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COMBINING ABILITY ANALYSIS IN WHEAT (*Triticum aestivum L.*) USING LINE X TESTER MATING DESIGN UNDER MOISTURE STRESS CONDITIONS

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ABSTRACT

The present study was conducted to assess the combining ability and gene action estimating yield and related traits in Wheat (*Triticum aestivum L.*) under moisture stress conditions using a line x tester mating design. A set of 7 lines and 3 testers were crossed to produce hybrids which along with their parents were evaluated under controlled moisture stress conditions and normal irrigation environments. Analysis of variance revealed significant differences among genotypes, parents, crosses, lines, testers and line x tester interactions for most traits, conforming the existence of genetic variability. The predominance of Specific combining ability (SCA) variances over General combining ability (GCA) variances suggested a greater role of non–additive gene action under moisture stress conditions. The results indicated that selection based on specific combiners and heterosis breeding could be effective for improving wheat yield under drought prone environments.
***Keywords* :** Wheat, Combining ability, line x tester, gene action analysis, moisture stress conditions, GCA, SCA.

Introduction

Wheat is one of the largest and most staple cereal crops globally contributing nearly about 20% of the total calories and protein in the human diet. Bread wheat contributes nearly one third of the total food grain production and is the second most important food crop after rice in India. It is one of the most important crops due to its high adaptation, several uses and high nutritive value. Its broad adaptability to diverse agro-climatic conditions, coupled with its high nutritional and economic value, has made it an indispensable component of global food security. However, wheat productivity is severely constrained by abiotic stresses, among which drought or moisture stress remains a major limiting factor in arid and semi-arid regions.

Wheat is a self-pollinating plant with less than one per cent cross pollination. Wheat belongs to the Poaceae family whose chromosome number is 42. All the species of Triticum have been divided into three basic groups based on the number of chromosomes in gametic cells i.e., diploid, tetraploid and hexaploid. Out of these three groups, hexaploids (*Triticum. aestivum*) and tetraploids (*Triticum. durum*) are the most widely cultivated species in the world. The common wheat (*Triticum aestivum L.*) is the youngest polyploid species among the agricultural crops which has originated from the spontaneous hybridization of tetraploid *Triticum durum* or *Triticum turgidum* sub sp. durum (2n = 4x = 28, AABB) with diploid *Aegilop tauschii* (also known as *Aegilops. squarrosa*) (2n = 2x = 14, DD).

An important task in wheat breeding is the development of high-yielding varieties with stable productivity and sufficiently good resistance to diseases and unfavourable environmental conditions. Therefore, genetic variability has been considered as an important factor that is also an essential pre requisite for crop improvement programs for obtaining high-yielding progenies. Understanding the nature of gene action governing yield and its associated traits under stress environments is crucial for effective selection and hybridization strategies. Combining-ability analysis, particularly through the line × tester (L×T) mating design, provides valuable insights into the relative importance of additive and non-additive genetic effects controlling quantitative traits [4,5]. Line × Tester evaluation is used to propagate both self and cross – pollinated plants and to estimate favourable parents and crosses. Its analysis provides information about combining ability effect of genotype and also knowledge regarding genetic mechanisms controlling yield component. Combining ability analysis is an important tool for the selection of desirable parents together with the information regarding nature and magnitude of gene effects controlling quantitative traits. GCA and SCA which identify the hybrids with high yield are the most important criteria in breeding programs. It is also necessary to know the performance of a cross combination in comparison to the parent involved in the hybrid.

The present study was conducted to estimate the measure of the phenotypic variability of the traits to obtain the general and specific combining ability and to estimate heritability, heterosis, correlation and path analysis to access the potential of variable germplasm in breeding for the development of variety that adapts to the environmental conditions prevailing in the region. The main objectives were to test the combining ability and character association of yield and yield attributing character and to estimate the amount of heterosis.

Materials and Method

The present investigation was carried out during two seasons first in rabi season, 2023- 2024 and second in rabi season, 2024-2025.

Experimental material

The experimental material for the present investigation contained 10 genotypes including 7 females (lines) and 3 males (testers) that were crossed in line × tester method in the first season. In the second season hybrids along with their parents were assessed during rabi 2025. The 10 genotypes used in the current study experimental material included 7 lines (MT- 20-01, MT- 20-02, MT- 20-03, MT- 20-04, MT- 20-05, MT- 20-06, MT- 20-07) and 3 testers (HPW373, HPW368 and HPW433). There were three replications, every plot constituted of a single, three-meter-long row with a space of 20 cm between rows and 10 cm between plants, respectively. Five plants that were in competition, one parent and one F1, were chosen at random to observe each replication. With the allowance of Days to 50% flowering, Days to 75% maturity, Plant height (cm), Number of branches per plant, biological yield per plant(g), Dry matter yield (g), Grain yield per plot (g), Harvesting index per plant (%), 1000 grain weight (TKW) (g), Number of spikes per plant, Number of tillers per plant, Grain per spike.

Genotype and Source

Line (female parents)

Sr. No.	Genotypes	Source
1	MT- 20-01	NBPGR Shimla
2	MT- 20-02	NBPGR Shimla
3	MT- 20-03	NBPGR Shimla
4	MT- 20-04	NBPGR Shimla
5	MT- 20-05	NBPGR Shimla
6	MT- 20-06	NBPGR Shimla
7	MT- 20-07	NBPGR Shimla

Tester (male parents)

Sr. no.	Genotypes	Source
1	HPW373	RWRC Malan, CSKHPKV Palampur
2	HPW368	RWRC Malan, CSKHPKV Palampur
3	HPW433	RWRC Malan, CSKHPKV Palampur

Observations recorded

For the purpose of documenting observation, five plants from each parent and five plants from each cross were randomly selected. with the exception of days to 50% flowering and days to 75% maturity which were determined based on plot basis, observation on eleven significant features were recorded using the mean of five randomly selected plants from the collection. The following traits were noted and observed –

Days to 50% Flowering

Record the number of days from sowing to when 50% of the plants in the plot have reached the flowering stage. This indicates the onset of reproductive growth. Accurate tracking helps in understanding crop development.

Days to 75% Maturity

Measure the number of days from sowing to when 75% of the plants in the plot have reached maturity. This marks the completion of the crop cycle. It's crucial for planning harvests and crop rotations.

Plant Height (cm)

Measure and record the height of each plant in centimeters. Plant height is an indicator of growth and development. It influences lodging resistance and harvest efficiency.

Number of Tiller per Plant

Count and record the number of tillers on each plant. Tillering influences plant density and yield potential.

Number of Spike per Plant

Count and record the number of spikes on each plant. Spike number affects grain yield and plant architecture.

Grain per Spike

Count and record the number of grains per spike. Grain number per spike is a determinant of yield and fertility.

1000 Grain Weight (TKW) (g)

Measure and record the weight of 1000 grains in grams. TKW is an indicator of grain size and quality, influencing market value.

Biological Yield per Plant (g)

Measure and record the total biological yield (including grains, leaves and stems) of each plant in grams. Biological yield indicates overall plant productivity and resource utilization.

Harvesting Index (%)

Calculate and record the harvesting index (grain yield/biological yield) of each plant as a percentage. The harvesting index indicates the efficiency of converting biomass into grain.

Grain Yield per Plot (g)

Measure and record the total grain yield of each plot in grams. Grain yield is the ultimate measure of crop productivity and economic viability.

Statistical Analysis of Variance

The concept of line × tester analysis was developed by Kempthorne in 1957. Analysis of variance for different characters consisting of 18 treatments in 3 replications was performed to test the significance of treatment, mean. In the presence of significant genotypic difference, data was further analyzed for combining ability and heterosis.

Analysis of variance

The data recorded on various quantitative characters were subjected to analysis of variance to test the significance of treatment means, followed by randomized block design (RBD). The first steps involved in the analysis of variance is to perform analysis of variance as per the design used and test the significance of differences among the genotypes including crosses and parents. If these differences are found significant, line × tester analysis is done.

Result and Discussion

This study aimed to evaluate the combining ability and trait associations of key yield-contributing characteristics in wheat, as well as estimate the degree of heterosis exhibited by these traits. By analyzing combining ability, we can pinpoint parents that possess desirable traits, thereby facilitating the development of high-performing cross. Furthermore, character association analysis revealed correlations between various agronomic traits, enabling informed selection of traits to enhance overall yield. The phenomenon of heterosis, where hybrids outperform their parents, is a crucial aspect of hybrid development. The findings of the study are presented in the following sections, providing insights into the genetic basis of trait expression and hybrid performance. The study aimed at combining ability, trait associations, and heterosis in wheat to identify promising parents and traits for cross. Our analysis focused on yield-contributing characteristics, aiming to enhance crop productivity through informed breeding decisions. The outcomes of this research are systematically presented and analyzed in the subsequent sections.

Analysis of variance

Estimates combining ability analysis

Estimation of Heterosis

Correlation and Path

Analysis of variance

Analysis of variance for line x tester mating design revealed that variance due to parents (testers) was highly significant for all the characters except non-significant variances for biological yield per plant in F1s. The analysis of variance of the present investigation was carried out as per the standard procedure of Panse and Sukhatme (1984) for each of the characters under investigation. To initiate any crop improvement program, adequate genetic variability is essential. Therefore, it is crucial to confirm the existence of sufficient genetic variability for various traits in the crop before beginning any breeding program. An analysis of variance (ANOVA) was conducted for all eleven traits to evaluate the significance of differences among different treatments, parents and crosses, lines and testers

Table 1 : Analysis of variance for various yield and yield attributing characters

	Source of variance		Replication	Genotypes	Error
Sr. No.	Traits	**Df**	**2**	**30**	**60**
1	Days to 50% flowering		**5.98**	**26.26***	**9.60**
2	Days to 75% maturity		**2.24**	**39.23***	**16.48**
3	Plant height		**68.61***	**66.08***	**14.88**
4	Number of tillers per plant		**7.53**	**6.24***	**3.16**
5	Spikes per plant		**0.33**	**2.29***	**1.12**
6	Grains per spike		**1.33**	**10.84***	**5.46**
7	1000 grain weight		**0.38**	**38.96***	**8.97**
8	Biological yield per plant		**3.79**	**16.63***	**6.02**
9	Harvest index		**12.11**	**96.56***	**34.65**
10	Grain yield per plant		**1.47**	**9.35***	**1.38**

Table 2 : Analysis of variance for line × tester design for various traits yield and yield attributing character

	Source of variance		Replication	Parents	Testers	Lines	Lines vs Tester	Crosses	Parents vs Crosses	error		Error
Sr. No.	**Traits**		**2**	**9**	**2**	**6**	**1**	**20**	**1**	**60**		**60**
1	Days to 50% flowering		5.98	32.08*	37.00*	17.76	108.13*	24.58*	7.67	9.60		9.60
2	Days to 75% maturity		2.32	19.70	11.68	9.38	97.66*	42.42*		16.48	151.45	16.48
3	Plant height		68.63	127.10*	35.62	120.42*	350.19*	41.79*	2.64	14.88		14.88
4	Number of tillers per plant		7.53	5.52	0.33	5.87	13.73*	6.78*	2.07	3.16		3.16
5	Spikes per plant	**Df**	0.33	3.29*	0.78	3.94*	4.46	1.95*	0.02	1.12		1.12
6	Grains per spike		1.33	16.16*	4.11	14.49*	50.29*	8.99	0.002	5.46	0.002	5.46
7	1000 grain weight		0.38	46.96*	14.90	25.13*	242.04*	36.03*	25.44	8.97	25.44	8.97
8	Biological yield per plant		3.79	20.71*	23.94*	13.22	59.15*	12.96*	53.28	6.02	53.28	6.02
9	Harvest index		12.11	109.28*	15.21	86.08*	436.62*	95.65*	0.05	34.65		34.65
10	Grain yield per plant		1.47	13.89*	9.39*	8.37*	56.02*	7.33*	9.01	1.38		1.38

Table 3 : Analysis of variance for combining ability analysis for yield and yield attributing characters

	Source of variance		Replication	Due to tester	Due to line	Lines x Tester	Error
Sr. No.	**Traits**		**2**	**2**	**6**	**12**	**40**
1	Days to 50% flowering		4.00	4.33	38.44*	21.02*	7.933
2	Days to 75% maturity		1.83	19.78	54.88	39.96*	19.13
3	Plant height		66.07*	19.74	65.02	33.85*	18.62
4	Number of tillers per plant		10.33*	1.86	2.48	9.75*	3.28
5	Spikes per plant	**df**	0.68	3.11	1.11	2.18*	1.08
6	Grains per spike		0.76	16.00	2.40	11.11*	5.51
7	1000 grain weight		10.85	10.56	60.68*	27.95*	10.40
8	Biological yield per plant		0.47	29.76*	5.95	13.67*	5.94
9	Harvest index		0.70	26.05	82.95	113.59*	30.12
10	Grain yield per plant		0.085	2.39	5.80*	8.91*	1.16

During the current investigation, a total of 21 crosses were evaluated for SCA effects, out of these MT-20-01 × HPW 368 (-2.95), MT-20-04 × HPW 433 (-3.02) and MT-20-07 × HPW433 (-3.35) had significant negative SCA estimates for early flowering,while MT-20-03 × HPW 433 (2.54) and MT-20-04 × HPW 368 (3.60) had significant positive SCA estimates for late flowering. These were supported by findings of (Singh et al.2010), Yadav (2013) and Sofi (2010)

Table 4 : Estimates of GCA effects of lines and testers for yield and yield attributing traits

Sr. No.	Genotypes	Days to 50% flowering	Days to 75% Maturity	Plant height	Number of tillers per plant	Spikes per plant	Grains per spike	1000 grain weight	Biological yield per plant	Harvest index	Grain yield per plant
1.	MT-20-01	-3.05*	-1.22	-0.31	-0.40	0.51	0.52	0.26	0.99	6.33*	1.57*
2.	MT-20-02	1.62	4.68*	-4.49*	0.05	0.18	0.30	0.59	0.12	0.55	0.11
3.	MT-20-03	-0.16	-2.94*	1.78	0.60	-0.16	0.64	-1.27	-0.56	-1.94	-0.63
4.	MT-20-04	-0.94	1.50	4.20*	-0.84	-0.60	0.08	4.45*	-1.03	-3.03	-0.90*

5.	MT-20-05	3.51*	-0.03	0.22	-0.18	0.06	-0.59	1.30	0.84	-1.10	0.08
6.	MT-20-06	-0.38	-1.41	-1.49	0.60	-0.16	-0.59	-3.84*	-0.82	0.10	-0.40
7.	MT-20-07	-0.60	-0.57	0.10	0.16	0.18	-0.37	-1.49	0.47	-0.90	0.16
	SE± GCA effects(lines)	0.87	1.35	1.33	0.55	0.32	0.73	1.00	0.75	1.69	0.33
8.	HPW433	0.24	0.87	-0.46	0.33	0.06*	0.76*	0.66	0.91*	-0.57	0.31
9.	HPW373	-0.52	0.17	1.11	-0.24	-0.41	-0.95	0.09	-1.35*	1.28	-0.36
10.	HPW368	0.29	-1.04	-0.66	-0.10	0.35	0.19	-0.75	0.43	-0.71	0.06
	SE± GCA effects(testers)	0.50	0.78	0.77	0.32	0.19	0.42	0.57	0.43	0.98	0.19

Table 5 : Estimates of SCA effects for for yield and yield attributing traits

	Genotypes	**Days to 50% flowering**	**Days to 75% maturity**	**Plant height**	**Number of tillers per plant**	**Spikes per plant**	**Grains per spike**	**1000 grain weight**	**Biological yield per plant**	**Harvest index**	**Grain yield per plant**
1.	MT-20-01× HPW 433	3.76*	-2.56	-0.31	-1.56	-0.18	-0.76	0.85	-0.85	2.48	0.05
2.	MT-20-01× HPW 373	-0.81	1.21	0.22	0.02	-0.37	-0.38	2.55	0.88	-4.37	-0.49
3.	MT-20-01× HPW 368	-2.95*	1.35	0.09	1.54	0.54	1.14	-3.41*	-0.03	1.89	0.44
4.	MT-20-02× HPW 433	-1.24	0.84	-3.99*	1.33	-0.18	1.13	-0.81	1.98	1.14	0.96*
5.	MT-20-02× HPW 373	-0.48	3.81	5.34*	-1.76*	0.30	-2.16*	0.39	-0.96	-1.36	-0.54
6.	MT-20-02× HPW 368	1.71	-4.65*	-1.35	0.43	-0.13	1.03	0.43	-1.02	0.21	-0.42
7.	MT-20-03× HPW 433	2.54*	4.35*	0.87	0.11	0.16	-1.87	-2.93*	-0.59	-2.35	-0.77
8.	MT-20-03× HPW 373	-0.37	-6.88*	3.40	2.02*	0.64	3.84*	0.88	0.76	4.95*	1.32*
9.	MT-20-03× HPW 368	-2.18	2.52	-4.27*	-2.13*	-0.79	-1.97	2.05	-0.17	-2.60	-0.55
10.	MT-20-04× HPW 433	-3.02*	-1.49	1.72	-2.11*	-0.40	1.02	-3.90*	-1.89	-3.83	-1.42*
11.	MT-20-04× HPW 373	-0.59	-0.04	-2.51	-0.21	-0.25	-0.60	2.76	-0.93	-1.25	-0.51
12.	MT-20-04X HPW 368	3.60*	1.53	0.79	2.32*	0.65	-0.41	1.14	2.81*	5.08*	1.93*
13.	MT-20-05× HPW 433	0.54	-0.01	2.70	-0.11	-1.06*	-1.65	4.11*	-2.34*	-0.68	-1.03*
14.	MT-20-05× HPW 373	0.64	3.68	-5.40*	-0.87	1.08*	1.73	-4.49*	2.73*	-3.64	0.27
15.	MT-20-05× HPW 368	-1.18	-3.67	2.70	0.98	-0.02	-0.08	0.38	-0.39	4.32	0.76
16.	MT-20-06× HPW 433	0.76	-1.44	-0.05	1.44	0.16	0.68	-0.58	0.24	-6.54*	-1.18*
17.	MT-20-06× HPW 373	0.52	-0.20	-0.23	0.68	-0.70	-1.27	0.02	-1.23	3.35	0.24
18.	MT-20-06× HPW 368	-1.29	1.64	0.28	-2.13*	0.54	0.59	0.56	0.99	3.18	0.93
19.	MT-20-07× HPW 433	-3.35*	0.32	-0.94	0.89	1.49*	1.46	3.26*	3.46*	9.78*	3.39*
20.	MT-20-07× HPW 373	1.08	-1.58	-0.81	0.13	-0.70	-1.16	-2.10	-1.26	2.31	-0.29
21.	MT-20-07× HPW 368	2.27	1.27	1.76	-1.02	-0.79	-0.30	-1.16	-2.20*	-12.09*	-3.10*
	SE± SCA effects	1.23	1.91	1.88	0.78	0.45	1.03	1.41	1.06	2.40	0.47

Table 6 : Proportional contribution of lines, testers and their interactions to total variance

Sr.No.	**Character**	**Contribution of lines**	**Contributions of testers**	**Contributions of L×T**
1.	Days to 50% flowering	69.48	3.11	27.41
2.	Days to 75% maturity	36.26	0.31	63.44
3.	Plant height	39.98	25.47	34.55
4.	Number of tillers per plant	20.12	18.54	61.34
5.	Spikes per plant	52.09	0.72	47.19
6.	Grains per spike	28.21	2.66	69.14
7.	1000 grain weight	83.56	1.03	15.41
8.	Biological yield per plant	23.80	1.59	74.61
9.	Harvest index	47.52	2.22	50.26
10.	Grain yield per plant	41.52	2.66	55.81

Table 7 : Mean performance of genotypes for various yield amd yield attributing chataracters

	Genotypes	Days to 50% flowering	Days to 75% maturity	Plant height (cm)	Number of tillers per plant	Spikes per plant	Grains per spike	1000 grain weight (g)	Biological yield per plant (g)	Harvest index (%)	Grain yield per plant (g)
1.	MT-20-01	119.33	158.33	66.87	7.67	5.67	43.67*	35.27	20.12*	37.56	4.76*
2.	MT-20-02	116.33	156.13	82.00	8.33*	2.33	41.33*	37.37	18.52*	25.69*	7.27*
3.	MT-20-03	118.00	160.87	73.40*	11.33	4.00	45.67	36.83	23.92	39.69	9.44*
4.	MT-20-04	121.33	159.83	74.20	11.00	4.33	46.67	35.13*	21.53	38.97	8.37*
5.	MT-20-05	121.00	160.10	68.63	10.33	4.00	47.00	31.23*	20.07*	37.03	7.49*
6.	MT-20-06	123.33	159.40	83.77	9.33	3.00*	42.33	30.57*	18.56*	28.84*	5.22*
7.	MT-20-07	122.00	161.43	77.30	8.67	2.67	45.67	31.07*	17.88*	34.60*	6.36*
8.	MT-20-01X HPW433	123.00	160.43	75.97	8.67	4.33	46.00	36.43*	20.43*	45.40	9.14*
9.	MT-20-01X HPW 373	117.67	163.50	78.07	9.67	3.67	44.67*	37.57	19.90*	40.41	7.93*
10.	MT-20-01X HPW 368	116.33	162.43	76.17	11.33	5.33	47.33	30.77*	20.78*	44.67	9.29*
11.	MT-20-02X HPW 433	122.67	169.73	68.10	12.00	4.00	47.67	35.10*	22.40	38.28	8.59*
12.	MT-20-02X HPW 373	122.67	172.00	79.00	8.33*	4.00	42.67	35.73*	17.21*	37.65	6.42*
13.	MT-20-02X HPW 368	125.67	162.33	70.53*	10.67	4.33	47.00	34.93*	18.92*	37.22	6.97*
14.	MT-20-03X HPW 433	124.67	165.63	79.23	11.33	4.00	45.00	31.13*	19.15*	32.31*	6.12*
15.	MT-20-03X HPW 373	121.00	153.70	83.33	12.67	4.00	49.00	34.37*	18.24*	41.46	7.54*
16.	MT-20-03X HPW 368	120.00	161.89	73.90	8.67	3.33	44.33*	34.70*	19.09*	31.91*	6.10*
17.	MT-20-04X HPW 433	118.33	164.23	82.50	7.67*	3.00*	47.33	35.87*	17.38*	29.73*	5.21*
18.	MT-20-04X HPW 373	120.00	164.97	79.83	9.00	2.67*	44.00*	41.97	16.08*	34.17*	5.44*
19.	MT-20-04X HPW 368	125.00	165.33	81.37	11.67	4.33	45.33	39.50	21.60*	38.51	8.30*
20.	MT-20-05X HPW 433	126.33	164.17	79.50	10.33	3.00*	44.00*	40.73	18.79*	34.82*	6.57
21.	MT-20-05X HPW 373	125.67	167.17	72.97*	9.00	4.67	45.67	31.57*	21.60*	33.71*	7.21*
22.	MT-20-05X HPW 368	124.67	158.60	79.30	11.00	4.33	45.00	35.60*	20.27*	39.68	8.11*
23.	MT-20-06X HPW 433	122.67	161.37	75.03	12.67	4.00	46.33	30.90*	19.71*	30.16	5.94*
24.	MT-20-06X HPW 373	121.67	161.90	76.43	11.33	2.67*	42.67*	30.93*	15.99*	41.90	6.69*
25.	MT-20-06X HPW 368	120.67	162.53	75.17	8.67	4.67	45.67	30.63*	19.99*	39.74	7.81*
26.	MT-20-07X HPW 433	118.33	163.97	75.73	11.67	5.67	47.33	37.10	24.23*	45.47	11.06*
27.	MT-20-07X HPW 373	122.00	161.37	77.43	10.33	3.00	43.00	31.17*	17.25*	39.86*	6.72*
28.	MT-20-07X HPW 368	124.00	163.00	78.23	9.33	3.67	45.00	31.27*	18.09*	23.47	4.33*
29.	HPW433	120.67	164.57	80.03	10.67	4.00	46.33	40.80	20.76*	41.18	8.51*
30.	HPW373	124.67	161.10	81.30	11.00	4.67	47.33	37.63	22.42	42.19	9.46*
31.	HPW368	127.67	164.47	86.53	11.33	5.00	48.67	41.93	26.27	45.48	11.94
	C.D.	5.07	6.65	6.32	2.91	1.73	3.82	4.90	4.02	9.64	1.93
	SE(m)	1.79	2.34	2.23	1.03	0.61	1.35	1.73	1.42	3.40	0.68
	C.V.	2.54	2.50	5.00	17.46	26.85	5.14	8.55	12.33	15.84	15.82

Table 8 : Estimates of relatives heterosis and heterobeltiosis in percent for various yield and yield attributing character

	Days to 50% flowering		Days to 75% maturity		Plant height		Number of tillers per plant		Spikes per plant	
	Relative Heterosis	Heterobeltiosis	Relative Heterosis	Heterobeltiosis	Relative Heterosis	Heterobeltiosis	Relative Heterosis	Heterobeltiosis	Relative Heterosis	Heterobeltiosis
MT-20-01× HPW 433	2.50	1.93	-0.63	-2.51	3.43	-5.08	-5.46	-18.75*	-10.35	-23.53
MT-20-01× HPW 373	-3.55	-5.62*	2.37	1.49	5.38	-3.98	3.57	-12.12	-29.03	-35.29*
MT-20-01× HPW 368	-5.80*	-8.88*	0.64	-1.24	-0.70	-11.98*	19.30	0.00	0.00	-5.88
MT-20-02× HPW 433	3.52	1.66	5.85*	3.14	-15.94*	-16.95	26.32	12.50	26.32	0.00
MT-20-02× HPW 373	1.80	-1.60	8.44*	6.77*	-3.25	-3.66	-13.79	-24.24*	14.29	-14.29
MT-20- 02×HPW 368	3.01	-1.57	1.27	-1.30	-16.30*	-18.49*	8.48	-5.88	18.18	-13.33
MT-20-03× HPW 433	4.47*	3.32	1.79	0.65	3.28	-1.00	3.03	0.00	0.00	0.00
MT-20- 03×HPW 373	-0.28	-2.94	-4.52*	-4.59*	7.74	2.50	13.43	11.77	-7.69	-14.29
MT-20-03× HPW 368	-2.31	-6.01*	-0.48	-1.57	-7.59	-14.60*	-23.53	-23.53*	-25.93	-33.33
MT-20-04× HPW 433	-2.20	-2.47	1.25	-0.20	6.98	3.08	-29.23*	-30.30*	-28.00	-30.77
MT-20- 04×HPW 373	-2.44	-3.74	2.81	2.40	2.68	-1.80	-18.18	-18.18	-40.74*	-42.86*

MT-20-04× HPW 368	0.40	-2.09	1.96	0.53	1.24	-5.97	4.48	2.94	-7.14	-13.33
MT-20- 05×HPW 433	4.55*	4.41*	1.13	-0.24	6.95	-0.67	-1.59	-3.13	-25.00	-25.00
MT-20-05× HPW 373	2.31	0.80	4.09	3.77	-2.67	-10.25*	-15.63	-18.18	7.69	0.00
MT-20- 05×HPW 368	0.27	-2.35	-2.27	-3.57	2.21	-8.36*	1.54	-2.94	-3.70	-13.33
MT-20- 06×HPW 433	0.55	-0.54	-0.38	-1.94	-8.38*	-10.43*	26.67	18.75	14.29	0.00
MT-20-06× HPW 373	-1.88	-2.41	1.03	0.50	-7.39	-8.75*	11.48	3.03	-30.44	-42.86*
MT-20-06× HPW 368	-3.85	-5.48*	0.37	-1.18	-11.72*	-13.14*	-16.13	-23.53*	16.67	-6.67
MT-20-07× HPW 433	-2.47	-3.01*	0.59	-0.37	-3.73	-5.37	20.69	9.38	70.00*	41.67
MT-20-07× HPW 373	-1.08	-2.14	0.06	-0.04	-2.35	-4.76	5.09	-6.06	-18.18	-35.71
MT-20-07× HPW 368	-0.67	-2.87	0.03	-0.89	-4.50	-9.59*	-6.67	-17.65	-4.35	-26.67

The present study was conducted with the objectives to test the combining ability, estimate heterosis and assess the character association of yield and yield contributing traits in wheat (*Triticum aestivium* L.) using a line × tester analysis of data obtained from 10 characters from 21 crosses, 7 lines and 3 testers shown in a randomized block design with 3 replications. Observations on important traits were recorded viz., days to 50% flowering, days to 75%maturity, plant height, number of tillers per plant, number of spikes per plant, grain per spike, 1000 grain weight, biological yield per plant, harvest index and grain yield per plant.

The results of the experiment have shown that the parents and crosses significantly for most of the characters studied, indicating the presence of sufficient variability among the parents chosen for the study. Analysis of variance revealed significant differences among genotypes, parents, crosses, lines, testers, and line × tester interactions for most traits, conforming the existence of genetic variability and the suitability of the experimental material for combining ability analysis.

General combining ability (GCA) analysis indicated that among the parents MT-20-01 was a good combiner for early flowering, high harvest index, and grain yield per plant, MT-20-02 for reduced plant height and moderate yield traits, MT-20-04 for 1000 grain weight and plant height and MT-20-03 for early maturity. Among testers, HPW 433 was the best combiner for biological yield and grain per spike. This genotype are potential donors for respective traits in breeding programmes.

Specific combining ability (SCA) analysis identified MT-20-07 × HPW 433 (grain yield per plant, harvest index). MT-20-03 × HPW 373 (grain per spike, tillers per plant), MT-20-04 × HPW 368 (biological yield, harvest index), and MT-20-02 × HPW 433 (grain yield, early flowering) as the best performing hybrids. These crosses showed significant positive SCA effect for the respective traits, indicating their potential for improvement of yield attributes in wheat breeding programmes.

Heterosis analysis revealed that MT-20-07 × HPW 433 recorded the highest grain yield and harvest index with significant heterosis over both mid and better-parent value. MT-20-03 × HPW 373 had the highest grain per spike and MT-20-04 × HPW 368 showed superior biological yield. Several hybrids displayed desirable heterosis for more than 1 trait indicating the role of non-additive gene action in their inheritance.

Correlation and path analysis revealed that grain yield per plant was strongly and positively correlated with biological yield, number of tillers per plant and harvest index. Path coefficient analysis showed that biological yield had the highest direct effect on grain yield, followed by harvest index and number of tillers, suggesting these traits as prime selection criteria in yield improvement programmes.

Conclusion

The present investigation on line × tester analysis for yield and its contributing traits in wheat (*Triticum aestivum* L.) identified MT-20-07 × HPW 433, MT-20-03 × HPW 373, MT-20-04 × HPW 368, and MT-20-02 × HPW 433 as the most promising crosses, showing superior performance for grain yield and yield-related traits. These crosses may be recommended for further evaluation and multi-location testing under different agro- climatic conditions for possible commercial release. Parental lines MT-20-01, MT-20-02, MT-20-04, and tester HPW 433 can be effectively utilized in hybridization programs to develop high-yielding, stress-tolerant wheat varieties.

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