Estimation of general and specific combining ability for grain yield traits in *Triticum aestivum*

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Abstract: A research experiment was performed to study the combining ability effects of various yield contributing characters of wheat genotypes by incorporating the line × tester analysis under standard field conditions (normal sowing) in the research area of Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, during 2012-14. it was found that for grains/spike, awn length, peduncle length and flag leaf area, genotype 9703 was the best general combiner. Genotype 9705 was best general combiner intended for plant height and spike length whereas genotypes 9554, 9704 and AARI-11 exhibited the best general combining ability effects for tillers/plant, extrusion length and grain yield/plant respectively. Cross combination 9705×AARI-11 came across as best specific combiner for 1000-grain weight plus grain yield/plant whereas, cross; 9703 × Millat-11, was best specific combiner for grains/spike and peduncle length. Cross 9705 × Millat-11 exhibited best specific combining ability estimates for awn length and spike length. Other best specific combiner in the present study were 9554 × Millat-11, 9546 × Pasban-11, 9595 × AARI-11, 9705 × Pasban-11, 9554 × Pasban-11 and 9703 × AARI-11 for plant height, grain yield/spike, tillers/plant, spikelets/spike, extrusion length and flag leaf area sequentially. So it can be illustrated from these results that cross combinations *viz*., 9705 × AARI-11, 9703 × Millat-11 and 9705 × Millat-11 will be the best suited F_1 hybrid combinations, having best specific combining ability for two traits each, to fit into future hybrid breeding programs. So these parents and F_1 genotypes having superior performance can be further incorporated into the hybrid breeding programs or selection of the most appropriate parents based upon their performance.

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1. Introduction

Triticum aestivum is regarded as one of the most imperative crop, extensively cultivated throughout the world, with main purpose of human consumption, supporting approximately 35% of the world's population (Debasis and Khurana, 2001). Being a Rabi crop, it plays an important role in meeting food and nutritive requirements of the country, used for making chapatti, bread, biscuits, pastries, cake and other bakery goods. The protein found in wheat is called gluten which renders wheat a multipurpose crop, and is a primary protein source for world's inhabitants (Hogg *et al.*, 2004). Due to these facts wheat deserves special attention. Area under its cultivation was 8.69 Mha during 2012-13 and its production was 24.30 M tonnes, sharing about 12.5% in agri. sector and 2.6% in GDP of Pakistan (Pakistan Economic survey, 2012-13). However, rapid increasing population and environmental fluctuation necessitate the breeders to bring further breakthrough in production and nutritive value of wheat. It is dire need of time to enhance wheat production to ensure the food security in developing countries. Sustainable increase in production of wheat requires breeders to explore possible ways to achieve the objectives. So, the main objective of breeders is to develop wheat cultivars with high yielding ability (Ehdaie and Waines, 1989). It is prerequisite to have proper knowledge of genetic architecture of yield, yield-related traits and nature of gene action for a successful breeding program. Selection based upon these estimates helps to improve complex associated traits related to yield (Sokoto *et al*., 2012; Mohammadi *et al*., 2012; Anwar *et al*. 2014; Ali *et al*. 2013; Khan *et al*. 2014; Tariq *et al*. 2014; Muhammad *et al*. 2013). Correlation analysis provides any opportunity to select genotypes for higher yield (Ali *et al*. 2014; Qamar *et al*. 2014ab; Ali *et al*. 2014abc; Azam *et al*. 2014; Jahangir *et al*. 2014).

2. Material and methods

The present study was carried to access combining ability effects for various yield traits in wheat by parents and F1 hybrids develop through line×tester design in the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The experimental material consisted of nine wheat genotypes, six wheat elite lines viz. 9546, 9554, 9595, 9703, 9704 and 9705 (Female parent) and three testers viz. AARI-11, Millat-11 and Pasban-11 These wheat genotypes were crossed in line × tester fashion during the 1st crop season in 2012-13. In the 2nd year of study, the F_1 seeds along with nine parents were planted in the field in the randomized complete block design (RCBD) with three replications per genotype during 3rd week of November 2013.The varieties/genotypes/lines were assigned at random to experimental units in each block. Each replication consisted of nine varieties (Parents) and 18 F_1 crosses with one meter long single row for treatment. Plant to plant and row to row distance were 15 and 30 cm, respectively. Two seeds per hole were sown with the help of dibbler and later thinned to one seedling per hole after germination. The experimental populations were kept under normal condition from sowing to maturity. Moreover, efforts were done to implement proper production technology. At maturity well-guarded plants from each line were selected to record the data on the traits including plant height, number of tillers/plant, flag leaf area, spike length, peduncle length, extrusion length, awn length, spiklets/spike, number of grains/spike, 1000-grain weight and grain yield/plant.

For detection of combining ability effects data were further subjected to line × tester analysis as given by Kempthorne (1957) to estimate specific and general combining ability.

Estimation of general combining ability (GCA) effects

(a) Lines:

$gl = X_i.../tr... - X.../ ltr$

(b) Testers:

$gt = X_i... / lr...- X.../ltr$

Where, l = Number of lines female parents, t = Number of tester male parents, r = Number of replication

$(X_i...)$ = Total sum of F_1 resulting from crossing ith lines with all tester, $(X...)$ = Total of all crosses

Estimation of specific combining ability (SCA) effects

$S_{ij} = (X_{ij}) / r - (X_i) / (tr) - (X_j) / (lr) - (X) / (ltr)$

Where,

(X_{ij}) = Total of F_1 resulting from crossing ith lines with all jth testers, (X_j) = Total of all crosses of jth testers with all lines

Results and discussions

It was found from table 1 that significant differences were reported for lines, testers and line × tester. For all the mentioned morphological yield traits GCA (general combining ability) and SCA (specific combining ability) effects were estimated using methodology and procedure mentioned in materials and methods section. Based on these studies best general and specific combiners are highlighted. Results of GCA and SCA estimates are reported in table 3 and are illustrated in their respective sections below: Specific combining ability (SCA) is the performance of a genotype in a single cross. SCA effects help us in selection of the best cross combination which will produce the genotype with the desirable attributes. Specific combining ability effects of different morphological traits derived from the line × tester analysis are presented in the table 3.

Plant height

Plants with lesser height are more desirable in wheat than plant with more height because there is a chance for the crop to get lodged having greater height. Short statured plants are more responsive toward the fertilizers use as well along with the lodging resistance. Therefore, negative estimates of combining ability are desirable in case of plant height. During the study undesirable positive estimates of combining ability were recorded for lines viz. 9704 (4.47), 9703 (1.66), 9546 (0.27) and testers viz. AARI-11 (1.61) and Millat-11 (0.46). Three lines viz. 9705, 9554, 9595 and one tester, Pasban-11, exhibited desirable negative estimate of general combining ability -2.97, -2.78, -0.64 and -2.07, respectively for plant height. Following results are in accordance to the results of Malik *et al.* (2005); Akbar (2009); Saeed *et al*. (2005) and Farooq *et al*. (2011b). So genotypes with the negative combining ability effects will be selected to design the plant architecture for plant height.

Specific combining ability effects represented by different cross combination showed different trends with most effective desirable negative effects recorded for 9554 × Millat-11 cross with magnitude of -9.316 followed by the crosses; 9554 × Pasban-11(-7.383), 9705 × Pasban-11 (-5.144), 9595 × AARI-11(-2.906), 9546 × AARI-11 (-2.450), 9705 × AARI-11 (-0.933) and 9703 × Millat-11 (-0.810). Plants with lesser height will serve the cause so, the best specific combiner for plant height was 9554 × Millat-11 (-9.316). Undesirable specific combinations were; 9704 × AARI-11 (9.089), 9704 × Pasban-11 (7.467), 9704 × Millat-11 (6.200), 9595 × Pasban-11 (2.106), 9546 × Pasban-11 (0.828), 9546 × Millat-11 (0.761), 9703 × AARI-11 (0.672), 9595 × Millat-11 (0.639), 9703 × Pasban-11 (0.561), 9554 × AARI-11 (0.394) and 9705 × Millat-11 (0.222). Results of present SCA estimates are in agreement with Chowdhry *et al.* (1999); Akbar (2009); Saeed *et al*. (2005) and Farooq *et al*. (2011b).

Number of grains/spike

Number of grains/spike is of vital importance as a yield contributing trait having positive relationship with grain yield. As grains/spike increases yield/plant increases so positive combining ability estimates for lines and testers will be beneficial for selection of parental genotypes to be utilized in hybridization. Positive desirable GCA effects were reported for four line; 9595 (0.99), 9704 (0.37), 9705 (1.61) and 9703

(2.37) and two testers; Pasban-11 (1.16) and Millat-11 (0.71) but undesirable negative GCA effects were obtained for two lines viz. 9554 and 9546 and one tester AARI-11 having -3.23, -2.12 and -1.86 general combining ability estimates, respectively. These results were according to the previously reported results by Akbar (2009) Saeed *et al*. (2005) and Farooq *et al*. (2011b).

Grains/spike has a direct impact on the plant yield so fruitful estimates of specific combining ability effects for this character are positive as it is correlated to the yield/plant as well. In the following study 9 out of 18 cross combinations represented the desirable positive specific combining ability estimates with 9703 × Millat-11 being the best specific combiner for grains/spike with SCA effects magnitude of 7.006. The close estimates of SCA effects were observed for 9595 × Pasban-11 (6.517) and 9546 × Millat-11 (4.239) followed by 9546 × Pasban-11 (3.217), 9705 × Pasban-11 (2.422), 9703 × AARI-11 (1.672), 9704 × Millat-11 (1.222), 9705 × Millat-11 (1.089) and lowest for 9704 × AARI-11 (0.844). The negative cross combinations were as follow; 9703 × Pasban-11 (-8.028), 9705 × AARI-11 (-6.511), 9554 × Pasban-11 (-4.928), 9546 × AARI-11 (-3.872), 9554 × AARI-11 (-3.494), 9595 × Millat-11 (-0.728), 9595 × AARI-11 (-0.572), 9704 × Pasban-11 (-0.067) and 9554 × Millat-11 (-0.028). Chandrakar *et al.* (1994); Chowdhry *et al*. (1990); Akbar (2009) Saeed *et al*. (2005) and Farooq *et al*. (2011b) presented the almost similar results as found in the current research.

Grains yield/spike

The main focus of the breeders is to produce the genotypes with high grain yield/plant for which they need to improve the traits associated to the grain yield. Grain yield/spike plays a primary role in the final yield of plant so breeder should focus to improve grain yield/spike which will ultimately add to the final grain yield in wheat. The combining ability estimates were positive for female parents (lines); 9546, 9704, 9705 (lines) in descending order 0.07, 0.05, 0.03, respectively and tester Millat-11 having 0.05. Undesirable negative GCA estimates were obtained for the 9554 (-0.02), 9595 (-0.05), 9703 (-0.05), AARI-11 (-0.02) and Pasban-11 (-0.02). Present results indicated that in maternal parent (lines) 9546 and in paternal parents (testers) Millat-11 were best general combiners for grain yield /spike. Similar results about grain yield/spike were reported by Majeed *et al.* (2011).

In case of grain yield/spike 10 crosses showed the positive SCA effects and the best of all was 9546 × Pasban-11 with 0.413 value with closer value observed for 9703 × AARI-11 (0.407). The positive SCA estimates for grain yield/spike are most favored as it contributes to yield positively. The range of positive estimates was from 9546 × Pasban-11 (0.413) to 9705 × AARI-11 (0.046) showing that maximum crosses with positive estimates were of Millat-11. Negative unwanted cross combinations ranged from 9703 × Millat-11 (-0.492) to 9704 × Pasban-11 (-0.037) having maximum negative estimates of SCA of Pasban-11, had only one positive value which was the best specific combiner for grain yield/spike. Saeed *et al*. (2005) recorded the somewhat similar results.

Number of tillers/plant

Number of tillers/plant is being regarded as the imperative component trait contributing yield/plant, as greater number of tillers/plant is considered to outcome good yield performance in wheat. Number of tillers is positively correlated to the grain yield so plants with positive GCA effects will be desirable. Maximum positive general combining ability effects were exhibited by line; 9554 (0.44) following 9704 (0.23), 9703 (0.22) and 9595 (0.04). The only desirable positive estimate of GCA was recorded for AARI-11 (0.31). Undesirable negative combining ability estimates were recorded for genotypes 9546(-0.73), 9705 (-0.21), Millat-11 (-0.18) and Pasban-11 (-0.13). Best general combiners were 9595 (female) and AARI-11 (male) in the present study. The GCA estimates obtained during current study are virtually near to those stated by Akbar (2009) Saeed *et al*. (2005) and Farooq *et al*. (2011b).

Grain yield is directly correlated to the number of tillers/plant, more the number of tillers/plant more will be yield. Maximum and minimum positive values of specific combining ability were recorded for cross combinations 9595 × AARI-11 and 9554 × Pasban-11 which were 1.889 and 0.211, respectively. Other positive estimates of specific combining ability effects were observed for 9705 × Pasban-11 (1.244), 9704 × AARI-11 (0.956), 9703 × AARI-11 (0.733), 9703 × Pasban-11 (0.700), 9554 × AARI-11 (0.511), 9704 × Pasban-11 (0.500) and 9595 × Millat-11 (0.311). Undesirable negative combinations ranged from -1.378 to -0.400 for 9546 × Pasban-11 and 9704 × Millat-11 respectively. Out of 18 cross combinations positive values of specific combining ability were observed in 9 crosses with crosses of AARI and Pasban-11 having 4 each and only one cross of Millat-11 exhibited positive value of specific combining ability estimate.

Number of spikelets/spike

Spikelets/spike is an important yield contributing component imparts positively to the grain yield also has a direct positive association with the grain yield/plant. Highest positive value of GCA was recorded for line 9546 (1.26) following 9554 (0.53), 9704 (0.04) and for testers Pasban-11 (0.62) following AARI-11 (0.02). So, 9546 (line) and Pasban-11 (tester) are the best general combiners for spikelets/spike.

Remaining estimates for GCA variances were negative for genotypes; 9595 (-0.54), 9703 (-0.49), 9705 (-0.80) and Millat-11 (-0.64). These results are supported by the similar results testified by Tosun *et al.* (1995) and Malik *et al.* (2005).

Number spikelets/spike is another vital trait helpful to enhance the yield in wheat and is directly proportional to the number of grains/spike and ultimate outcome of which is boasted grain yield/spike and yield/plant. Positive SCA effects from top to bottom were reported in 9705 × Pasban-11 (2.626), 9546 × Pasban-11 (2.359), 9554 × Pasban-11 (2.093), 9703 × Millat-11 (1.304), 9554 × AARI-11 (0.981), 9546 × AARI-11 (0.693), 9704 × Pasban-11 (0.559), 9703 × AARI-11 (0.437), 9595 × AARI-11 (0.149), 9595 × Pasban-11 (0.148) and 9704 × Millat-11 (0.093). 7 cross combinations out of 18 showed negative values of SCA effects ranging from 9705 × Millat-11 with -4.819 to 9703 × Pasban-11 with -0.052 SCA estimates. Pasban-11 had the maximum number of crosses with positive specific combining ability effects. These results resembles to the findings reported by Mahmood and Chowdhry (2002), Akbar *et al*. (2009) and Farooq *et al*. (2011a).

Awn length

Awned varieties of wheat produce more yield than awnless varieties so greater awn length will be desirable to produce higher yield. For awn length three females; 9703 (0.74), 9705 (0.11) and 9595 (0.01) and two males; Millat-11 (0.02) and AARI-11 (0.01) showed positive estimates of general combining ability effects. The result of general combining ability effects were negative in case of 9546(-0.19), 9554(-0.37), 9704 (-0.31) and Pasban-11 (-0.03).

Out of total 18 crosses 9 crosses gave the positive estimates of specific combining ability on the present research. Maximum positive value of SCA effects in case of awn length was observed for 9705 × Millat-11 (1.272) followed by; 9703 × AARI-11 (0.872), 9703 × Millat-11 (0.861), 9595 × Pasban-11 (0.506), 9546 × AARI-11 (0.211), 9704 × Millat-11 (0.194), 9546 × Millat-11 (0.156) and 9704 × Pasban-11 (0.050). Negative SCA effects were recorded in crosses *viz*., 9705 × AARI-11 (-1.350), 9554 × AARI-11 (-0.922), 9554 × Pasban-11 (-0.522), 9704 × AARI-11 (-0.550), 9546 × Pasban-11 (-0.422), 9554 × Millat-11 (-0.233), 9595 × AARI-11 (0.139), 9595 × Millat-11 (0.117), 9703 × Pasban-11 (-0.094) and 9705 × Pasban-11 (-0.050).

Number of spike length

Spike length is another important yield related component impart directly to grain yield in wheat plants. More spike length will result in more number of spikelets/spike which will ultimately increase the yield because they are directly correlated. The positive desired general combining ability effects for maternal genotypes in descending order are 9705 (1.25), 9595 (0.06) and for paternal parents is Millat-11 (0.61). Negative general combining ability effects were reported for 9546(-0.07), 9554 (-0.65), 9703 (-0.33), 9704 (-0.25), AARI-11 (-0.19) and Pasban-11 (-0.42). According to these results 9705 in female parents and Millat-11 in male parents are the good general combiners for spike length. These results coincide with that obtained by Akbar *et al.* (2009) and Chandrakar *et al.* (1994).

Positive SCA effects are desired for spike length. Best crosses are the ones having higher and positive values of specific combining ability. Best general combiner for spike length was 9705 × Millat-11 (4.256) and the second best combiner was 9705 × AARI-11 with SCA estimate of 2.044. Other positive SCA effects were observed in the crosses; 9546 × Millat-11 (1.822), 9704 × Millat-11 (0.722), 9704 × Pb-11 (0.544), 9595 × Pb-11 (0.378), 9554 × AARI-11 (0.144) and 9554 × Millat-11 (0.056). Out of total 18 crosses 10 crosses exhibited negative SCA effects with range from -2.944 to -0.078 for 9703 × Pb-11 and 9703 × Millat-11 crosses respectively. Crosses of Millat-11 produced better results for spike length having maximum positive cross combinations for specific combining ability effects. These results are in accordance to the ones reported by Akbar *et al.* (2009) and Farooq. (2011ab).

Extrusion length

The best general combiners female for extrusion length was 9703 (1.77) followed by 9554 (0.57) and in case of male parents only positive combining ability was recorded for Pasban-11 (0.74). So in the present study line 9703 came across as the best general combiner for extrusion length. Four lines; 9546 (-1.23), 9595 (-0.66), 9704 (-0.13) and 9705 (-0.33) and two testers; AARI-11 (-0.60) and Millat-11 (-0.14) exhibited negative general combining ability effects for peduncle length. Following results for extrusion length were verified by similar findings reported by Fedin *et al.* (1987). Extrusion length exerts direct negative effect on the grain yield so less SCA effects are meaningful for this trait. Higher the extrusion length lower will be grain yield produced by the plant. Positive specific combining ability effects were recorded for extrusion length in 10 crosses out of 18 which were 9703 × Millat-11, 9554 × Pasban-11, 9705 × Pasban-11, 9595 × Pasban-11, 9703 × Pasban-11, 9704 × Pasban-11, 9554 × Millat-11, 9703 × AARI-11, 9704 × AARI-11 and 9546 × AARI-11 with magnitude as follow; 2.637, 2.059, 1.715, 1.526, 1.393, 1.048, 0.770, 0.393, 0.348 and 0.159. For remaining 8 crosses values of specific combining ability effects were; -4.219, -2.719, -2.007, -1.341, -0.607, -0.374, -0.441 and -0.341 for crossed; 9705 × AARI-11, 9704 × Millat-11, 9705 × Millat-11, 9595 × AARI-11, 9554

× AARI-11, 9546 × Millat-11, 9595 × Millat-11 and 9546 × Pb-11. Results of specific combining ability indicated that maximum number of crosses of Pb-11 had positive estimated of SCA effects (five crosses) but the best specific combination was 9703 × Millat-11 (2.637) which will be suitable to utilize into the future breeding scheme.

Peduncle length

Maximum positive GCA effects were recorded for peduncle length in 9704 (1.73) remaining in the descending order were, for lines 9703 (1.65), 9546 (1.21), 9554 (0.07) and testers; Pasban-11 (1.06) and Millat-11 (0.27). Negative estimates of GCA in descending order are; 9595 (-2.77), 9705 (-1.89), AARI-11 (-1.34). As peduncle length imparts directly to grain yield/plant so, larger peduncle length is desirable which will directly contribute to the overall yield. 9704 (1.73) is the best general combiner in the present research for extrusion length. For peduncle length nine crosses showed positive and other nine crosses showed negative values of specific combining ability effect. Maximum and minimum positive values of SCA were observed for 9554 × Pasban-11 (5.893) and 9595 × Pasban-11 (0.020), respectively. On the other hand maximum and minimum negative SCA effects were observed for 9705 × AARI-11 (-7.813) and 9703 × Millat-11 (-0.013), respectively. From 18 crosses all six crosses of Pasban-11 exhibited higher positive desirable estimates of specific combining ability for peduncle length and five crosses of AAR-11 given the negative undesirable specific combining ability effects.

Flag leaf area

Flag leaf area plays an important role in grain development and grain filling as it is a yield contributing trait desirable with high positive general combining ability effects. Due to its contribution to the grain yield, the main objective of breeder is the selection of genotypes with large flag leaf area. General combining ability estimates were maximum for 9703 (4.53) and AARI-11 (2.07) in line and tester, respectively so, 9703 is best general combiner. The other positive GCA estimates were obtained for 9554 (0.94) and Pasban-11 (0.57). From total genotypes four lines and one tester shown undesirable negative estimates of general combining ability effects. The results of the research were in agreement to Joshi *et al.* (1990) and Saeed *et al.* (2002). The best specific combiner for flag area was 9703 × AARI-11 with very high specific combining ability effects of 18.356. other cross combinations with higher specific combining ability effects were 9703 × Pasban-11, 9704 × AARI-11, 9595 × Pasban-11, 9554 × Millat-11, 9595 × AARI-11, 9705 × Pasban-11 and 9554 × Pasban-11 with SCA effects from top to bottom as follow; 8.900, 6.306, 6.222, 3.006, 1.350, 0.922, and 0.517 which can be utilized in the crop improvement programs in future. The negative estimates of specific combining ability were in the range of -9.694 to -0.728 for cross combinations 9705 × AARI-11 and 9546 × Pasban-11 respectively. Maximum number of crosses of Pb-11 gave the positive specific combining ability effects and five crosses of Millat-11 showed negative estimates of specific combining ability. Akbar *et al.* (2009) and Chowdhry *et al.* (1999) reported similar results to the present study.

1000-grain weight

Positive GCA effects are preferred in case of 1000-grain weight because it is directly associated to the grain yield/plant which is an important trait associated to the grain yield. In the present research the female parent 9546 with GCA effects of 3.05 was proved as the best general combiner for 1000-grain weight. Genotype 9554 (3.04) was second and 9704 (0.08) was third good combiner with positive GCA effects. The testers AARI-11 with 1.13 and Millat-11 with 0.27 general combining ability effects were among the other good general combiners. For three lines and one tester negative GCA effects were recorded which is undesirable for grain yield. Same results were obtained by Akbar *et al.* (2009) and Farooq *et al.* (2011a). For 1000-grain weight maximum specific combining ability effects recorded were 6.757 for cross combination 9705 × AARI-11. Cross combination 9554 × Millat-11 showed second maximum positive value of specific combining ability. The range of positive meaningful SCA effects was 6.757 to 0.752 for cross combinations 9705 × AARI-11 and 9595 × Pasban-11, respectively. For nine crosses positive SCA effects were recorded, three crosses each of AARI-11, Millat-11 and Pasban-11. The best specific combiner was 9705 × AARI-11 (6.757). Nine cross combinations gave negative non-beneficial SCA effects ranged from -13.937 to -0.132 for crosses; 9703 × Millat-11 and 9704 × AARI-11, respectively. Pasban-11, Millat-11 and AARI-11 exhibited negative estimates of specific combining ability in their three crosses each.

Grain yield/plant

Grain yield/plant is the most vital trait of interest to the breeders. Main effort of plant breeding programme is to improve the grain yield/plant. For this trait one tester AARI-11 (2.01) and three lines, 9703 (1.28), 9554 (.25), 9704 (0.41), shown positive general combining ability (GCA effects) effects for grain yield/plant. AARI-11 with 2.01 GCA was the best general combiner in present research. Negative general combining ability effects were recorded for genotypes; 9546 (-0.41), 9595 (-1.19), 9705 (-0.35), Millat-11 (-0.59), Pasban-11 (-1.42) and AARI-11 (2.01). The same results were previously reported by Akbar *et al.* (2009) and and Chowdhry *et al.* (1999).

More variability for grain yield/plant was detected in the grain yield/plant than any other character. The estimates of specific combining ability were positive and higher for grain yield/plant than both Millat-11 and Pasban-11. The best specific combiner was 9705 × AARI-11 with specific combining ability estimate of 5.157 other crosses of AARI-11 exhibited positive SCA effects in the following sequence; 9704 × AARI-11 (4.557), 9703 × AARI-11 (4.619) and 9595 × AARI-11 (0.419) but two of them had negative SCA effects as 9546 × AARI-11 (-4.309) and 9554 × AARI-11 (-1.009). Four crosses of Millat-11 gave negative specific combining ability estimates; 9554 × Millat-11 (-3.031), 9546 × Millat-11 (-2.243), 9705 × Millat-11 (-0.631) and 9595 × Millat-11 (-0.548) but two of them exhibited positive SCA effects as follow; 9704 × Millat-11 (0.891) and 9703 × Millat-11 (0.062). In case of Pasban-11 two crosses gave positive SCA estimates and remaining four gave negative estimates of SCA effects as follow; 9704 × Pasban-11 (1.402), 9546 × Pasban-11 (0.635), 9705 × Pasban-11 (-2.643), 9554 × Pasban-11 (-2.576), 9703 × Pasban-11 (-0.414) and 9595 × Pasban-11 (-0.337). Akbar *et al.* (2009) and Farooq *et al.* (2011ab) stated the results similar to the present ones.

Table 1. Mean squares of some morphological traits in bread wheat (line × tester analysis)

SOV	**df Grain**	**Plant**	**Flag**	**number**	**Extrusion**	**Peduncle**	**Spike**	**Awn**	**Spikelets/**	**Number**	**Grain**	**1000-**
height	**Leaf**	**of**	**length**	**length**	**length**	**length**	**spike**	**of**	**yield/**	**grain**	**yield/**	
area	**tillers/plant**		**grains/spike spike**		**weight**	**plant**						
Replications 2			11.26** 52.57**	13.40^{NS} 413.06**	0.80*	2.23**	26.58**	2.19**	0.11**	0.52**	25.87**	0.01^{NS}
Genotype	26 17.78**	166.80**	100.71**	1.59*	16.22**	29.26**	3.06**	0.89**	7.46**	73.91**	0.27**	72.81**
Parents (P)	62.81**	8 11.37**	392.94**	44.20*	1.04*	37.63**	57.71**	0.80^{NS}	0.63**	6.02**	101.32**	0.35**
Parents vs.												
Crosses	1 47.47**	192.51**	205.37**	6.16**	6.16**	0.19^{NS}	5.59**	0.02^{NS}	11.41**	42.63**	0.52**	47.80*
Crosses	17 19.05**	58.89**	121.15**	1.59*	6.74**	17.57**	3.97**	1.07**	7.90**	62.86**	0.22**	78.98**
Lines (L)	5 6.47**	71.45**	56.02*	1.59*	9.97**	33.19**	3.91**	1.50**	5.50**	43.62**	0.02**	58.28**
Testers (T)	29.87**	2 57.67**	63.55**	104.53**	1.31*	8.39**	26.86**	5.29**	0.01^{NS}	7.10**	47.67**	0.03**
L x T	10 17.62**	51.68**	157.04**	1.64**	4.79**	7.90**	3.73**	1.07**	9.27**	75.52**	0.36**	99.16**
Error	52 5.69	4.49	40.86	0.45	0.23	1.23	2.01	0.12	1.17	12.14	0.02	14.76
Highly significant =		** , Significant		=	*	Non-significant		=	NS			

Table 2. GCA estimates for some morphological traits in bread wheat (line × tester analysis)

Lines/testers	**Grain**	**Plant**	**Grains/**	**Grain**	**number**	**Spikelets/**	**Awn**	**Spike**	**Extrusion**	**Peduncle**	**Flag**	**1000-**
height	**spike**	**yield/**	**of**	**spike**	**length**	**length**	**length**	**length**	**leaf**	**grain**	**yield/**	
spike	**tillers/plant**		**area**	**weight**	**plant**							
Lines												
9546	0.27	-2.12	0.07	-0.73	1.26	-0.19	-0.07	-1.23	1.21	-1.33	3.05	-0.41
9554	-2.78	-3.23	-0.02	0.44	0.53	-0.37	-0.65	0.57	0.07	0.94	3.04	0.25
9595	-0.64	0.99	-0.05	0.04	-0.54	0.01	0.06	-0.66	-2.77	-1.77	-2.34	-1.19
9703	1.66	2.37	-0.05	0.22	-0.49	0.74	-0.33	1.77	1.65	4.53	-2.64	1.28
9704	4.47	0.37	0.05	0.20	0.04	-0.31	-0.25	-0.13	1.73	-0.20	0.08	0.41
9705	-2.97	1.61	0.03	-0.21	-0.80	0.11	1.25	-0.33	-1.89	-2.17	-1.19	-0.35
Testers												
AARI-11	1.61	-1.86	-0.02	0.31	0.02	0.01	-0.19	-0.60	-1.34	2.07	1.13	2.01
Millat-11	0.46	0.71	0.05	-0.18	-0.64	0.02	0.61	-0.14	0.27	-2.64	0.27	-0.59
Pasban-11	-1.40	-2.07 -1.42	1.16	-0.02	-0.13		0.62	-0.03	-0.42	0.74	1.06	0.57

Table 3. SCA estimates for some morphological traits in bread wheat (line × tester analysis)

Crosses	Plant	Grains/	Grain	number	Spikelets/	Awn	Spike	Extrusion	Peduncle	Flag	1000-	Grain
height	spike	yield/	of	spike	length	length	length	length	leaf	grain	yield/	
spike	tillers/plant		area	weight	plant							
9546 × AARI-11	-4.309	-2.450	-3.872	-0.343	-0.533	0.693	0.211	-0.556	0.159	0.493	-3.994	-2.098
9546 × Millat-11	-2.243	0.761	4.239	0.213	-0.978	-0.574	0.156	1.822	-0.374	2.893	-3.339	-1.220
9546 × Psb-11	0.635	0.828	3.217	0.413	-1.378	2.359	-0.422	-0.256	-0.341	5.737	-0.728	5.324
9554 × AARI-11	-1.009	0.394	-3.494	0.046	0.511	0.981	-0.922	0.144	-0.607	-3.852	-9.061	3.857
9554 × Millat-11	-3.031	-9.316	-0.028	0.247	-0.567	-0.285	-0.233	0.056	0.770	0.703	3.006	6.269
9554 × Psb-11	-2.576	-7.383	-4.928	-0.276	0.211	2.093	-0.522	-2.244	2.059	5.893	0.517	-0.665
9595 × AARI-11	0.419	-2.906	-0.572	-0.415	1.889	0.149	0.139	-0.956	-1.341	-4.057	0.922	-7.637
9595 × Millat-11	-0.548	0.639	-0.728	-0.259	0.311	-1.252	-0.117	-0.411	-0.441	-3.624	-2.356	-4.692
9595 × Psb-11	-0.337	2.106	6.517	0.374	-0.478	0.148	0.506	0.378	1.526	0.020	6.222	0.752
9703 × AARI-11	4.619	0.672	1.672	0.407	0.733	0.437	0.872	-0.489	0.393	-0.668	8.356	4.819
9703 × Millat-11	0.062	-0.8096	7.006	-0.492	-1.289	1.304	0.861	-0.078	2.637	-0.013	-7.878	-13.937
9703 × Psb-11	-0.414	0.561	-8.028	-0.215	0.700	-0.052	-0.094	-2.944	1.393	3.309	8.900	4.129
9704 × AARI-11	4.557	7.089	0.844	0.057	0.956	-3.641	-0.550	-0.089	0.348	-0.702	6.306	-0.132
9704 × Millat-11	0.891	6.200	1.222	0.179	-0.400	0.093	0.194	0.722	-2.719	-1.035	-5.472	1.746
9704 × Psb-11	1.402	7.467	-0.067	-0.037	0.500	0.559	0.050	0.544	1.048	5.243	-0.994	-0.909
9705 × AARI-11	5.157	-0.933	-6.511	0.046	-0.444	-0.819	-1.350	2.044	-4.219	-7.813	-9.694	4.157
9705 × Millat-11	-0.631	0.222	1.089	0.313	-0.989	-4.819	1.272	4.256	-2.007	-2.657	-2.061	4.102
9705 × Psb-11	-2.64	-5.144	2.422	-0.276	1.244	2.626	-0.050	-1.944	1.715	0.131	1.350	-6.465

Conclusion

On a concluding note, it can be established that in case of parental genotypes 9546, 9703, 9705 and AARI-11 would be the best suited parents for further evaluation and hybrid development programs. Whereas, crosses like 9705 × AARI-11, 9703 × Millat-11 and 9705 × Millat-11 also needed to be evaluated to develop future breeding strategy, which will have higher chances of success as compared to other cross combinations.

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