (136.50) than the mean squares due to SCA (14.32) and reciprocal effects (8.31). Similar findings were also reported by Saleem (2005): Munis *et al.* (2012). The results indicated that the trait flag leaf area was controlled by additive type of gene action. The Table 3 displayed that maximum positive GCA value was exhibited by 9276 (4.57) followed by SH-95 (1.82). The lowest GCA value was depicted by Millat-11 (-4.09) Maximum SCA effects were shown by cross combination SH-95x 9272 (4.26). The lowest SCA value was recorded in the cross combination Aas-11 x Millat-11 (-3.08). The highest reciprocal effects was exhibited by 9276 x Millat-11 (2.70). Due to presence of additive type of gene action and absences of epistasis, selection will be possible in early generation.

Table 3.GCA, SCA and Reciprocal effects for yield related morphological markers in diallel cross.

Parents/Crosses	Plant Height	Flag Leaf Area	Spike Length	Spike Density	No. of Grains / spike	1000-Grain Weight	Grain Yield/ Plant
GCA							
Aas-11	-2.77	-3.49	-0.41	-0.06	-6.72	0.13	-0.21
Millat-11	-2.03	-4.09	-0.56	0.096	0.83	-1.79	0.08
SH-95	7.06	1.82	1.01	-0.07	6.16	0.17	2.30
9272	-0.57	1.19	0.20	-0.02	-3.30	0.76	-1.11
9276	-1.69	4.57	-0.24	0.04	3.02	0.72	-1.06
SCA							
Aas-11x Millat-11	-2.38	-3.08	-0.19	0.03	3.68	-0.17	2.87
Aas-11x SH-95	1.21	0.11	0.18	-0.003	4.02	-0.33	-4.26
Aas-11x 9272	1.94	1.38	0.18	-0.006	3.88	1.25	2.68
Aas-11x 9276	5.16	1.88	0.06	-0.06	-3.60	0.91	2.79
Millat-11 x SH-95	-4.004	-0.22	-0.02	-0.007	-2.20	-0.64	0.30
Millat-11 x 9272	0.07	-0.45	0.02	-0.01	4.03	-0.30	1.68
Millat-11 x 9276	1.78	-1.23	0.05	0.05	4.58	3.07	-0.37
SH-95 x 9272	0.93	4.26	-0.15	-0.04	-8.12	3.47	5.74
SH-95 x 9276	2.56	-0.19	0.20	-0.03	1.25	1.24	2.50
9272 x 9276	-1.94	0.42	0.12	-0.005	-0.22	-0.11	-1.58
Rec							
Millat-11 x Aas-11	0.26	2.60	0.03	-0.008	1.83	-1.10	-3.75
SH-95 x Aas-11	-2.83	2.56	-0.24	-0.012	2.70	-2.43	1.82
9272 x Aas-11	-0.33	0.75	0.21	-0.003	-1.90	-2.07	-4.16
9276 x Aas-11	-1.21	0.41	0.05	0.03	1.93	-0.83	-2.77
SH-95 x Millat-11	2.31	-1.90	0.17	0.007	-3.43	1.67	5.14
9272 x Millat-11	-2.31	-1.09	-0.06	-0.008	8.07	2.53	-0.03
9276 x Millat-11	0.36	2.70	-0.04	0.015	2.67	0.53	3.06
9272 x SH-95	0.11	1.55	0.18	-0.007	0.36	-1.20	-1.72
9276 x SH-95	0.197	0.73	-0.38	-0.005	-0.13	-0.47	-0.87
9276 x 9272	-1.62	-3.54	-0.21	-0.015	-2.67	1.03	-0.18

Spike Length (cm)

Spike length is an important yield related trait of wheat. It directly contributes to the yield. More spike length produces more spikelets per spike that ultimately produces more grains per spike thus leading to yield increase. The analysis of variance for combining ability (Table 4.4) indicated that mean square due to GCA (3.99) was greater than the variances due to SCA (0.073) and reciprocal effects (0.072) These results are in accordance with the results of Sudesh *et al.* (2002) and Chowdhry *et al.* (2005) who reported the predominance of additive type of gene action. The parent (Table 3) SH-95(1.01) showed the highest GCA value while the Manthar-2003, Aas-11and 9276 exhibited -0.56, -0.41 and -0.24 respectively. The highest positive SCA effects (Table 4.6) indicated by SH-95x 9276 (0.20) while the cross combinations SH-95 x 9272 the negative SCA effects with values of -0.15. The highest reciprocal effects (Table 3) were depicted by 9272 x Aas-11(0.21). Selection possible in early generation due to additive genetic effect.

Spike Density

The mean square due to GCA (0.048) was higher than SCA mean square (0.0038) that indicated the predominance of additive type of gene interaction. These results are in agreement with the results of Kashif and Khaliq (2003) Chowdhry *et al.* (2007). Parent Millat-11 (0.096) was the best general combiner indicated in table 3. The weakest performance was displayed by the parent SH-95 (-0.07). Among the crosses (Table 3) Millat-11 x 9276 (0.05) was the best specific combiner followed by Aas-11x Millat-11 (0.03), remaining all crosses showed the negative SCA value. The poorest performance of reciprocal effects was exhibited by 9276 x 9272 (-0.015) followed by SH-95x Aas-11(-0.012). Selection will be fruitful in early generation due to the absence of dominant effects.

Number of Grains per Spike

It is obvious from analysis of variance for combining ability (Table 3) that mean square due to GCA (259.50) was higher the mean square due to SCA (53.05) and reciprocal effects (21.84) which showing the absence of epistasis and dominant gene effect. Similar findings were also represented by Mahmood and Chowdhry (2002); Awan *et al.* (2005); Khan *et al.* (2007) The highest GCA value (Table 3) was depicted by the parent SH-95(6.16). The poor performance was displayed by the parent Aas-11(-6.72) followed by 9272 (-3.30). Cross Millat-11 x 9276 (4.58) exhibited the highest SCA value while the lowest SCA value was shown by the cross SH-95 x 9272 (-8.12). The highest positive reciprocal effects was exhibited by the cross combination 9272 x Millat-11 (8.07), while the lowest value due to reciprocal effects was showed by the crosses SH-95x Millat-11 (-3.43). Due to absence of non-additive genetic effects the selection will be easy in early generation

1000-Grain Weight (g)

1000-grain weight is a vital yield component and is more or less stable character of wheat cultivars. Table 3 displayed that mean square due to SCA effects (11.74) was greater than mean square due to GCA effects (10.86). These results are in accordance with the results of Shekhawat *et al.* (2000); Siddique *et al.* (2004); Seboka *et al.* (2009) ;Anwar *et al.* (2011) which depicted that this trait was controlled by non additive gene interaction. Among parents (Table 3), the excellent performance was displayed by the parent 9272 (0.76) followed by 9276 (0.72), parents Millat-11 having negative GCA effects with value -1.79. In case of SCA effects (Table 3) the best specific combiner was the SH-95x 9272 (3.49) while the negative SCA effects was revealed by Millat-11 x SH-95(-0.64). It is clear from the Table 3 that 9272 x Millat-11 (2.53) showed the highest reciprocal effects and the negative reciprocal effects were shown by the cross combinations SH-95x Aas-11(-2.43). Due the presence of epistasis and dominant genetic effect the selection will be difficult in early generation.

Grain Yield per Plant (g)

The Table 4.4 indicated that mean square due to GCA effects (19.18) was greater than the mean squares due to SCA (31.15) and reciprocal effects (16.39) showing the importance of non-additive type of gene action. These results were matched with the results of earlier findings by Asif *et al.* (2000); Iqbal and Khan (2006); Dere and Yildirim (2006); Adel and Ali (2013) The Table 3 reveals that highest positive GCA value was depicted by the parent SH-95(2.30) followed by Millat-11 (0.08) while, the remaining showing the negative GCA effects. In case of SCA effects (Table 4.6) the excellent specific combiner was SH-95x 9272

(5.74). Hybrid Aas-11x SH-95(-4.26) was the poorest specific combiner. The highest value for reciprocal effects (Table 4.7) was depicted by the cross SH-95x Millat-11 (5.14) followed by 9276 x Millat-11 (3.06) and SH-95x Aas-11(1.82). The remaining crosses showed the negative reciprocal effects. Selection will be difficult in early generation due the presence of epistasis and dominant genetic effects.

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