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Gene action and combining ability studies for yield and its component traits in wheat (*Triticum aestivum* L.)

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Abstract: Eight bread wheat (*Triticum aestivum* L.) genotypes were crossed in a line × tester mating design. The 15 F_1's and their parents were evaluated in a randomized complete block design with three replications at the research area of Plant Breeding and Genetics, UAF. The characters studied were plant height, spike length, peduncle length, flag leaf area, number of tillers per plant, number of grains per spike, number of spikelet per spike, density of spike, thousand grain weight and yield of grain/ plant at. The results indicated that sufficient genetic variability was observed for all characters studied. Among lines, Aas 2011 proved best general combiner and exhibited significant general combining ability effects for most of the characters. Among testers, 9459 proved best general combiner for most of the traits studied. Among crosses, AARI 2011×9459 and Ujala 2016×9515 were best specific combiners for most of the studied traits and showed highly significant SCA effects. GCA to SCA variances ratio revealed predominantly non-additive gene action for these traits. Development of new varieties with improved agronomic traits is, therefore, suggested through selection in late segregation generations of these crosses.
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Key words: Wheat (*Triticum aestivum* L.), yield, combining ability, Line × tester analysis

Introduction

Wheat (*Triticum aestivum* L.) is a crop which is staple and belongs to Poaceae family. It is growing widely in large areas of world including Pakistan because it is leading grain in Pakistan. It is using to make noodles, bread and bakery products. It is comprising of 22% carbohydrates and 20% calories world's need annually (Widyaratne and Zijlstra, 2007).

As population of world increasing as day passes but the wheat yield will not increase up to some increasing extent. It is evaluated that at about 2050 there will be 9.3 billion increases in population of world (Celand, 2013). As population is increasing fastly so we meet to those moments when there is maximum increase in wheat production. These achievements will possible when we use those germplasm of wheat whose genetic potential has maximum potential.

Wheat a staple human food, it is specified for its taste and it is big sources of protein, carbohydrates and minerals which is essential for human body. About one third of world population wheat implement the protein and caloric need. (Bakhsh *et al*., 2003). The most important property of wheat is that it contains gluten protein, a united network of hard endosperm and protein support in dough making which makes flour of wheat ideal among all other cereals.

After rice wheat made her position at 2^{nd} number and it is using for different aims because of its changing in physical and chemical changes (Shoran *et al.,* 2003). Wheat grain is used as daily food in Pakistan. The population of Pakistan is mainly based on 70 percentage on agriculture. As a production based Pakistan brings its name in top 10 countries. In Pakistan agriculture policies, it is considering most needed food grain so that it occupies main importance of country.

As yield is most important and complex attribute economically. So, for developing an effective breeding programme of wheat varieties with great potential, the knowing of type of gene action, selection of best parents, knowing of genetic behaviour and knowledge of yield related traits is really necessary. The identification of parents with high potential is achievable through studying combining ability (Kumar et al., 2015). The genetic variance is known by combining ability results. It is necessary to select high performing crosses instead of weak crosses. Combining ability tells us that for fast improvement in breeding material select good potential cross combinations and select elite parents.

For estimation of combining ability effects of yield and yield related traits and genetic study analysis which is line×tester is powerful method (Kempthorne, 1957). The impact of GCA and SCA conclude for potential of yield and its properties influences breeders to select most desirable parents and hybrid formation in plant. Through less combinations more parents would be estimated by line×tester mating design. The mode of gene action is also modified in yield parameters. General combining ability comprises of additive and additive ×additive interaction which is fixable. The dominance and non-additive or non-additive×non-additive genetic action will be because of SCA effects.

The current study is to evaluate combining ability effects and behaviour of genes along with wheat genotypes having good GCA and SCA for yield or yield characteristics. Here present research can be fruitful for selection of desirable parents and selection of best cross combination for effective wheat breeding programme.

Materials and methods

The experiment was performed in University of Agriculture Faisalabad at experimental area of department of Plant Breeding and Genetics for estimation of combining ability effects by applying line×tester mating design. The experiment contains five different lines namely (Ujala 2016, Johar 2016, Aas 2011, Punjab 2011 and AARI 2011) of spring wheat and 9515, 9459 and 10065 used as testers. These wheat varieties were crossed in line ×tester method during 2017-2018. At matured stage, the seeds were selected each and harvested.

1. Ujala 2016×9515
2. Johar 2016×9515
3. Aas 2011×9515
4. Punjab 2011×9515
5. AARI 2011×9515
6. Ujala 2016×9459
7. Johar 2016×9459
8. Aas 2011×9459
9. Punjab 2011×9459
10. AARI 2011×9459
11. Ujala 2016×10065
12. Johar 2016×10065
13. Aas 2011×10065
14. Punjab 2011×10065
15. AARI 2011×10065

In 2nd year of experiment the F_1 seeds along with its 8 maternal were grown at field in RCBD pattern along its 3 blocks in 2nd last week of November. In each block, the lines are placed randomly in experimental unit. Every replication contained eight parents as well as fifteen F_1 crosses along with 3m single row for treatment. P-P Distance was 10cm as well as R-R distance is 30cm. In each hole 2 seeds were sown with dibbler. After germination, the thinning was done one seedling/hole. The experimental population is under normal condition as per sowing to maturity. For good production, all efforts were implemented in field. The best 10 plants were selected from each line for the data analysis. Data were recorded for plant height, spike length, peduncle length, flag leaf area, number of tillers per plant, number of grains per spike, number of spikelet per spike, density of spike, thousand grain weight and yield of grain/ plant from selected plant at maturity stage.

Statistical analysis

The analysis of variances was done to all data taken from different traits of wheat and estimated the significant difference of parents and crosses as given by (Steel *et al*., 1997).

Line×tester analysis

For calculation of combining ability the recorded data were placed next for mating design which is line× tester (Kempthorne, 1957) and further analysed GCA and SCA. The data of specific combining ability and general combining ability along with lines, tester and F_1 hybrids information were estimated.

Results and discussion

Line × tester analysis:

Line × tester analysis explained by scientist kempthorne (1957) is majorly organized method is to explain general combining ability (GCA) and specific combining ability (SCA) effects of varieties and also applied to explain the genetic action of all characters. In mine present research and study the experiment which is done under line×tester analysis are described below. The plant characters like plant height, flag leaf area, peduncle length, number of tillers per plant, spike length, spike density, number of spikelets per spike, number of grains/spike, 1000 grain weight and grain yield/ plant mean squares are highly significant effects for various varieties are prescribed in Table 1.

For maternal parents and lines, the traits plant height, spike length, number of tillers per plant, number of grains per spike, spike density, thousand grain weight and grain yield per plant the results were highly significant. For flag leaf area the results were significant. The non-significant effects were seen for peduncle length and number of spikelets per spike.

Among testers the highly significant differences were showed from plant height, number of grains per spike, spike density and 1000 grain weight. The number of spikelets per spike results were significant. The non-significant differences were exhibited for peduncle length, number of tillers per plant, grain yield and for spike length.

For parents the plant height, flag leaf area, number of grains per spike, number of tillers per plant and 1000 grain weight were revealed highly significant effects while another hand the significant effects were not seen in any character. The non-significant effects were observed from grain yield, spike density, number of spikelets per spike and peduncle length.

Among parents and crosses the traits flag leaf area, peduncle length, number of grains per spike the results showed highly significant. For spike length and spike density the results were significant differences. The non-significant effects were prescribed for characters plant height, number of tillers per plant, number of spikelets per spike, 1000 grain weight and grain yield.

The line×tester components the highly significant differences were observed from plant height, flag leaf area, peduncle length, number of tillers per plant, number of grains per spike, number of spikletes per spike and thousand grain weight. The significant differences were showed for grain yield. The spike length and spike density the results were non-significant.

The interpretation of line×tester analysis exhibited variety of changes in genes in case of wheat varieties significant differences were observed for all characters related to yield or yield related traits. So, these varieties utilised for future breeding development programme of wheat.

Table 1: Mean square ANOVA of line × tester analysis for traits studied in wheat

	D.F	Plant height (cm)	Flag leaf area (cm^2)	Spike length (cm)	Peduncle length (cm)	No. of tillers per plant	No. of grains per spike	No. of spikelets per spike	Spike density	1000-grain weight (g)	Grain yield per plant (g)
Replication	2	0.686NS	37.853NS	1.694NS	0.935NS	0.144NS	7.15NS	0.889NS	0.061*	0.233NS	12.935NS
Genotypes	22	60.694**	145.232**	2.296**	15.77**	9.143**	220.845**	2.772**	0.038**	15.413**	23.082**
Crosses	14	73.984**	125.044**	1.953*	15.964**	8.961**	235.891**	3.8**	0.043**	18.653**	26.936**
Lines	4	77.149**	88.42*	3.351**	6.571NS	12.326**	426.42**	1.501NS	0.061**	35.061**	50.917**
Testers	2	132.113**	148.41**	1.422NS	6.241NS	3.883NS	427.955**	2.289*	0.077**	11.698**	5.482NS
L × T	8	57.869**	137.515**	1.387NS	23.091**	8.549**	92.61**	5.327**	0.026NS	12.187**	20.309*
Parents	7	42.051**	92.965**	2.63**	5.337NS	10.31**	106.521**	1.095NS	0.027NS	10.245**	18.583NS
C vs P	1	5.131NS	793.744**	4.759*	86.084**	3.514NS	810.47**	0.125NS	0.056*	6.238NS	0.618NS
Error	44	3.6359	28.3345	0.8167	5.2802	2.3376	15.174	0.6845	0.0135	2.1092	8.7817

*= Significant at $P < 0.05$
** = Significant at $P < 0.01$
ns = Non- significant

Estimate of GCA effects for yield and its related traits in wheat

Combining ability will be modified 2 types general combining ability and specific combining ability.

The average performance of varieties or genotypes in series of crosses termed as general combining ability. In specific combination of cross the varieties workout or performance termed as specific combining ability (SCA). The average workout of lines is used to explain general combining ability in case of hybrid combinations while on other hand the specific workout of particular cross combination which performed good as compared to average workout of lines is used to described specific combining ability (Sprague and Tatum 1942).

The parents can be evaluated which could be used in future breeding improvement or development programmed is identified from variations appeared from effects of general combining ability for yield or yield characters by using female as lines or testers as males. The results of GCA among most of were explained in Table 2 below.

Plant height (cm)

The negative general combining ability were necessary for plant height because at maximum height there is chances of lodging of crop. Small heighted plants are preferred because they were difficult to lodge. Therefore, negative combining ability effects will be preferred. During mine studied time the unlikely positive general combining ability effects were observed in lines Johar 2016(2.34) and Punjab 2011(3.23) while on other hand the required negative general combining ability effects were observed in lines Ujala 2016(-0.60), Aas 2011(-4.16) and AARI 2011(-0.81). For testers the undesirable positive general combining ability effects were observed in 9515(2.68) and in 9459(0.51) and negative or desired general combining ability effects were exhibited in 10065(-3.91). For plant height the line Punjab 2011 and tester 9515 were exhibited good general combining ability effects. The results were similar to Jain and Sasty (2012).

Flag leaf area (cm^2)

During mine studied time the positive general combining ability effects were observed in lines Johar

2016(1.39), Punjab 2011(0.36) and Ujala 2016(4.20) while on other hand the negative general combining ability effects were observed in lines Aas 2011(-2.02) and AARI 2011(-3.93). For testers the positive general combining ability effects were observed in 10065(2.58) and in 9459(0.93) and negative general combining ability effects were exhibited in 9515(-3.51). For flag leaf area the line Ujala 2016 and tester 10065 were exhibited good general combining ability effects. The results were similar to Aslam *et al.* (2014) and Barot *et a*l. (2014).

Peduncle length (cm)

During mine studied time the positive general combining ability effects were observed in lines Johar 2016(1.48) while on other hand the negative general combining ability effects were observed in lines Aas 2011(-0.16), AARI 2011(-0.20), Punjab 2011(-0.65) and Ujala 2016(-0.48). For testers the positive general combining ability effects were observed in 10065(0.51) and in 9515(0.22) and negative general combining ability effects were exhibited 9459(-0.73). For peduncle length the line Johar 2016 and tester 10065 were exhibited good general combining ability effects. The results were similar to Lohithaswa *et al.* (2013).

Number of tillers per plant

The number of tillers per plant is related to grain development as number of grains are more there is more yield. So, the number of tillers per plant has direct relation with yield or yield related characters. During mine studied time the positive general combining ability effects were observed in lines Johar 2016(0.55), Ujala 2016(1.53) and AARI 2011(0.18) while on other hand the negative general combining ability effects were observed in lines Aas 2011(-0.76) and Punjab 2011(-1.49). For testers the positive general combining ability effects were observed in 9459(0.58) and negative general combining ability effects were exhibited in 9515(-0.38) and 10065(-0.20). For number of tillers per plant the line Ujala 2016 and tester 9459 were exhibited good general combining ability effects. The results were similar to Majeed *et al*. (2011), Lohithaswa *et al*. (2013) and Hussain *et al.* (2014).

Spike length (cm)

During mine studied time the positive general combining ability effects were observed in lines Ujala 2016(0.24) and Johar 2016(0.46) and Aas 2011(0.60) while on other hand the negative general combining ability effects were observed in lines AARI 2011(-0.56) and Punjab 2011(-0.74). For testers there were showed positive GCA effects in 10065(0.33) and negative general combining ability effects were exhibited 9459(-0.28) and 9515(-0.05). For spike length the line Aas 2011 and tester 10065 were exhibited good general combining ability effects. The results were similar to Majeed *et a*l. (2011) and Hussain *et al.* (2014.

Number of spikletes per spike

During mine studied time the positive general combining ability effects were observed in lines Ujala 2016(0.70) and Punjab 2011(0.03) while on other hand the negative general combining ability effects were observed in lines AARI 2011(-0.24), Aas 2011(-0.28) and Johar 2016(-0.21). For testers the positive general combining ability effects were observed in 9459(0.44) and negative general combining ability effects were exhibited 10065(-0.29) and 9515(-0.16). For number of spikletes per spike the line Ujala 2016 and tester 9459 were exhibited good general combining ability effects. The results were similar to Kumar *et al.* (2011).

Spike density

During mine studied time the positive general combining ability effects were observed in lines Ujala 2016(0.02), AARI 2011(-0.09) and Punjab 2011(-0.08) while on other hand the negative general combining ability effects were observed in line Aas 2011(0.05) and Johar 2016(0.10). For testers the positive general combining ability effects were observed in 9459(0.08) and negative general combining ability effects were exhibited 9515(-0.01) and 10065(-0.07). For spike density the line AARI 2011 and tester 9459 were exhibited good general combining ability effects. The results were similar Nour *et a*l. (2011).

Number of grains per spike

During mine studied time the positive general combining ability effects were observed in lines AARI 2011(8.51) and Punjab 2011(5.91) while on other hand the negative general combining ability effects were observed in line Ujala 2016(-4.16), Aas 2011(-7.60) and Johar 2016(-2.67). For testers the positive general combining ability effects were observed in 9515(3.35) and 10065(2.81) and negative general combining ability effects were exhibited 9459(-6.16). For number of grains per spike the line AARI 2011 and tester 9515 were exhibited good general combining ability effects. The results were similar Ammar *et al*. (2014).

1000- grain weight (g)

During mine studied time the positive general combining ability effects were observed in lines Aas 2011(3.23) and Punjab 2011(0.26) while on other hand the negative general combining ability effects were observed in line Ujala 2016(-0.40), AARI 2011(-1.82) and Johar 2016(-1.27). For testers there were existence observed positive GCA effects in 9459(0.98) and negative general combining ability effects were exhibited 9515(-0.74) and 10065(-0.24). For 1000-grain weight the line Aas 2011 and tester 9459 were exhibited good general combining ability effects. The results were similar Jain and Sastry (2012) but results were differed from findings of Aslam *et al*. (2014).

Grain yield per plant (g)

The most significant factor of wheat is grain yield per plant which needs to be better improvement. The breeders work on betterment of this character of wheat because it majorly related with yield of crop. During mine studied time the positive general combining ability effects were observed in lines Johar 2016(1.57), AARI 2011(2.46) and Punjab 2011(0.74) while on other hand the negative general combining ability effects were observed in line Ujala 2016(-3.43), Aas 2011(-1.34). For testers the positive general combining ability effects were observed in 9515(0.65) and negative general combining ability effects were exhibited 9459(-0.55) and 10065(-0.10). For grain yield per plant the line AAR 2011 and tester 9515 were exhibited good general combining ability effects. The results were similar by Jain and Sastry (2012), and Ammar *et al*. (2014).

Table 2: GCA effects of lines and testers for yield and its related traits in wheat

Parents	Plant height (cm)	Flag leaf area (cm^2)	Spike length (cm)	Peduncle length (cm)	No. of tillers per plant	No. of grains per spike	No. of spikelets per spike	Spike density	1000-grain weight (g)	Grain yield per plant (g)
Lines (female)										
Ujala 2016	-0.60 ns	4.20 *	0.24 ns	-0.48 ns	1.53 **	-4.16 *	0.70 **	0.02 ns	-0.40 ns	-3.43 **
Johar 2016	2.34 **	1.39 ns	0.46 ns	1.48 ns	0.55 ns	-2.67 ns	-0.21 ns	-0.08 ns	-1.27 *	1.57 ns
Aas 2011	-4.16 **	-2.02 ns	0.60 ns	-0.16 ns	-0.76 ns	-7.60 **	-0.28 ns	-0.09 *	3.23 **	-1.34 ns
Punjab 2011	3.23 **	0.36 ns	-0.74 *	-0.65 ns	-1.49 **	5.91 **	0.03 ns	0.10 *	0.26 ns	0.74 ns
AARI 2011	-0.81 ns	-3.93 *	-0.56 ns	-0.20 ns	0.18 ns	8.51 **	-0.24 ns	0.05 ns	-1.82 **	2.46 *
S.E (GCA for lines)	0.7294	1.652	0.316	0.8774	0.5084	1.5066	0.2237	0.0402	0.4841	1.0208
Testers (male)										
9515	2.68 **	-3.51 *	-0.05 ns	0.22 ns	-0.38 ns	3.35 **	-0.16 ns	-0.01 ns	-0.74 ns	0.65 ns
9459	0.51 ns	0.93 ns	-0.28 ns	-0.73 ns	0.58 ns	-6.16 **	0.44 *	0.08 *	0.98 *	-0.55 ns
10065	-3.19 **	2.58 ns	0.33 ns	0.51 ns	-0.20 ns	2.81 *	-0.29 ns	-0.07 *	-0.24 ns	-0.10 ns
S.E (GCA for testers)	0.565	1.2796	0.2448	0.6796	0.3938	1.167	0.1732	0.0311	0.375	0.7907

0.000** = Highly significant
0.000* = Significant

Estimates of specific combining ability (SCA) effects for yield or related traits in wheat

Specific combining ability is occurring in single cross and its performance of varieties will be checked. The good or desirable cross combination are selected through specific combining ability. By line×tester mating design the specific combining ability effects among overall traits of wheat would be explained a Table 3.

Plant height (cm)

In plant height the variations came in high range positive or negative among cross combinations which is revealed through specific combining ability effects. The desirable or negative specific combining ability effects were exhibited through crosses AARI 2011×10065(-6.65) which is followed by other negative specific combining ability crosses Punjab 2011×9459(-4.40), Ujala 2016×9515(-4.16), Aas 2011×9515(-2.00) and Johar 2016×9459(-1.65). the cross AARI 2011×10065(-6.65) were best specific combining ability. The under desirable or positive specific combining ability were showed in following crosses AARI 2011×9459(5.48) which is followed by Punjab 2011×9515(4.00), Ujala 2016×10065(3.75), AARI 2011×9515(1.18), Aas 2011×10065(1.83), Johar 2016×9515(0.99), Johar 2016×10065(0.66), Ujala 2016×9459(0.41), Punjab 2011×10065(0.41) and Aas 2011×9459(0.17). The results were similar of specific combining effects by Jain and Sastry (2012) and Ammar *et al*. (2014). For plant height there is best specific combining effects it proved that there is presence of non-additive genetic action.

Flag leaf area (cm^2)

For flag leaf area the negative specific combining ability effects were exhibited through crosses Aas 2011×10065(-7.96) which is followed by other negative specific combining ability crosses Ujala2016×9515(-7.50), AARI2011×10065(-6.65), Johar2016×9459(-3.03), Johar 2016×9515(-2.94), Ujala 2016×9459(-1.06), Punjab 2011×9459(-0.29) and Punjab 2011×9515(-0.28). the cross Aas 2011×10065(-7.50) were best specific combining ability. The positive specific combining ability were showed in following crosses Ujala 2016×10065(8.56) which is followed by Johar 2016×10065(5.98), AARI 2011×9459(5.48), ARRI 2011×9515(5.38), Aas 2011×9515(5.34), Aas 2011×9459(2.62) and Punjab 2011×10065(0.57). The results were similar of specific combining effects of Ahmad *et al*. (2013) and Ammar *et al*. (2014). The higher the effects of specific combining ability as compared to general combining ability showed that there is dominant effect of non-additive genetic action.

Peduncle length (cm)

For peduncle length the negative specific combining ability effects were exhibited through crosses Ujala 2016×9515(-4.22) which is followed by other negative specific combining ability crosses Aas 2011×9459(-2.46), Punjab 2011×9515(-1.99), AARI 2016×10065(-1.52), Johar 2016×9459(-1.94), Johar 2016×10065(-0.25), Punjab 2011×10065(-0.22) and Aas 2011×10065(-0.21) and the cross Ujala 2016×9515(-4.22) were best specific combining ability. The positive specific combining ability were showed in following crosses Aas 2011×9515(2.67), Punjab2011×9459(2.21), Ujala2016×10065(2.20), Johar2016×9515(2.19), Ujala 2016×9459(2.02), AARI 2011×9515(1.36) and AARI 2011×9459(0.16). The results of specific combining effects were similar to Ammar *et al*. (2014). The specific combining ability effects were significant indicating the presence of non-additive genetic action.

Number of tillers per plant

For number of tillers per plant the negative specific combining ability effects were exhibited through crosses which is followed by other negative specific combining ability crosses AARI 2011×9459(-2.06), Ujala 2016×9515(-1.08), Aas 2011×9459(-0.87), Ujala 2016×10065(-0.62), Johar 2016×9459(-0.31), Aas 2011×10065(-0.29) and AARI 2011×9515(-0.07) and the cross AARI 2011×9459(-2.06) were best specific combining ability. The positive specific combining ability were showed in following crosses Ujala 2016×9459(2.70), AARI 2011×10065(2.12), Johar2016×10065(0.36), Punjab2011×9515(0.29), Johar2016×9515(0.26), Aas 2011×9515(1.18) and Punjab 2011×10065(0.00). The results were similar of specific combining effects Hammad *et al.* (2013) and Ahmad *et al*. (2013) but the results were not similar with other research work Aslam *et al.* (2014). The results were significant of specific combining ability so there is non-additive gene action present.

Spike length (cm)

For spike length the negative specific combining ability effects were exhibited through crosses Ujala 2016×9515(-0.88) which is followed by other negative specific combining ability crosses Punjab 2011×9515(-0.73), Aas 2011×10065(-0.50), AARI 2011×10065(-0.37), AARI 2011×9459(-0.26), Johar 2016×9459(-0.17), Johar 2016×10065(-0.15) and Aas 2011×9459(-0.15) and the cross Ujala 2016×9515(-0.88) were best specific combining ability. The positive specific combining ability were showed in following crosses Punjab 2011×10065(0.71), Aas 2011×9515(0.66), AARI 2011×9515(0.63), Ujala 2016×9459(0.57), Johar 2016×9515(0.32), Ujala 2016×10065(0.31) and Punjab 2011×9459(0.01). The results were similar of specific combining effects by Ammar *et al.* (2014) while results of specific combining ability effects for this trait were not matched with the results of Hussain *et al.* (2014). So, there will present non-additive type gene behaviour.

Number of spikelets per spike:

For number of spikelets per spike the negative specific combining ability effects were exhibited through crosses Punjab 2011×9515(-1.78) which is followed by other negative specific combining ability crosses Aas 2011×10065(-1.73), Johar 2016×9459(-1.60), AARI 2011×10065(-0.58), Ujala 2016×10065(-0.04) and Ujala 2016×9515(-0.11) and the cross Punjab 2011×9515(1.78) were best specific combining ability. The positive specific combining ability were showed in following crosses Johar 2016×10065(1.20), Punjab 2011×10065(1.16), Aas 2011×9459(0.73), Punjab 2011×9459(0.62), AARI 2011×9515(0.49), Ujala 2016×9459(0.16) and AARI 2011×9459(0.09). The results were similar of specific combining effects by showed Ammar *et al.* (2014) while these results were in contrast with the results of Aslam *et al*. (2014) and Hussain *et al.* (2014). The variances of specific combining ability indicates the non-additive genetic effect present.

Spike density

For spike density the negative specific combining ability effects were exhibited through crosses Johar 2016×10065(-0.12) which is followed by other negative specific combining ability crosses Ujala 2011×9459(-0.07), Aas 2011×10065(-0.07), Punjab 2011×9515(-0.05), AARI 2011×9515(-0.04), Ujala 2016×10065(-0.04), AARI 2011×10065(-0.01) and Punjab 2011×9515(-0.01) and the cross Johar 2016×10065(-0.12) were best specific combining ability. The positive specific combining ability were showed in following crosses Johar 2016×9459(0.11), Ujala 2016×9515(0.11), Aas 2011×9459(0.08), Punjab 2011×9459(0.06), AARI 2011×9459(0.05) and Johar 2016×9515(0.01). The variances are significant for spike density as there will present gene action non-additive type for specific combining ability effects.

Number of grains per spike:

For number of grains per spike the negative specific combining ability effects were exhibited through crosses AARI 2011×9515(-5.05) which is followed by other negative specific combining ability crosses Ujala 2016×9515(-4.36), Ujala 2016×10065(-3.92), Punjab 2011×9515(-3.32), Aas 2011×10065(-2.75), Johar 2016×9459(-2.94), Johar 2016×10065(-2.11), AARI 2011×9459(-1.25) and Aas 2011×9459(-0.77) and the cross AARI 2011×9515(-5.05) were best specific combining ability. The positive specific combining ability were showed in following crosses Ujala 2016×9459(8.28), AARI 2011×10065(6.31), Johar 2016×9515(5.05), Aas 2011×9515(3.52) and Punjab 2011×9459(0.84). For number of grains per spike the non-additive behaviour of genes were seen as significant effects of SCA were observed.

1000 grain weight (g)

For 1000-grain weight the negative specific combining ability effects were exhibited through crosses AARI 2011×9459(-3.01) which is followed by other negative specific combining ability crosses Punjab 2011×9515(-2.16), Ujala 2016×9515(-1.10), Johar 2016×10065(-1.76), Aas 2011×9459(-0.83), Aas 2011×10065(-0.27) and Punjab 2011×10065(-0.19) and the cross AARI 2011×9459(-3.01) were best specific combining ability. The positive specific combining ability were showed in following crosses Punjab 2011×9459(2.35), AARI 2011×10065(1.84), AARI 2011×9515(1.17), Aas 2011×9515(1.10), Johar 2016×9515(0.99), Johar 2016×9459(0.77), Ujala 2016×9459(0.72) and Ujala 2016×10065(0.38). The greater variances of specific combining ability are more as compared to GCA effects so there is non-additive genetic action were present.

Grain yield per plant (g)

For grain yield per plant the negative specific combining ability effects were exhibited through crosses Aas 2011×9459(-2.28) which is followed by other negative specific combining ability crosses Johar 2016×9515(-2.28), Punjab 2011×10065(-1.98), AARI 2011×10065(-1.93), Punjab 2011×9459(-0.81), Ujala 2016×10065(-1.73) and Aas 2011×9515(-1.56) and the cross Aas 2011×9459(2.28) were best specific combining ability. The positive specific combining ability were showed in following crosses Aas 2011×10065(3.84), Punjab 2011×9515(2.80), AARI 2011×9515(1.31), Ujala 2016×9459(1.30), AARI 2011×9515(0.62), Johar 2016×9459(0.48) and Ujala 2016×9515(0.42). The variances of specific combining ability is dominant so there is occurrence of non-additive genetic effects.

Table 3: SCA effects of crosses for yield and its related traits in wheat

Crosses	Plant height (cm)	Flag leaf area (cm^2)	Spike length (cm)	Peduncle length (cm)	No. of tillers per plant	No. of grains per spike	No. of spikelets per spike	Spike density	1000-grain weight (g)	Grain yield per plant (g)
Ujala 2016×9515	-4.16 **	-7.50 *	-0.88 ns	-4.22 **	-1.08 ns	-4.36 ns	-0.11 ns	0.11 ns	-1.10 ns	0.42 ns
Ujala 2016×9459	0.41 ns	-1.06 ns	0.57 ns	2.02 ns	2.70 **	8.28 **	0.16 ns	-0.07 ns	0.72 ns	1.30 ns
Ujala 2016×10065	3.75 **	8.56 **	0.31 ns	2.20 ns	-1.62 ns	-3.92 ns	-0.04 ns	-0.04 ns	0.38 ns	-1.73 ns
Johar 2016×9515	0.99 ns	-2.94 ns	0.32 ns	2.19 ns	0.26 ns	5.05 ns	0.40 ns	-0.01 ns	0.99 ns	-2.28 ns
Johar 2016×9459	-1.65 ns	-3.03 ns	-0.17 ns	-1.94 ns	-0.62 ns	-2.94 ns	-1.60 **	-0.11 ns	0.77 ns	0.48 ns
Johar 2016×10065	0.66 ns	5.98 *	-0.15 ns	-0.25 ns	0.36 ns	-2.11 ns	1.20 **	0.12 ns	-1.76 *	1.80 ns
Aas 2011×9515	-2.00 ns	5.34 ns	0.66 ns	2.67 ns	1.18 ns	3.52 ns	1.00 *	-0.00 ns	1.10 ns	-1.56 ns
Aas 2011×9459	0.17 ns	2.62 ns	-0.15 ns	-2.46 ns	-0.31 ns	-0.77 ns	0.73 ns	0.08 ns	-0.83 ns	-2.28 ns
Aas 2011×10065	1.83 ns	-7.96 **	-0.50 ns	-0.21 ns	-0.87 ns	-2.75 ns	-1.73 **	-0.07 ns	-0.27 ns	3.84 *
Punjab 2011×9515	4.00 **	-0.28 ns	-0.73 ns	-1.99 ns	-0.29 ns	0.84 ns	-1.78 **	-0.05 ns	-2.16 *	2.80 ns
Punjab 2011×9459	-4.40 **	-0.29 ns	0.01 ns	2.21 ns	0.29 ns	-3.32 ns	0.62 ns	0.06 ns	2.35 **	-0.81 ns
Punjab 2011×10065	0.41 ns	0.57 ns	0.71 ns	-0.22 ns	0.00 ns	2.48 ns	1.16 **	-0.01 ns	-0.19 ns	-1.98 ns
AARI 2011×9515	1.18 ns	5.38 ns	0.63 ns	1.36 ns	-0.07 ns	-5.06 ns	0.49 ns	-0.04 ns	1.17 ns	0.62 ns
AARI 2011×9459	5.48 **	1.76 ns	-0.26 ns	0.16 ns	-2.06 *	-1.25 ns	0.09 ns	0.05 ns	-3.01 **	1.31 ns
AARI 2011×10065	-6.65 **	-7.14 *	-0.37 ns	-1.52 ns	2.12 *	6.31 *	-0.58 ns	-0.01 ns	1.84 *	-1.93 ns
S.E of SCA effects	1.2634	2.8613	0.5474	1.5197	0.8805	2.6095	0.3874	0.0696	0.8385	1.768

*= Significant at P < 0.05

** = Significant at P < 0.01

ns = Non- significant

Table 4: Estimates of GCA variance, SCA variance, additive and dominance variance

Genetic components	Plant height (cm)	Flag leaf area (cm^2)	Spike length (cm)	Peduncle length (cm)	No. of tillers per plant	No. of grains per spike	No. of spikelets per spike	Spike density	1000-grain weight (g)	Grain yield per plant (g)
Cov. H. S. lines	2.142	-5.455	0.218	-1.836	0.42	37.09	-0.425	0.004	2.542	3.401
Cov. H. S. testers	4.95	0.726	0.002	-1.123	-0.311	22.356	-0.203	0.003	-0.033	-0.988
Cov. H. S. average	0.57	-0.441	0.02	-0.252	0.015	5.066	-0.054	0.001	0.229	0.234
Cov. F. S.	27.705	33.701	0.371	1.848	1.966	95.034	0.899	0.013	5.694	5.241
$б^2$GCA	0.57	-0.441	0.02	-0.252	0.015	5.066	-0.054	0.001	0.229	0.234
$б^2$SCA	17.694	37.651	0.163	5.388	2.074	24.06	1.626	0.004	3.359	3.644
$б^2$A	1.139	-0.882	0.04	-0.504	0.029	10.131	-0.108	0.001	0.457	0.469
$б^2$D	17.694	37.651	0.163	5.388	2.074	24.06	1.626	0.004	3.359	3.644
$б^2$GCA/$б^2$SCA	0.032	-0.012	0.123	-0.047	0.007	0.211	-0.033	0.162	0.068	0.064

Genetic variances:

The content of GCA effects related the SCA effects its mean that there was additive genetic action. While the content of specific combining ability effects was higher as compared to specific combining effects so there was presence of non-additive genetic action used in hybrid development in case of action of traits. In next Table the wheat varieties or genotypes GCA effect variance, SCA effect variance, ratio in between GCA and SCA, dominance and additive various. For wheat traits like plant height, flag leaf area, peduncle length, number of tillers per plant, spike length, number of spiklets per spike, spike density, number of grains per spike, 1000-grain weight and yield of grain per plant the specific combining ability effects were less as compared to general combining ability it means that there was presence of non-additive genetic action therefore hybrid breeding will be explained by these traits.

All studied characters the ratio of GCA and SCA effects varainaces showed that there is gene action of non-additive type or dominance effects. The results were same as another scientist work Fellahi *et al.* (2013) and Ammar *et al.* (2014). Additive genetic character was exhibited for results of Farooq *et al.* (2006), Ahmad *et al.* (2011), and Jain and Sastry (2012).

Discussion:

Combining ability method is most appropriate technique used to explained some biostatistical method for evaluation of combining ability effects which explained by F_1 hybrids and its parents (Griffing, 1956). The combining ability effects of varieties is found from line×tester analysis Kempthorne (1957) which give knowledge about genetic behaviour associated with important characters.

The table explained that the lines namely Ujala 2016, Johar 2016, Aas 2011, Punjab 2011 and AARI 2011 will be highly significant effects while on the hand the significant difference effects will be seen for flag leaf area. For all traits the testers namely 9515, 9459 and 10065 exhibited non-significant effects while another hand spike density.

The interaction in between line×tester explained that there will non-significant effects for spike length and significant effects for all other characters. Among parents the characters plant height, flag leaf area, number of tillers per plant, number of grains per spike, 1000-grain weight and spike length showed highly significant effects. The results were similar to their work Farooq *et al.* (2006), Ahmad *et al.* (2011), and Jain and Sastry (2012).

For crosses the results were non-significant for plant height, number of grains per spike, thousand grain weight and grains yield per plant while another hand remaining traits were highly significant and significant.

Among parent v cross interaction, the highly significant effects and significant effects for flag leaf area, peduncle length, spike length, number of grains per spike and spike density while remaining were non-significant effects.

Among testers the positive general combining ability were showed for all traits like plant height, flag leaf area, peduncle length, number of tillers per plant, number of spikletes per spike, number of grains per spike, spike length, spike density, 1000-grain weight and grain yield per plant. The results were similar by Fellahi *et al.* (2013) and Ammar *et al.* (2014).

Among crosses the cross AARI 2011×10065 were best specific combining ability while another hand the cross Aas 2011×10065 for flag leaf area and grain yield per plant had best specific combining ability effects. For number of spikletes per spike the cross Johar 2016×10065 were showed best general combining ability. These results were matched with finding of Majeed *et al.* (2011), Lohithaswa *et al.* (2013) and Hussain *et al.* (2014).

The research evaluated that the parental material namely Ujala 2016, Johar 2016, Aas 2011, Punjab 2011 and AARI 2011 could be used in hybridization method for future breeding procedures. The cross combination of Aas 2011×10065, Aas 2011×9459 and Punjab 2011×9515 can be used in future breeding programs.

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