RESEARCH ARTICLE

Combine Ability and Yield Associated Traits of F2 Wheat Lines

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ABSTRACT

The current study was conducted with the objectives to evaluate the genetic variability and combine ability effects in F2 hybrid population. The F2 hybrids were generated by crossing six wheat lines (Auqaab, Fatehjung, Anmol-91, Khattakwal, KT-06, PR-128) and three testers (YR-5, YR-10, YR-15) in line by testers matting design during 2021-22. A total of twenty-seven (27) wheat lines were analyzed in complete randomize block design with three replications i.e. six lines, three testers and eighteen F2 hybrids. Significance (P 0.05) differences were observed among the genotypes for days to heading, plant height, spike length, spikelets per spike, 1000 grain weight, biological yield, and grain yield in contrast to tiller per plant and flag leaf area, which showed non-significance genetic variation. The line by testers showed non-significance variation for the entire traits except spikelets per spike, 1000 grain weight, biological yield, and grain yield in F2 population. In general, a significant positive GCA (general combine ability) effect was observed in Khattakwal line for days to heading, plant height, 1000 grain weight, biological yield, and Auqaab line for spike length, spikelet per spike, for grain yield and Fatehjung for tiller per plant and PR-128 line for flag leaf area. The tester lines including YR-5 revealed a positive significance GCA effect for days to heading, spike length, 1000 grain weight, and grain yield and YR-10 for plant height and tiller per plant, and YR-15 for flag leaf area and spikelet's per spike. In contrast F2 population showed a positive SCA (specific combine ability) effect for days to heading (PR-128*YR-5), plant height (PR-128*YR-15/FatehJung*YR-10/PR-128 *YR-15/KT-06*YR-10) tillers per plant, flag leaf area, spike length, revealed significance (Auqaab *YR-5), spikelet per spike (PR-128*YR-5), 1000 grain weight (Khattakwal*YR-15), biological yield and grain yield (Auqaab*YR-5). All the genotypes including parental, tester lines and F2 population showed best mean performance for all the traits analyzed.

Key words: GCA, SCA, YR-10, YR-5, YR-15, F2 Population, Line by tester

INTRODUCTION

Wheat is one of the most important and oldest cereal crops (Ji et al., 2013). Thousands of varieties are known, the most important are common bread wheat (*Triticum aestivum* L.). *T. aestivum* L. is hexaploid and possesses 42 chromosomes derived from its three ancestral genomes (Martinez-Perez et al., 2003). The 21 pairs of chromosomes can be further divided into seven groups of six chromosomes (one chromosome pair being derived from each of the three ancestral genomes), based on the similarity of their gene order (Martinez-Perez et al., 2003). It is a major source of fulfilling the daily calorific needs of people in developing countries and the second most important cereal staple food (Kumar & Kalita, 2017). Wheat is the

major source of carbohydrate, protein, vitamins B & E, which is used in countless breads and baking items (Khan, 2016). Wheat can be refined into starch, grain oil and for beer production. Beside this, it is also used as fodder for animal both at pre and postharvest stages.

Wheat is a wildly cultivated cereal crop and is adapted from irrigated to dry, warm as well as from humid to cold environments. The wheat cultivars are further classified by the breeders in terms of growing seasons such as winter vs spring wheats (Rauf et al., 2023), on kernel texture such as soft and hard wheats as well as grain color (red, white, and amber). Wheat is grown on more than 240 million ha, larger than for any other crop, and world trade is greater than for all other crops combined (Shiferaw et al., 2013). China is one of the top wheat producers and the production was 134,250 thousand tonnes that accounts for 20.66% of the world's in 2020 (Pal et al., 2022). In 2021-22 the world wheat production was recorded 780.28 million tonnes, with an increase of 4.45 million tonnes compared to 775.83 million tonnes in 2020-21 (USDA Forcaste, 2022). The crisis of the wheat was increased with time due to different diseases like, stripe and leaf rust, all caused by members of the Basidiomycete family, genus *Puccinia graminis* fsp. *Tritici* (*Pgt*), *P. striiformis* f.sp. *tritici* (*Pst*) and *P. triticina* (*Pt*), respectively (McIntosh et al., 1995). Rust fungi are obligate biotrophic organisms that are completely dependent on nutritional resources obtained from living host cells for growth and reproduction (Duplessis et al., 2012). Yield losses caused by stem rust are associated with a reduction in grain size and lodging of the plant (Leonard & Szabo, 2005). For controlling such loss in production of wheat, different approaches and advanced cultural practices (Hybridization) need to be adopted by the breeders to have environmentally friendly varieties.

Wheat is considered a major source of food in Pakistan. Wheat is the third exporting crop after cotton and Pakistan occupied 8th position worldwide (Narayan & Bhattacharya, 2019). It adds 9.6 % value to agriculture and 1.9 % of the GDP (gross domestic product) of Pakistan (Babar et al., 2019). The total wheat production in Pakistan has declined due to drought, flooding and rapid population growth. To improve such losses of wheat production, the researchers going to estimate the grain yield, which is positively correlated to such traits (day to heading, grain per spike, leaf flag area, plant height, spike length, spikelets per spike, 1000 grain weight). The positive significance of different traits with the grain yield compelled the researchers and breeders to influence the genetic assessment and gene-related traits among different varieties. The production of wheat is affected in many ways like nutrient availability, water unbalancing, and different diseases. The presence of the three rusts found on wheat genetic resistance is the most economical and preferable method of reducing yield losses due to rust infection. Various wheat breeding programs throughout the world have had mixed results in producing cultivars with long-lasting, effective resistance to rust diseases.

MATERIALS AND METHODS

Present study was conducted at Cereal Crop Research Institute (CCRI) Pirsabak, Nowshera, Khyber Pakhtunkhwa, Pakistan to evaluate the GCA (general combine ability) and SCA (specific combine ability) effects for various traits through line by tester combining ability in wheat. Six wheat lines i.e., Auqaab, Fateh jung, Anmol-91, Khttakwall, KT-06, PR-128 and three testers i.e., YR-5, YR-10, YR-15 were crossed during 2021-22 using line×tester mating fashion to produce 18 F_1 hybrids at CCRI. The parental genotypes (lines and testers) and 18-hybrids F2 populations of said breeding material were evaluated during the crop season 2021-22 at CCRI (Table 1). All the genotypes including parental lines, testers and their 18 F2 populations were sown in a randomized complete block design (RCBD) with three replications. Each entry was grown in four rows. Each row was five meters in length with 10 and 30 cm distance between plants and rows, respectively. Recommended cultural practices were applied to all the entries to minimize the environmental effects.

Table 1: All the 27 genotypes of wheat including 6-parental lines, 3-testers, and 18-F2 population.

S No.	Genotypes names	S No.	F2 population
Parental lines		13	Fateh jung-16 x YR-5
1	Auqaab-2000	14	Fateh jung-16 x YR-10
2	Fateh Jung-16	15	Fateh jung-16 x YR-15
3	Anmol-91	16	Anmol-91 x YR-5
4	Khattakwal	17	Anmo-19l x YR-10
5	KT-06	18	Anmol-19 x YR-15
6	PR-128	19	Khattakwal x YR-5
Testers		20	Khattakwal x YR-15
7	YR-5	21	Khattakwal x YR-5
8	YR-10	22	KT-06 x YR-5
9	YR-15	23	KT-06 x YR-10
F2-population		24	KT-06 x YR-5
10	Auqaab-2000 x YR-5	25	PR-128 x YR-5
11	Auqaab-2000 x YR-10	26	PR-128 x YR-10
12	Auqaab-2000 x YR-15	27	PR-128 x YR-15

Collection of Data

Different parameters were used to collect data including days to heading, flag leaf area, tiller per plant, plant height, spike length, spikelets per spike, 1000 grain weight, grain yield and biological. Data were collected randomly selected ten healthy plants in each replication for a single trait.

RESULTS AND DISCUSSION

Genetics Variance

Genetics differences for all the traits are highly significant in their variance comprised for parental lines, testers and F2 population. Days to heading and plant height are significant in their genetic variance for F2 hybrids and non-significance for line by tester, with the coefficient of variation (CV) 1.41 and 11.86 respectively. Tiller per plant, flag leaf area, spikelets per spike and biological yield are non-significant in all genotypes. In their genetic variation all the genotypes were non significance for tiller per plant, spikelets per spike, flag leaf area, biological yield in their F2 hybrids and lines by tester with the coefficient off variance were 19.16, 1.60, 5.05 respectively (Table 2). With contrast 1000 grain weight, grain yield were significant in their genetic differences shown in (Table) 2.

Mean Performance

Overall minimum days to heading was recorded for 116.00 in lines i.e. Auqaab and maximum headings interval was observed for F2 population i.e. Khattakwal*YR-5 (127.5). In parental lines plant height range from 86.5 (YR-5) to 124.0 (Khttakwal) line by tester varies from 282.7 (KT-06) to 286.6 (Fateh jung). In F2 population plant height reported from 93.9 (Fateh Jung*YR-5) to 120.8 (Khattakwal*YR-10). Overall minimum plant height was observed 92.3 in lines i.e. Auqaab in maximum plant height was observed 124.0 in lines i.e khattakwal. In F2 population, the tillers per plant observed from 38.5 (Fateh jung*YR-10) to 10.0 (Anmol*YR-15). Minimum tillers per plant was recorded 10.0 in F2 population i.e. (Anmol*YR-15). The maximum plant height was observed, which is 38.5 in F2 population i.e. Fateh jung*YR-10. Analysis of variance

showed a highly significant genetic variation in line by tester for flag leaf area and the LSD at 5% probability was 4.66%. In parental lines flag leaf area range from 20.6 (Anmo 91) to 17.3 (YR-15) line by tester varies from 58.7 (PR-128) to 52.9 (Fateh jung). In F2 population flag leaf area noted from (PR-128*YR-15) 22.5 to (Anmol*YR-5)16.2. Overall maximum flag leaf area was recorded for 22.5 in F2 population i.e. PR-128*YR-15 in minimum flag leaf area was observed for 16.2 in F2 population i.e. Anmol*YR-5. In parental lines Spike length range from 15.4 (Auqaab) to 10.6 (YR-15), line by tester varies from 39.9 (Auqaab) to 34.5 (anmol-91). In F2 population Spike length noted from 13.4 (Auqaab*YR-5) to 11.1 (KT-06-YR-15). Overall minimum spike length was recorded for 11.1(KT-06*YR-15) in lines in maximum spike length was observed for 15.4 in lines i.e. Auqaab. In parental lines spikelet per spike range from 23.9 (Khattakwal) to 21.1 (Anmol-91) line by tester varies from 64.7 (Auqaab) to 60.0 (Anmol-91). In F2 population spikelet per spike noted from 22.3 (Auqaab*YR-5) to 19.3 (Khattakwal*YR-10). Overall minimum spikelet per spike was recorded for 19.3 in F2 population i.e. Khatakwal*YR-10 in maximum spikelet per spike was observed for 23.9 in lines i.e. khattakwal. In parental lines 1000-grain weight range from 59.4 (PR-128) to 49.1 (YR-15) line by tester varies from 172.0 (Khattakwal) to 163.9 (PR-128). In F2 population days to heading noted from 69.2 (PR-128*YR-5) to 38.4 (PR-128*YR-15). Overall maximum 1000 grain weight was recorded for 69.2 (PR-128*YR-5) in F2 population in minimum 1000 Grain weight was observed for 38.4 (PR-128*YR-15) in F2 population. In parental lines biological yield range from 86.7 (fateh jung) to 85.1 (Auqaab) line by tester varies from 283.3 (Khtakkwal) to 22.9 (fateh jung). In F2 population biological yield noted for 118.0 (khttakwalYR-5) to 66.0 (Fateh jung*YR-15). Overall maximum days to heading was recorded for 118.0 (Khttakwal*YR-5) in F2 population in minimum biological yield was observed for 81.1(Auqaab) in line. In parental lines grain yield range from 43.3 (YR-15) to 19.6 (Khattakwal) line by tester varies from 162.1 (Auqaab) to 99.2 (Khattakwal). In F2 population days to heading noted from 64.2 (Auqaab*YR-5) to 24.2 (Khattakwal*YR-5). Overall minimum days to heading

Table 2: Means square for various traits among line by tester population in wheat. For Days to heading, Spike length, Plant Height, Spikelet per spike biological yield, 1000 grain weight, flag leaf area tiller per plant, grain yield. (**ns)=significance and non-significance at five percent probability. CV= Coefficient of variation.

Source of variation	d.f	Days to heading	Spike length	Plant height	Spikelet per spike	Biological Yield	1000 Yield	Grain Flag leaf area	Tillers per plant	Grain yield
Solution										
Replication	2	17.12**	16.57**	91.89NS	7.97**	1101.70ns	42.18ns	3780.06**	94.53ns	129.54
Genotypes	26	26.06**	4.57**	252.92**	3.61NS	544.60ns	100.00**	5.79ns	92.97ns	284.29
Parents	8	39.83**	8.01**	340.00**	2.30NS	201.68ns	69.56ns	3.20ns	30.33ns	144.27
P vs F1	1	116.71**	29.82**	34.53NS	43.11**	2037.93**	51.45ns	0.52ns	127.45ns	2484.30
F1(Cross)	17	14.24**	1.47ns	224.79**	1.91NS	618.13ns	117.18**	7.32ns	120.42ns	220.77
Lines	5	35.04**	3.91ns	650.99**	3.97NS	492.43ns	25.84ns	3.85ns	161.34ns	486.79
Testers	2	13.84**	0.07ns	105.60NS	0.14NS	610.05ns	260.81ns	28.60**	175.18ns	81.47
L x T	10	3.92ns	0.53ns	35.53NS	1.23NS	682.59	134.12**	4.79ns	89.01ns	115.62
Error	52	3.05	2.51ns	52.43	2.21s	436.83	39.11	7.86	69.80	27.27
CV	-	11.43	12.74	7.34	7.05	19.12	11.43	14.93	20.00	14.29

Table 3: Mean performance for days to heading, spike length, spikelet per spike, plant height, flag leaf area, biological yield, grain yield, 1000 grain weight, tiller per plant.

Lines, testers, population	F2 Days to heading	Plant height	Spike length	Spikelete per spike	Flag leaf area	1000 grain weight	Biological yield	Tiller per plant	Grain yield
Parental lines									
Auqaab	116.00	92.3	15.4	23.0	18.2	49.6	58.1	9.6	28.3
Fateh jung	122.00	95.6	13.0	21.2	18.3	56.7	86.7	10.6	29.0
Anmol-91	120.00	98.5	13.3	22.1	20.6	47.0	63.9	10.5	23.5
Khattakwal	126.00	124.0	15.1	23.9	19.2	55.2	68.0	16.2	19.6
KT-06	121.00	98.3	12.6	21.5	19.1	61.0	65.5	16.7	28.1
PR-128	117.50	98.0	13.0	22.4	20.0	59.4	73.5	7.9	23.5
Tester									
YR-5	124.00	86.5	11.6	21.5	19.3	51.9	72.5	15.9	28.2
YR-10	125.00	90.6	14.9	22.1	18.0	52.1	72.0	12.6	34.6
YR-15	126.00	95.1	10.6	21.4	17.3	49.1	76.0	13.6	43.3
F2 population									
Auqaab x YR-5	125.50	97.0	13.4	22.3	18.6	54.6	86.1	11.7	64.2
Auqaab x YR-10	126.00	94.6	13.4	21.4	18.7	53.8	75.5	14.7	48.5
Auqaab x YR-15	124.50	95.3	13.2	21.1	19.6	56.1	88.3	16.0	49.4
Fateh jung x YR-5	126.00	93.9	12.1	20.0	17.8	55.9	71.8	16.8	47.1
Fateh jung x YR-10	126.00	96.7	11.3	19.6	16.4	55.1	85.1	38.5	37.4
Fateh jung x YR-15	122.50	95.4	11.9	19.8	18.7	56.2	66.0	14.7	39.0
Anmol x YR-5	126.50	97.4	11.6	20.0	16.2	53.8	72.9	11.0	37.9
Anmol x YR-10	124.50	102.7	11.7	20.9	18.8	53.6	63.8	12.2	34.6
Anmol x YR-15	125.00	94.3	11.3	20.2	21.8	50.2	86.9	10.0	34.7
Khattakwal x YR-5	127.50	111.3	12.2	20.5	19.1	66.6	118.0	15.6	24.2
Khattakwal x YR10	125.00	120.8	11.8	19.3	17.1	51.6	64.1	13.4	39.0
Khattakwal x YR-15	127.00	116.3	11.9	20.7	18.9	53.8	101.2	15.3	36.0
KT-06 x YR-5	125.50	89.9	11.5	19.5	18.5	56.5	64.1	13.2	43.3
KT-06 x YR-10	125.00	95.0	12.3	21.0	18.4	56.1	89.4	13.3	34.5
KT-06 x YR-15	122.00	97.8	11.1	20.7	19.6	57.0	91.3	12.1	45.4
PR-128 x YR-5	121.00	94.0	11.7	20.8	18.5	69.2	74.4	14.2	36.1
PR-128 x YR-10	120.83	100.8	11.3	21.1	17.8	56.3	75.5	21.1	34.4
PR-128 x YR-15	120.50	89.2	12.3	21.7	22.5	38.4	89.5	11.5	42.1
LSD	2.86	11.86	13.69	4.59	4.59	10.25	34.24	13.69	8.56

was recorded for 19.6 in lines i.e. Khattakwal in maximum headings to interval was observed for 64.2 in F2 population i.e. Auqaab*YR-5. All the data are present in (Table 3).

Combine Ability Analysis

Greater the genetic variation in assumed breading material allow further analysis in the partition of its combined ability into its component i.e. general and specific combine ability effects in lines, testers and line-by-tester interactions, respectively according to GCA and SCA effect. The positive values originated desirable for the majority of the traits and crop plants i.e. growth and yield-related traits however negative GCA and SCA are fortunate for those traits, where minimum values are required i.e. flowering and maturity.

General and Specific Combine Ability Effect

Days to heading in line GCA effect range from -0.32 to -3.71 i.e. KT-06 and PR-128 show negative and desirable GCA effect, while Auqaab, Fateh jung, Anmol-91, Khttakwal, YR-05, YR-10 i.e. 0.84, 0.34, 0.84, 2.01, 0.84, 0.06 shown positive GCA effect (Table 4). The maximum positive GCA effect were detected in line Khattakwal (2.01) followed by Auqaab, anmol-19, YR-05 (0.84) in case of testers GCA effect varied from -0.91 to 0.84 for days to heading the tester YR-15 showed Non-

significant negative GCA effect while the remaining two testers i.e. YR-5,YR-10 revealed positive GCA effect while the maximum positive GCA effects were exhibited by YR-5 and overall parental lines and testers the highest negative and desirable GCA effect were recorded in line PR-128 (-3.71) and testers -0.91. For days to heading in F2 population, the SCA effect range from six out of eighteen F2 hybrids, reveled negative and desirable SCA effect noted from -1.56 (Khattakwal*YR-10) to -1.43 (Fateh jung YR-15) while the other twelve F2 hybrids showed positive SCA effect 1.10 (Fateh jung*YR-10) to 1.41 (Khttakwal*YR-15) for days to heading the maximum negative SCA effect were detected in F2 population -1.56 (Khttakwal*YR-10) followed by -1.43 (Fateh jung*YR-15) and -1.26 (KT-06*YR-15) however the maximum positive SCA effect were observed in F2 population 1.41 (Khttakwal*YR-15) followed by two other F2 population i.e. 1.10 (Fateh jung*YR-15) and 0.77(KT-6*YR-15) (Table 5). Plant height in line GCA effect range from -4.79 to -4.36 i.e. KT-06,PR-128 show negative and desirable GCA effect while the other Khattakwal i.e. 17.14 shown positive GCA effect while maximum positive GCA effect were detected in line Khattakwal (17.14) in case of testers GCA effect varied from -1.78 to 2.76 for plants height the tester YR-5 (-1.7),YR-15(-0.98) showed significant negative GCA effect while the remaining tester i.e.

YR10(2.76), revealed positive GCA effect while the maximum positive GCA effects were exhibited by 2.76. For plant height in F2 population the SCA effect range from seven out of eighteen F2 population reveled negative and desirable SCA effect noted from -4.46 to -1.36 while the other eleven F2 population shown positive SCA effect 4.57 to 0.35 for plant height the significant negative SCA effect were detected in F2 population -4.46 (PR-128*YR-15) followed by -3.78 (Auqaab*YR-10) however the maximum positive SCA effect were observed in F2 population 4.57(KT-06*YR-15) followed by two other F2 population i.e. 3.14 (Auqaab*YR-5) and 3.37(PR-128*YR-10).

Tillers per plant in line GCA effect range from -2.43 to 0.28 show negative and desirable GCA effect while the other PR-128(0.28), Fateh jung (8.03) shown positive GCA effect while maximum positive GCA effect were detected in line Fateh jung (8.03) in case of testers GCA effect varied from -2.04 to-1.55 for tillers per plant the tester YR-05 and YR-15 showed significant negative GCA effect while the remaining tester i.e. YR-10, revealed positive GCA effect while the maximum positive GCA effects were exhibited by YR-10(3.59). For tillers per plant in F2 population the SCA effect range from eight out of eighteen F2 population reveled negative and desirable SCA effect noted from -6.60 to -0.90 while the other ten F2 population shown positive SCA effect 11.60 to 3.90 for Tillers per plant the minimum negative SCA effect were detected in F2 population (Fateh jung*YR-15) -6.06 however the maximum positive SCA effect were observed in F2 population 11.60 (Fateh jung*YR-10) (Table 4 & 5).

Flag leaf area in line GCA effect range from -1.08 to -0.34 i.e. Fateeh jung, Khattakwal show negative and desirable GCA effect while the other 0.86 to 0.10 i.e. PR-128,KT-06 shown positive GCA effect while maximum positive GCA effects were detected in line PK-128 (0.86) followed by Auqaab (0.25) in case of testers GCA effect varied from 1.482 to -0.60 for flag leaf area the tester YR-05 and YR-10 showed significant negative GCA effect while the remaining tester YR-15 revealed positive GCA effect while the maximum positive GCA effects were exhibited by YR-15 (1.45) (Tab. 4). For flag leaf area in F2 population the SCA effect range from seven out of eighteen F2 population revealed negative and desirable SCA effects noted from -2.15 to -0.37 while the other eleven F2 population show positive SCA effect 1.44 to 0.22 for flag leaf area the minimum negative SCA effect were detected in F2 population Anmol*YR-5(-2.15). However the maximum positive SCA effect was observed in the F2 population PR-128*YR-15.

Spike length in line GCA effect range from -0.37 to -0.01 i.e. PR-128,Khattakwal show negative and desirable GCA effect while the other Auqaab i.e. 1.30 shown positive GCA effect while maximum positive GCA effect were detected in line Auqaab (1.30) in case of testers GCA effect varied from -0.04 to 0.07 for spike length the tester YR-15 and YR-10, showed significant negative GCA effect while the remaining tester YR-5 revealed positive GCA effect while the maximum positive GCA effects were exhibited by 0.07 (YR-05). For Spike length in F2 population the SCA effect range from eleven out of eighteen F2 population reveled negative and desirable SCA effect noted from -0.01 to -0.47, while the other seven F2 population shown positive SCA effect 0.69 to 0.11 for spike length the minimum negative SCA effect were detected in F2 population Anmol*YR-5(-0.01). However, the maximum positive SCA effect were observed in F2 population KT-06*YR-10(0.69).

Spikelet per spike in line GCA effect range from -0.76 to -0.19 i.e. Fateh jung show negative and desirable GCA effect while the other PR-128 and Auqaab i.e. 0.59,1.01 shown positive GCA effect while maximum positive GCA effect were detected in line 1.01 (Auqaab) in case of testers GCA effect varied from 0.10 to -0.03 for spikelet per spike the tester YR-5 AND YR-10 showed significant negative GCA effect while the remaining tester YR-15 revealed positive GCA effect while the maximum positive GCA effects were exhibited by YR-15. For spikelet per spike in F2 population the SCA effect range from ten out of eighteen F2 population reveled negative and desirable SCA effect noted from -0.84 to -0.05 while the other eight F2 population shown positive SCA effect 0.82 to 0.22 for spikelet per spike the minimum negative SCA effect were detected in F2 population 0.05 (PR-128*YR-10), however the maximum positive SCA effect were observed in F2 population 0.82 (Auqaab*YR-5).

The 1000 grain weight in line GCA effect range from -2.76 to -0.44 i.e. Anmol-91, Auqaab show negative and desirable GCA effect, while the other KT-06, Khttakwal and Fateh jung i.e 1.26, 2.08, 0.49 shown positive GCA effect while maximum positive GCA effect were detected in line Khattakwal (2.08) in case of testers GCA effect varied from -0.31 to 4.16 for 1000 grain weight the tester YR-10 and YR-15 showed significant negative GCA effect while the remaining tester YR-5 revealed positive GCA effect while the maximum positive GCA effects were exhibited by YR-5 (4.16). For 1000 grain weight in F2 population the SCA effect range from eight out of eighteen F2 population reveled negative and desirable SCA effect noted from -12.90 to -0.19 while the other ten F2 population shown positive SCA effect 10.38 to 0.24 for 1000 Grain weight the minimum negative SCA effect were detected in F2 population PR-128*YR-15 (12.90) however the maximum positive SCA effect were observed in F2 population PR-128*YR-5 (10.28).

Biological yield in line GCA effect range from -7.03 to -1.51 i.e. Fateh jung, PR-128 show negative and desirable GCA effects, while the other Auqaab, khttakwal, KT-06 i.e. 1.98, 13.10, 0.26 shown positive GCA effect while maximum positive GCA effect were detected in line Khttakwal (13.10) in case of testers GCA effect varied from -5.77 to 5.87 for biological yield the tester YR-5 and YR-10 showed significant negative GCA effect while the remaining tester YR-15 revealed positive GCA effect while the maximum positive GCA effects were exhibited by 5.87. For days to heading in F2 population the SCA effect range from nine out of eighteen F2 population

reveled negative and desirable SCA effect noted from -24.54 to -1.54 while the other nine F2 population shown positive SCA effect 23.67 to 0.87 for biological yield the minimum negative SCA effect were detected in F2 population Khattakwal*YR-10 (-24.54) however the maximum positive SCA effect were observed in F2 population Khattakwal*YR-5 (23.67).

Grain yield in line GCA effect range from -7.37 to -2.90 i.e. Khttakwal, PR-128 show negative and desirable GCA effect while the other Auqaab, Fateh jung KT-6 i.e. 13.59,0.74 and 0.65 shown positive GCA effect while maximum positive GCA effect were detected in line 13.59 (Auqaab) in case of testers GCA effect varied from -2.38 to 0.67 for Grain yield the tester YR-10 showed significant negative GCA effect while the remaining two testers i.e. YR-05,YR-15 revealed positive GCA effect while the maximum positive GCA effects were exhibited by 1.71. For Grain yield in F2 population the SCA effect range from eight out of eighteen F2 population reveled negative and desirable SCA effect noted from -10.58 to -0.79 while the other ten F2 population shown positive SCA effect 8.48 to 0.54 for Grain yield the minimum negative SCA effect were detected in F2 population Khtakwal*YR-5, however the maximum positive SCA effect were observed in F2 population (8.48).

Table 4: General combine ability effect among the lines and testers for various traits in wheat. For Days to heading, Plant Height, Tiller per plants, Flag leaf area Biological Yield, 1000 Grain weight, Spike length, Grain yield, Spikelets per spike. C.D= critical differences, S.E = standard error.

Parental genotypes	Days to heading	Plant height	Tiller per plants	Flag leaf area	Biological yield	1000 grain weight	Spike length	Grain yield	Spikelet per spike
Lines									
Auqaab	0.84	-3.43	-1.14	0.25	1.98	-0.44	1.30	13.59	1.01
Fateh jung	0.34	-3.69	8.03	-1.08	-7.03	0.49	-0.20	0.74	-0.76
Anmol-91	0.84	-0.87	-4.20	0.21	-6.80	-2.76	-0.51	-4.71	-0.23
Khattakwal	2.01	17.14	-0.53	-0.34	13.10	2.08	-0.01	-7.37	-0.41
KT-06	-0.32	-4.79	-2.43	0.10	0.26	1.26	-0.37	0.65	-0.19
PR-128	-3.71	-4.36	0.28	0.86	-1.51	-0.62	-0.22	-2.90	0.59
S.E (for gca)	0.58	2.41	2.78	0.93	6.97	2.08	0.53	1.74	0.50
C.D (5%)	1.18	4.90	5.66	1.90	14.15	4.23	1.07	3.54	1.01
C.D (1%)	1.59	6.58	7.59	2.55	19.00	5.68	1.44	4.75	1.35
Tester									
YR-05	0.84	-1.78	-1.55	-0.60	-0.10	4.16	0.07	1.71	-0.07
YR-10	0.06	2.76	3.59	-0.85	-5.77	-0.85	-0.03	-2.38	-0.03
YR-15	-0.91	-0.98	-2.04	1.45	5.87	-3.31	-0.04	0.67	0.10
S.E (for gca)	0.41	1.71	1.97	0.66	4.93	1.47	0.37	1.23	0.35
C.D (5%)	0.84	3.47	4.00	5.34	10.01	2.99	0.76	2.50	0.71
C.D (1%)	1.12	4.65	1.37	1.80	13.43	4.02	1.02	3.36	0.96

Table 5: Specific combine ability effect among the F2 population for various traits in wheat. For Days to Heading, Plant Height, Tillers per plant, Flag leaf area, Biological yield, 1000 grain yield, Spike length, Grain weight, Spikelets per spike. C.D= critical differences, S.E= standard error.

F2 Hybrids	Days to heading	Plant height	Tiller per plants	Flag leaf area	Biological yield	1000 grain weight	Spike length	Grain weight	Spikelets per spike
Auqaab x YR-5	-0.68	3.14	-0.90	0.22	2.89	-4.38	-0.02	8.48	0.82
Auqaab x YR-10	0.60	-3.78	-3.00	0.61	-2.05	-0.19	0.11	-3.16	-0.20
Auqaab x YR-15	0.07	0.63	3.90	-0.83	-0.84	4.57	-0.09	-5.32	-0.61
Fateh jung x YR-5	0.32	0.35	-5.00	0.77	-2.35	-4.03	0.24	4.20	0.30
Fateh jung x YR-10	1.10	-1.36	11.60	-0.37	16.56	0.24	-0.43	-1.37	-0.16
Fateh jung x YR-15	-1.43	1.01	-6.60	-0.40	-14.21	3.79	0.19	-2.83	-0.14
Anmol x YR-5	0.32	1.06	1.50	-2.15	-1.54	-2.88	-0.01	0.49	-0.31
Anmol x YR-10	-0.90	1.83	-2.44	0.73	-5.00	1.91	0.21	1.22	0.58
Anmol x YR-15	0.57	-2.89	0.95	1.42	6.53	0.97	-0.19	-1.71	-0.27
Khattakwal x YR-5	0.16	-3.04	2.38	1.34	23.67	5.13	0.15	-10.58	0.39
Khattakwal x YR10	-1.56	1.90	-4.93	-0.41	-24.54	-4.93	-0.11	8.30	-0.79
Khattakwal x YR-15	1.41	1.14	2.55	-0.92	0.87	-0.20	-0.04	2.28	0.40
KT-06 x YR-5	0.49	-2.60	1.86	0.29	-17.41	-4.22	-0.22	0.54	-0.84
KT-06 x YR-10	0.77	-1.97	-3.13	0.41	13.59	0.45	0.69	-4.20	0.62
KT-06 x YR-15	-1.26	4.57	1.27	-0.70	3.82	3.77	-0.47	3.66	0.22
PR-128 x YR-5	-0.62	1.09	0.16	-0.46	-5.26	10.38	-0.14	-3.13	-0.35
PR-128 x YR-10	-0.01	3.37	1.91	-0.97	1.44	2.52	-0.47	-0.79	-0.05
PR-128 x YR-15	0.63	-4.46	-2.07	1.44	3.82	-12.90	0.60	3.92	0.40
S.E (sca effect)	1.01	4.18	4.82	1.62	12.07	3.61	0.91	3.02	0.86
C.D (5%)	2.05	8.49	9.80	3.29	24.51	7.33	1.86	6.12	1.75
C.D (1%)	2.75	11.40	13.15	4.41	32.91	9.85	2.49	8.22	2.34

Discussion

The specific and general combine ability differences were evaluated of the maturity and yield related traits of F2 population line by testers and lines in wheat. The combine ability provides utilize information about the potential parental lines and testers in hybridization program (Zafar et al., 2022). Combine ability showed the breeding value of parental lines and testers to produce F2 population in a breeding program and to examine the selection in terms of maturity and grain related traits in wheat (Romanus et al., 2008)

Present study exhibited that significance variation were noted among the parental line testers and there F2 population for all the traits. In combine ability analysis of variation testers revealed significance differences for majority of the traits However line by testers were significant and there mean square performance for the majority of the traits. In past study reported significance differences among the wheat genotype for the concerned parameters, predicted sufficient genetic variations for the selection of best individual genotype in wheat (Ahmad et al., 2017; Rahul, 2017; Farooq et al., 2019; Rauf et al., 2023). Past study of line by testers combine ability analysis effect showed significance differences among the parental genotype and there F2 populations for maturity and yield related traits in wheat (Esmail, 2007; Ingle et al., 2018; Kumar et al., 2018).

General combine ability effect (GCA) and specific combine ability effect (SCA) and line by testers combine ability observed significance among the parental lines testers and line by testers population for maturity and yield traits in wheat by   Past study about line by testers general combine ability represented same pattern of significance for various traits in wheat population (Akram et al., 2008 & 2009; Fellahi et al., 2013; Tabassum et al., 2017). Finding significance differences for spike length, spikelet per spike, 1000 Grain weight and grain yield per plant in line by testers combine ability analysis in wheat were studied in their past experimental work by (Bibi et al., 2013).

General combine ability for parental genotype and their line by testers with specific combine ability of F2 population were studied to estimate the ability of parental population. In wheat crop increase spikelet number of spikelet's are preferred because it contributes to the grain yield Therefore the F2 populations Auqaab in lines YR-10 and in Auqaab*YR-10 i.e. in testers in F2 population performed better for spike length with desirable GCA and SCA effect this trait could be used in future by breeder to increase the spike length and spikelet's per spike in wheat. Spikelet length and spikelet per spike or the important component of grain yield present result showed that wheat genotype with maximum spike length found more produce greater grain yield which got supported from the past work in wheat by (Farooq et al.,2019; Parveen et al.,2019). In present study the genotype

with greater 1000 Grain weight were selected for increased grain yield same result were showed by (Hei et al., 2015). There for days on mean performance and desirable SCA and GCA effect the F2 population i.e. Fateh jung, Khttakwall, KT06 in lines PR-128*YR-5, Khattakwall*YR-5 in F2 population could be used in future wheat breeding programs. In previous studies reported that the wheat genotype exhibited significant differences foe seed index and grain yield totally depend on 1000 grain weight (Akbar et al., 2009). For 1000 grain weight SCA and GCA effect in wheat were identified as a best combination in their past papers (Khan et al., 2007). In other study 1000 Grain weight and spike traits in wheat revealed positive GCA effect for their F2 population and line by testers (Farooq et al., 2006; Saeed and Khalil, 2017). Wheat genotype with great morphologically growth, more foliage and increase biological yield with provide more help in food security of the livestock. In present study the F2 population i.e. Khattakwall*YR-5, Khttakwall*YR-15 and in line YR-15 and Fateh Jung were found as a best wheat performance for biological yield with desirable GCA and SCA effect, and which can use for increasing of the genotype with enhancing biological yield in future wheat breeding programs. Previous study revealed that F2 population with desirable SCA effect showed greater mean performance than parental genotype for biological wheat in wheat (Khan et al., 2007; Khattab et al., 2010). While F2 population were also identified as a best specific combiner for biological yield in wheat (Jain and Sastry, 2012). Similarly, variation for tillers per plants were observed among the wheat tester's parental lines and F2 population. And their study revealed that Genotypes with maximum teller have greater biological and grain yield (Ahmad et al., 2017; Abd-El-Mohsen et al., 2012). Previous study about line by testes analyses significance differences among lines testers and line by testers for plant height, and the population revealed greater genetic variability for vegetative and yield traits (Nour et al., 2011; Ahtisham et al., 2014; Tripathi et al., 2015). The past study showed that line and testers and their combine populations showed desirable GCA and SCA effect and advocated as a best general and specific for biological yield in wheat (Murugan and Kannana, 2017). Grain yield per plant directly affect the total grain yield therefore the F2 population Auqqb*YR-5, AuqaabYR-15, AuqaabYR-10 and KT06*YR-15 showed best mean performance and desirable GCA and SCA effect and to further evaluated in future wheat breeding programs the lines YR-15 and YR-10 also performed best. Previous study reported that grain yield or primary suffered by several traits i.e. Tillers per plants, Spikelet's per spike, 1000 grain weight and grain yield. Grain yield was directly involved by improving yield in wheat (Ingle et al., 2018). Significance differences were noted among the parental genotypes and there f1 hybrid and F2 population revealed increased grain yield then the parental genotype in wheat (Jatav et al., 2014). F2

population's line by testers and testers performed better for yield traits with desirable GCA and SCA effects (Fellahi et al., 2013; Istipliler et al., 2015).

Conclusion

The present study was carry out with the objective to estimate the genetic variability combine ability effect among the population of wheat six parental wheat lines. And three testers YR-10, YR-15, YR-5 and there eighteen F2 populations were grown during 2021-2022 and complete randomiza block design with three replication and serial crop research institute (CCRI Persabak Nowshera Pakistan) data were recorded on days to heading, Flag leaf area, Plant height, Spike length, Spikelet per spike, Thousand grain weight, Grain Yield and biologically weight. In Spike length show significance genetic variations for parental F2 Population and non-significant for line by testers. Lines Auqaab show more positive GCA effect while KT-06 showed lowest negative GCA effect while in testers Yr-5 show positive GCA effect for F2 population KT-06 cross YR-10 exhibit height positive Significance SCA effect. For mean performance Auqaab (15.4 cm) showed best mean performance in lines while YR-15 showed less mean performance (10.6) in days to heading show significance genetic variation for parent F2 population and line by testers. Late variety for mean performance showed by Khttakwal*YR-15(127 days) While in early variety was auqaab-116.00 Days in lines. While in General combine ability khattakwal Estimate maximum positive significant GCA effect 2.01 While in testers YR-5 showed maximum positive GCA effect. For specific combine ability in F2 population (crosses) Fateh jung*YR-10 revealed Maximum positive SCA effect. Plant height also showed significance genetic variability for parents and F2 population. For mean performance Khattakwal from lines showed maximum mean performance (124.0) while minimum for YR-5 (86.5). In general combine ability for plant height Khattakwal showed maximum positive GCA effect in testers YR-10 exhibit (2.76). For plant height I F2 population the SCA effect range from seven out of fifteen population reveled negative and desirable GCA effect while the rest of Eleven showed positive SCA effect. However, KT-06*YR-15) (4.57) showed maximum positive SCA effect. Tiller per plant was non-significant for parental tester, line by and F2 population. Maximum plant height was observed for Fateh jung*YR-10 in F2 population (38.5), minimum while for Anmol*YR-15 (10.0). In general combine ability Fateh jung (8.03), while in case of a tester Maximum positive GCA effect was noted for YR-10 (3.59). Specific combine ability (SCA) for F2 population eight out of eighteen showed negative SCA effect while the rest of ten showed positive SCA effect. For tiller per plant Fateh jung*YR-10 showed maximum positive SCA effect while Fateh jung*YR-15 showed minimum SCA effect. For flag leaf area parental and F2 population was non significance for their genetic variability for mean performance PR-

128*YR-15(22.5) estimate maximum flag leaf area and minimum was observed for Anmol*YR-15(16.2) in F2 population. For flag leaf area General Combine ability was positive maximum for PK-128(0.86) in case of testers maximum positive SCA effect was exhibits by YR-15(1.45) in F2 population SCA effect were noted negative for seven out of eighteen in the remaining eleven showed positive SCA effect. However maximum positive SCA effect was observed in F2 population for PR-128*YR-15(1.4) and minimum for Anmol*YR-5 (2.15). Spikelet per spike was significance for parental in F2 population. In mean performance Khattakwal reveled maximum Spikelet per spike (23.9) and overall minimum spikelet per spike were noted for Khattakwal*YR-10 in F2 population. For General combine ability Auqaab showed maximum Positive GCA effect (1.01). While in case of tester YR-15 exhibited Positive GCA effect. Specific combine ability for F2 population eight out of eighteen shown Positive SCA effect while the remaining ten revealed negative SCA effect. Auqaab*YR-5 in F2 population showed maximum SCA effect while PR-128*YR-15 in F2 population exhibited minimum SCA effect. For 1000 Grain weight the analysis of variance showed significance of genetic variation for parental in F2 population in overall mean performance PR-128*YR-5 in F2 population estimate maximum 1000 Grain weight (69.2g) While minimum was observed for PR-128YR-15 in F2 population (38.4). For GCA effect in line maximum positive significance for Khattakwal (2.08) in case of testers YR-5 revealed maximum positive GCA effect (4.16) for F2 population SCA effect Range from eight out of eighteen F2 population revealed negative SCA effect while the rest of ten F2 population showed positive SCA effect. However maximum positive SCA effect was observed in F2 population maximum for PR-128*YR-5(10.28) and minimum for PR-128 YR-15(12.90). Biological yield was significant for parental in F2 population. In mean performance Khttakwal*YR-5(118.0) estimate maximum biological yield in F2 population While in minimum was observed for Auqaab in line (81.1) GCA effect for biological yield was maximum positive in line for khattakwal (13.10) While in case of testers YR-15 revealed positive GCA effect. In F2 population for negative specific combine ability were showed by nine out of eighteen F2 population while the rest of nine F2 population showed positive SCA effect. In biological yield minimum SCA effect was Exhibited in F2 population Khttakwal*YR-10(-24.54) However maximum positive SCA effect was noted in F2 population for Khattakwal*YR-5. Grain yield was also significant for parental in F2 population in mean performance maximum grain yield was recorded for Auqaab*Yr-5 in F2 population (64.2) while minimum for Khattakwal(19.6) For general combine ability in lines Auqaab showed maximum positive GCA effect (13.59) in case of testers YR-5, YR-15 Reveled positive SCA effect. For grain yield in F2 population SCA effect Range from eight out of eighteen population reveled negative

and desirable SCA effect While the other ten F2 population showed positive SCA effect in F2 population Khttakwal*YR-5 Showed minimum SCA effect in F2 population.

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