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Original Research Article

ASSESSMENT OF COMBINING ABILITY FOR YIELD AND YIELD RELATED TRAITS IN SPRING WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract *Grain yield and other related characters were studied in 18 F1 generations along with nine parents (six lines and three testers) which were evaluated for combining ability with three replications in a randomized complete block design (RCBD). The results indicated that among various lines, line 9479 was identified as a good general combiner for the traits, viz., spike length, spikelet's per spike, and 1000-grain weight, whereas, Line 9486 appeared as a good general combiner for the characters, flag leaf area, plant height, peduncle length, number of tillers per plant and 1000-grain weight. Line 9515 for flag leaf area, plant height, and spike length. Line 9519 for the number of tillers per plant, grain yield per plant, and plant height; line 9520 for peduncle length, number of tillers per plant, grains per spike, grain yield per plant and 9521 was identified as good general combiner for the characters spike length, spikelet's per spike, number of grains per spike and spike density. Tester Punjab-11 emerged as a good general combiner for the traits; peduncle length, plant height, flag leaf area, and number of tillers per plant, whereas, Tester Ass-11 appeared as a good combiner for the spike length, peduncle length, 1000-grain weight, and flag leaf area. Tester Chakwal-50 identified a good general combiner for the number of tillers per plant, plant height, grains per spike, spikelets per spike, grain yield per plant, 1000-grain weight, and spike density. Out of 18 cross combinations, seven crosses viz. 9479 × Aas-11, 9486 × Aas-11, 9515 × Aas-11, 9519 × Chakwal-50, 9520 × Punjab-11, 9521 × Punjab-11, and 9521 × Aas-11 emerged with significant positive SCA effects for grain yield per plant. Thus, these crosses can be exploited for grain yield per plant by using biparental mating system.*

Keywords: *Combining ability; yield; Line × Tester analysis; spring wheat, biparental mating*

Introduction

Wheat (*Triticum aestivum* L.) is the most important cereal crop in terms of food for the majority of the world's population. It has a share of 8.2 % value added in agriculture and contributes 1.9 % to the gross domestic product of Pakistan. Wheat cultivated on an area increased from 8,977 thousand hectares to 9,043 thousand hectares in 2022-2023 (a 0.7 percent increase) against last year's area. Production of wheat increased from 26.208 million tonnes to 27.634 million tonnes contributing to a 5.4% increase in growth of wheat production (Pakistan Economic Survey; 2022-23). Pakistan is the eighth largest producer of wheat worldwide (Ahmad *et al*., 2021). The most significant wheat species in the world, covering 90% of the total area, is *aestivum* species of wheat, followed by durum wheat, which covers about 9% of the total area while less than 1% of the total area is covered by *T. diccoum* and *T. monococcum* (Abou-Elwafa and Shehzad, 2021). Nearly 40% of the world's population consumes it, and more than 4.5 billion people in developing countries rely on it to meet 21% of their daily protein needs (Giraldo *et al*., 2019). It provides approximately 55% of the carbohydrates and 20% of the world's caloric needs annually (Widyaratne and Zijlstra, 2007). The world's population will reach 9.3 billion people by the year 2050 (Cleland, 2013). The population is increasing at an alarming rate so there is a need to develop superior wheat varieties to fulfill food needs. The production of wheat in Pakistan is lower as compared to the developed countries of the world (Ahmad *et al*., 2013). To minimize this shortage, the high-yielding varieties for diverse agro-climatic conditions are needed to develop. Thus genetic variation among parental material was assessed to establish an association between performances of F_1 with a degree of genetic variation through combining ability. Yield potential of recent wheat varieties is decreasing over time by the number of factors i.e. biotic factors, abiotic factors, genetic drift, contamination by cross-pollination and mixing of seeds with varietal seeds during threshing cause a gradual decrease in the yield. To overcome this yield barrier, the genetic material of varieties and genotypes have to be reshuffled so that these varieties and genotypes may attain an ideal genetic makeup which would help them to give better performance in a range of changing environments. Wheat is cultivated over a wide range of climatic conditions and therefore understanding of genetics is of great value for plant breeding purposes. Line × tester mating design is a statistical design for the evaluation of parental genotypes and their cross combinations to develop new varieties. It facilitates testing

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more parental genotypes with less number of cross combinations. It involves both first and second-order statistics and is extensively used to estimate combining ability (GCA, SCA) in several crops like wheat, rice, barely, sugarcane, maize, and other cash crops to understand the genetics of yield and its contributing characters. This experiment was conducted to understand the gene action and identification of best-combining genotypes for seed yield and its contributing traits. Thus information obtained might help to choose desirable parents and their cross combinations to develop a successful breeding programme.

Material and Methods

The experimental material consisted of nine wheat genotypes, and six wheat lines viz. 9479, 9486, 9515, 9519, 9520, and 9521 (Female parents) and three testers viz. Punjab-11, Aas-11, Chakwal-50 (Male parents). These wheat genotypes were crossed in line × tester fashion during the crop season in 2020-21 in the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The F_1 Seeds along with nine parents were planted in the field using a randomized complete block design with three replications during 3rd week of November 2020. Each replication consisted of nine parents and 18 F_1 crosses. Plant-to-plant and row-to-row distances were 10 cm and 25 cm respectively. Two seeds per hole were sown with the help of a dibbler which were later thinned to one seedling per hole after germination. The experiment was conducted under normal conditions from sowing to maturity following normal production technology. At maturity, five well-guarded plants from each line were selected to record the data for plant height, number of tillers per plant, flag leaf area, peduncle length, spike length, number of spikelets per spike, number of grain per spike, 1000 grain weight, grain yield per plant and spike density. The data was subjected to analysis of variance to calculate significant differences among crosses and parents (Steel *et al*. 1997). Specific and general combining ability effects were estimated through combining ability analysis by using the method proposed by Kempthorne (1957).

Results

The analysis of variance results, presented in Table 1 explains that there were highly significant genotypic differences present for all the ten characters viz., flag leaf area, plant height, peduncle length, spike length, tillers per plant, spikelets per spike, grains per spike, 1000 grain weight grain yield per plant and spike density studied among F_1 progenies and the parental lines. Interpretation of line × tester mating design analysis revealed that significant differences existed between parents, crosses, interaction parents vs crosses, testers, lines, and interaction lines × testers for yield and its related traits. General combining ability and specific combining ability analysis are presented in table-3 and table-4. The negative GCA effects for plant height were observed for line 9486 (-3.34) and among testers in Punjab-11(-0.44) and Chakwal-50 (-2.18). The negative SCA effects were observed for 9520 × Chakwal-50 (-2.31), 9519 × Aas-11 (-1.35), and 9486 × Chakwal-50 (-1.35). Among lines and testers 9520 and Chakwal-50 had the highest and positive GCA effects (0.53, 0.51) for productive tillers per plant respectively. In the case of tillers per plant the cross combination, 9515 × Chakwal-50 had the highest and positive SCA effects (0.61) followed by 9486 × PB-11 (0.45). The positive and highest GCA effect for flag leaf area is present in line 9486 and tester Ass-11 (5.20, 2.22 cm^2) respectively. The cross combination 9486 × Chakwal-50 (6.93) had the highest and positive SCA effects for the flag leaf area. All the genotypes were significant for peduncle length. Among lines, 9486 had the highest positive GCA effects (2.04) and among testers, Aas-11 had the highest positive GCA effects (1.55) for peduncle length. The line 9486 and tester Aas-11 were good general combiners for peduncle length. Among lines, 9479 (0.45) and among testers, Aas-11 (0.39) had positive and highest GCA effects for spike length. Among crosses, 9479 × Chakwal-50 had the highest and positive SCA effects (0.81) followed by 9486 × Chakwal-50 (0.48), 9519 × Aas-11 (0.43) for spike length. Among lines, 9521 had the highest and positive GCA effects (0.87) and among testers, Chakwal-50 had the highest and positive GCA effects (0.84) for spikelets per spike. Among crosses, the cross 9515 × Chakwal-50 had the highest and positive SCA effects (1.02) for the number of spikelets per spike followed by 9486 × Aas-11 (0.76), 9520 × PB-11 (0.67), 9521 × Aas-11 (0.76). Among female parents, 9521 had the highest and positive GCA effects (2.35) and among males, Chakwal-50 and Aas-11 had positive GCA effects (0.36, 0.05) for grains per spike respectively. The highest SCA effects were observed for 9479 × Aas-11 (3.64) for grains per spike. The line 9486 and tester Chakwal-50 had highest and positive GCA effects (2.63, 1.91) respectively for 1000-grain weight. Among crosses, the cross 9479 × AAS-11 had highest and positive SCA effects (11.58) followed by 9520 × PB-11 (5.44), and 9515 ×PB-11(4.70) for 1000-grain weight. For grain yield two female and one male parent show the positive GCA value as shown in table 3. The line 9521 had highest and positive GCA effects (0.06) and among testers, Chakwal-50 had highest GCA effects (0.06) for spike density. The highest and positive SCA effects were observed for 9515 × Chakwal-50 (0.13) followed by 9486 × PB-11 (0.10) for spike density.

Table 1: Mean Square ANOVA Of RCBD Design For Yield And Yield Related Traits Studied In Wheat.

Source of variation	Plant height (cm)	No. of Tillers per plant	Peduncle length (cm)	Spike length (cm)	Flag leaf area(cm^2)	Number of spikelets per spike	No. of grains per spike	1000 grain weight (g)	Grain yield per plant (g)	Spike density
Genotype	5202.28**	36.90**	497.6**	72.71**	233.14**	161.24**	1449.9**	1182.11**	185.95**	0.9921**
Replication	0.24^{ns}	0.081^{ns}	25.06**	0.497^{ns}	7.06*	0.171^{ns}	0.21^{ns}	0.4087^{ns}	4.929*	0.0101^{ns}
Error	0.29	0.033	23.79	0.27	0.53	0.22	0.95	0.866	4.895	0.0038

* = Significant at P < 0.05 ** = Significant at P < 0.01 NS = Non-significant

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Table 2: Mean Squares ANOVA Of Line × Tester Analysis For Yield And Yield Related Traits Studied In Wheat.

	Plant height (cm)	Number of tiller per plant	Peduncle length (cm)	Spike length (cm)	Flag leaf area (cm^2)	Spikelets per spike	No. of grains per spike	1000-grain weight (g)	Grain yield per plant (g)	Spike density
Replication	0.243961^{ns}	0.080753^{ns}	25.05702**	0.497587^{ns}	7.064859**	0.170753^{ns}	0.214301^{ns}	0.408717^{ns}	4.929906^{ns}	0.010005^{ns}
Genotypes	5202.279**	36.89067**	497.5978**	72.71557**	233.1378**	161.2424**	1449.923**	1182.108**	185.9525**	0.992082*
Parents	4256.328**	54.62126**	477.6267**	56.80004**	164.6055**	133.6307**	1246.647**	1052.134**	193.1064**	0.993221*
Crosses	5953.122**	24.4222**	531.3931**	84.32891**	278.8954**	183.4629**	1617.683**	1309.72**	192.5995**	1.021933*
P vs C	5.547012*	107.0099**	82.84608*	2.612945*	3.515817*	4.389751*	224.2179**	52.51106**	15.72089*	0.475507*
Lines	20170.62**	79.8776**	1732.541**	283.7484**	825.764**	615.1408**	5464.134**	4207.573**	612.8675*8	3.410964**
Testers	91.07873**	4.193611*	69.82139*	2.287257*	96.88019**	9.965714**	2.298254*	91.77968**	44.55294**	0.048139*
L × t	3422.401**	55.13822**	413.5196**	46.72885**	173.9002**	109.6668**	1037.273**	951.3389**	168.1321**	0.864304*
Error	0.293853	0.032663	23.79284	0.274995	0.535494	0.214458	0.952142	0.866494	4.894919	0.003863

Highly Significant = 0.00** Significant = 0.00*

Table 3: General combining ability effects of lines and testers for yield and yield related traits in wheat

Parents	Plant height (cm)	Number of tiller per plant	Peduncle length (cm)	Spike length (cm)	Flag leaf area (cm^2)	Spikelets per spike	No. of grains per spike	1000-grain weight (g)	Grain yield per plant (g)	Spike density
Lines (female)										
9479	2.55*	0.11*	0.12	0.45*	0.50*	0.78*	0.94*	1.39*	-1.03*	0.004
9486	-3.34*	-0.87*	2.04*	-1.07*	5.20*	-1.27*	-1.74*	2.63*	-0.73	0.029*
9515	-1.49*	0.05	-0.65	0.33*	0.19	0.33*	-1.16*	-0.13	-0.53	-0.009
9519	-0.74*	0.42*	-1.53	0.11	-2.77*	-0.60*	-1.96*	-0.81*	1.58*	-0.06*
9520	2.42*	0.53*	0.11	0.15	-1.17*	-0.11	1.59*	-1.15*	1.03*	-0.03*
9521	0.60	-0.25*	-0.09	0.03	-1.94*	0.87*	2.35*	-1.93*	-0.31	0.06*
S.E. of GCA for lines	0.18	0.06	1.63	0.17	0.244	0.15	0.33	0.310	0.74	0.02
Testers (males)										
Punjab-11	-0.44*	0.03	0.88	-0.38*	0.50*	-0.76*	-0.41*	-2.75*	-0.92*	-0.01
Aas-11	2.62*	-0.53*	1.55*	0.39*	2.22*	-0.09	0.05	0.84*	-1.04*	-0.05*
Chakwal-50	-2.18*	0.51*	-2.43*	-0.01	-2.72*	0.84*	0.36*	1.91*	1.96*	0.06*
S.E. of GCA for testers	0.13	0.04	1.15	0.12	0.17	0.11	0.23	0.22	0.52	0.01

Table 4: Specific Combining Ability Effects Of Crosses For Yield And Yield Related Traits In Wheat

Genotypes (crosses)	Plant height (cm)	Number of tiller per plant	Peduncle length (cm)	Spike length (cm)	Flag leaf area (cm^2)	Spikelets per spike	No. of grains per spike	1000-grain weight (g)	Grain yield per plant (g)	Spike density
9479 × Punjab-11	18.51*	-3.68*	-18.75*	-6.47*	-11.42*	-8.34*	-31.26*	-28.35*	-9.30*	-0.66*
9479 × Aas-11	2.89*	-0.79*	1.24	0.23	2.83*	-0.33	3.64*	11.58*	1.21	-0.05
9479 × Chakwal-50	3.23*	0.39*	0.80	0.81*	-0.91*	0.44*	-0.77	-2.62*	-1.64	-0.06*
9486 × Punjab-11	-0.16	0.45*	-1.92	-0.74*	-2.18*	0.09	3.41*	-0.14	-0.30	0.10
9486 × Aas-11	1.51*	-0.02	-3.52	0.26	-4.75*	0.76*	-1.19*	4.27*	0.64	0.02
9486 × Chakwal-50	-1.35*	-0.43*	5.44*	0.48*	6.93*	-0.84*	-2.22*	-4.13*	-0.34	-0.12
9515 × Punjab-11	-1.21*	-0.17*	-0.03	0.37*	2.86*	-0.98*	-2.24*	-1.72*	-0.46	-0.12
9515 × Aas-11	-0.60*	-0.44*	1.85	0.08	-0.47*	-0.04	-0.23	1.76*	1.16	-0.01
9515 × Chakwal-50	1.80*	0.61*	-1.81	-0.45*	-2.39*	1.02*	2.46*	-0.04	-0.69	0.13
9519 × Punjab-11	2.17*	-0.40*	0.44	0.24	2.07*	0.36	-1.10*	4.70*	-1.38	-0.006
9519 × Aas-11	-1.35*	0.36*	0.9	0.43*	2.14*	0.09	0.24	-7.22*	-2.57*	-0.03
9519 × Chakwal-50	-0.82*	0.05	-1.34	-0.67*	-4.21*	-0.44*	0.86*	2.51*	3.95*	0.04
9520 × Punjab-11	1.68*	0.02	0.79	0.43*	-2.18*	0.67*	-0.06	5.44*	1.33	0.0009
9520 × Aas-11	0.63*	0.05	-0.30	-0.29	0.63*	-0.67*	-0.59	-7.75*	-0.80	-0.02
9520 × Chakwal-50	-2.31*	-0.06	-0.50	-0.14	1.55*	0	0.64	2.31*	-0.52	0.02
9521 × Punjab-11	0.64*	0.27*	1.96	0.03	-0.44*	-0.58*	2.45*	-2.52*	0.64	-0.04
9521 × Aas-11	-0.09	0.30*	0.63	0.001	1.41*	0.76*	-1.47*	0.56*	0.12	0.05
9521 × Chakwal-50	-0.55*	-0.56*	-2.59	-0.03	-0.97*	-0.18	-0.98*	1.96*	-0.76	-0.009
S. E. of SCA effects	0.44	0.10	3.98	0.30	0.42	0.38	0.80	0.54	1.81	0.051

Highly Significant = 0.00** Significant = 0.00*

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Table 5: Mean Values Of Lines And Testers For Different Yield And Its Related Traits In Wheat.

Parents	Plant height (cm)	Number of tiller per plant	Peduncle length (cm)	Spike length (cm)	Flag leaf area (cm^2)	Spikelets per spike	No. of grains per spike	1000-grain weight (g)	Grain yield per plant (g)	Spike density
Lines (female)										
9479	106.80	7.167	25.00	12.66	21.17	20.87	54.60	50.73	16.80	1.63
9486	108.00	6.467	24.93	10.60	24.77	17.27	51.80	48.47	14.23	1.633
9515	116.27	13.133	31.46	13.33	18.77	19.80	55.40	58.27	20.87	1.500
9519	116.60	12.467	32.80	12.667	22.60	18.07	56.73	53.47	17.10	1.433
9520	116.60	12.667	30.80	12.53	21.07	18.20	58.67	53.00	18.64	1.467
9521	117.00	7.800	35.60	13.03	20.27	19.93	58.80	51.98	15.87	1.533
Testers (males)										
Punjab-11	100.50	8.600	37.000	12.933	21.23	19.33	62.47	51.87	25.03	1.467
Aas-11	110.07	5.067	35.400	13.46	22.53	20.07	62.27	49.93	18.37	1.467
Chakwal-50	112.20	6.733	29.400	10.20	19.85	21.53	59.00	44.80	16.67	2.133

Table 6: Mean Values Of Crosses For Different Yield And Yield Related Traits In Wheat.

Genotypes (crosses)	Plant height (cm)	Number of tiller per plant	Peduncle length (cm)	Spike length (cm)	Flag leaf area (cm^2)	Spikelets per spike	No. of grains per spike	1000-grain weight (g)	Grain yield per plant (g)	Spike density
9479×Punjab-11	113.20	7.067	33.147	13.240	22.97	20.33	61.07	44.93	17.99	1.567
9486 × Punjab-11	110.27	7.067	34.387	11.30	25.61	17.96	60.60	46.80	17.81	1.587
9515 × Punjab-11	111.07	7.000	33.580	13.81	25.64	18.47	55.53	47.47	17.84	1.333
9519 × Punjab-11	115.20	7.000	33.173	13.46	21.89	18.87	55.87	45.20	19.05	1.433
9520 × Punjab-11	117.87	7.667	35.173	13.69	19.24	19.67	60.47	46.60	18.20	1.433
9521×Punjab-11	115.00	5.933	36.133	13.18	20.22	19.40	63.73	42.87	16.17	1.467
9479 × Aas-11	119.27	6.667	35.493	13.847	25.86	19.67	63.27	42.67	16.16	1.433
9486 × Aas-11	115.00	5.800	33.460	13.07	24.76	19.27	56.47	40.80	13.45	1.467
9515 × Aas-11	114.73	6.000	36.133	14.29	24.04	20.07	58.0	44.53	17.35	1.433
9519 × Aas-11	114.73	7.267	34.307	14.43	23.69	19.27	57.67	44.87	17.74	1.333
9520 × Aas-11	119.87	7.133	34.753	13.75	23.77	19.00	56.20	44.00	16.95	1.400
9521 × Aas-11	117.33	6.600	35.480	13.92	23.79	21.40	60.27	51.53	18.54	1.53
9479 × Chakwal-50	117.80	7.933	31.880	14.75	18.97	21.93	58.87	52.73	19.05	1.50
9486 × Chakwal-50	107.33	8.733	38.440	12.89	31.52	18.60	55.73	52.47	20.66	1.433
9515 × Chakwal-50	112.33	8.267	28.500	13.37	17.18	22.07	61.00	55.80	22.50	1.70
9519 × Chakwal-50	110.47	8.067	28.093	12.93	16.10	19.67	58.60	53.67	21.26	1.567
9520 × Chakwal-50	112.13	8.067	30.580	13.51	19.76	20.60	61.93	52.13	20.23	1.53
9521 × Chakwal-50	112.07	6.783	28.287	13.49	16.47	21.40	61.07	45.00	16.66	1.60

Discussions

The main objective of wheat breeders are development of wheat varieties possessing improved yield-related characteristics. Availability of genetically based variation is a pre-requisite for the selection of new cultivars. Present wheat material was deliberated to generate information on GC and SC for yield and yield-related traits. The assessment of genetic components of variation revealed that in the inheritance of studied traits non-additive gene effects were predominant. As short-stature plants are desired so negative value is best for plant height. The results are similar reported by Kumar and Kerkhi, (2015), Majeed *et al*. (2011), and Malik *et al*. (1988). Productive tillers per plant are a major yield component. These findings conform with those of Saeed *et al*. (2001), Majeed *et al.* (2011), Yadav and Sirohi (2011), and Saeed *et al.* (2016). Flag leaf area had a positive association with grain yield. These outcomes are following the results of Awan *et al*. (2005), Moosavi *et al*. (2005), Saeed *et al*. (2001), and Rehman *et al* (2013). The spike length is an important trait as a longer spike length produces more yields. These results are following Dhadhal *et al.* (2008) Baloch *et al.* (2011), Ajmal *et al.* (2004), Faisal *et al.* (2005), and Guo et al. (2018). Spikelets per spike contribute positively towards grain yield. The more spikelets per spike, the greater will be the yield. These findings conform with the results reported by Saeed *et al*. (2005), Malik *et al.* (2005) Chowdhry *et al.* (2007), Ajmal *et al.* (2004), Faisal *et al.* (2005); Bibi *et al.* (2013). Grains per spike are also an important factor for enhanced grain yield. These findings match with the results of Saeed *et al.* (2001), Singh *et al.* (2002), Hassan *et al.* (2007) and Malano (2008), Khan *et al.* (2007), and Philipp *et al.* (2018). The results of Nazir *et al.* (2005) differ from these findings. 1000-grain weight is also a very important character positively contributing towards grain yield which is our main objective. Similar results are reported by Majeed *et al.* (2011), Singh *et al.* (2002), Ajmal *et al.* (2004), and Mecha *et al.* (2017). Positive value of spike density is essential for enhanced yield as it is related

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to more spike length and more spikelets per spike. These findings were quite close to the results of Awan *et al.* (2005), Hassan *et al.* (2007), Saeed *et al.* (2005), Iqbal and Khan (2006), Mahpara *et al.* (2008) and Pesaraklu *et al.* (2016) for spike density.

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Declaration

Ethics Approval and Consent to Participate

Not applicable.

Consent for Publication

The study was approved by authors.

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Conflict of Interest

There is no conflict of interest among the authors regarding this case study.

Authors Contribution

All authors contributed equally.

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