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Estimation of combining ability for grain yield and yield component traits in bread wheat (*Triticum aestivum* L.) using half diallel analysis

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Abstract

The present study involved 100 treatments (10 parents, 45 F₁s, and 45 F₂s) and 10 advanced lines, arranged in a Randomized Block Design during the 2024 Rabi season at three locations: Crop Research Farm (Aligarh), Crop Research Farm (Kaushambi) and Student Instructional Farm (CSAUAT, Kanpur). The experimental material consisted of 10 parental lines (DBW-173, DBW-187, DBW-222, DBW-398, HD-3059, K-1006, PBW-386, PBW-644, HI-1563 and HI-1612). Good general combiners were observed for all yield and yield related characters based on gca effect and *per se* performance of parents. On the basis of overall performance, DBW 222, K 1006 and DBW 173 were best general combiners for yield and its contributing traits including some quality traits. The parents may be used for simultaneous improvement in grain yield and quality attributes through an inter-mating population involving all possible combinations among themselves. On the basis of sca effects and *per se* performance, crosses DBW 398 × K 1006, DBW 187 × DBW 173, DBW 398 × PBW 644, HD 3059 × DBW 173, and HD 3059 × DBW 222 in F₁ generation and DBW 398 × K 1006, DBW 398 × PBW 644, and DBW 187 × DBW 173 in F₂ generation were found to be good specific combiners for grain yield per plant. Crosses HI 1563 × K 1006, HD 3059 × DBW 222 and DBW 398 × K 1006 showing high sca effects with at least one good general combiner could produce desirable transgressive segregants in subsequent generations. The results, therefore, satisfied the basic requirement for the present study.

Keywords: Wheat, combining ability, and yield

Introduction

Wheat (*Triticum aestivum* L.) is one of the leading food crops of the world farming and occupies significant position among the cultivated cereals. Cultivation of wheat has been the symbolic of green revolution that played pivotal role in making the nation a food surplus nation. Wheat is a member of the Poaceae family and a self-pollinated crop. India's wheat production is projected to reach 111.32 million tonnes in 2023-2024, up from 109.52 million tonnes in 2022-2023, reflecting a compound annual growth rate (CAGR) of 1.64%. Wheat is used for both human and animal nutrition and plays an important role in the nutrition of rapidly growing populations both in our country and the world (Patil *et al.*, 2024) [11]. The common wheat (*Triticum aestivum* L.) which is good for chapatti making, bread making and bakery products is grown in whole of North India and also in Central and South India. The durum wheat which is good for 'suji', 'semya', 'sphagti' and 'macaroni' is grown only in central and south India and that too under rainfed conditions. The dicoccum wheat is good for the south India dish 'Uppumav' (Singh *et al.*, 2018) [14]. Durum wheat (*Triticum turgidum* L.) is the main tetraploid type, its large, very hard grains yield low gluten flour that is the main source of semolina suitable for pasta, couscous, burghul and other local end-products. (Nachit 1995) [10]. It is grown under a wide range of climatic conditions from Kashmir and other mountainous regions to semi-arid regions with mild to severe winter. (Yadav *et al.*, 2021) [19]. Since ages, wheat has been playing an important role in the economy of several countries (Singh *et al.*, 2010) [15]. A number of biometrical techniques are extensively used for genetic evaluation of plants. Out of them, diallel, partial diallel and line X tester analyses have been frequently used by breeders for genetic study because they provide more genetic

information about the material studied. Diallel mating design is used to evaluate several material in terms of combining ability variances and effects. Its provides information about general combining ability (gca) and specific combining ability (sca) variances and effects and additive (D) and dominance (H) components of genetic variance. Diallel analyses helps in the selection of suitable parents for use in the hybridization programme as well as in the choice of appropriate breeding for the genetic improvement of various quantitative traits in a crop species.

Materials and Methods

The current study was conducted during *Rabi* 2024 at three locations: Crop Research Farm at Kalai, Aligarh, Crop Research Farm at Saini, Kaushambi and Student Instruction Farm at CSAUAT, Kanpur. It involved 100 treatments (10 parents, 45 F_1 's and 45 F_2 's) in a Randomized Block Design. The experimental material comprised 10 parental lines: DBW-173, DBW-187, DBW-222, DBW-398, HD-3059, K-1006, PBW-386, PBW-644, HI-1563 and HI-1612. The 100 treatments (10 parents, 45 F_1 's, and 45 F_2 's) were evaluated for combining ability of nine quantitative traits in wheat. Half diallel analysis was analyzed as suggested by Sprague and Tatum (1942) [17] Fisher divided the component of variance into additive, dominance and epistatic.

Result and Discussion

Analysis of variance for combining ability revealed highly significant variances in both general and specific combining ability in both the generations for several traits. This showed the important role of both additive and non-additive gene action in the expression of these traits as reported by Srivastava (2005) [18], Singh *et al.* (2012) [13] and Mallikarjuna (2014) [9] in which additive and non-additive genetic effects were involved in determining the traits. The magnitude of δg were lower than the δg for all the traits in both the generations except plant height in F_2 generation which indicated that non-additive genetic component was higher than that of additive component for all the attributes in both the generation except plant height in F_2 .

Average degree of dominance $(\wedge/\wedge)^{0.5}$ were found more than unity for all the attributes in both the generation except plant height in F_2 generation reflected over dominance gene action.

δs δg

The gca effects includes both additive and additive x additive (A x A) interaction components of genetic

variability (Griffing, 1956b; Sprague, 1966) [5, 16] which observed fixable genetic variance as also reported by Gillbert (1967) [4]. The additive parental effects as measured by gca affects are of practical use, whereas non-allelic interactions are unpredictable and can-not be easily manipulated.

The *per se* performance of the parents was compared with their gca effects in both F_1 and F_2 generations for all the traits under study. It was concluded that the parents having high *per se* performance were proved to be the best general combiners for all the characters. It may be reported that if the attribute is unidirectionally controlled by a set of alleles and additive effects are important, selection of the parents on the basis of *per se* performance in most of the cases may be correct. But the selection of parents should be made based on their combining ability estimates.

The parents may be used for simultaneous improvement in grain yield and quality attributes through an inter-mating population involving all possible combinations among themselves. These varieties may be utilized for obtaining transgressive segregants in the segregating generation or to undertake intense crossing in the early generation for getting desirable recombinants. The possible combination for multiple parents comes under central gene pool, which supplements in the faster speed of recombination and also breaking the genetic barriers if present (Jensen, 1970) [6]. In such situation mass selection with concurrent random mating (Redden and Jensen, 1974) [12] could be a useful breeding procedure in wheat. Moreover, modified mass selection or modified pedigree method in an early generation could be most useful for developing plant ideotypes for different conditions.

The sca effects showing dominance and epistatic components of genetic variability would not contribute much for improvement of autogamous crops except where commercial exploitation of heterosis is feasible, the crosses involving good general combiners and showing high sca effects may be used for further breeding purposes. Desirable transgressive segregants are expected to be produce by making a large number of crosses. Jinks and Jones (1958) [7] also suggested due to non-fixable genetic effects.

The diversity of origin of parents combined with additive x additive interaction effects is likely to give better recombinants in their cross combinations with high yield on the advancement of generation. Genetic diversity within a population can be an appropriate compromise between the demands for uniformity and advantage of diversity (Allard and Hansche, 1963) [1].

Table 1: Analysis of variance for combining ability for 14 characters in wheat

Source of variation	d. f.	Generation	Days to 50% flowering	Days to maturity	Plant height (cm)	Tillers/plant	Spike length (cm)	Spikelets/spike	Grains/spike	Grain weight/spike (g)	Seed hardness (kg/seed)	Protein content (%)	Biological yield/plant (g)	1000-grain weight (g)	Harvest index (%)	Grain yield/plant (g)
GCA	9	F ₁	2.069**	2.096**	4.283**	0.510**	0.391**	1.847**	32.27**	0.059**	0.373**	0.643**	102.81**	1.71**	2.50**	16.39**
		F ₂	4.022**	0.807	0.740**	0.286**	0.236**	1.379**	9.75**	0.037**	0.638**	0.216**	75.70**	2.42**	5.61**	15.69**
SCA	45	F ₁	14.458**	2.858**	11.567**	1.126**	0.668**	0.758**	15.24**	0.372**	0.903**	1.135**	38.50**	2.64**	7.57**	7.44**
		F ₂	7.140**	7.151**	4.107**	0.227**	0.419**	0.820**	12.97**	0.072**	0.674**	1.071**	22.23**	1.43**	3.47**	5.19**
Error	108	F ₁	0.510	0.842	0.282	0.064	0.072	0.176	1.47	0.017	0.078	0.037	1.85	0.35	0.89	0.18
		F ₂	1.129	0.619	0.522	0.148	0.057	0.186	1.15	0.022	0.103	0.040	0.73	0.19	0.70	0.15
$\hat{\sigma}_g$		F ₁	0.130	0.105	0.333	0.037	0.027	0.139	2.57	0.004	0.025	0.051	8.41	0.11	0.13	1.35
		F ₂	0.241	0.016	0.018	0.012	0.015	0.099	0.72	0.001	0.045	0.015	6.25	0.19	0.41	1.29
$\hat{\sigma}_s$		F ₁	13.948	2.016	11.285	1.062	0.596	0.581	13.77	0.355	0.825	1.099	36.65	2.29	6.68	7.27
		F ₂	6.011	6.533	3.585	0.079	0.363	0.634	11.82	0.050	0.571	1.031	21.50	1.24	2.77	5.04
$\hat{\sigma}_g/\hat{\sigma}_s$		F ₁	0.009	0.052	0.030	0.035	0.045	0.240	0.19	0.010	0.030	0.046	0.23	0.05	0.02	0.19
		F ₂	0.040	0.002	0.005	0.146	0.041	0.157	0.061	0.024	0.078	0.014	0.291	0.150	0.148	0.257
$(\hat{\sigma}_s/\hat{\sigma}_g)^{0.5}$		F ₁	10.358	4.390	5.818	5.34	4.73	2.04	2.32	10.07	5.79	4.66	2.09	4.50	7.05	2.32
		F ₂	4.993	20.398	14.034	2.61	4.92	2.52	4.06	6.42	3.58	8.38	1.86	2.58	2.60	1.97

* Significant at 5%, ** Significant at 1% level.

Table 2: Estimates of mean performance and GCA effect for 14 characters of 10 diallel parents in wheat

S. No	Genotypes	Days to 50% flowering			Days to Maturity			Plant height (cm)			No. of productive tillers per plant			Spike length (cm)		
		F ₁	F ₂	Mean	F ₁	F ₂	Mean	F ₁	F ₂	Mean	F ₁	F ₂	Mean	F ₁	F ₂	Mean
1.	HI-1563	-1.28 **	-0.71 **	83.00	-1.18 **	-1.98 **	124.97	0.15	-0.64 **	123.77	-0.14	-0.68 **	10.00	-0.56 **	-0.18	11.80
2.	DBW-187	-0.54 *	-0.42 *	84.00	-0.66 *	-0.43	128.27	-0.13	0.72 **	126.10	-0.33 *	-0.17	11.60	0.18	-0.04	11.20
3.	PBW-386	1.76 **	1.81 **	88.67	1.61 **	1.72 **	129.67	0.15	0.11	125.10	-0.07	0.18	10.13	-0.23	-0.18	10.80
4.	HD-3059	0.13	-0.14	85.03	-1.63 **	-1.20 **	122.47	1.02 **	2.40 **	128.13	0.12	-0.32	11.27	0.23	-0.16	12.80
5.	DBW-398	-3.48 **	-3.32 **	77.00	-4.60 **	-4.44 **	118.77	0.95 **	-0.15	124.67	-0.62 **	-0.38 **	8.53	-0.55 **	-0.01	12.40
6.	DBW-173	1.38 **	1.01 **	84.23	2.14 **	1.11 **	129.37	0.83 **	1.30 **	128.47	-0.27	-0.22	11.20	-0.05	-0.05	12.07
7.	PBW-644	0.47 *	0.63 **	85.03	1.68 **	1.74 **	136.37	-4.09 **	-6.31 **	112.77	-0.31 *	-0.38 *	9.33	-0.25	-0.34 *	12.00
8.	K-1006	2.28 **	1.83 **	85.33	3.72 **	3.71 **	137.97	1.41 **	2.16 **	127.37	0.69 **	0.83 **	11.53	-0.35 *	-0.32 *	11.80
9.	DBW-222	3.21 **	2.78 **	91.80	2.91 **	3.06 **	133.37	3.87 **	5.24 **	130.30	1.23 **	1.57 **	13.67	0.69 **	0.48 **	12.27
10.	HI-1612	-3.94 **	-3.47 **	75.23	-4.00 **	-3.29 **	120.67	-4.17 **	-4.82 **	115.37	-0.31 *	-0.43 *	9.47	0.90 **	0.78 **	11.00
	SE (gi)±	0.216	0.213	-	0.291	0.287	-	0.227	0.222	-	0.154	0.176	-	0.158	0.148	-
	SE (gi-gj)±	0.292	0.434	-	0.375	0.321	-	0.217	0.295	-	0.103	0.157	-	0.109	0.097	-

S. No	Genotypes	Number of spikelets per spike			No. of grains per spike			Biological yield per plant (gm)			1000-grain weight (gm)			Harvest index (%)		
		F ₁	F ₂	Mean	F ₁	F ₂	Mean	F ₁	F ₂	Mean	F ₁	F ₂	Mean	F ₁	F ₂	Mean
1.	HI-1563	-0.53 **	-0.65 **	18.70	0.59	0.84 *	54.37	-0.40	-0.06	48.67	1.93 **	1.61 **	45.40	-2.01 **	-2.81 **	35.62
2.	DBW-187	0.06	0.06	20.07	-2.99 **	-2.60 **	52.13	-4.56 **	-1.90 **	51.17	-3.07 **	-1.29 **	32.80	3.74 **	1.57 **	32.26
3.	PBW-386	0.27	0.21	21.00	-0.26	0.14	57.80	0.38	-1.89 **	53.87	-1.86 **	-2.01 **	37.20	-0.83 *	1.15 **	34.70
4.	HD-3059	0.17	0.32	19.13	-1.35 **	-1.16 **	49.33	-1.92 **	-2.08 **	46.00	-0.98 **	-0.76 **	38.10	-1.18 **	-1.50 **	24.91
5.	DBW-398	-0.38	-0.17	19.53	-2.17 **	-2.20 **	47.17	-2.74 **	-2.06 **	43.73	-3.56 **	-3.74 **	36.50	-1.91 **	-1.50 **	34.16
6.	DBW-173	-0.07	-0.09	20.47	4.10 **	3.77 **	64.00	2.24 **	-0.44	53.60	3.65 **	1.74 **	41.10	-1.02 **	0.78	38.62
7.	PBW-644	-0.44 *	0.09	21.40	3.27 **	2.55 **	68.13	-0.24	1.63 **	52.37	-0.12	2.28 **	42.27	-0.36	-1.64 **	34.99
8.	K-1006	-0.13	-0.61 **	19.83	-2.65 **	-2.85 **	53.07	3.69 **	4.92 **	54.13	-0.57 **	-0.37 *	38.67	-1.47 **	-2.33 **	32.44
9.	DBW-222	0.47 *	0.68 **	22.53	3.65 **	3.34 **	58.83	6.01 **	4.10 **	58.73	4.25 **	4.08 **	39.53	1.72 **	2.44 **	43.51
10.	HI-1612	0.57 **	0.16	21.07	-2.19 **	-1.83 **	50.43	-2.46 **	-2.21 **	45.53	0.32 *	-1.54 **	39.27	3.31 **	3.83 **	36.54
	SE (gi)±	0.196	0.176	-	0.429	0.413	-	0.220	0.269	-	0.159	0.173	-	0.394	0.426	-
	SE (gi-gj)±	0.171	0.176	-	0.495	0.438	-	0.555	0.349	-	0.242	0.178	-	0.385	0.343	-

* Significant at 5%, ** Significant at 1% level.

S. No	Genotypes	Seed Hardness (kg)			Protein content (%)			Grain weight per spike (gm)			Grain yield per plant (gm)		
		F ₁	F ₂	Mean	F ₁	F ₂	Mean	F ₁	F ₂	Mean	F ₁	F ₂	Mean
1.	HI-1563	-0.05	0.03	9.47	0.09	-0.13	12.21	0.00	-0.04 **	1.34	-1.11 **	-1.24 **	17.50
2.	DBW-187	-0.64 **	-0.71 **	10.97	0.27 **	0.30 **	13.09	0.06 **	0.03 **	1.45	0.06	-0.08	16.50
3.	PBW-386	0.06	-0.03	12.47	-0.19 *	-0.21 *	12.01	-0.03 *	0.04 **	1.55	-0.16	-0.08	18.70
4.	HD-3059	-0.06	-0.01	11.20	-0.51 **	-0.59 **	11.19	-0.05 **	-0.01	1.34	-1.20 **	-1.21 **	11.47
5.	DBW-398	-0.36 *	-0.28	12.73	-0.01	-0.17	13.01	0.03 *	-0.01	1.38	-1.53 **	-1.46 **	14.87
6.	DBW-173	0.23	0.07	11.93	0.24 **	0.37 **	11.83	0.01	-0.01	1.23	0.05	0.08	20.43
7.	PBW-644	0.59 **	0.50 **	12.93	-0.02	0.12	12.55	-0.02	-0.01	1.51	-0.22 *	-0.18	18.40
8.	K-1006	0.15	0.12	11.93	0.28 **	0.37 **	13.82	0.01	0.03 *	1.36	0.50 **	0.76 **	17.57
9.	DBW-222	0.14	0.19	11.87	-0.32 **	0.16	12.13	-0.03 *	-0.02 *	1.34	2.39 **	2.32 **	21.80
10.	HI-1612	-0.05	0.13	12.40	0.18 *	-0.23 *	11.97	0.02 *	0.00	1.33	1.22 **	1.10 **	19.53
	SE (gi)±	0.163	0.154	-	0.084	0.098	-	0.013	0.012	-	0.112	0.181	-
	SE (gi-gj)±	0.114	0.131	-	0.078	0.082	-	0.053	0.061	-	0.172	0.159	-

* Significant at 5%, ** Significant at 1% level.

Table 3: Estimates of specific combining ability and corresponding mean performance of 45 F₁ s and 45 F₂ s for 14 characters in wheat

S. No.	Crosses	Days to 50% flowering				Days to Maturity			
		F ₁	Mean	F ₂	Mean	F ₁	Mean	F ₂	Mean
1.	DBW 187/HI 1563	5.90 **	88.47	5.23 **	86.37	8.99 **	134.60	3.00 **	126.27
2.	PBW 386/HI 1563	-0.65 *	84.21	-2.54 **	80.83	-2.48 **	125.40	-1.02 **	124.40
3.	HD 3059/HI 1563	4.83 **	88.07	2.67 **	84.10	5.73 **	130.37	4.31 **	126.80
4.	DBW 398/HI 1563	-5.06 **	74.57	-4.60 **	73.63	-4.90 **	116.77	-5.95 **	113.30
5.	DBW 173/HI 1563	-4.96 **	79.53	-7.54 **	75.03	-4.61 **	123.80	-10.35 **	114.47
6.	PBW 644/HI 1563	2.19 **	85.77	3.18 **	85.37	1.05 **	129.00	-0.88 *	124.57
7.	K 1006/HI 1563	0.99 **	86.37	2.61 **	86.00	0.71	130.70	6.29 **	133.70
8.	DBW 222/HI 1563	-2.15 **	84.17	-2.21 **	82.13	0.42	129.60	-0.45	126.30
9.	HI 1612/HI 1563	-3.44 **	75.73	-1.10 **	77.00	-4.67 **	117.60	-1.44 **	118.97
10.	PBW 386/DBW 187	-3.44 **	82.17	-1.29 **	82.37	-7.14 **	121.27	-1.88 **	125.10
11.	HD 3059/DBW 187	2.59 **	86.57	1.69 **	83.40	2.20 **	127.37	7.92 **	131.97
12.	DBW 398/DBW 187	-5.24 **	75.13	-3.52 **	75.00	-2.39 **	119.80	-5.41 **	115.40
13.	DBW 173/DBW 187	4.20 **	89.43	3.38 **	86.23	2.77 **	131.70	3.60 **	129.97
14.	PBW 644/DBW 187	-5.65 **	78.67	-6.74 **	75.73	-8.67 **	119.80	-9.80 **	117.20
15.	K 1006/DBW 187	-1.62 **	84.50	-3.18 **	80.50	-1.51 **	129.00	-4.70 **	124.27
16.	DBW 222/DBW 187	-3.13 **	83.93	-3.96 **	80.67	-4.93 **	124.77	-7.11 **	121.20
17.	HI 1612/DBW 187	4.99 **	84.90	3.25 **	81.63	6.41 **	129.20	7.51 **	129.47
18.	HD 3059/PBW 386	-3.38 **	82.90	-4.05 **	79.90	-0.07	127.37	-4.83 **	121.37
19.	DBW 398/PBW 386	3.47 **	86.13	2.97 **	83.73	5.37 **	129.83	7.24 **	130.20
20.	DBW 173/PBW 386	-1.49 **	86.03	-1.63 **	83.47	-1.24 **	129.97	-1.12 **	127.40
21.	PBW 644/PBW 386	-3.15 **	83.47	-3.61 **	81.10	-2.94 **	127.80	-4.95 **	124.20
22.	K 1006/PBW 386	0.18	88.60	0.62 *	86.53	-1.78 **	131.00	-2.72 **	128.40
23.	DBW 222/PBW 386	4.38 **	93.73	2.33 **	89.20	6.60 **	138.57	5.71 **	136.17
24.	HI 1612/PBW 386	2.56 **	84.77	1.65 **	82.27	5.70 **	130.77	2.49 **	126.60
25.	DBW 398/HD 3059	-3.41 **	77.63	-6.58 **	72.23	-2.75 **	118.47	-4.73 **	115.30
26.	DBW 173/HD 3059	0.66 *	86.57	1.59 **	84.73	0.00	127.97	-1.59 **	124.00
27.	PBW 644/HD 3059	0.21	85.20	-0.63 *	82.13	0.46	127.97	1.98 **	128.20
28.	K 1006/HD 3059	-0.40	86.40	1.20 **	85.17	-0.34	129.20	-2.42 **	125.77
29.	DBW 222/HD 3059	-3.07 **	84.67	-1.22 **	83.70	-2.96 **	125.77	0.80 *	128.33
30.	HI 1612/HD 3059	1.21 **	81.80	-0.74 *	77.93	1.18 **	123.00	0.18	121.37
31.	DBW 173/DBW 398	5.84 **	88.13	5.34 **	85.30	3.61 **	128.60	3.35 **	125.70
32.	PBW 644/DBW 398	3.08 **	84.47	2.52 **	82.10	-1.13 **	123.40	1.48 **	124.47
33.	K 1006/DBW 398	-0.35	82.83	-2.58 **	78.20	-0.06	126.50	-3.49 **	121.47
34.	DBW 222/DBW 398	1.34 **	85.47	2.10 **	83.83	0.45	126.20	1.51 **	125.80
35.	HI 1612/DBW 398	1.19 **	78.17	1.59 **	77.07	0.75	119.60	2.06 **	120.00
36.	PBW 644/DBW 173	2.76 **	89.00	2.36 **	86.27	2.13 **	133.40	1.43 **	129.97
37.	K 1006/DBW 173	-1.48 **	86.57	-1.64 **	83.47	-0.51	132.80	-0.34	130.17
38.	DBW 222/DBW 173	0.85 **	89.83	0.14 ns	86.20	0.90 *	133.40	2.31 **	132.17
39.	HI 1612/DBW 173	-0.54	81.30	-1.88 **	77.93	1.67 **	127.27	-0.20	123.30
40.	K 1006/PBW 644	5.66 **	92.80	3.17 **	87.90	2.75 **	135.60	3.66 **	134.80
41.	DBW 222/PBW 644	-0.61 *	87.47	-2.65 **	83.03	1.56 **	133.60	-2.15 **	128.33
42.	HI 1612/PBW 644	-3.89 **	77.03	-0.60 *	78.83	-6.33 **	118.80	-5.17 **	118.97
43.	DBW 222/K 1006	2.09 **	91.97	0.25 ns	87.13	-0.27	133.80	-0.59	131.87
44.	HI 1612/K 1006	2.14 **	84.87	0.73 *	81.37	-5.17 **	122.00	-5.40 **	120.70
45.	HI 1612/DBW 222	-1.67 **	82.00	-2.69 **	78.90	-1.96 **	124.40	-3.18 **	122.27
	SE(Sij)±	0.728	-	0.717	-	0.978	-	0.964	-
	SE(Sij-Sik)±	0.292	-	0.287	-	0.392	-	0.386	-

S. No.	Crosses	Plant height (cm)				Number of productive tillers/plant			
		F ₁	Mean	F ₂	Mean	F ₁	Mean	F ₂	Mean
1.	DBW 187/HI 1563	-1.14 **	121.60	-0.54	123.53	1.15 **	11.93	1.52 **	10.83
2.	PBW 386/HI 1563	-1.02 **	122.00	-0.20	123.27	-0.12	10.93	-1.93 **	7.73
3.	HD 3059/HI 1563	-0.96 **	122.93	-0.32	125.43	1.13 **	12.37	0.00	9.17
4.	DBW 398/HI 1563	3.71 **	127.53	-0.67 *	122.53	0.90 **	11.40	0.74 **	9.83
5.	DBW 173/HI 1563	0.30	124.00	0.21	124.87	-3.15 **	7.70	-1.56 **	7.70
6.	PBW 644/HI 1563	3.22 **	122.00	-0.78 **	116.27	-0.98 **	9.83	-1.30 **	7.80
7.	K 1006/HI 1563	-9.22 **	115.07	0.02	125.53	0.72 **	12.53	1.63 **	11.93
8.	DBW 222/HI 1563	-9.61 **	117.13	0.21	128.80	-0.15	12.20	-0.59 *	10.47
9.	HI 1612/HI 1563	13.23 **	131.93	-0.03	118.50	2.46 **	13.27	-0.92 **	8.13
10.	PBW 386/DBW 187	0.26	123.00	0.04	124.87	0.68 **	11.53	0.26	10.43
11.	HD 3059/DBW 187	1.85 **	125.47	-0.34	126.77	-0.51 *	10.53	0.36	10.03
12.	DBW 398/DBW 187	-3.68 **	119.87	-0.62 *	123.93	0.50 *	10.80	-0.01	9.60
13.	DBW 173/DBW 187	-1.09 **	122.33	0.19	126.20	0.68 **	11.33	0.23	10.00
14.	PBW 644/DBW 187	1.10 **	119.60	-0.66 *	117.73	-0.98 **	9.63	-1.54 **	8.07
15.	K 1006/DBW 187	-2.00 **	122.00	-0.26	126.60	-0.08	11.53	-2.48 **	8.33
16.	DBW 222/DBW 187	0.64 *	127.10	1.22 **	131.17	-1.55 **	10.60	0.94 **	12.50
17.	HI 1612/DBW 187	-3.22 **	115.20	-0.39	119.50	-1.91 **	8.70	-2.86 **	6.70
18.	HD 3059/PBW 386	1.55 **	125.45	-0.53	125.97	0.32	11.63	0.48 *	10.50
19.	DBW 398/PBW 386	-2.53 **	121.30	-0.42	123.53	1.23 **	11.80	0.57 *	10.53
20.	DBW 173/PBW 386	-0.11	123.60	0.03	125.43	1.68 **	12.60	0.45	10.57
21.	PBW 644/PBW 386	-3.58 **	115.20	-0.49	117.30	0.59 **	11.47	-0.09	9.87
22.	K 1006/PBW 386	1.18 **	125.47	-0.23	126.03	-0.41 *	11.47	-0.97 **	10.20
23.	DBW 222/PBW 386	1.79 **	128.53	0.73 *	130.07	0.88 **	13.30	0.29	12.20
24.	HI 1612/PBW 386	-1.70 **	117.00	-0.68 *	118.60	-2.88 **	8.00	1.72 **	11.63
25.	DBW 398/HD 3059	-4.43 **	120.27	-0.46	125.77	-1.69 **	9.07	-1.56 **	7.90
26.	DBW 173/HD 3059	-1.61 **	122.97	0.18	127.87	-0.87 **	10.23	-0.19	9.43
27.	PBW 644/HD 3059	-3.89 **	115.77	0.13	120.20	-0.80 **	10.27	-1.36 **	8.10
28.	K 1006/HD 3059	2.84 **	128.00	0.69 *	129.23	1.46 **	13.53	1.13 **	11.80
29.	DBW 222/HD 3059	1.62 **	129.23	1.58 **	133.20	0.02	12.63	-1.85 **	9.57
30.	HI 1612/HD 3059	-3.71 **	115.87	0.37	121.93	1.40 **	12.47	-0.51 *	8.90
31.	DBW 173/DBW 398	2.46 **	126.97	-0.11	125.03	-1.10 **	9.27	-1.92 **	7.63
32.	PBW 644/DBW 398	-1.68 **	117.90	-0.06	117.47	1.10 **	11.43	1.61 **	11.00
33.	K 1006/DBW 398	3.24 **	128.33	0.44	126.43	2.00 **	13.33	0.93 **	11.53
34.	DBW 222/DBW 398	3.99 **	131.53	0.99 **	130.07	-0.73 **	11.13	0.65 **	12.00
35.	HI 1612/DBW 398	-1.14 **	118.37	-1.08 **	117.93	0.74 **	11.07	0.72 **	10.07
36.	PBW 644/DBW 173	-5.66 **	113.80	-1.88 **	117.10	-0.01	10.67	0.38	9.93
37.	K 1006/DBW 173	0.13	125.10	-0.45	127.00	-1.08 **	10.60	-0.73 **	10.03
38.	DBW 222/DBW 173	-0.06	127.37	-0.26	130.27	0.32	12.53	-0.55 *	10.97
39.	HI 1612/DBW 173	-2.52 **	116.87	-1.64 **	118.83	2.56 **	13.23	0.92 **	10.43
40.	K 1006/PBW 644	5.76 **	125.80	0.26	120.10	0.56 **	12.20	1.27 **	11.87
41.	DBW 222/PBW 644	5.60 **	128.10	0.85 **	123.77	1.59 **	13.77	0.99 **	12.33
42.	HI 1612/PBW 644	2.67 **	117.13	-0.16	112.70	1.56 **	12.20	0.15	9.50
43.	DBW 222/K 1006	-1.81 **	126.20	1.42 **	132.80	0.19	13.37	-0.63 **	11.93
44.	HI 1612/K 1006	-3.76 **	116.20	-0.02	121.30	-1.14 **	10.50	0.41	10.97
45.	HI 1612/DBW 222	-1.82 **	120.60	1.59 **	126.00	-0.45 *	11.73	0.03	11.33
	SE(Sij)±	0.762	-	0.745	-	0.518	-	0.591	-
	SE(Sij-Sik)±	0.305	-	0.299	-	0.208	-	0.237	-

S. No.	Crosses	Spike length				Number of spikelets per spike			
		F ₁	Mean	F ₂	Mean	F ₁	Mean	F ₂	Mean
1.	DBW 187/HI 1563	-0.61 **	11.60	-1.21 **	10.40	-0.61 *	19.57	-1.38 **	17.60
2.	PBW 386/HI 1563	0.79 **	12.60	-0.26	11.20	0.01	20.40	0.68 **	19.80
3.	HD 3059/HI 1563	-0.46 *	11.80	0.52 **	12.00	1.65 **	21.93	-0.27	18.97
4.	DBW 398/HI 1563	1.72 **	13.20	0.36	12.00	0.93 **	20.67	0.72 **	19.47
5.	DBW 173/HI 1563	-1.18 **	10.80	-0.19	11.40	0.22	20.27	-0.59 *	18.23
6.	PBW 644/HI 1563	1.52 **	13.30	1.80 **	13.10	0.13	19.80	1.73 **	20.73
7.	K 1006/HI 1563	-1.48 **	10.20	0.28	11.60	0.21	20.20	0.43	18.73
8.	DBW 222/HI 1563	-2.52 **	10.20	-2.32 **	9.80	-0.24	20.33	-0.54 *	19.07
9.	HI 1612/HI 1563	1.57 **	14.50	0.34	12.77	-0.54 *	20.13	-1.65 **	17.43
10.	PBW 386/DBW 187	1.66 **	14.20	2.39 **	14.00	0.29	21.27	-0.87 **	18.97
11.	HD 3059/DBW 187	-0.20	12.80	-0.86 **	10.77	1.56 **	22.43	1.62 **	21.57
12.	DBW 398/DBW 187	1.38 **	13.60	2.12 **	13.90	1.51 **	21.83	1.91 **	21.37
13.	DBW 173/DBW 187	1.48 **	14.20	1.13 **	12.87	0.63 *	21.27	-0.27	19.27
14.	PBW 644/DBW 187	0.15	12.67	-0.48 *	10.97	0.10	20.37	0.15	19.87
15.	K 1006/DBW 187	-0.02	12.40	-1.07 **	10.40	-1.18 **	19.40	-0.62 **	18.40
16.	DBW 222/DBW 187	0.14	13.60	0.03	12.30	-1.53 **	19.63	-1.38 **	18.93
17.	HI 1612/DBW 187	-0.47 *	13.20	-0.97 **	11.60	0.60 *	21.87	0.11	19.90
18.	HD 3059/PBW 386	1.61 **	14.20	0.42 *	11.90	-0.55 *	20.53	-2.59 **	17.50
19.	DBW 398/PBW 386	-1.62 **	10.20	-2.34 **	9.30	0.33	20.87	0.60 *	20.20
20.	DBW 173/PBW 386	-2.11 **	10.20	-0.99 **	10.60	-0.58 *	20.27	-2.55 **	17.13
21.	PBW 644/PBW 386	0.15	12.27	0.23	11.53	1.19 **	21.67	2.63 **	22.50
22.	K 1006/PBW 386	0.59 **	12.60	-0.33	11.00	-2.72 **	18.07	-1.63 **	17.53
23.	DBW 222/PBW 386	0.14	13.20	1.27 **	13.40	1.62 **	23.00	1.17 **	21.63
24.	HI 1612/PBW 386	1.47 **	14.73	0.94 **	13.37	0.79 **	22.27	0.53 *	20.47
25.	DBW 398/HD 3059	-0.87 **	11.40	-1.46 **	10.20	-1.63 **	18.80	-0.31	19.40
26.	DBW 173/HD 3059	0.83 **	13.60	-0.41 *	11.20	-0.44	20.30	1.01 **	20.80
27.	PBW 644/HD 3059	-0.40	12.17	-0.55 **	10.77	-0.84 **	19.53	-2.67 **	17.30
28.	K 1006/HD 3059	0.03	12.50	-0.44 *	10.90	0.78 **	21.47	-0.11	19.17
29.	DBW 222/HD 3059	-0.11	13.40	-0.14	12.00	1.13 **	22.40	1.70 **	22.27
30.	HI 1612/HD 3059	0.05	13.77	0.32	12.77	2.02 **	23.40	3.75 **	23.80
31.	DBW 173/DBW 398	1.54 **	13.53	-0.16	11.60	0.67 *	20.87	-0.24	19.07
32.	PBW 644/DBW 398	-4.19 **	7.60	-2.61 **	8.87	-3.86 **	15.97	-4.89 **	14.60
33.	K 1006/DBW 398	-0.49 *	11.20	0.40 *	11.90	2.46 **	22.60	2.28 **	21.07
34.	DBW 222/DBW 398	0.07	12.80	0.90 **	13.20	-0.46	20.27	0.48 *	20.57
35.	HI 1612/DBW 398	0.66 **	13.60	1.60 **	14.20	0.74 **	21.57	-1.16 **	18.40
36.	PBW 644/DBW 173	-0.89 **	11.40	-1.63 **	9.80	-1.74 **	18.40	-0.90 **	18.67
37.	K 1006/DBW 173	-0.79 **	11.40	1.55 **	13.00	1.09 **	21.53	0.13	19.00
38.	DBW 222/DBW 173	2.20 **	15.43	0.15	12.40	0.69 **	21.73	1.41 **	21.57
39.	HI 1612/DBW 173	-0.24	13.20	-0.15	12.40	-0.47	20.67	-0.17	19.47
40.	K 1006/PBW 644	0.41	12.40	-0.66 **	10.50	0.92 **	21.00	1.58 **	20.63
41.	DBW 222/PBW 644	2.27 **	15.30	1.04 **	13.00	-0.60 *	20.07	-2.61 **	17.73
42.	HI 1612/PBW 644	1.16 **	14.40	1.14 **	13.40	1.43 **	22.20	1.68 **	21.50
43.	DBW 222/K 1006	0.27	13.20	-1.19 **	10.80	0.09	21.07	-1.51 **	18.13
44.	HI 1612/K 1006	1.66 **	14.80	0.24	12.53	-0.55 *	20.53	-3.52 **	15.60
45.	HI 1612/DBW 222	0.95 **	15.13	1.31 **	14.40	-2.61 **	19.07	-1.92 **	18.50
	SE(Sij)±	0.531	-	0.498	-	0.658	-	0.590	-
	SE(Sij-Sik)±	0.213	-	0.200	-	0.264	-	0.237	-

S. No.	Crosses	No. of grains per spike				Biological yield per plant (gm)			
		F ₁	Mean	F ₂	Mean	F ₁	Mean	F ₂	Mean
1.	DBW 187/HI 1563	-1.21 *	55.33	-0.93	54.37	2.08 **	49.53	0.03	47.93
2.	PBW 386/HI 1563	-1.74 **	57.53	-2.70 **	55.33	-0.39	52.00	2.13 **	50.03
3.	HD 3059/HI 1563	6.76 **	64.93	5.73 **	62.47	2.18 **	52.27	-0.32	47.40
4.	DBW 398/HI 1563	4.11 **	61.47	5.11 **	60.80	0.52	49.80	-0.27	47.47
5.	DBW 173/HI 1563	-6.63 **	57.00	-7.23 **	54.43	-13.98 **	40.27	-7.86 **	41.50
6.	PBW 644/HI 1563	1.07	63.87	0.52	60.97	2.63 **	54.40	-2.50 **	48.93
7.	K 1006/HI 1563	-3.82 **	53.07	-2.94 **	52.10	4.03 **	59.73	-3.25 **	51.47
8.	DBW 222/HI 1563	4.89 **	68.07	5.31 **	66.53	0.32	58.33	-6.80 **	47.10
9.	HI 1612/HI 1563	8.06 **	65.40	5.87 **	61.93	8.52 **	58.07	20.98 **	68.57
10.	PBW 386/DBW 187	2.77 **	58.47	2.03 **	56.63	2.51 **	50.73	2.40 **	48.47
11.	HD 3059/DBW 187	0.60	55.20	-1.40 *	51.90	1.48 **	47.40	-0.15	45.73
12.	DBW 398/DBW 187	1.55 **	55.33	1.25 *	53.50	0.76 *	45.87	-1.37 **	44.53
13.	DBW 173/DBW 187	-3.39 **	56.67	-1.49 **	56.73	-4.75 **	45.33	-7.99 **	39.53
14.	PBW 644/DBW 187	-0.25	58.97	-1.91 **	55.10	-6.07 **	41.53	1.71 **	51.30
15.	K 1006/DBW 187	0.56	53.87	1.02	52.63	-4.74 **	46.80	4.92 **	57.80
16.	DBW 222/DBW 187	2.40 **	62.00	3.81 **	61.60	-0.92 **	52.93	1.27 **	53.33
17.	HI 1612/DBW 187	-1.37 *	52.40	-2.93 **	49.70	-6.12 **	39.27	-11.02 **	34.73
18.	HD 3059/PBW 386	-1.87 **	55.47	-1.37 *	54.67	1.13 **	52.00	2.71 **	48.60
19.	DBW 398/PBW 386	7.62 **	64.13	6.51 **	61.50	2.35 **	52.40	6.29 **	52.20
20.	DBW 173/PBW 386	-5.52 **	57.27	-3.73 **	57.23	-3.49 **	51.53	-4.32 **	43.20
21.	PBW 644/PBW 386	-0.15	61.80	-0.28	59.47	-0.08	52.47	-10.03 **	39.57
22.	K 1006/PBW 386	-3.90 **	52.13	-5.78 **	48.57	0.65 *	57.13	-8.55 **	44.33
23.	DBW 222/PBW 386	-1.40 *	60.93	-0.23	60.30	3.80 **	62.60	1.13 **	53.20
24.	HI 1612/PBW 386	5.43 **	61.93	4.64 **	60.00	-7.86 **	42.47	-7.35 **	38.40
25.	DBW 398/HD 3059	-5.68 **	49.73	-6.49 **	47.20	-3.88 **	43.87	-5.59 **	40.13
26.	DBW 173/HD 3059	8.71 **	70.40	7.87 **	67.53	9.74 **	62.47	1.20 **	48.53
27.	PBW 644/HD 3059	1.54 **	62.40	3.49 **	61.93	-3.78 **	46.47	0.66	50.07
28.	K 1006/HD 3059	1.66 **	56.60	0.49	53.53	9.02 **	63.20	1.03 **	53.73
29.	DBW 222/HD 3059	-0.37	60.87	-1.33 *	57.90	-7.33 **	49.17	7.05 **	58.93
30.	HI 1612/HD 3059	2.46 **	57.87	3.81 **	57.87	-3.42 **	44.60	-7.20 **	38.37
31.	DBW 173/DBW 398	-1.37 *	59.50	-2.25 **	56.37	-0.64 *	51.27	12.91 **	60.27
32.	PBW 644/DBW 398	-5.04 **	55.00	-5.07 **	52.33	1.03 **	50.47	-6.70 **	42.73
33.	K 1006/DBW 398	4.94 **	59.07	5.40 **	57.40	6.57 **	59.93	8.58 **	61.30
34.	DBW 222/DBW 398	6.38 **	66.80	5.05 **	63.23	-4.48 **	51.20	-4.64 **	47.27
35.	HI 1612/DBW 398	2.35 **	56.93	1.45 **	54.47	4.19 **	51.40	-5.19 **	40.40
36.	PBW 644/DBW 173	1.96 **	68.27	-4.97 **	58.40	-1.21 **	53.20	-3.71 **	47.33
37.	K 1006/DBW 173	8.47 **	68.87	8.46 **	66.43	-1.67 **	56.67	4.10 **	58.43
38.	DBW 222/DBW 173	3.98 **	70.67	2.84 **	67.00	5.02 **	65.67	-4.95 **	48.57
39.	HI 1612/DBW 173	0.08	60.93	1.68 **	60.67	17.55 **	69.73	1.36 **	48.57
40.	K 1006/PBW 644	-1.56 **	58.00	-1.99 **	54.77	-5.30 **	50.57	-2.18 **	54.23
41.	DBW 222/PBW 644	-0.99	64.87	-1.61 **	61.33	9.56 **	67.73	7.24 **	62.83
42.	HI 1612/PBW 644	-1.89 **	58.13	-0.14	57.63	2.36 **	52.07	17.02 **	66.30
43.	DBW 222/K 1006	0.79	60.73	-1.84 **	55.70	9.76 **	71.87	6.82 **	65.70
44.	HI 1612/K 1006	-5.98 **	48.13	-6.24 **	46.13	-6.97 **	46.67	-0.33	52.23
45.	HI 1612/DBW 222	-0.87	59.53	-2.22 **	56.33	-4.35 **	51.60	-8.48 **	43.27
	SE(Sij)±	1.442	-	1.389	-	0.740	-	0.905	-
	SE(Sij-Sik)±	0.578	-	0.557	-	0.297	-	0.363	-

S. No.	Crosses	1000-grain weight (gm)				Harvest index			
		F ₁	Mean	F ₂	Mean	F ₁	Mean	F ₂	Mean
1.	DBW 187/HI 1563	1.14 **	41.00	-1.10 **	39.00	-4.91 **	33.24	-6.87 **	28.22
2.	PBW 386/HI 1563	1.15 **	42.23	1.29 **	40.67	3.87 **	37.46	0.02	34.68
3.	HD 3059/HI 1563	-0.55 **	41.40	-1.67 **	38.97	-0.73	32.50	0.45	32.47
4.	DBW 398/HI 1563	1.69 **	41.07	-0.19	37.47	-0.64	31.87	0.47	32.50
5.	DBW 173/HI 1563	-1.05 **	45.53	0.27	43.40	15.97 **	49.37	10.25 **	44.55
6.	PBW 644/HI 1563	-3.58 **	39.23	-6.18 **	37.50	-5.50 **	28.56	-1.66 **	30.21
7.	K 1006/HI 1563	-1.16 **	41.20	-0.36	40.67	-3.43 **	29.52	-0.31	30.89
8.	DBW 222/HI 1563	3.82 **	51.00	5.49 **	50.97	-5.91 **	30.23	1.13 *	37.09
9.	HI 1612/HI 1563	-2.52 **	40.73	-2.32 **	37.53	-5.16 **	32.56	-13.29 **	24.05
10.	PBW 386/DBW 187	1.25 **	37.33	-3.58 **	32.90	1.28 *	40.61	-0.92	38.13
11.	HD 3059/DBW 187	0.21	37.17	-1.83 **	35.90	0.12	39.10	1.05	37.45
12.	DBW 398/DBW 187	4.92 **	39.30	2.64 **	37.40	4.13 **	42.39	5.81 **	42.21
13.	DBW 173/DBW 187	-1.25 **	40.33	-2.66 **	37.57	12.71 **	51.86	12.29 **	50.97
14.	PBW 644/DBW 187	-1.28 **	36.53	21.86 **	62.63	1.95 **	41.76	-2.93 **	33.33
15.	K 1006/DBW 187	1.54 **	38.90	1.51 **	39.63	-3.24 **	35.45	-8.98 **	26.60
16.	DBW 222/DBW 187	-3.68 **	38.50	-7.51 **	35.07	-1.31 *	40.57	-0.35	39.99
17.	HI 1612/DBW 187	1.28 **	39.53	-0.52 *	36.43	12.58 **	56.05	15.33 **	57.06
18.	HD 3059/PBW 386	4.37 **	42.53	3.32 **	40.33	3.03 **	37.43	2.21 **	38.19
19.	DBW 398/PBW 386	2.57 **	38.17	4.17 **	38.20	-4.21 **	29.47	-8.30 **	27.68
20.	DBW 173/PBW 386	-4.56 **	38.23	-3.44 **	36.07	2.87 **	37.45	1.78 **	40.04
21.	PBW 644/PBW 386	1.24 **	40.27	-1.69 **	38.37	-3.60 **	31.64	2.68 **	38.51
22.	K 1006/PBW 386	-1.94 **	36.63	-1.90 **	35.50	0.32	34.44	8.56 **	43.71
23.	DBW 222/PBW 386	-0.83 **	42.57	-1.28 **	40.57	-4.57 **	32.74	-4.61 **	35.30
24.	HI 1612/PBW 386	-3.07 **	36.40	0.24	36.47	1.13 *	40.02	6.42 **	47.73
25.	DBW 398/HD 3059	0.87 **	37.33	0.91 **	36.20	4.57 **	37.90	5.02 **	38.35
26.	DBW 173/HD 3059	-2.14 **	41.53	-2.63 **	38.13	-1.67 **	32.54	2.19 **	37.81
27.	PBW 644/HD 3059	-3.53 **	36.37	-5.98 **	35.33	5.09 **	39.97	-1.02	32.17
28.	K 1006/HD 3059	2.29 **	41.73	3.31 **	41.97	-6.02 **	27.75	-0.98	31.52
29.	DBW 222/HD 3059	5.13 **	49.40	7.16 **	50.27	9.04 **	45.99	-1.77 **	35.50
30.	HI 1612/HD 3059	-4.75 **	35.60	-2.25 **	35.23	4.84 **	43.38	9.70 **	48.36
31.	DBW 173/DBW 398	-4.96 **	36.13	-3.32 **	34.47	-18.37 **	15.12	-22.66 **	12.95
32.	PBW 644/DBW 398	-1.43 **	35.90	-2.70 **	35.63	5.27 **	39.43	11.58 **	44.77
33.	K 1006/DBW 398	0.56 **	37.43	-1.21 **	34.47	6.14 **	39.18	2.31 **	34.81
34.	DBW 222/DBW 398	-4.26 **	37.43	-5.73 **	34.40	5.69 **	41.92	3.22 **	40.49
35.	HI 1612/DBW 398	-5.17 **	32.60	-2.94 **	31.57	-5.68 **	32.14	0.92	39.58
36.	PBW 644/DBW 173	11.77 **	56.30	11.86 **	55.67	-1.25 *	33.79	0.91	36.38
37.	K 1006/DBW 173	-2.41 **	41.67	-0.96 **	40.20	-3.30 **	30.64	-5.07 **	29.71
38.	DBW 222/DBW 173	10.40 **	59.30	10.86 **	56.47	-1.39 **	35.73	4.28 **	43.83
39.	HI 1612/DBW 173	8.62 **	53.60	-5.65 **	34.33	-14.05 **	24.66	-5.42 **	35.52
40.	K 1006/PBW 644	1.96 **	42.27	-1.70 **	40.00	6.01 **	40.61	3.46 **	35.82
41.	DBW 222/PBW 644	-7.56 **	37.57	-8.81 **	37.33	-9.05 **	28.73	-8.57 **	28.56
42.	HI 1612/PBW 644	-0.60 **	40.60	-2.49 **	38.03	2.50 **	41.87	-8.33 **	30.19
43.	DBW 222/K 1006	3.75 **	48.43	3.97 **	47.47	-5.51 **	31.16	-4.00 **	32.45
44.	HI 1612/K 1006	-2.22 **	38.53	-1.88 **	36.00	11.11 **	49.37	3.49 **	41.32
45.	HI 1612/DBW 222	13.19 **	58.77	12.68 **	55.00	5.71 **	47.15	6.09 **	48.69
	SE(Sij)±	0.533	-	0.581	-	1.325	-	1.431	-
	SE(Sij-Sik)±	0.214	-	0.233	-	0.531	-	0.574	-

S. No	Crosses	Seed Hardness				Protein content			
		F ₁	Mean	F ₂	Mean	F ₁	Mean	F ₂	Mean
1.	DBW 187/HI 1563	-2.25 **	9.43	-2.29 **	8.20	0.08	12.93	-0.36 **	11.79
2.	PBW 386/HI 1563	1.81 **	14.20	1.30 **	12.47	0.37 **	12.77	-0.45 **	11.19
3.	HD 3059/HI 1563	0.67 **	12.93	0.68 **	11.87	0.84 **	12.92	0.15	11.41
4.	DBW 398/HI 1563	0.11	12.07	0.25	11.17	0.52 **	13.09	0.46 **	12.14
5.	DBW 173/HI 1563	1.28 **	13.83	1.00 **	12.27	0.50 **	13.33	-0.09	12.13
6.	PBW 644/HI 1563	1.52 **	14.43	1.36 **	13.07	-0.77 **	11.79	0.54 **	12.50
7.	K 1006/HI 1563	0.46 *	12.93	-0.75 **	10.57	-1.32 **	11.54	-1.64 **	10.58
8.	DBW 222/HI 1563	-0.23	12.23	-0.39	11.00	0.63 **	12.89	0.77 **	12.78
9.	HI 1612/HI 1563	2.23 **	14.50	2.37 **	13.70	0.10	12.86	-0.35 **	11.27
10.	PBW 386/DBW 187	0.87 **	12.67	0.91 **	11.33	-0.97 **	11.61	-0.19	11.89
11.	HD 3059/DBW 187	2.73 **	14.40	2.02 **	12.47	1.32 **	13.58	0.37 **	12.07
12.	DBW 398/DBW 187	-1.74 **	9.63	-1.81 **	8.37	-0.27 *	12.49	-0.96 **	11.16
13.	DBW 173/DBW 187	0.11	12.07	-0.26	10.27	-0.31 **	12.70	-1.06 **	11.60
14.	PBW 644/DBW 187	2.35 **	14.67	2.07 **	13.03	1.10 **	13.84	-0.09	12.31
15.	K 1006/DBW 187	1.32 **	13.20	1.06 **	11.63	-0.38 **	12.66	-0.54 **	12.12
16.	DBW 222/DBW 187	-1.61 **	10.27	-2.11 **	8.53	-0.88 **	11.56	-0.77 **	11.68
17.	HI 1612/DBW 187	-1.51 **	10.17	-2.06 **	8.53	0.22	13.16	2.58 **	14.64
18.	HD 3059/PBW 386	0.06	12.43	-0.22	10.90	-0.41 **	11.39	0.46 **	11.65
19.	DBW 398/PBW 386	-0.98 **	11.10	-1.56 **	9.30	0.30 **	12.60	-0.76 **	10.85
20.	DBW 173/PBW 386	-2.00 **	10.67	-2.61 **	8.60	0.85 **	13.39	1.34 **	13.49
21.	PBW 644/PBW 386	-0.99 **	12.03	-1.61 **	10.03	0.27 *	12.56	-0.12	11.77
22.	K 1006/PBW 386	-2.22 **	10.37	-2.22 **	9.03	-0.34 **	12.25	-0.90 **	11.26
23.	DBW 222/PBW 386	2.69 **	15.27	2.34 **	13.67	0.27 *	12.25	0.04	11.98
24.	HI 1612/PBW 386	0.82 **	13.20	0.93 **	12.20	-0.11	12.38	-0.28 *	11.26
25.	DBW 398/HD 3059	0.45 *	12.40	0.02	10.90	-0.63 **	11.34	-0.45 **	10.77
26.	DBW 173/HD 3059	0.03	12.57	-0.09	11.13	-0.65 **	11.58	-0.16	11.61
27.	PBW 644/HD 3059	-1.43 **	11.47	-1.73 **	9.93	-0.34 **	11.62	-1.05 **	10.46
28.	K 1006/HD 3059	0.14	12.60	0.16	11.43	-0.20	12.07	-0.33 *	11.44
29.	DBW 222/HD 3059	-0.68 **	11.77	-0.88 **	10.47	-0.09	11.58	0.48 **	12.04
30.	HI 1612/HD 3059	0.11	12.37	-0.09	11.20	0.73 **	12.90	-0.23	10.93
31.	DBW 173/DBW 398	-0.74 **	11.50	-1.43 **	9.53	-0.07	12.65	-0.54 **	11.65
32.	PBW 644/DBW 398	0.27	12.87	-0.09	11.30	-0.06	12.40	-0.88 **	11.06
33.	K 1006/DBW 398	0.51 *	12.67	0.49 *	11.50	-0.45 **	12.31	0.56 **	12.75
34.	DBW 222/DBW 398	-0.55 *	11.60	-0.78 **	10.30	-0.28 *	11.88	-0.42 **	11.56
35.	HI 1612/DBW 398	0.51 *	12.47	0.64 **	11.67	-0.13	12.53	0.26 *	11.85
36.	PBW 644/DBW 173	0.31	13.50	0.12	11.87	0.49 **	13.20	1.89 **	14.36
37.	K 1006/DBW 173	2.09 **	14.83	2.24 **	13.60	1.21 **	14.22	0.95 **	13.68
38.	DBW 222/DBW 173	-0.18	12.57	-0.33	11.10	-0.05	12.36	0.04	12.56
39.	HI 1612/DBW 173	0.89 **	13.43	0.09	11.47	0.32 **	13.23	-0.57 **	11.55
40.	K 1006/PBW 644	-0.01	13.10	-0.29	11.50	-0.21	12.54	-0.33 *	12.14
41.	DBW 222/PBW 644	1.17 **	14.27	0.57 **	12.43	-0.80 **	11.35	-0.22	12.04
42.	HI 1612/PBW 644	-1.97 **	10.93	-1.94 **	9.87	0.14	12.79	-0.41 **	11.46
43.	DBW 222/K 1006	0.74 **	13.40	0.52 *	12.00	0.15	12.61	1.19 **	13.71
44.	HI 1612/K 1006	-1.57 **	10.90	-2.26 **	9.17	0.00	12.95	-1.13 **	10.99
45.	HI 1612/DBW 222	0.24	12.70	0.38	11.87	0.49 **	12.84	-0.77 **	11.14
	SE(Sij)±	0.548	-	0.519	-	0.283	-	0.329	-
	SE(Sij-Sik)±	0.220	-	0.208	-	0.113	-	0.132	-

S. No.	Crosses	Grain yield per plant (gm)				Grain weight per spike (gm)			
		F ₁	Mean	F ₂	Mean	F ₁	Mean	F ₂	Mean
1.	DBW 187/HI 1563	-0.27 **	2.53	-0.46 **	2.15	-0.08 **	1.35	-0.02	1.33
2.	PBW 386/HI 1563	0.24 **	3.12	-0.11 *	2.59	-0.08 **	1.26	-0.02	1.34
3.	HD 3059/HI 1563	0.00	2.77	0.20 **	2.86	-0.18 **	1.13	0.11 **	1.41
4.	DBW 398/HI 1563	-0.18 **	2.55	0.21 **	2.85	0.16 **	1.56	-0.09 **	1.21
5.	DBW 173/HI 1563	0.41 **	3.14	0.50 **	3.10	0.06 **	1.44	0.11 **	1.41
6.	PBW 644/HI 1563	-0.15 **	2.69	-0.35 **	2.33	-0.07 **	1.28	-0.21 **	1.10
7.	K 1006/HI 1563	0.29 **	3.03	0.30 **	2.85	0.08 **	1.46	0.10 **	1.44
8.	DBW 222/HI 1563	-0.20 **	2.64	-0.25 **	2.46	0.14 **	1.48	0.04 **	1.34
9.	HI 1612/HI 1563	0.19 **	2.85	-0.03	2.53	0.01	1.40	-0.15 **	1.16
10.	PBW 386/DBW 187	-0.25 **	2.79	-0.32 **	2.52	0.12 **	1.53	0.09 **	1.52
11.	HD 3059/DBW 187	0.15 **	3.09	-0.02	2.78	-0.13 **	1.25	-0.04 **	1.33
12.	DBW 398/DBW 187	-0.02	2.88	-0.13 **	2.65	-0.03	1.43	-0.02	1.36
13.	DBW 173/DBW 187	0.38 **	3.28	0.35 **	3.10	0.12 **	1.56	0.08 **	1.46
14.	PBW 644/DBW 187	0.02	3.03	-0.01	2.82	-0.05 **	1.37	0.05 **	1.43
15.	K 1006/DBW 187	0.24 **	3.16	0.39 **	3.08	0.02	1.46	-0.06 **	1.36
16.	DBW 222/DBW 187	-0.05	2.95	-0.24 **	2.61	0.24 **	1.64	-0.01	1.36
17.	HI 1612/DBW 187	-0.01	2.82	0.23 **	2.93	-0.11 **	1.35	-0.14 **	1.25
18.	HD 3059/PBW 386	0.00	3.01	0.05	2.93	-0.13 **	1.15	-0.06 **	1.33
19.	DBW 398/PBW 386	0.22 **	3.19	0.16 **	3.02	-0.06 **	1.31	0.03 *	1.42
20.	DBW 173/PBW 386	-0.17 **	2.81	-0.03	2.79	-0.11 **	1.23	-0.23 **	1.16
21.	PBW 644/PBW 386	0.07 *	3.16	0.17 **	3.08	-0.25 **	1.08	0.03	1.42
22.	K 1006/PBW 386	0.16 **	3.15	0.05	2.82	-0.18 **	1.16	-0.01	1.41
23.	DBW 222/PBW 386	0.23 **	3.31	-0.03	2.90	0.14 **	1.46	0.00	1.37
24.	HI 1612/PBW 386	-0.38 **	2.52	-0.23 **	2.54	0.07 **	1.44	-0.05 **	1.35
25.	DBW 398/HD 3059	0.17 **	3.04	0.12 **	2.94	0.06 **	1.41	-0.01	1.32
26.	DBW 173/HD 3059	0.15 **	3.02	0.17 **	2.95	0.07 **	1.39	0.10 **	1.43
27.	PBW 644/HD 3059	-0.53 **	2.46	-0.30 **	2.57	-0.11 **	1.19	-0.16 **	1.18
28.	K 1006/HD 3059	0.25 **	3.13	-0.04	2.69	0.17 **	1.49	-0.09 **	1.28
29.	DBW 222/HD 3059	0.14 **	3.12	0.18 **	3.07	0.04 *	1.32	0.07 **	1.39
30.	HI 1612/HD 3059	-0.02	2.78	-0.20 **	2.53	0.06 **	1.40	0.08 **	1.43
31.	DBW 173/DBW 398	0.28 **	3.10	0.11 *	2.87	0.08 **	1.48	0.14 **	1.46
32.	PBW 644/DBW 398	-0.29 **	2.65	-0.30 **	2.55	-0.08 **	1.30	-0.16 **	1.18
33.	K 1006/DBW 398	0.23 **	3.07	0.30 **	3.01	0.04 *	1.44	-0.08 **	1.29
34.	DBW 222/DBW 398	-0.09 **	2.84	0.14 **	3.01	-0.18 **	1.20	0.04 *	1.35
35.	HI 1612/DBW 398	0.41 **	3.16	0.07	2.78	0.13 **	1.55	0.06 **	1.40
36.	PBW 644/DBW 173	-0.22 **	2.72	-0.37 **	2.44	0.27 **	1.63	0.07 **	1.41
37.	K 1006/DBW 173	-0.22 **	2.62	-0.38 **	2.30	-0.08 **	1.30	0.01	1.38
38.	DBW 222/DBW 173	-0.41 **	2.53	-0.43 **	2.40	-0.10 **	1.25	-0.17 **	1.15
39.	HI 1612/DBW 173	-0.05	2.71	0.02	2.70	0.09	1.40	0.08 **	1.42
40.	K 1006/PBW 644	0.15 **	3.12	0.06	2.83	0.03	1.39	0.08 **	1.45
41.	DBW 222/PBW 644	0.03	3.08	-0.12 **	2.80	-0.14 **	1.18	-0.07 **	1.25
42.	HI 1612/PBW 644	0.25 **	3.13	0.23 **	3.00	0.04 *	1.41	0.03	1.38
43.	DBW 222/K 1006	0.11 **	3.07	0.07	2.85	-0.11 **	1.24	0.02	1.38
44.	HI 1612/K 1006	-0.22 **	2.56	-0.23 **	2.40	0.08 **	1.48	0.14 **	1.53
45.	HI 1612/DBW 222	-0.13 **	2.74	0.08	2.86	-0.09 **	1.28	0.02	1.35
	SE(Sij)±	0.083	-	0.109	-	0.043	-	0.041	-
	SE(Sij-Sik)±	0.033	-	0.044	-	0.017	-	0.016	-

* Significant at 5%, ** Significant at 1% level.

Conclusion

Good general combiners were observed for all yield and yield related characters based on gca effect and *per se* performance of parents. On the basis of overall performance, DBW 222, K 1006 and DBW 173 were best general combiners for yield and its contributing traits including some quality traits. The parents may be used for simultaneous improvement in grain yield and quality attributes through an inter-mating population involving all possible combinations among themselves. On the basis of sca effects and *per se* performance, crosses DBW 398 × K 1006, DBW 187 × DBW 173, DBW 398 × PBW 644, HD 3059 × DBW 173, and HD 3059 × DBW 222 in F₁ generation and DBW 398 × K 1006, DBW 398 × PBW 644, and DBW 187 × DBW 173 in F₂ generation were found to be good specific combiners for grain yield per plant. Crosses

HI 1563 × K 1006, HD 3059 × DBW 222 and DBW 398 × K 1006 showing high sca effects with at least one good general combiner could produce desirable transgressive segregants in subsequent generations.

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