Original Research Article

Evaluation of Heterosis and Inbreeding Depression for Seed Yield and Associated Traits in Wheat (*Triticum aestivum* L.)

تعليق عليه [طارق1]: The title is good

Abstract

Wheat (*Triticum aestivum* L.) is the most important cereal crop and a good source of global food security. With rising population demands, hybrid breeding offers an effective strategy to enhance productivity. The present investigation was carried out at Nawabganj Farm, C.S. Azad University of Agriculture and Technology, Kanpur during *Rabi* 2023–24 and 2024–25, comprising 157 treatments (21 parents, 68 F_1s, and 68 F_2s). Heterosis and inbreeding depression were studied for 16 yield and its contributing traits. Significant positive heterosis was observed for seed yield in crosses such as DBW-107 × DBW-278, HD-3440 × DBW-278, and HD-3171 × K-9423. The cross, PBW-833 × DBW-278 exhibited maximum heterosis for productive tillers, while DBW-308 × K-1006 and PBW-833 × K-9423 excelled for flag leaf area. For canopy temperature depression, PBW-902 × K-1006, whereas HI-1654 × K-9423 and DBW-342 × K-9423 were found superior for protein content. These promising crosses can be used for yield improvement of wheat.

تعليق عليه [طارق2]: At the end of the abstract you must add the recommendation.

Keywords: *Wheat, Heterosis, Inbreeding depression, Seed yield, Canopy temperature depression*

Introduction

تعليق عليه [طارق3]: It did not clearly address the research gap or justify why this particular study is novel or necessary.

Some references are outdated (1966, 1919). Recent references (from the last 5 years) on heterosis in wheat should be included.

تعليق عليه [طارق4]: Very old

Wheat (*Triticum aestivum* L) is the most important cereal in the world and was one of the first crops to be domesticated some 10000 years ago (**Harlan and Zohary, 1966**). It is a self-pollinating crop in the Poaceae family with 2n=6x=42. The three species of wheat namely, *Triticum aestivum* 2n=6x=42 (Bread wheat), *Triticum durum* 2n=4x=28 (Macaroni or Pasta wheat) and *Triticum dicoccum* 2n=4x=28 (Emmer or Khapli wheat) grown on commercial basis in the Indian subcontinent from pre-historic times with the share of production in percent 95%, 4% and 1% respectively, are being cultivated in the country.

As the population of the world is increasing rapidly day-by-day, the risks of food crisis are also increasing. According to an estimate by **Singh *et al.*, 2019,** with the ongoing expansion of population in the nation, there will be a requirement of more than 140 million tons of wheat grain to be produced by 2050 and local production is insufficient to fulfil current demand.

Heterosis is a quicker, cheaper, and easier method of increasing crop production. With a sufficient level of heterosis, commercial production of hybrid varieties will be justified, and heterotic studies can provide the basis for the exploitation of valuable hybrid combinations in breeding programs. Hybrid wheat technology can play an effective role in enhancing grain yield. Although the presence of heterosis in wheat was earlier reported in 1919 by Freeman, its large- scale exploitation had not been

طارق تعليق عليه [5]: old

طارق تعليق عليه [6]: The main objective of the study was not explicitly stated at the end of the introduction in a clear sentence.

طارق تعليق عليه [7]: What method or plant breeding design did you use? You didn't specify. Did you use a Krvenc method, for example? Or Heymann? A strain in the tester, etc.

experimental design (RCBD? factorial?), and number of replications.

طارق تعليق عليه [8]: The statistical software used is not mentioned.

realized in the recent past. Studies on heterosis would help in generating breeding strategies for hybrid wheat production **(Hassan *et al.* 2006)**.

Keeping these points in mind present investigation has been taken.

Materials and Methods

The present experiment was conducted at Nawabganj Farm of C. S. Azad University of Agriculture and Technology, Kanpur-208002 (U.P.) during Rabi, 2023-24 and Rabi, 2024-25. The experimental material consists of a total of 157 treatments (21 parents + 68 F_1s + 68 F_2s).

Heterosis and inbreeding depression for 16 metric traits namely., days to 50% heading, days to maturity, plant height (cm), number of total tillers per plant, number of productive tillers per plant, flag leaf area (cm^2), spike length (cm), number of spikelet per spike, number of grains per spike, biological yield per plant (g), 1000 seed weight (g), harvest index (%), seed yield per plant (g), chlorophyll content (µmol m^{-2}), canopy temperature depression (°C) and protein content (%) was worked out by using the overall mean of each hybrid for each trait.

The nature and magnitude of heterosis was computed as per cent increase or decrease of the mean value of F_1 over better parent (BP) mean and economic parent (K-1006) with the help of following formula:

Heterosis (%) over better parent (BP) = $(\bar{F}_1 - \overline{BP}/\overline{BP}) \times 100$

Where,

$\bar{F}_1$ = Mean of the F_1

$\overline{BP}$ = Mean of the better parent

Heterosis (%) over economic parent (EP) = $(\bar{F}_1 - \overline{EP}/\overline{EP}) \times 100$

Where,

$\bar{F}_1$ = Mean of the F_1

$\overline{EP}$ = Mean of the economic parent

Test of significance: Significance of heterosis over better parents was tested as;

S.E. = $(2M_{e1}/r)^{0.5}$

C.D. = SE x 't' ('t' value at 5% and 1%) error d.f.

Where,

M_{e1} = Error variation obtained from parents + F_1s ANOVA

r = Number of replications

The coefficient of inbreeding depression was calculated by the following formula:

Inbreeding depression value (%) = $\frac{\overline{F1} - \bar{F}2}{\overline{F1}} \times 100$

Where,

$\overline{F1}$ = Mean of F_1 generation

$\bar{F}_2$ = Mean of F_2 generation

Test of significance:

Significance of the estimate was tested as:

SE (Inbreeding depression) = $(2M_{e2}/r)^{0.5}$

Where,

M_{e2} = Error variance obtained from parents + F_2s ANOVA combination

تعليق عليه [طارق9]: Where is ANOVA????? And means??
The statistical analysis is a major weakness of this manuscript. The authors did not provide an ANOVA table, nor did they use any mean comparison test (LSD, Duncan, Tukey, etc.). As a result, it is not possible to confirm whether the differences among genotypes are statistically valid or due to random variation. This omission significantly reduces the scientific rigor of the study and must be addressed before publication.

r = number of replications

Results and Discussion

Heterosis means superiority of F_1 over parents or economic variety, while inbreeding depression describe the reduction in performance of progeny due to inbreeding. In wheat crop finding heterosis is very tedious job. Heterosis in wheat crop is desirable in negative direction for traits *viz.,* days to 50% heading, days to maturity and plant height (cm). In present investigation, heterosis was estimated in F_1 generation over better parent (Heterobeltiosis) and standard check *i.e.* K-1006 (Economic heterosis). The findings of heterosis and inbreeding depression is depicted in Table 1 and discussed below;

(i) Days to 50% heading

The hybrids showing earliness should have negative heterosis along with positive inbreeding depression. The extent of heterosis over better parent ranged from -11.46 to 9.85 % while over economic parent ranged from 1.35 to 15.9* % for days to 50% heading. Among the 68 F_1s, 46 exhibited negative but non-significant heterosis while 22 exhibited positive but non-significant heterobeltiosis. The extent of inbreeding depression ranged from -10.60 to 0.48 for days to 50% heading. None of the hybrids were showed significant positive inbreeding depression. Similar types of findings for this trait were reported by **Yadav *et al.* (2025)** for different crosses.

(ii) Days to maturity

The hybrids showing superiority for days to maturity had negative heterosis and positive inbreeding depression. Among the 68 F_1s, 37 exhibited negative but non-significant, heterobeltiosis while none of the hybrids were showed significant negative heterosis over economic parent. DBW-107 × K-9423 was among top performer which exhibited considerable amount of heterobeltiosis (-5.04) as well as standard heterosis (-0.33). 19 cross combinations exhibited positive but non-significant value of inbreeding depression. This indicates selection is depends on the heterosis while inbreeding depression can be used for selection of early maturing varieties. Similar finding was reported by **Kumar *et al.,* (2017)** for this trait.

(iii) Plant Height

The superiority for plant height over better parents and economic parent was observed as desirable in 25 cross combinations and 13 cross combinations respectively which exhibiting significant and negative performance. However, none of the hybrids were showing significant positive inbreeding depression. This indicates, the selection procedure is more depended on the basis of heterosis for plant height. These findings were supported by **Lal *et al.* (2013), Nagar *et al.* (2019)** and **Yadav *et al.* (2025).**

(iv) Number of total tillers per plant

The positive value of heterobeltiosis and economic heterosis for number of total tillers per plant was exhibited by all cross combinations indicates that crosses produced a greater number of tillers. PBW-833 × DBW-278 was among the top performer which show high degree of significant positive heterosis over better parent and economic parent. The inbreeding depression was positive for all crosses. EC-27051 × K-9423 (1.1), HD-3440 × K-9423 (2.46) and EC-27051 × DBW-278 (5.49) were top three crosses which showing lowest value of inbreeding depression for number of total tillers per plant. **Kalimullah (2011)** and **Kumar *et al.* (2017)** also reported similar result for different cross combinations.

(v) Number of productive tillers per plant

The number of productive tillers per plant depicted a strong and positive association with the seed yield in wheat, as suggested by **Baloch *et al.* (2016).** Increasing number of productive tillers per plant results in more seed yield **(Khanzada *et al.,* 2025)**. The extent of heterosis for number of productive tillers per plant over better parent ranged from 2.95 (EC-27051 × K-1317) to 91.03** (PBW-833 × DBW-278) and for economic heterosis from 0.14 (PBW-870 × K-1006) to 54.51** (DBW-187 × DBW-278). Out of 68 F_1s, 51 exhibited significantly positive heterobeltiosis and 40 exhibited significantly positive economic heterosis. HD-3440 × K-9423 (-10.57), DBW-166 × K-1006 (-4.47) and HI-1612 × K-1317 (-3.82) exhibited lowest inbreeding depression among all crosses for number of productive tillers per plant.

(vi) Flag leaf area (cm^2)

The leaf area is an effective source for high photosynthesis which will strengthen the seeds and ultimately increase the seed yield. The significant and positive heterosis for flag leaf area over better parent shown by 30 crosses. However, 30 cross combinations exhibited significantly positive economic heterosis. Top three crosses showing positive and significant economic heterosis in order of merits were DBW-308 × K-1006 (42.65**), PBW-833 × K-1006 (40.59**) and PBW-833 × K-9423 (39.22**) for flag leaf area. None of the hybrids were showing significant negative inbreeding depression. These findings are supported by **Kumar *et al.* (2017)**.

(vii) Spike length (cm)

The maximum heterobeltiosis and economic heterosis for spike length was exhibited by HI-8830 × K-9423 (62.48**) and Karan Poshan-2 × K-1317 (48.38**) respectively. However, minimum inbreeding depression was shown by DBW-107 × K-1317 (5.58) for spike length. **Khokhar *et al.* (2019)** and **Kalimullah (2011)** made crosses in bread wheat and found several cross combinations showing positive heterosis and negative inbreeding depression for spike length, which ultimately increased grain yield.

(viii) Number of spikelets per spike

Spikelets are the most important architectures which have direct effect on number of grains per spike. Among the 68 cross combinations, 14 exhibited positive heterobeltiosis while 12 exhibited significantly positive economic heterosis for number of spikelets per spike. Karan Poshan-2 × K-1006 was among the top three cross combinations which exhibited high degree of heterobeltiosis and standard heterosis. None of the hybrids were showing significant negative inbreeding depression. **Kumar *et al.* (2017)** observed a wide range of heterosis and inbreeding depression for this trait in wheat.

(ix) Number of grains per spike

Karan Poshan-2 × K-1317 exhibited highest value of positive and significant heterosis over better parent, while PBW-833 × DBW-278 exhibited significantly positive and highest value of economic heterosis. None of the hybrids were showing significant negative inbreeding depression. **Nagar *et al.***

(2019) found that maximum degree of heterosis over standard check and better parent was depicted by PBW 343 × K 8962 for grain number per spike.

(x) Biological yield per plant (g)

Out of 68 F_1s, 34 exhibited significantly positive heterosis over better parent as well as standard check for this trait. HI-8830 × K-9423 was among the top most desirable cross which exhibited significantly positive heterobeltiosis (49.27**) and standard heterosis (44.37**). The extent of inbreeding depression ranged from -0.60 to 13.36 for biological yield per plant. None of the hybrids were showing significant negative inbreeding depression. Similarly, **Kumar *et al.* (2017),** found significantly desirable heterosis and inbreeding depression for biological yield per plant in wheat.

(xi) 1000-seed weight (g)

The high value of 1000-seed weight is the indication of higher seed yield. The result of heterotic performance of F_1s revealed that DBW-107 × K-9423 (23.42*) and PBW-902 × K-1006 (8.74) had highest better parent heterosis and economic heterosis respectively. The minimum value of inbreeding depression among 68 F_2s resulted from the cross PBW-833 × DBW-278 (-7.61) for 1000-seed weight. **Jaiswal *et al.* (2018)** reported significant heterosis over the better parent and commercial variety for 1000 seed weight in desirable direction.

(xii) Harvest index (%)

The significant and positive heterosis for harvest index over better parent was exhibited by seven crosses and nine exhibited significantly positive economic heterosis. The cross combination, HI-1612 × DBW-278 exhibited highest value of economic heterosis (25.76**) and third most for better parent heterosis (27.93**). None of the hybrids were showing significant negative inbreeding depression. Similar finding for harvest index reported by **Burdak *et al.* (2023).**

(xiii) Seed yield per plant (g)

During selection of a plant, seed yield per plant is in prime focus of plant breeder because every plant breeding program had yield enhancement as a ultimate objective. Therefore, highly positive and significant heterosis while negative significant inbreeding depression is desirable for seed yield per plant. Out of 68 F_1s, 20 exhibited significantly positive and 30 exhibited positive but non-significant heterobeltiosis for seed yield per plant. Among them top three crosses in order of merits were DBW-107 × DBW-278 (52.04**), HD-3440 × DBW-278 (47.27**) and HD- 3171 × K-9423 (46.89**). The extent of economic heterosis for seed yield per plant ranged from -20.98** to 22.61**. Out of 68 F_1s, 12 exhibited significantly positive and 38 positive but non-significant economic heterosis. Top three crosses showing positive economic heterosis in order of merits were DBW-187 × DBW-278 (22.61**), PBW-833 × K-1006 (21.52**) and DBW-187 × K-1006 (21.30**) for seed yield per plant. None of the hybrids were showing significant negative inbreeding depression. However, Karan Poshan-2 × K-1317 (5.9), EC-27051 × K-1006 (6.07) and DBW-342 × DBW-278 (6.25) showing lowest value of inbreeding depression among all crosses in increasing order of merit for seed yield per plant. The significant and desirable heterosis as well as inbreeding depression for seed yield per plant was also reported by **Busa *et al.* (2022), Saeed *et al.* (2024)** and **Khanzada *et al.* (2025).**

Table 1. Heterosis over better parent (BP), standard variety i.e. K-1006 (SH) and inbreeding depression (IBD) for 16 traits in wheat

SN	Name	DH			DM			PH			NTT		
		BP	SH	IBD	BP	SH	IBD	BP	SH	IBD	BP	SH	IBD
1	DBW-107 × K-9423	-1.54	5.7	-3.2	-5.04	-0.33	-0.06	-16.98*	3	-1.56	57.75**	41.89 **	14.22*
2	DBW-107 × DBW-278	-4.26	5.2	-3.02	1.86	2.53	0.18	13.21	9.95	-1.51	52.55**	37.09 **	12.96
3	DBW-107 × K-1006	3.36	6.04	-3.48	6.37	7.04	-0.28	-3.36	-4.81	-1.61	18.15	16.52	12.58
4	DBW-107 × K-1317	2.37	3.53	-5.56	6.26	6.28	-1.43	14.05	21.63 **	-1.45	40.89**	42.30 **	14.61*
5	HD- 3171 × K-9423	2.62	10.16	-2.93	2.31	7.4	-1.16	-2.29	21.22 **	-1.45	26.99*	14.23	14.25*
6	HD- 3171 × DBW-278	-1.34	8.42	-3.48	8.13	9.34 *	0.53	-7	-9.68	-1.65	39.74**	25.57 **	14.13*
7	HD- 3171 × K-1006	-0.2	5.02	-5.59	3.78	4.94	-0.65	2.54	1	-1.57	47.59**	45.56 **	14.65*
8	HD- 3171 × K-1317	2.03	7.36	-3.97	5.01	6.19	0.22	-13.3	-7.53	-1.63	42.3**	43.72 **	14.07*
9	EC-27051 × K-9423	-5.05	6.71	-3.88	-4.82	2.23	0.85	-26.04**	-8.25	-1.64	13.54	2.13	1.1
10	EC-27051 × DBW-278	-6.44	5.15	-3.72	-3.22	3.94	-1.26	-16.61	-19.01 *	-1.74	14.9	3.25	5.49
11	EC-27051 × K-1006	-6.28	5.33	-5.5	-5.3	1.71	-1.45	7.5	5.88	-1.54	7.15	5.67	12.35
12	EC-27051 × K-1317	1.29	13.84	-2.17	-2.09	5.16	-0.17	-5.16	1.14	-0.7	9.62	10.72	9.96
13	DBW-187 × K-9423	-11.46	2.85	-5.02	-0.14	4.82	-0.91	-34.58**	-18.84 *	-1.7	22.05*	16.85	13.72*
14	DBW-187 × DBW-278	-6.45	8.66	-1.86	-4.56	-0.02	0.27	-10.41	-10.74	0.26	55.42**	48.81 **	14.47*
15	DBW-187 × K-1006	-7.04	7.98	-4.94	5.21	10.22 *	0.1	16.41	15.98 *	-1.06	47**	44.97 **	14.52*
16	DBW-187 × K-1317	-5.13	10.2	-4.43	0.3	5.08	-1.52	-19.16*	-13.79	-1.84	35.81**	37.17 **	14.56*
17	PBW-644 × K-9423	5.94	14.07	-1.77	-3.18	1.63	-0.32	-33.82**	-17.89 *	-1.88	22.7*	24.70 **	13.81*
18	PBW-644 × DBW-278	-1.61	8.12	-2.33	3.15	7.11	0.11	-0.02	-2.91	-1.72	12.73	14.56	12.94
19	PBW-644 × K-1006	6.18	14.33	-1.7	-1.95	1.82	0.16	20.47*	18.66 *	-1.58	33.21**	35.38 **	14.5*
20	PBW-644 × K-1317	-0.5	7.14	-4.59	2.24	6.17	-1.24	-19.06*	-13.67	-1.83	35.06**	37.25 **	14.49*
21	DBW-342 × K-9423	4.22	12.37	-1.55	-0.9	4.02	0.46	-15.34	5.03	-1.67	45.92**	31.25 **	12.7
22	DBW-342 × DBW-278	-1.74	7.98	-4.71	-1.35	-0.12	-0.52	2.53	8.91	-1.64	35.47**	21.74 *	14.17*
23	DBW-342 × K-1006	2.25	10.24	-4.54	0.1	1.34	0.39	-18.91*	-13.86	-1.84	17.05	15.44	13.97*
24	DBW-342 × K-1317	4	12.13	-2.89	2.67	3.95	-1.24	0.77	7.47	-1.65	33.33**	34.67 **	14.08*
25	PBW-833 × K-9423	-2.7	6.97	-2.89	-3.87	0.91	-0.69	-19.07*	0.41	6.95	45.59**	30.96 **	13.94*
26	PBW-833 × DBW-278	1.37	11.45	-1.44	-1.87	2.86	0.09	-3.45	3.29	-1.68	62.3**	45.85 **	18.77**
27	PBW-833 × K-1006	1.85	11.97	-3.15	-2.03	2.7	-1.04	-3.4	3.35	-1.68	41.37**	39.42 **	18.21**
28	PBW-833 × K-1317	1.73	11.84	-2.03	1.01	5.88	-1.32	-7.37	-0.9	-1.71	13.8	14.94	13.9*
29	K-1711 × K-9423	-6.93	6.26	-3.88	-3.45	1.34	-0.42	-35.73**	-20.27 **	-1.91	35.48**	29.83 **	13.95*
30	K-1711 × DBW-278	-5.62	7.75	-5.31	-0.22	0.53	-0.94	7.01	12.12	-1.62	24.9*	19.69 *	12.66
31	K-1711 × K-1006	-6.37	6.91	-3.9	1.1	1.86	-0.19	-14.34	-10.25	-1.8	14.68	13.1	14.08*
32	K-1711 × K-1317	-6.18	7.12	-2.86	2.25	3.02	-1.46	-21.32*	-16.09 *	-1.86	24.04*	25.28 **	14.17*
33	PBW-902 × K-9423	-2.03	7.91	-6.15	1.33	6.37	-2.68	-37.47**	-22.42 **	-1.94	41.95**	36.09 **	14.99*
34	PBW-902 × DBW-278	2.04	12.39	-1.41	0.71	5.31	1.37	3.98	1.5	-1.69	39.03**	33.29 **	14.32*

35	PBW-902 × K-1006	-5.16	4.46	-5.62	1.18	5.8	-1.82	6.86	5.26	-1.66	28.76**	26.99 **	14.14*
36	PBW-902 × K-1317	-2.11	7.82	-4.32	-2.39	2.06	-1.45	-28.25**	-23.48 **	-1.96	24.74*	25.99 **	11.18
37	PBW-870 × K-9423	-5.37	5.88	-3.87	-2.18	3	-2.06	-20.95**	-1.93	-1.72	31.51**	21.36 *	13.48
38	PBW-870 × DBW-278	-7.46	3.53	-3.78	-4.59	0.46	-0.97	-17.81	-14.35	-1.84	45.52**	34.29 **	14.14*
39	PBW-870 × K-1006	-6.69	4.4	-4.18	0.54	5.87	0.11	-0.33	3.86	-1.67	23.6*	21.90 *	14.28*
40	PBW-870 × K-1317	-1.67	10.01	-3.08	0.42	5.74	0.37	-21.82*	-16.62 *	-1.87	16.48	17.65	14.24*
41	HD-3440 × K-9423	-3.16	6.79	-4.42	0.62	5.62	-1.66	-14.68	5.85	-1.66	5.1	3.25	2.46
42	HD-3440 × DBW-278	-3.49	6.43	-4.98	0.9	5.67	-1.38	-8.41	-7.38	-1.77	14.61	12.6	14.48*
43	HD-3440 × K-1006	-4.41	5.42	-3.56	0.28	5.03	0.6	15.24	16.53 *	-1.59	15.23	13.64	13.11
44	HD-3440 × K-1317	-0.14	10.13	-4.6	-2.26	2.37	-0.89	-23.32*	-18.22 *	-1.89	30.57**	31.87 **	11.92
45	DBW-166 × K-9423	-7.69	5.12	-4.25	-4.5	0.24	-0.16	-26.95**	-9.37	-1.79	50.7**	35.54 **	14.29*
46	DBW-166 × DBW-278	-6.22	6.79	-3.21	5.19	8.03 *	-1.67	-26.74**	-19.26 *	-1.9	40.81**	26.53 **	13.84*
47	DBW-166 × K-1006	-2.92	10.55	-1.83	-1.53	1.13	-2.02	5.27	16.01 *	-1.59	39.38**	37.46 **	13.46
48	DBW-166 × K-1317	-2.46	11.07	-2.15	3.44	6.24	-0.06	3.39	13.94	-1.61	33**	34.33 **	13.92*
49	DBW-308 × K-9423	1.61	12.79	-2.01	-4.13	0.63	-2.25	-29.86**	-12.98	-1.83	33.09**	23.32 *	12.27
50	DBW-308 × DBW-278	-1.93	8.86	-4.01	-0.31	3.57	0.43	0.38	4.5	-1.67	30.44**	20.86 *	8.56
51	DBW-308 × K-1006	-0.19	10.79	-3.31	2.07	6.05	-0.14	6.94	11.34	-1.62	30.46**	28.66 **	13.05
52	DBW-308 × K-1317	0.89	11.98	-0.86	-1.94	1.88	-0.55	-6.29	-0.05	-1.71	19.04*	20.23 *	13.01
53	HI-1612 × K-9423	-1.42	8.71	-2.48	-2.7	2.13	0.2	-20.33*	-1.16	-1.71	39.89**	25.82 **	12.14
54	HI-1612 × DBW-278	4.36	15.09 *	0.48	7.67	9.46 *	0.46	-19.31*	-13.69	-1.83	41.74**	27.37 **	10.99
55	HI-1612 × K-1006	-1.41	8.73	-6.45	-4.65	-3.05	-1.98	-25.36**	-20.15 **	-1.91	25.17*	23.45 *	13.57*
56	HI-1612 × K-1317	-3.78	6.12	-5.47	1.9	3.61	1.35	7.33	14.81 *	-1.6	23.5*	24.74 **	10.91
57	HI-8830 × K-9423	1.48	8.93	-2.92	0.95	5.96	-0.43	-7.34	14.96 *	-1.6	33.06**	26.78 **	14.03*
58	HI-8830 × DBW-278	-7.77	1.35	-10.6	-1.4	0.73	-0.69	4.14	3.33	-1.68	36.82**	30.37 **	12.33
59	HI-8830 × K-1006	9.85	14.46	-2.06	-1.86	0.26	-2.42	-8.74	-9.46	-1.79	27.33**	25.57 **	14.18*
60	HI-8830 × K-1317	8.47	13.02	-1.96	-1.19	0.95	-1.58	-14.68	-9.01	-1.79	34.7**	36.05 **	13.82*
61	HI-1654 × K-9423	-1.73	7.75	-4.02	-4.34	0.41	-1.3	-13.45	7.37	-1.65	48.14**	33.25 **	11.96
62	HI-1654 × DBW-278	-5.39	3.97	-3.22	-1.98	2.51	-0.92	18.08	14.80 *	-1.6	40.11**	25.91 **	10.87
63	HI-1654 × K-1006	2.29	12.16	-2.55	-2.86	1.59	-0.41	16.12	14.37	-1.6	32.49**	30.66 **	14.76*
64	HI-1654 × K-1317	0.48	10.17	-1.12	-0.08	4.5	-0.48	2.88	9.72	-1.63	22.22*	23.45 *	13.63*
65	Karan Poshan-2 × K-9423	-7.85	3.63	-5.27	1.71	6.84	-1.33	-26.35**	3.71	-1.68	36.87**	23.11 *	12.99
66	Karan Poshan-2 × DBW-278	-2.62	9.5	-4.37	-0.94	4.05	-1.42	-43.56**	-20.53 **	-1.92	25.21*	12.52	14.39*
67	Karan Poshan-2 × K-1006	-4.95	6.88	-1.94	-2.09	2.84	-0.19	-41.17**	-17.16 *	-1.87	15.27	13.68	13.96*
68	Karan Poshan-2 × K-1317	-3.72	8.26	-5.67	-0.06	4.98	-1.83	-18.43**	14.87 *	-1.6	22.14*	23.36 *	17.47*

DH = Days to 50% Heading, DM = Days to Maturity, PH = Plant Height (cm), NTT = Number of Total Tillers per plant

**, ** significant at 5 and 1 per cent probability levels, respectively*

Cont.

SN	Name	NPT			FLA			SL			NSS		
		BP	SH	IBD	BP	SH	IBD	BP	SH	IBD	BP	SH	IBD
1	DBW-107 × K-9423	66.05**	35.61 **	10.77	17.53	7.61	4.66	54.99**	39.72 **	5.62	3.13	8.21	6.81
2	DBW-107 × DBW-278	65.36**	32.15 **	6.35	15.68	6.35	4.68	-5.19	-9.51	10.04	-7.73	3.37	6.72
3	DBW-107 × K-1006	29.04**	20.28 *	13.24*	-14.44	-14.75	4.98	4.69	5.2	9.12	9.66	14.50 *	6.74
4	DBW-107 × K-1317	28.76**	32.43 **	6.77	6.83	3.57	4.71	47.89**	42.60 **	5.58	-11.11	0.96	5.98
5	HD- 3171 × K-9423	39.19**	13.68	16.93**	9.48	1.07	4.74	59.13**	45.99 **	6.04	0.4	16.48 *	7.39
6	HD- 3171 × DBW-278	55.61**	24.36 *	14.72*	26.04**	16.35 *	4.57	27.2**	21.41 *	8.37	-5.09	10.1	6.79
7	HD- 3171 × K-1006	47.99**	37.94 **	8.61	18.14*	17.71 *	4.56	24.56**	25.17 **	8.22	-10.29	4.07	6.86
8	HD- 3171 × K-1317	29.59**	33.29 **	6.74	-21.34*	-23.74 **	5.15	17.63	13.43	8.71	-16.39*	-3.01	6.95
9	EC-27051 × K-9423	28.66*	5.08	-3.17	8.57	-0.59	4.76	14.76	3.46	9.22	-18.18*	-4.33	6.97
10	EC-27051 × DBW-278	33.57**	6.74	10.9	27.32**	17.05 *	4.57	10.77	5.72	9.09	-7.4	8.27	6.81
11	EC-27051 × K-1006	10.8	3.28	6.93	8.83	8.43	4.65	27.21**	27.83 **	8.12	-5.65	10.32	3.19
12	EC-27051 × K-1317	2.95	5.89	-0.56	37.43**	33.23 **	4.43	37.93**	33.00 **	7.94	-9.43	5.9	4.78
13	DBW-187 × K-9423	12.95	16.76	16.03**	30.36**	19.37 *	4.55	50.27**	35.47 **	7.86	-11.23	3.45	1.46
14	DBW-187 × DBW-278	49.47**	54.51 **	18.2**	-8.06	-15.47 *	4.99	41.81**	35.35 **	7.86	9.64	27.78 **	17.76
15	DBW-187 × K-1006	48.19**	53.18 **	18.68**	-21.68*	-21.97 **	5.11	-9.95	-9.51	10.04	5.14	22.53 **	9.48
16	DBW-187 × K-1317	28.57**	32.91 **	12.09*	21.93*	18.20 *	4.56	20.68*	16.36	8.58	1.26	18.01 *	6.47
17	PBW-644 × K-9423	48.52**	21.37 *	12.86*	-18.14	-25.05 **	5.18	-2.1	-11.74	10.2	-5.55	8.02	6.68
18	PBW-644 × DBW-278	38.18**	12.92	10.11	24.24*	14.22	4.59	25.66*	19.94 *	8.43	-1.73	12.39	6.27
19	PBW-644 × K-1006	34.69**	25.55 **	8.41	39.64**	39.13 **	4.39	12.45	13	8.73	-3.3	10.59	6.28
20	PBW-644 × K-1317	27.56**	31.20 **	11.65	17.09	13.51	4.6	46.84**	41.59 **	7.67	-3.34	10.55	6.66
21	DBW-342 × K-9423	51.74**	23.93 *	1.74	9.58	0.34	4.75	18.89	7.19	9.02	-2.24	4.35	6.54
22	DBW-342 × DBW-278	41.71**	13.25	9.99	28.63**	18.26 *	4.56	-3.43	-7.83	9.92	-6.13	5.16	6.3
23	DBW-342 × K-1006	26.24*	17.66	18.12**	5.67	5.28	4.69	-6.66	-6.21	9.81	-2.54	4.03	6.35
24	DBW-342 × K-1317	24.52*	28.06 **	10.24	14.9	11.4	4.62	38.47**	33.52 **	7.92	-3.23	9.91	6.5
25	PBW-833 × K-9423	45.06**	18.47	6.06	52.05**	39.22 **	4.39	37.92**	24.34 **	8.25	-3.03	13.17	6.25
26	PBW-833 × DBW-278	91.03**	52.66 **	39.06**	8.97	0.19	4.75	-4.49	-8.84	9.99	0.07	16.80 *	6.41
27	PBW-833 × K-1006	60.52**	49.62 **	37.87**	41.11**	40.59 **	4.38	-10.41	-9.97	10.07	-3.49	12.64	6.49
28	PBW-833 × K-1317	14.45	17.71	18.15**	40.96**	36.66 **	4.41	34.51**	29.69 **	8.06	-7.21	8.29	6.6
29	K-1711 × K-9423	34.5**	18.47	6.07	-6.42	-13.17	4.95	-0.95	-10.7	10.13	2.21	17.48 *	6.62
30	K-1711 × DBW-278	28.36*	13.06	6.95	-16	-22.05 **	5.12	43.96**	37.40 **	7.8	-1.21	13.56	6.64
31	K-1711 × K-1006	16.1	8.21	12.82*	-19.55*	-19.84 *	5.07	29.34**	29.97 **	8.05	-4.45	9.83	6.6
32	K-1711 × K-1317	17.22	20.56 *	12.4*	-23.28*	-25.62 **	5.19	-6.79	-10.12	10.09	-3.89	10.47	6.35
33	PBW-902 × K-9423	45.21**	27.35 **	9.73	-16.24	-20.28 **	5.08	-0.14	-9.97	10.07	-4.32	3.77	6.77
34	PBW-902 × DBW-278	40.55**	23.27 *	8.24	27.2**	21.07 **	4.53	55.08**	48.01 **	7.49	-4.72	6.74	5.86

35	PBW-902 × K-1006	33.77**	24.69 **	13.85*	-21.63*	-21.91 **	5.11	8.13	8.65	8.94	-2.95	5.27	6.58
36	PBW-902 × K-1317	28.86**	32.53 **	7.23	-1.53	-4.53	4.81	12.43	8.41	8.96	-4.13	8.89	6.79
37	PBW-870 × K-9423	30.63**	16.24	9.14	34.56**	32.42 **	4.44	51.76**	36.82 **	7.82	-4.96	11.53	6.99
38	PBW-870 × DBW-278	34.9**	20.04 *	5.74	-24.07**	-25.27 **	5.19	52.39**	45.44 **	7.56	-1.91	15.11 *	6.77
39	PBW-870 × K-1006	7.44	0.14	-1.71	30.77**	30.29 **	4.46	47.2**	47.92 **	7.49	-15.89	-1.3	-12.99
40	PBW-870 × K-1317	12	15.19	14.92*	-5.61	-7.12	4.85	37.9**	32.97 **	7.94	-21.4**	-7.76	-16.54
41	HD-3440 × K-9423	6.8	0.62	-10.57	-18.95*	-18.62 *	5.05	16.44	8.75	8.94	-14.21	4.37	-1.42
42	HD-3440 × DBW-278	14.72	8.07	14.27*	21.52*	22.02 **	4.52	-5.77	-10.06	10.08	-9.85	9.68	3.15
43	HD-3440 × K-1006	24.7*	17.47	16.53**	16.77	17.25 *	4.57	33.87**	34.53 **	7.89	-16.16*	2	-6.02
44	HD-3440 × K-1317	27.47**	31.10 **	5.16	34.17**	34.72 **	4.42	24.99*	20.52 *	8.4	-10.39	9.02	-0.77
45	DBW-166 × K-9423	30.34**	24.83 **	9.32	36.22**	24.73 **	4.5	24.12*	11.9	8.78	-16.54*	-0.83	-3.88
46	DBW-166 × DBW-278	31.04**	25.50 **	14.38*	40.89**	29.53 **	4.46	49.6**	42.78 **	7.63	-22.66**	-8.1	-17.81
47	DBW-166 × K-1006	24.19*	18.95 *	-4.47	-6.76	-7.1	4.85	-8.67	-8.23	9.95	-14.37	1.75	-2.41
48	DBW-166 × K-1317	23.92*	27.45 **	9.76	-11.75	-14.44	4.97	20.58*	16.27	8.58	-9.31	7.76	0.97
49	DBW-308 × K-9423	24.35*	16.38	-0.33	24.14**	25.82 **	4.49	-5.33	-14.65	10.43	-0.5	9.51	6.61
50	DBW-308 × DBW-278	30.59**	22.22 *	-1.67	28.02**	29.75 **	4.46	20.19*	14.71	8.65	-1.64	10.19	6.52
51	DBW-308 × K-1006	24.61*	16.62	2.89	40.76**	42.65 **	4.37	-12.23	-11.8	10.21	3.25	13.64	4.65
52	DBW-308 × K-1317	17.17	20.51 *	12.38*	0.73	2.09	4.73	-4.31	-7.74	9.91	-6.94	5.69	-0.12
53	HI-1612 × K-9423	44.29**	26.07 **	7.37	8.36	-0.79	4.76	-2.65	-7.86	9.92	-9.98	0.41	-2.11
54	HI-1612 × DBW-278	37.01**	19.71 *	-2.44	38.82**	27.62 **	4.48	32.3**	26.27 **	8.18	-11.51	-0.87	6.84
55	HI-1612 × K-1006	33.32**	24.26 *	13.53*	-2.62	-2.98	4.79	31.89**	32.54 **	7.96	-6.9	3.84	5.57
56	HI-1612 × K-1317	14.73	18	-3.82	42.82**	38.46 **	4.4	26.58**	22.05 **	8.34	-2.97	10.21	3.13
57	HI-8830 × K-9423	33.23**	22.98 *	12.67*	45.49**	33.37 **	4.43	62.48**	46.48 **	7.53	1.5	8.25	3.22
58	HI-8830 × DBW-278	39.2**	28.49 **	4.62	12.25	3.2	4.71	13.84	8.65	8.94	-17.11*	-7.14	-14.24
59	HI-8830 × K-1006	30.36**	21.51 *	13.06*	26.28**	25.82 **	4.49	2.46	2.97	9.24	-2.92	3.54	2.84
60	HI-8830 × K-1317	28.95**	32.62 **	11.91*	30.04**	26.07 **	4.49	45.64**	40.43 **	7.71	-18.6*	-7.55	-6.04
61	HI-1654 × K-9423	45.77**	37.46 **	8.16	-14.7	-19.66 *	5.07	9.84	-0.98	9.47	-5.73	1.73	2.35
62	HI-1654 × DBW-278	39.02**	31.10 **	5.1	44.91**	36.47 **	4.41	53.44**	46.45 **	7.53	-8.11	2.94	4.84
63	HI-1654 × K-1006	31.52**	24.03 *	8.74	8.97	8.57	4.65	-14.97	-14.56	10.43	-10.11	-3.01	4.85
64	HI-1654 × K-1317	12.79	16	8.95	35.26**	31.13 **	4.45	52.39**	46.94 **	7.52	-7.75	4.78	2.45
65	Karan Poshan-2 × K-9423	12.24	8.4	-2.64	-4.23	-4.43	4.81	-4.22	-12.63	10.27	6.75	30.42 **	13.11
66	Karan Poshan-2 × DBW-278	11.5	7.69	14.02*	36.26**	35.98 **	4.42	48.64**	41.87 **	7.66	6.21	29.76 **	19.97
67	Karan Poshan-2 × K-1006	12.54	8.69	13.18*	0.63	0.42	4.75	17.86	18.44 *	8.49	8.48	32.53 **	16.04
68	Karan Poshan-2 × K-1317	11.27	14.43	24.66**	-26.01**	-26.16 **	5.21	53.89**	48.38 **	7.48	5.81	29.27 **	14.1

NPT = Number of Productive Tillers per plant, FLA = Flag Leaf Area (cm2) SL = Spike Length (cm) NSS = Number of Spikelet per Spike
**, ** significant at 5 and 1 per cent probability levels, respectively*

Cont.

SN	Name	NGS			BYP			TSW			HI		
		BP	SH	IBD	BP	SH	IBD	BP	SH	IBD	BP	SH	IBD
1	DBW-107 × K-9423	-5.35	20.10 *	7.03	43.89**	26.11 **	12.79	23.42*	3.94	1.55	-15.78	-20.37 *	-4.86
2	DBW-107 × DBW-278	11.32	31.06 **	6.98	43.41**	33.46 **	12.76	0.57	-5.9	1.67	3.87	-10.42	-4.11
3	DBW-107 × K-1006	13.86	22.57 *	7.02	9.84	13.56	12.3	-14.29	-13.93 *	1.79	0.88	-5.02	-7.44
4	DBW-107 × K-1317	10.88	11.25	7.09	20.01*	18.92 *	-0.6	4.66	0.75	1.59	-16.71	-15.57	8.17
5	HD- 3171 × K-9423	-5.83	19.49 *	-2.71	57.93**	38.41 **	12.89	7.7	-3.14	1.64	-9.73	-14.65	-3.82
6	HD- 3171 × DBW-278	7.43	26.48 **	5.7	14.89	6.92	12.32	6.95	0.07	1.6	21.32	4.62	-5.25
7	HD- 3171 × K-1006	6.59	19.75 *	7.04	17.98*	21.98 **	5.13	0.57	0.99	1.59	-18.43	-23.2*	1.32
8	HD- 3171 × K-1317	14.31	28.41 **	5.06	10.46	9.46	12.84	10.86	6.72	1.53	-1.74	-0.39	-5.62
9	EC-27051 × K-9423	-7.98	16.76	-2.07	18.37	9.13	12.6	-4.41	-19.50 **	3.17	-13.95	-18.64*	-6.41
10	EC-27051 × DBW-278	0.39	20.18 *	-5.12	3.12	-4.04	11.67	10.13	3.05	21.95	15.01	-0.81	-3.49
11	EC-27051 × K-1006	-2.35	16.91	7.05	22.79**	26.95 **	13.01	-10.87	-10.49	12.93	-17.55	-22.37*	-8.38
12	EC-27051 × K-1317	-6.54	11.89	-0.58	18.12*	17.04 *	12.74	2.52	-1.31	26.32	-33.27**	-32.36**	-5.99
13	DBW-187 × K-9423	-7.9	16.86	7.05	-3.77	-7.23	12.4	-4.77	-14.39 *	1.8	20.99	18.69*	-5.71
14	DBW-187 × DBW-278	3.94	27.65 **	7.7	1.81	-1.85	13.12	-3.36	-9.57	1.13	27.75**	25.33**	-7.52
15	DBW-187 × K-1006	8.98	33.84 **	6.97	29.29**	33.67 **	12.25	-11.32	-10.95	-2.78	-5.71	-7.5	-4.39
16	DBW-187 × K-1317	2.07	25.35 **	7.01	-0.48	-1.39	12.93	-14.77	-17.95 **	1.86	11.2	12.73	-5.21
17	PBW-644 × K-9423	-10.13	14.03	7.07	12.47	-1.11	12.71	3.8	-4	1.65	7.56	7.93	-5.88
18	PBW-644 × DBW-278	-3.49	14.48	-7.79	18.47	10.25	12.29	-1.36	-7.7	1.7	-18.65	-18.37	-6.96
19	PBW-644 × K-1006	1.87	20.84 *	0.71	34.75**	39.31 **	12.55	-5.04	-4.64	1.66	-25.78*	-25.53**	-5.88
20	PBW-644 × K-1317	3.29	22.53 *	7.02	-0.8	-1.7	13.17	-0.05	-3.78	1.65	0.81	2.2	-6.95
21	DBW-342 × K-9423	5.48	33.84 **	6.97	39.25**	22.04 **	6.91	8.42	1.67	1.58	-22.18*	-26.42**	-0.14
22	DBW-342 × DBW-278	2.92	23.21 *	0.19	50.52**	40.07 **	12.08	-5.54	-11.42	1.75	-9.48	-21.42*	-6.47
23	DBW-342 × K-1006	4.76	25.41 **	-2.71	-6.13	-2.95	13.01	-2.22	-1.81	1.62	23.19*	16	-8.13
24	DBW-342 × K-1317	-0.03	19.68 *	7.04	26.22**	25.07 **	12.24	-11.37	-14.68 *	1.8	-17.87	-16.74	-6.08
25	PBW-833 × K-9423	-0.2	28.18 **	6.99	3.3	0.72	12.67	0.06	-5.96	1.68	17.28	16.99	-7.07
26	PBW-833 × DBW-278	11.19	42.82 **	20.44	20.46*	17.45 *	13.07	-13.17	-18.39 **	-7.61	-1.75	-2	-7.16
27	PBW-833 × K-1006	8.61	39.50 **	14.71	19.33*	23.37 **	12.45	-14.16	-13.81 *	-4.91	-1.1	-1.35	-7.33
28	PBW-833 × K-1317	-0.05	28.38 **	6.99	12.83	11.81	12.35	-11.82	-15.11 *	1.81	-1	0.36	-4.53
29	K-1711 × K-9423	-5.52	19.88 *	7.04	-15.05	-9.39	12.5	-3.13	-4.13	1.65	14.8	19.77*	-4.21
30	K-1711 × DBW-278	-13.82	8.55	7.1	21.12*	29.19 **	12.4	-11.41	-12.33	1.77	-27.87**	-24.75**	-4.16
31	K-1711 × K-1006	6.56	34.24 **	5.14	-7.74	-1.59	12.34	2.22	2.65	1.57	14.14	19.08*	-7.88
32	K-1711 × K-1317	-1.72	23.80 *	5.7	-16.72	-11.17	12.78	-0.29	-1.32	1.62	16.47	21.5*	-6.64
33	PBW-902 × K-9423	-9.22	15.19	5.56	-13.47	-12.16	12.67	3.18	-6.41	-7.22	20.49	13.92	-6.8
34	PBW-902 × DBW-278	2.8	25.60 **	4.94	22.04*	23.87 **	12.27	9.96	2.88	1.57	2.68	-5.31	-6.39

35	PBW-902 × K-1006	5.11	28.42 **	4.97	22.95**	27.12 **	12.88	8.29	8.74	1.5	-6.58	-12.04	-8.14
36	PBW-902 × K-1317	5.01	28.30 **	2.52	-20.58*	-19.39 *	12.9	-1.63	-5.3	1.67	16.52	18.12	-8.15
37	PBW-870 × K-9423	-11.8	11.92	5.15	32.44**	16.07 *	12.2	9.04	4.99	1.54	-0.34	-5.77	-6.49
38	PBW-870 × DBW-278	-6.38	17.74	-4.41	7.22	-0.22	13.36	-5.3	-8.81	1.71	18.87	5.5	-6.93
39	PBW-870 × K-1006	-3.78	21.00 *	3.82	9.16	12.86	12.24	0.13	0.55	1.59	-10.74	-15.95	-7.24
40	PBW-870 × K-1317	-7.19	16.71	4.85	-4.32	-5.19	12.76	-9.42	-12.79 *	1.77	20.93*	22.6*	-6.23
41	HD-3440 × K-9423	-10.8	26.88 **	3.91	13.08	2.85	9.79	2.21	-7.88	1.7	5.72	-0.04	-1.67
42	HD-3440 × DBW-278	-10.92	26.71 **	3.47	14.14	6.22	12.3	-4.82	-10.94	1.75	27.43*	9.89	-5.29
43	HD-3440 × K-1006	-19.38*	14.67	-7.64	37.68**	42.35 **	12.57	-18.3*	-17.96 **	1.86	-23.22*	-27.7**	-5.76
44	HD-3440 × K-1317	-16.51*	18.75 *	7.55	-1.53	-2.42	12.74	-0.27	-4	1.65	-1.56	-0.21	-5.03
45	DBW-166 × K-9423	-6.2	19.67 *	3.5	22.06*	6.97	12.64	3.92	-7.7	1.7	9.31	3.35	-7.59
46	DBW-166 × DBW-278	-11.65	12.72	3.64	-0.25	-7.18	12.35	1.9	-4.65	1.66	28.53*	16.27	-5.68
47	DBW-166 × K-1006	-7.72	17.74	2.65	18.02*	22.02 **	3.38	-12.52	-12.15	2.66	-22.23*	-26.77**	4.93
48	DBW-166 × K-1317	-3.43	23.22 *	2.33	34.48**	33.25 **	12.57	5.62	1.67	1.58	-23.28*	-22.23*	-6.06
49	DBW-308 × K-9423	-9.63	14.67	1.94	9.8	-3.77	12.91	3.59	-11.41	1.75	-3.22	5.15	-6.23
50	DBW-308 × DBW-278	-5.18	11.63	5.06	27.62**	18.76 *	4.53	4.94	-1.81	1.62	-31.59**	-25.67**	3.12
51	DBW-308 × K-1006	12.99	33.00 **	1.91	32.19**	36.67 **	12.48	-15.04	-14.69 *	1.8	-24.9*	-18.4	-4.85
52	DBW-308 × K-1317	2.84	21.05 *	1.17	20.52*	19.42 *	12.33	-2.31	-5.96	1.68	-15.55	-8.25	-5.85
53	HI-1612 × K-9423	-3.44	22.53 *	7.02	42.91**	25.25 **	12.17	-3.09	-18.39 **	1.87	-17	-18.41	-5.18
54	HI-1612 × DBW-278	2.04	20.14 *	-0.17	-0.5	-7.4	12.48	-7.88	-13.81 *	1.79	27.93**	25.76**	-5.91
55	HI-1612 × K-1006	9.88	28.40 **	2.7	-8.67	-5.57	12.74	-15.47	-15.11 *	1.81	20.76	18.7*	-3.95
56	HI-1612 × K-1317	8.7	27.02 **	-2.98	27.97**	26.81 **	4.83	-0.4	-4.12	1.65	-30.44**	-29.49**	2.61
57	HI-8830 × K-9423	-8.11	16.59	4.57	49.27**	44.37 **	12.61	4.11	-12.32	1.77	-26.09*	-23.47*	-6.22
58	HI-8830 × DBW-278	-4.46	12.48	-1.34	35.3**	30.85 **	12.23	9.71	2.66	1.57	-21.08*	-18.28	-5.17
59	HI-8830 × K-1006	5.03	13.6	6.7	0.2	3.59	12.95	-1.74	-1.32	1.62	-13.29	-10.21	-3.62
60	HI-8830 × K-1317	4.11	12.6	3.11	5.8	4.84	11.98	5.91	1.96	1.58	-2.28	1.19	-5
61	HI-1654 × K-9423	-5.4	20.04 *	1.61	25.03**	31.84 **	12.12	18.06	2.89	1.57	-27.2**	-24.78**	-6.09
62	HI-1654 × DBW-278	1.82	19.88 *	7.04	13.67	19.86 *	0.06	1.57	-4.96	4.7	-29.54**	-27.19**	7.54
63	HI-1654 × K-1006	13.8	23.24 *	13.46	33.09**	40.34 **	12.82	-5.7	-5.3	1.67	-23.76*	-21.22*	-6.74
64	HI-1654 × K-1317	16.25	25.90 **	1.46	28.42**	35.41 **	12.36	9.07	4.99	1.54	-21.61*	-19*	-3.58
65	Karan Poshan-2 × K-9423	-1.06	25.54 **	7.01	33.07**	21.88 **	12.27	1.19	-12.31	1.77	-10.87	-15.73	7.01
66	Karan Poshan-2 × DBW-278	-0.16	17.54	7	-0.97	-7.84	12.38	9.71	2.66	1.57	29.6**	21.13*	0.03
67	Karan Poshan-2 × K-1006	19.25	28.37 **	6.99	-6.84	-3.68	12.28	-1.74	-1.32	1.62	19.73	12.73	2.87
68	Karan Poshan-2 × K-1317	27.2*	31.20 **	6.98	35.81**	34.58 **	12.73	5.91	1.96	1.58	-24.42*	-23.39*	-6.86

NGS = Number of Grains per Spike BYP = Biological Yield Per Plant (g) TSW = 1000 Seed Weight (g) HI = Harvest index (%)

**, ** significant at 5 and 1 per cent probability levels, respectively*

Cont.

SN	Name	SYP			CC			CTD			PC		
		BP	SH	IBD	BP	SH	IBD	BP	SH	IBD	BP	SH	IBD
1	DBW-107 × K-9423	26.84*	-0.62	7.62	18.1*	12.66	4.2	55.92**	28.92 **	2.74	12.33	9.02	5.24
2	DBW-107 × DBW-278	52.04**	19.62 **	9.61	10.58	3.41	7.31	-6.8	-2.8	3.31	7.36	12.32	5.23
3	DBW-107 × K-1006	6.1	7.74	7.68	-5.79	-11.14	7.57	-5.42	8.92	2.92	2.3	2.3	5.24
4	DBW-107 × K-1317	1.91	0.4	7.67	-4.3	0.7	7.35	-2.74	6.88	3.21	0.03	5.63	5.24
5	HD- 3171 × K-9423	46.89**	15.09 *	7.36	21.8**	20.49 **	7.08	-19.18	-15.27	3.46	9.32	8.99	5.24
6	HD- 3171 × DBW-278	42.04**	11.76	7.68	-12.33	-13.27	7.61	2.87	7.85	3.21	12.17	17.35 *	5.23
7	HD- 3171 × K-1006	-7.62	-6.2	7.9	1.73	0.64	7.35	4.2	20.00 *	2.82	12.35	12.35	5.23
8	HD- 3171 × K-1317	10.04	8.41	7.68	-1.77	3.36	7.31	-0.59	9.25	2.73	4.79	10.66	5.23
9	EC-27051 × K-9423	13.27	-11.25	7.69	14.54	9.26	7.22	-28.28*	-27.20 **	2.85	10.59	7.32	5.24
10	EC-27051 × DBW-278	19.09	-6.3	7.64	23.3**	15.94 *	16.02	27.11*	32.58 **	3.03	1.78	6.48	5.24
11	EC-27051 × K-1006	-3.76	-2.28	6.07	7.28	1.18	7.34	52.66**	75.81 **	2.85	9.81	9.81	5.23
12	EC-27051 × K-1317	-19.79*	-20.98 **	7.32	-3.82	1.21	7.34	-7.63	1.51	3.26	7.19	13.2	5.23
13	DBW-187 × K-9423	10.66	10.42	7.68	17.75*	17.72 *	7.11	13.95	15.91	3.14	0.35	8.14	5.24
14	DBW-187 × DBW-278	22.88**	22.61 **	7.55	5.67	5.64	7.27	34.12**	39.89 **	2.32	-2.74	4.81	5.24
15	DBW-187 × K-1006	19.46*	21.30 **	7.32	12.34	12.32	9.19	-38.38**	-29.03 **	3.69	1.88	9.78	5.23
16	DBW-187 × K-1317	10.17	9.93	7.39	0.42	5.67	7.27	-24.85*	-17.42	3.49	-2.46	5.11	5.24
17	PBW-644 × K-9423	18.33	6.76	7.68	-6.77	-7.5	3.67	-8.31	2.04	3.26	6.73	3.58	5.24
18	PBW-644 × DBW-278	-1.39	-11.03	7.33	-5.26	-6.01	7.46	-34.49**	-27.10 **	3.65	-4	0.44	5.24
19	PBW-644 × K-1006	2	3.57	7.32	8.47	7.61	7.24	-15.03	-2.15	3.3	-0.36	-0.36	5.24
20	PBW-644 × K-1317	1.91	0.4	7.19	-0.93	4.25	7.29	45.89**	62.37 **	2.9	-7.84	-2.68	5.24
21	DBW-342 × K-9423	14.36	-10.4	7.12	23.19**	20.98 **	18.99	54.45**	36.34 **	3.01	6.02	5.87	5.24
22	DBW-342 × DBW-278	39.72**	9.93	6.25	3.71	1.86	7.33	10.21	14.95	2.73	-7.73	-3.47	5.24
23	DBW-342 × K-1006	10.9	12.61	7.43	13.1	11.08	7.19	-7.56	6.45	1.62	6.99	6.99	5.24
24	DBW-342 × K-1317	4.85	3.3	7.46	7.65	13.28	7.17	12.52	23.66 *	3.09	9.08	15.19 *	5.23
25	PBW-833 × K-9423	21.26*	17.16 *	7.13	-4.28	-8.68	4.92	31.67*	10.43	3.18	13.63	10.27	5.23
26	PBW-833 × DBW-278	17.74*	13.75 *	7.22	22.54*	14.59 *	7.15	24.23*	29.57 **	3.05	3.81	8.61	5.24
27	PBW-833 × K-1006	19.68*	21.52 **	7.83	18.5*	11.76	11.98	41.83**	63.33 **	2.89	5.38	5.38	5.24
28	PBW-833 × K-1317	11.99	10.33	7.12	14.12	20.09 **	1.52	1.57	11.61	3.17	-1.03	4.51	5.24
29	K-1711 × K-9423	-2.01	6.92	7.09	-7.03	-7.18	7.49	61.69**	68.82 **	2.87	-2.81	2.08	5.24
30	K-1711 × DBW-278	-12.63	-4.67	6.99	4.24	4.07	7.3	28.84*	34.52 **	3.02	5.75	11.07	5.23
31	K-1711 × K-1006	7.39	17.17 *	7.25	12.29	12.11	10.49	36.6**	57.31 **	2.92	5.36	10.66	5.23
32	K-1711 × K-1317	-1.25	7.75	7.18	10.25	16.01 *	-3.17	26.22*	38.71 **	3	1.63	7.32	5.24
33	PBW-902 × K-9423	14.18	0.38	6.98	12.96	7.76	7.24	8.79	15.81	3.14	-7.06	6.45	5.24
34	PBW-902 × DBW-278	32.19**	16.21 *	7.28	19.47*	11.71	7.19	46.87**	56.34 **	2.74	-4.13	9.81	5.23

35	PBW-902 × K-1006	10.06	11.76	7.44	-0.8	-6.44	7.21	66.11**	91.29 **	2.8	-1.19	13.17	5.23
36	PBW-902 × K-1317	-3.33	-4.76	7.86	12.38	18.25 *	26.27	-17.12	-8.92	3.37	-5.58	8.14	5.24
37	PBW-870 × K-9423	39.58**	9.37	7.52	-2.74	-4.59	7.44	43.18**	43.33 **	2.74	6.05	4.81	5.24
38	PBW-870 × DBW-278	33.55**	5.07	7.2	18.26*	16.01 *	0.22	40.93**	46.99 **	2.96	4.96	9.81	5.23
39	PBW-870 × K-1006	-6.6	-5.16	7.6	-2.95	-4.79	7.44	0.19	15.38	2.73	5.11	5.11	5.24
40	PBW-870 × K-1317	17.62*	15.87 *	7.7	-10.11	-5.41	7.45	20.65	32.58 **	2.81	-1.94	3.55	5.24
41	HD-3440 × K-9423	29.69**	1.85	7.46	-7.68	-11.93	7.58	16.12	37.10 **	3.01	3.49	0.44	5.24
42	HD-3440 × DBW-278	47.27**	15.87 *	7.4	13.88	6.49	7.26	-38.8**	-27.74 **	3.66	-4.75	-0.36	5.24
43	HD-3440 × K-1006	1.37	2.93	7.67	17.07	10.42	7.2	-5.46	11.61	3.17	-2.68	-2.68	5.24
44	HD-3440 × K-1317	-1.91	-3.37	7.71	-15.13	-10.69	7.56	31.88**	55.70 **	2.92	0.28	5.9	5.24
45	DBW-166 × K-9423	40.88**	10.38	7.33	22.34**	19.33 **	7.09	38.77**	38.17 **	2.89	-7.42	-3.47	5.24
46	DBW-166 × DBW-278	36.91**	7.72	7.62	8.38	5.71	7.27	5.57	10.11	3.19	2.27	6.99	5.24
47	DBW-166 × K-1006	-12.4	-11.05	7.66	11.45	8.7	7.23	-20.92*	-8.92	3.37	10.48	15.19 *	5.23
48	DBW-166 × K-1317	5.15	3.59	7.67	-0.05	5.18	7.28	0.78	10.75	6.82*	4.42	10.27	5.23
49	DBW-308 × K-9423	7.16	0.04	7.56	8.49	3.49	7.3	30.27**	32.80 **	4.86	11.46	8.17	5.24
50	DBW-308 × DBW-278	-5.57	-11.85	7.41	17.83*	10.2	7.21	46.8**	53.12 **	2.93	0.18	4.81	5.24
51	DBW-308 × K-1006	8.76	10.43	7.37	18.22*	11.5	11.34	-16.43	-3.76	3.32	9.78	9.78	5.23
52	DBW-308 × K-1317	11.16	9.51	7.46	7.72	13.35	11.83	2.25	12.37	3.17	-0.47	5.11	5.24
53	HI-1612 × K-9423	19.85	2.16	7.67	28.93**	22.99 **	7.05	-16.67	-28.49 **	3.67	1.69	3.55	5.24
54	HI-1612 × DBW-278	36.58**	16.41 *	7.52	28.35**	20.02 **	12	9.79	14.52	1.62	-4	0.44	5.24
55	HI-1612 × K-1006	7.89	9.55	7.4	8.49	2.32	7.32	-23.9*	-12.37	3.42	-2.12	-0.33	5.24
56	HI-1612 × K-1317	-9.19	-10.54	7.88	-6.89	-2.03	7.39	46.67**	61.18 **	2.9	-7.84	-2.68	5.24
57	HI-8830 × K-9423	17.52	10.34	7.68	19.26*	13.77	7.16	12.81	12.69	3.17	4.96	5.9	5.24
58	HI-8830 × DBW-278	13.87	6.92	7.68	9.49	3.81	7.3	51.24**	57.74 **	2.92	-7.73	-3.47	5.24
59	HI-8830 × K-1006	-10.4	-9.02	7.83	-7.6	-12.39	7.59	50.51**	73.33 **	2.86	6.04	6.99	5.24
60	HI-8830 × K-1317	6.2	4.62	7.39	-11.5	-6.87	7.48	25.34*	37.74 **	4.08	9.08	15.19 *	5.23
61	HI-1654 × K-9423	-12.94	-0.87	7	12.72	16.81 *	7.12	-18.29	1.83	3.26	11.15	10.27	5.23
62	HI-1654 × DBW-278	-23.4**	-12.79	7.57	-3.97	-0.49	-6.74	-43.57**	-29.68 **	3.7	3.81	8.61	5.24
63	HI-1654 × K-1006	-2.91	10.54	7.68	5.8	9.63	26.1	-27.35**	-9.46	3.38	11.09	11.09	5.23
64	HI-1654 × K-1317	-3.68	9.67	9.44	-8.84	-4.07	7.43	10.61	37.85 **	1.89	4.79	10.66	5.23
65	Karan Poshan-2 × K-9423	12.96	2.16	18.04	0.25	-3.7	7.42	42.14**	34.19 **	5.39*	9.69	7.32	5.24
66	Karan Poshan-2 × DBW-278	23.56*	11.74	13.05	19.67*	14.95 *	7.14	57.84**	64.62 **	2.89	1.78	6.48	5.24
67	Karan Poshan-2 × K-1006	6.67	8.32	14.77	13.07	8.61	4.81	21.85*	40.32 **	8.06**	9.84	9.84	5.23
68	Karan Poshan-2 × K-1317	3.71	2.17	5.9	0.55	5.81	7.14	-0.49	9.35	4.08	7.14	13.14	5.23

**, ** significant at 5 and 1 per cent probability levels, respectively*

SYP = Seed Yield Per Plant (g), CC = Chlorophyll Content (µmol m−2) CTD = Canopy Temperature Depression (°C) PC = Protein Content (%)

(xiv) Chlorophyll content (µmol m^{-2})

The significantly positive heterosis for chlorophyll content was shown by 16 crosses over better parent and 14 crosses over standard check. On the other side the extent of inbreeding depression ranged from -6.74 to 26.27 for chlorophyll content. None of the hybrids were showing significant negative inbreeding depression. HI-1654 × DBW-278 (-6.74), K-1711 × K-1317 (-3.17) and PBW-870 × DBW-278 (0.22) showing lowest value of inbreeding depression among all crosses in increasing order of merit for chlorophyll content. This finding is supported by **Kumar *et al.* (2017).**

(xv) Canopy temperature depression (°C)

Out of 68 F_1s, 28 exhibited significantly positive heterobeltiosis and 32 exhibited significantly positive economic heterosis for canopy temperature depression. PBW-902 × K-1006 exhibited highest value of heterosis over better parent (66.11**) as well as over standard check (91.29**). The extent of inbreeding depression ranged from 1.62 to 8.06* for canopy temperature depression. This indicates some of the cross combinations create cool micro-environment during high temperature situation as supported by **Kumar *et al.* (2017)**.

(xvi) Protein content (%)

The extent of heterosis for protein content over better parent ranged from -7.84 (HI-1612 × K-1317) to 13.63 (PBW-833 × K-9423) and over standard check from -3.47 (PBW-644 × W-278) to 17.35** (HI-1654 × K-9423). Top three crosses showing positive economic heterosis in order of merits were HI-1654 × K-9423 (17.35*), DBW-342 × K-9423 (15.19*) and DBW-107 × K-1317 (15.19*) for protein content. None of the hybrids were showing significant negative inbreeding depression. These results are accordance with **Yadav *et al.* (2025)**.

Conclusions

The present investigation revealed presence of wide genetic variation among crosses for yield and its contributing traits. For traits days to 50% heading and days to maturity, desirable negative heterosis with positive inbreeding depression was observed, indicating scope for selecting early maturing genotypes. Yield-contributing traits including number of tillers, productive tillers, flag leaf area, spike length, grains per spike, biological yield, and seed yield per plant exhibited high levels of positive and significant heterosis, with some crosses like PBW-833 × DBW-278, DBW-107 × DBW-278, and HI-8830 × K-9423 emerging as promising combinations. Importantly, seed yield per plant and related physiological traits such as canopy temperature depression, chlorophyll content, and protein content also showed significant heterotic expression, demonstrating their role in yield stability and stress tolerance.

تعليق عليه [طارق10]: The conclusion notes that some crosses can be utilized in breeding programs. However, it does not clarify how exactly these crosses will be exploited (e.g., as parental lines for hybrid development, or for varietal improvement). Recommendations are vague and should be made more practical and targeted.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

طارق[11] تعليق عليه: Add doi to references or research link

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