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Original Research Article

EVALUATING COMBINING ABILITY AND HETEROSIS EFFECTS ON YIELD, ASSOCIATED TRAITS, AND YELLOW RUST RESISTANCE IN WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract *Wheat is a considerable energy source for the people of Pakistan and many other countries. Yellow rust is the most unpropitious biotic stress for wheat yield. The research was conducted to study the combining ability, heterosis and response of genotypes for yellow rust resistance. For this impetus, eight wheat genotypes, namely (five genotypes viz; Dharabi-11, Hp-1, Ehsan-16, Pak-13 and Morocco) were kept as lines and three genotypes viz; Markaz-19, Borlauge-16 and Fakhar-e-Bhakar used as testers. Lines X Testers matting design developed fifteen F1 hybrids sown in proper symmetry for crossing during rabi season 2020-21 at the university research farm, PMAS-Arid Agriculture University Rawalpindi, during 2020-21. During Rabi 2021-22, developed hybrids along with the eight parents in a randomized complete block design (RCBD) using three replications with plant-to-plant and row-to-row distances of 15cm and 25cm, respectively. Morocco was used as a spreader and sown after every five rows; two rows are the border of each replication. Data was recorded for the traits viz. flag leaf area, canopy temperature, chlorophyll content, days to maturity, 1000 grain weight, seed yield per plant and disease score. Mean value showed a maximum in Markaz-19 for flag leaf area, Pakistan-13 for chlorophyll content among parents. HP-1 x Markaz-19 showed maximum seed yield per plant (29.27 g). Minimum disease score was observed in Borlague-16.*

Keywords: *Wheat; Yellow Rust; Line x Tester; Gene Action; Combining ability*

Introduction

The most widely grown wheat species worldwide is *Triticum Aestivum L.*, commonly called 'Bread Wheat'' a hexapliod species. Wheat is a big source of dietary fibers, and phytochemicals, micronutrients, and also contain significant amounts of protein vitamin (particularly vitamin B), which are needed or beneficial to health (Shewry & Hey. 2015). In Pakistan, wheat contributes to 1.8 % of the GDP and 7.8 % of the value addition in agriculture. Wheat crop production is 26.394 million tonnes from 8.976 million hectares of cultivated area of wheat (Pakistan Economic Survey 2021-22). Wheat yield needs to improve by 1.8 percent annually by 2050 to feed a world population of 9 billion (Godfray. 2010 & Ray. 2013). China is the world's leading country among the world wheat's producing countries. China produced 134,250 thousand tons of wheat in 2020, accounting for 20.65 percent of global wheat production. India, Russian Federation, the United States of America, and Canada are the top five countries, accounting for 63.43 percent of the total (World Data Atlas. 2020). World wheat production in 2021-22 was 778.8 million ton (USDA. 2022). Nutritional quality and crop yield are decreasing day by day due to presence of biotic and abiotic factors. Among the biotic stresses, fungal diseases are the major wheat production restraint in most wheat-cultivated areas of the world (Ali. 2014 & Dean. 2012). Amongst the fungal diseases such as leaf, stem and stripe caused by Puccinia spp. are more disturbing (Hovmøller *et al.* 2010). Wheat yellow rust (*Puccinia striformis*) is an airborne biotrophic and obligates fungal pathogen. Yellow rust attacks occur more frequently in areas of mild climate during the growing wheat crop season. For their germination, infection, growth and survival, pathogen needs low temperatures and high humidity, which means that climate change plays a very positive role in the yellow rust disease development (de Vallavieille-Pope. 1995 & Hau and de Vallavieille-Pope. 2006 & Mboup. 2012). Wheat yellow rust is one of the most damaging diseases in

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wheat production, significantly affecting wheat quality and yield (Wellings *et al*. 2011). Yellow rust caused by *Puccinia striiformis* f. sp. tritici (Pst.), is a significant wheat disease that occurs during the growing season when the weather is cool and contains high humidity (Hovmøller. 2011 & Mboup. 2009). Stripe rust, the current primary rust disease harming winter cereal production worldwide, has been extensively studied for over a century. Across multiple wheat growing seasons, China, Pakistan, and Iran caused significant yield losses. Wheat production reduces due to various diseases, particularly wheat rust, 10-50% depending upon the susceptibility and crop stages of the disease (Beddow *et al*. 2015). Yellow rust is mostly found 70% of the total wheat-growing area in Pakistan (Sing *et al*., 2004). The Line × Tester analysis (Kempthorne, 1957) is the most potent tool for estimating combining ability impacts and assisting in selecting appropriate crosses and parents. Performances of the genotypes alone do not tell whether a parent is a good or bad combiner. More information about the nature of gene activities is required to overcome this challenge. Gene effects of the additive type are attributed to general combining ability, whereas nonadditive gene activities are linked to specific combining ability. Nonadditive gene type of action is not reliably fixable, whereas the additive type of gene action or complementary type epistatic gene interaction is reliably fixable (Fellahi, Hannachi, Bouzerzour & Boutekrabt. 2013).

Materials and methods

This study was conducted at University Research Farm (URF), Chakwal road, Rawalpindi, from 2020 to 22. The experimental material comprised twenty-three wheat genotypes, including 8 parents and 15 crosses. Eight (3+5) genetically diverse wheat genotypes were selected out of these three (Borlgue-16, Fakhar e Bhakar and Markaz-19) were used as testers and five (Ehsan-16, Pakistan-13, Hp-1, Morocco and Dharabi-11) as lines. During rabi season 2020-21 these genotypes were sown and crossed in a line x tester mating design. This study identified the best cross combination for stripe rust resistance and yield related attributes. During rabi season 2021-22, twenty-three wheat genotypes, including 8 parents and 15 crosses, were sown in RCBD (randomized complete block design) with 3 replications. The wheat genotype morocco was also used as a spreader for yellow rust pathogen. One row of morocco was planted after every three rows in addition to two rows in border of each replication. Data were collected from five randomly selected guarded plants of each genotype. The recorded data were subjected to analysis of variance according to Steel et al. (1997) to estimate diversity among the mean value of these genotypes per replication. The estimate of general combining ability and specific combining ability effect of parents and hybrids were calculated according to Kempthorne (1957). Heterobeltiosis was also calculated. Data on the following parameters were collected at the appropriate time, flag leaf area, canopy temperature, chlorophyll content, days to maturity, thousand grain weight, seed yield, and disease score.

Results and discussion

Study was conducted on 23 genotypes, including 8 parents (5 lines & 3 testers) and 15 crosses. Genetic variability among the genotypes was found through analysis of variance. The contribution of lines, testers, line x tester interaction, SCA, and GCA were calculated. The performance of the general combining ability and specific combining ability study is helpful for selecting best parents and crosses, respectively. Parameter-wise studies are as follows:

Flag Leaf Area (cm^2)

Flag leaf has a great role in wheat yield by providing plants a maximum percentage of photosynthesis (Ahmad et al., 2013). Analysis variance showed significant differences among parents and F_1 hybrids for the flag leaf area. Flag leaf area ranged from 30.11 to 44.33 cm^2 for parents. The maximum flag leaf area (44.33 cm^2) was reported in Markaz-19, while the minimum flag leaf area (30.11 cm^2) showed in Ehsan-16. The maximum flag leaf area (43.00 cm2) was recorded in F1 hybrid Dhrabbi-11 x Bor-16, while the minimum (27.27 cm2) was in Pak-13 x Bor-16 (Table 1). Similar types of results were observed by Din et al., 2021. General and specific combining abilities are important statistical parameters for selecting parents and crosses for further breeding programs. Significant and positive general combining ability (GCA) for flag leaf area was found in Fakhar e Bhakkar and HP-1 (2.56 and 2.67, respectively) (Table 3). These types of results were also reported by Farooq et al. 2006. These genotypes can be used to increase flag leaf area. Rest of the parental lines and testers were found poor general combiner for flag leaf area having non-significant values (Table 3). Pakistan-13 x Borlague-19 showed significant and positive heterosis (2.5) among F_1 hybrids and can be used for heterosis breeding (Table 5).

Canopy Temperature

Analysis of variance for canopy temperature showed highly significant differences among the genotypes (Table 1). Parents' vs Crosses also indicated a highly significant difference. The line, testers and line x tester interaction are significant. Mean for canopy temperature was recorded 30.27 to 32.37 among parental genotypes and 30.43 to 33.33 among crosses (Table 2). Among parental genotypes Morocco had maximum canopy temperature (32.37), while HP-1 had the minimum canopy temperature (30.27).

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Among crosses, the maximum canopy temperature (33.33) was observed for cross Dharabbi-11 x Markaz-19, while Morocco x Borlaug-16 showed the minimum canopy temperature. Canopy temperature is usually low in high-yielding varieties with deep root as reported by Lopes et al., (2012). General combining ability effect for canopy temperature was recorded as negatively significant in Morocco (-3.10) among the parents and can be used to develop a low canopy temperature good general combiner for the breeding program (Table 3). Significant negative specific combining ability effect for canopy temperature was found in cross Ehsan-16 x Markaz-19. The best parent showing negative heterosis was observed in Dharabbi-11 x Fakhar e Bhakkar for lowering the canopy temperature (Table 5).

Chlorophyll Content

Chlorophyll is the most important trait that contributes to increased total crop production. Analysis of variance indicated highly significant differences among genotypes for chlorophyll content (Table 1). Parents vs. Crosses, lines and testers indicated highly significant mean square values for chlorophyll content. Mean values for chlorophyll content ranged from 25.93 to 35.93 among parents and 29.71 to 36.68 among crosses (Table 2). Among the parental genotypes' maximum chlorophyll content (35.93) was found in Pakistan-13, while minimum chlorophyll content (25.93) was observed in Fakhar e Bhakkar. Ehsan-16 x Fakhar e Bhakar indicated maximum chlorophyll content (36.68) among F_1 crosses while minimum chlorophyll content (29.71) was observed in HP-1 x Borlaug-16. Khayatnezhad et al. (2011) reported that wheat varieties with higher chlorophyll content in the reproductive stage yield higher. General combining ability effect for chlorophyll content was recorded as a significant positive among parents in Ehsan-16 and Fakhar e Bhakar (Table 3). Parental line Ehsan-16 (3.44) and tester Fakhar e Bhakar (4.97) were the best general combiner for chlorophyll content. These parents (Ehsan-16 & Fakhar e Bhakkar) could be selected as the best parents for the breeding program because they showed positive and significant GCA for chlorophyll content. SCA value of crosses indicated the significant positive specific combining ability effect. Ehsan-16 x Fakhar e Bhakar showed a significant and positive SCA effect (3.47) among the F_1 hybrids (Table 4). The significant best parent heterosis showed by Pakistan-13 x Borlaug-16, which exhibited the higher best parent heterosis (2.54) for chlorophyll content (Table 5) and can be used for heterosis breeding.

Days to Maturity

Days to maturity affiliated with crop suitability in existing cropping systems for a specific area. Analysis of variance indicated the highly significant differences among genotypes for days to maturity (Table 1). The present study revealed that the grown wheat genotypes indicated the different maturity days. Mean for days to maturity ranged from 131.67 to 139.33 among the parents, while among F_1 crossed, it ranged from 128 to 139.00 days. Among the parents, maximum days to maturity were recorded in Borlaug-16 (139.33), while minimum days to maturity were recorded in HP-1 (131.67). Among F_1 hybrid Dharabbi-11 x Fakhar e Bhakkar (139.00) showed maximum maturity days while the minimum days to maturity was recorded in Hp-1 x Markez-19. The early maturity genotypes could not be beneficial because of low yield. These results showed similarities with previously reported results by (Akram et al., 2009; Afridi et al., 2018). A general combined ability effect for day to maturity revealed significantly positive results in Borlaug-16 and Pakistan-13 among parental genotypes. Pakistan-13 (2.25) showed a significant positive GCA effect among the line, while Borlaug-16 (2.14) showed a positive effect among testers (Table 3). These parents can be selected as the best general combiner for further breeding. Specific combining effects observed were significant and positive in F_1 hybrids. Hybrid Dharabbi-11 x Borlaug-16 showed a positive and significant SCA effect (Table 4).

Previous studies reported that lines, testers, and their hybrid populations were found to have significant negative GCA and SCA effects and took less time to mature in wheat (Esmail, 2007; Akram et al., 2008). Past findings also revealed that wheat genotypes with minimum days to maturity were more preferable from farmer and end-user point of view

1000 Grain Weight

The weight of the seed is the indicator of seed yield, which ultimately leads to an increase in crop production. Analysis of variance showed a highly significant difference among the genotypes for 1000 grain weight (Table 1). Parents and F1 hybrid showed significant genetic variance. Parents' vs Crosses also indicated highly significant difference. Mean for 1000 grain weight was recorded in the 33.13 to 45.27 g range among parental genotypes and 32.23 to 43.60 among crosses (Table 2). Among parental genotypes Borlaug-16 produces maximum grain weight (45.27 g) while the minimum grain weight (33.13 g) showed by Dharabbi-11. Ehsan-16 x Markaz-19 showed the maximum grain weight (43.60 g), while Dharabbi-11 x Markaz-19 showed the minimum grain weight (32.23 g). The effect of general and specific combining ability are important statistical parameters to select the best parents and crosses for further breeding programs. General combining ability effect was observed to be significant and positive for thousand grain weight in HP-1 (3.58) among lines and Borlaug-16 (2.20) among testers (Table 3) and can be used for further breeding. Specific combining ability effect for thousand-grain weight, F_1 hybrid Morocco x Fakhar e Bhakar (5.59), Pakistan-13 x Borlaug-16 (3.85) and Dharabi-11 x Markaz-19 (3.04) showed high positive significance (Table 4). The significant best parent heterosis was observed in F1 hybrid Ehsan-16 x Markaz-19, which indicated best parent heterosis value (6.20) for grain weight (Table 5). The significant and positive value for 1000 grain weight was also reported by Protic et al. (2007).

Seed Yield

Analysis of variance indicated the significant difference among genotypes for seed yield (Table 1). Mean value for seed yield ranged from 10.20 to 25.17 g per plant among the parents and 9.40 g to 29.27 g per plant among crosses (Table 2). Among the parental genotypes,, Borlaug-16 indicated maximum yield (25.17 g), while minimum seed yield (10.20 g) was recorded in HP-1. On the other hand, HP-1 x Markez-19 indicated a maximum seed yield (29.27 g) among F1 crosses, while a minimum seed yield (9.40) was observed in Morocco x Fakhar e Bhakkar. To increase wheat crop productivity, enhancement of seed yield is the main objective in the notice for breeding programs. General combining ability effect for seed yield per plant was recorded as significantly positive in Ehsan-16 and Dharabi-11(3.81 & 2.30 respectively) among line and Borlaug-16 and Markaz-19 (3.53 & 2.72 respectively) among testers (Table 3). These are the best general combiners for seed yield per plant and can be used for further breeding. The positive and significant value of GCA seed yield was also studied by Zare Kohan & Heidari (2014). On the other hand, the specific combining ability effect for seed yield per plant was significantly positive in Ehsan-16 x Markaz-19 (3.60) (Table 4). The crosses revealed the independent GCA and SCA. This biparental system increases the seed yield per plant (Yadav and Sirohi, 2011). The best parent heterosis was observed significantly in Dharabbi-11 x Borlaug-16 among F_1 hybrids, which indicated the best parent heterosis value (3.52) and can be used for heterosis breeding (Table 5). The significant and positive differences among the genotypes for seed yield were also reported by (Menon and Sharma, 1997; Ali and Khan, 1998; Javaid et al., 2001; Solomon, 2002).

Disease Score

Analysis of variance showed a highly significant difference among the genotypes for disease score (Table 1). Parents' vs Crosses also indicated a highly significant difference. The line indicated significant differences, testers showed highly significant differences, and line x tester interaction was also significant. Mean values for disease score ranged from 1.67 to 7 among parental genotypes and 1.33 to 8.67 among crosses (Table 2). Among parental genotypes, Morocco (7) showed the maximum disease score, while the minimum disease score was recorded in Borlaug-16 (1.67). Maximum disease score among the F_1 hybrid was observed in Morocco x Fakhar e Bhakar, and the minimum disease score was recorded in HP-1 x Markaz-19. General combining ability effect for the disease was recorded as significantly negative in HP-1 (-2.08) among lines and Borlaug-16 (-2.81) among testers (Table 3). The specific combining ability effect for disease score was negative and significant in HP-1 x Borlaug-16 (-3.63) among F1 hybrids (Table 4). The significant best parent heterosis was observed in F1 hybrid HP-1 x Borlaug-16, which exhibits a value (-2.04) for best parent heterosis and can be used for heterosis breeding (Table 5). These results had similarities with previously studies by Khodarahmi et al., (2009). Their study found that genotypes and crosses the lower yellow rust value can be used for further breeding programs.

Table 1: Mean square value of the studied traits of 23 wheat genotypes sown in 2021-22 at URF, Chakwal Road Rawalpindi

SOV	DF	FLA	CT	CC	DM	TGW	SY	DS
Replication	2	273.72	1.21	4.52	4.35	154.54	3.56	2.19
Genotypes	22	69.92**	1.89	24.18**	32.33**	57.95**	6.01**	11.81**
Parents	7	94.97**	2.87**	28.38**	49.52**	13.50**	5.84**	15.76**
Parent vs. crosses	1	130.99**	9.41**	141.76**	105.80**	70.33**	7.27**	58.34**
Crosses	14	53.03**	0.87	13.67**	18.48**	79.28**	6.52**	6.51**
Line (L)	4	111.37**	2.43*	14.59**	26.70**	55.68**	5.80**	2.11*
Tester (T)	2	54.96**	3.96**	5.91**	0.20	15.82**	9.23**	14.15**
L X T	14	23.37**	4.06**	15.16**	18.95**	106.96**	6.21**	6.79**
Error	44	29.13**	0.36	6.80**	13.28**	9.25**	3.96**	2.34*

*, ** = Significant at 5 and 1% probability level respectively.

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Table 2: Mean of the studied traits of 23 wheat genotypes sown in 2021-22 at URF, Chakwal Road Rawalpindi

GENOTYPES	FLA	CT	CC	DM	TGW	SY	DS
Parents							
Ehsan-16	30.11	31.10	33.66	134.67	36.62	13.53	2.67
Pak-13	32.78	31.63	35.93	136.67	39.09	14.93	6.33
Hp-1	31.40	30.27	31.55	131.67	38.97	10.2	2.33
Morocco	33.08	32.37	28.72	137.33	37.03	14.47	7
Dhrabi-11	34.85	30.42	29.44	138.33	33.13	16.17	2.67
Bor-16	35.93	30.57	29.78	139.33	45.27	25.17	1.67
FB	33.97	30.55	25.93	137.33	36.3	12.43	3.33
Markaz-19	44.33	30.58	30.18	132.00	36.73	14.97	3.67
F_1 Crosses							
Ehsan-16 X Bor-16	32.90	30.95	35.11	138.67	35.52	13.13	2.67
Ehsan-16 X FB	28.54	30.59	36.68	132.67	36.23	12.10	2.67
Ehsan-16 X Markez-19	31.73	30.69	32.95	136.33	43.60	26.67	4.00
Pak-13 X Bor-16	27.27	30.55	34.44	133.00	38.23	18.63	2.67
Pak-13 X FB	28.66	30.75	29.79	136.67	35.60	12.07	2.33
Pak-13 X Markez-19	28.52	30.91	35.35	134.33	35.81	13.13	3.67
Hp-1 X Bor-16	29.80	30.49	29.71	135.00	43.46	16.53	4.00
Hp-1 X FB	34.69	31.18	33.29	132.33	37.47	14.07	4.00
Hp-1 X Markez-19	32.05	32.53	32.05	128.00	36.93	29.27	1.33
Morocco X Bor-16	40.07	30.43	35.17	130.67	39.40	12.30	3.67
Morocco X FB	30.02	31.08	35.97	129.33	38.25	9.40	8.67
Morocco X Markez-19	32.13	31.04	32.23	131.33	35.60	11.48	3.67
Dhrabbi-11 X Bor-16	43.00	32.20	33.59	138.33	36.82	11.17	4.00
Dhrabbi-11 X FB	41.33	31.01	35.85	139.00	36.53	11.73	7.67
Dhrabbi-11 X Markez-19	27.91	33.33	32.73	135.00	32.23	9.57	8.00
$\bar{x}$	33.27	31.09	32.61	134.70	38.02	15.79	4.12
CV %	16.23	1.93	8.00	2.71	8.00	39.67	37.16

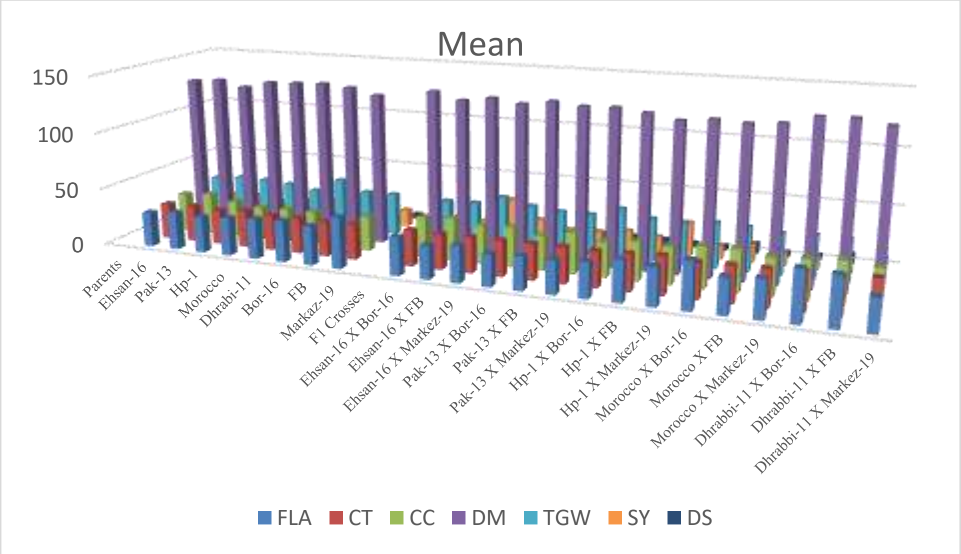

Figure 1: Mean square of all traits studied.
FLA; flag leaf area, CT; canopy temperature, CC; chlorophyll content, DM; days to maturity, TGW; thousand grain weight, SY; seed yield, DS; disease score

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Table 3: General combining ability effect (GCA) of 5 lines and 3 testers of studied traits 23 wheat genotypes sown in 2021-22 at URF, Chakwal road Rawalpindi

	Genotypes	FLA	CT	CC	DM	TGW	SY	DS
	Ehsan-16	-0.46	3.85**	3.44**	-1.05**	-2.46*	3.81**	0.86
	Pak-13	1.31	2.45*	-0.54	2.25*	0.65	-2.9**	-1.10
Lines	Hp-1	2.67*	-0.70	-2.28*	0.33	3.58**	1.63	-2.08*
	Morocco	-1.71	-3.1**	0.91	-1.32	1.86	-0.87	3.6**
	Dhrabbi-11	-1.81	-0.55	2.45**	-0.21	-0.47	2.30**	-0.22
	SE of GCA for lines	0.79	0.20	0.87	1.22	1.01	2.09*	0.51
	Bor-16	-0.99	1.55	-0.08	2.14	2.20*	3.53**	-2.8**
Testers	FB	2.56*	2.13*	4.97**	-0.07	-2.39*	-1.19	1.75
	Markez-19	-0.57	-1.68	-0.89	-0.06	-0.22	2.72**	1.06
	SE of GCA for testers	3.12	0.15	0.67	0.94	0.78	1.63	0.39

Table 4: Specific combining ability effect (SCA) of 15 crosses of studied traits sown in 2021-22 at URF, Chakwal road Rawalpindi

F1 Crosses	FLA	CT	CC	DM	TGW	SY	DS
Ehsan-16 X Bor-16	0.02	-0.09	0.17	0.13	-1.26	-0.81	-0.13
Ehsan-16 X FB	-0.27	2.41*	3.74**	1.59	-0.43	-0.79	-2.16*
Ehsan-16 X Markez-19	0.25	-0.31	-0.91	-1.73	1.70	3.60**	2.29*
Pak-13 X Bor-16	2.05*	0.67	2.87**	-0.75	3.85**	2.34*	-2.13
Pak-13 X FB	-0.63	-0.48	-2.70**	0.04	-2.41*	-0.17	-0.28
Pak-13 X Markez-19	0.68	-0.19	1.83	0.71	-1.44	2.18*	0.40
Hp-1 X Bor-16	-0.55	-0.26	-1.28	0.80	1.55	-0.34	-3.63
Hp-1 X FB	1.63	-0.09	2.63*	-2.61*	-0.71	-0.73	2.62*
Hp-1 X Markez-19	-1.08	0.34	0.64	1.82	-0.85	1.07	-1.99
Morocco X Bor-16	0.24	-0.17	0.51	-0.97	-3.15**	-2.06*	0.76
Morocco X FB	0.12	2.04*	0.57	1.59	5.59**	1.36	0.23
Morocco X Markez-19	-0.36	0.13	-2.08*	-0.62	-2.44*	-1.30	-0.98
Dhrabbi-11 X Bor-16	0.34	-0.14	-0.27	0.80	-1.00	2.13*	0.13
Dhrabbi-11 X FB	-0.85	4.12**	0.75	-0.62	-2.04*	0.33	-0.40
Dhrabbi-11 X Markez-19	0.52	0.03	-0.48	-0.18	3.04**	-2.20*	-0.13

Table 5: Heterobeltiosis of studied traits of 15 F_1 sown in 2021-22 at URF, Chakwal road Rawalpindi

GENOTYPES	FLA	CT	CC	DM	TGW	SY	DS
Ehsan-16 X Bor-16	-0.06	-0.46	0.67	1.84**	4.41**	3.03**	0.00
Ehsan-16 X FB	-2.20*	-0.33	1.01	-7.83**	-0.14	-0.19	0.02
Ehsan-16 X Markez-19	-1.51	-0.30	-0.24	-4.18**	6.20**	2.95**	-0.01
Pak-13 X Bor-16	-1.92	-0.59	2.54*	-5.95**	3.18**	-1.64	3.23**
Pak-13 X FB	-2.15*	5.10**	-2.21*	-2.30*	-1.37	-0.43	0.25
Pak-13 X Markez-19	-2.66*	1.10	-0.21	-6.97**	-1.28	-0.27	4.17**
Hp-1 X Bor-16	-1.41	-1.61	-0.58	-3.20**	-0.82	-2.17*	-2.04
Hp-1 X FB	-0.06	0.19	0.55	-8.30**	-0.58	0.20	-0.02
Hp-1 X Markez-19	-1.39	4.60**	-2.16*	-15.79**	-0.79	2.14*	0.01
Morocco X Bor-16	-1.89	-0.63	1.61	-9.15**	-2.66*	-3.24**	0.23

Morocco X FB	-6.34**	0.15	2.08*	-12.45**	0.45	0.28	-0.12
Morocco X Markez-19	-5.41**	3.14**	0.62	-11.15**	-0.53	-0.52	2.23*
Dhrabbi-11 X Bor-16	3.28**	-0.05	1.14	1.37**	-3.83**	3.52**	-0.04
Dhrabbi-11 X FB	2.26*	-2.03*	-2.89**	0.93	0.08	-0.72	-0.14
Dhrabbi-11 X Markez-19	-2.88**	0.69	0.77	-6.03**	-1.65	-0.26	-0.16

Conclusion

Dharabi-11 and Markaz-19 found the best general combiner for seed yield per plant. These parents are good general combiners and best for the parent selection. F_1 hybrid Pakistan-13 x Borlague-16, Pakistan-13 x Markaz-19 and Dharabi-11 x Borlague-16 were the best specific combiner for seed yield per plant and used further for heterosis breeding. Heterobeltiosis was observed in Ehsan-16 x Markaz-19 and Dharabi-11 x Borlague-16.

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