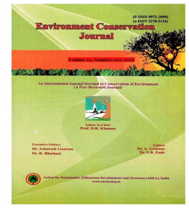
Environment Conservation Journal 22 (3):85-95, 2021

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Estimation of heterosis for grain yield and yield attributes in bread wheat genotypes utilizing line x tester analysis (*Triticum aestivum* L. em. Thell)

Amitava Roy ✉
Department of Genetics and Plant Breeding, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar,Uttarakhand, India

Anil Kumar
Department of Genetics and Plant Breeding, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Karthick Babu S.
Department of Genetics and Plant Breeding, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Anu Singh
Department of Genetics and Plant Breeding, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Simran Sisodiya
Department of Genetics and Plant Breeding, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

ARTICLE INFO

Received : 28 April 2021
Revised : 22 June 2020
Accepted : 06 July 2021

Available online: 19 November 2021

Key Words:
Bread Wheat
Genetic divergence
Grain yield
Heterosis
Line x tester cross
Transgressive Seggregants

ABSTRACT

Eleven genotypes of bread wheat were crossed with three testers in the rabi season of 2018-19 inline x tester mating fashion to obtain 33 F1 hybrids, which were evaluated with parents and two standard checks of wheat viz., UP 2855 and HD 2967. The experiment was laid out in randomized block design with three replications at Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar in the rabi season 2019-20. Observations were recorded on various qualitative and quantitative characters including grain yield. The results obtained revealed significant differences among all the genotypes, indicating the presence of aconsiderable amount of genetic variability. The cross combinations SOKOLL x HI 1621, followed by QBP 12-11 x HI 1621, NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/ 2*PASTOR/5/… x HD 3237 were observed to be the better heterotic F1s in terms of grain yield. The hybrid QLD 75 x HI 1621 was identified as the best heterotic combination for grain weight per spike and harvest index. Whereas, for grains per spike F1, NW 6036 x HI 1621, for 1000 grain weight F1, SOKOLL x HD3237, for spike length F1, NAC/TH.AC//3*PVN/3/ MIRLO/BUC/4/2*PASTOR/5/… x HD 3237, for peduncle length F1, VORB/4/D67.2/PARANA 66.270 x HI 1621 and for days to 75% heading and days to maturity F1, PRL/2*PASTOR*2//FH6-1-7/3/KINGBIRD#1//… x PBW 725 were observed to be the better heterotic combinations. The crosses with higher heterotic values may provide an opportunity for isolation of desirable purelines in advanced generations.

Introduction

Bread wheat (*Triticum aestivum* L. em. Thell) is one of the most central food grain crops serving as staple food for a large section of people in Asia and also throughout the world. The scenario of wheat production has been changed significantly over the past few decades especially post green revolution. Currently, India is the second-largest producer of bread wheat in the world after China with a humongous production of 101.20 million tones in the year 2018-19. With the population expansion,

Corresponding author E-mail: *amitavo66@gmail.com*
Doi: https://doi.org/10.36953/ECJ.2021.22310

there is an urgent requirement for an increase in wheat production potential as crop acreage cannot be extended beyond a certain ceiling. In response to this challenge, there is a prime breeding interest in developing superior high yielding cultivars of the crop.

One of the imperative approaches of developing high yielding cultivars is through the exploitation of heterosis and hybrid vigour. Heterosis has been first reported by Shull (1908) in maize. It is explained as the greater performance of F1s in comparison to their parents. The crosses with higher heterotic values may provide a better opportunity for isolation of desirable purelines in advanced generations as opposed to the hybrids with lower heterosis (Sharif *et al*., 2001). Analysis of heterosis thus enables a breeder to eliminate less productive cross combinations in F1 generation itself (Ibrahim *et al*., 2020). The exploitation of heterosis heavily depends upon the genetic divergence and the nicking ability between the lines to be utilized as parents. Some parents will perform better than others and will have better nicking ability than the rest of the crosses. Therefore, proper identification of parents is one of the most essential steps in developing superior high yielding hybrids. Selection of superior cross combinations will allow the breeder to focus on those parents who will be passing superior performances in the progeny and it will be helpful in taking more productive progenies into consideration. Exploitation of heterosis in wheat has also been observed earlier by Solomon *et al.* (2007), Bilgin *et al.* (2011), Devi *et al.* (2013), Singh *et al*. (2013), Pankaj *et al.* (2015), Jaiswal *et al.* (2018), Hussain *et al.* (2019), Khokar*et al.* (2019) and Adhikari *et al.* (2020).

Keeping in view all the previously mentioned aspects, the present research investigation was undertaken to estimate the magnitude of heterosis for yield and yield attributes in 33 F1s developed by crossing eleven lines with three testers in a line x tester mating scheme. The present investigation will be important in the purview of selecting suitable parents for hybridization and the development of superior transgressive segregants which will have enhanced yield potential.

Material and Methods

The experimental material of the present research investigation was generated by crossing eleven lines with three testers of bread wheat. These 33 F1s along with fourteen parents and two standard checks viz., UP 2855 and HD 2967 were then evaluated in rabi 2019-20 at Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar in randomized block design with three replications. The details of lines, testers and checks are presented in Table 1. Each plot consisted of two rows of one-meter length and the plants were spaced at 20 cm between row to row and 10 cm between plant to plant. Recommended cultural practices were provided accordingly to the plants. Observations were recorded on thirteen characters viz., days to 75% heading, days to maturity, number of productive tillers per plant, plant height, peduncle length, spike length, number of spikelets per spike, number of grains per spike, grain weight per spike, 1000 grain weight, biological yield per plant, grain yield per plant and harvest index.

Table 1: Lines, Testers and Checks utilized for the study

SN	Lines	Testers	Checks
1	QBP 12-11	HD 3237	UP 2855
2	SOKOLL	PBW 725	HD 2967
3	WH 1182	HI 1621	
4	QLD 75		
5	PRL/2*PASTOR*2//FH6-1-7/3/KINGBIRD#1//…		
6	QLD 65		
7	NW 6036		
8	K 1402		
9	VORB/4/D67.2/PARANA 66.270		
10	HPBW 01		
11	NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/…		

Statistical Analysis

Heterosis is expressed as the performance of F1 or hybrid in terms of percent increase or decrease over mid parent (relative heterosis), better parent (heterobeltiosis) and check parent (standard heterosis) values for various quantitative characters. These were calculated for each character using the following formula

$$\textbf{Relative heterosis} = \frac{(\overline{F_1} - \overline{MP})}{\overline{MP}} \text{ X } 100$$

Heterobeltiosis = $\frac{(\overline{F_1} - \overline{BP})}{\overline{BP}}$ X 100

Standard heterosis = $\frac{(\overline{F_1} - \overline{CP})}{\overline{CP}}$ X 100

Where,

$\overline{F_1}$ = Mean value of F_1 hybrid,

$\overline{MP}$ =Mid Parent value i.e. $(\overline{P_1} + \overline{P_2})/2$

$\overline{P_1}$ = Mean performance of parent one

$\overline{P_2}$ = Mean performance of parent two

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

$\overline{CP}$ = Mean performance of the check parent

The critical differences in the magnitude of relative heterosis and better parent heterosis were tested according to the method suggested by Panse and Sukhatme (1961). The C.D. were calculated by using standard errors as follows.

a. C.D. for mid parent or relative heterosis = SE of $(\overline{F1} - \overline{MP})$ x $t_{error\ df}$

b. C.D. for better parent heterosis = SE of $(\overline{F1} - \overline{BP})$ x $t_{error\ df}$

Where,

$$\text{SE of } (\overline{F1} - \overline{MP}) = \sqrt{\frac{3M_e}{2r}}$$

$$\text{SE of } (\overline{F1} - \overline{BP}) = \sqrt{\frac{2M_e}{r}}$$

M_e = error mean square

r = number of replications

$t_{error\ df}$ = table value of 't' at error degree of freedom.

Results and Discussion

Analysis of variance revealed that mean sum of squares for all the characters was highly significant ($P \leq 0.05$). Analysis of variance for different characters is presented in Table 2a and 2b. Variance due to F1s was also found to be significant which indicated that hybrids differ significantly from each other. Comparison of mean performance of F1s with that of parents also showed a significant difference between hybrid performances with that of the parents. For the majority of the characters, a substantial amount of heterosis was observed. Almost all the characters exhibited a sizeable extent of heterosis over the mid parent, better parent and check parent values. Although, the magnitude of heterosis was varying significantly for different traits.

Estimation of heterosis for various quantitative traits. The percent heterosis for the various characters under stiudy is presented in the Table 3a ,3b and 3c

For days to 75% heading, amount of heterosis over better parent varied in a range from 4.511% to 4.580%. Cross combination VORB/4/D67.2/ PARANA 66.270 x PBW 725 (-4.511%) followed by K 1402 x HD 3237 (-4.15%) showed good amount of significant negative heterobeltiosis. Whereas, the F1 K 1402 x HD 3237 (-5.22%) was observed to possess considerable negative heterosis for the trait over the check parent HD 2967. Development of early flowering varieties is one of the major breeding objective under intensified modern cultivation systems to incorporate more no. of crops under rotation. The cross combination VORB/4/D67.2/ PARANA 66.270 x PBW 725 (-4.511%) exhibited significant heterosis over mid-parent, better parent and check values. Thus it can be utilized for heterosis exploitation for the characters.

Days to maturity

Relative heterosis for days to maturity was ranging from -5.4% to 3.27%, while heterobeltiosis for the trait ranged from -6.122% to 2.33%. Cross combination VORB/4/D67.2/PARANA 66.270 x PBW 725 exhibited the highest negative heterosis over the mid parent and better parent values, whereas F1 VORB/4/D67.2/PARANA 66.270 x PBW725 followed by QBP 12-11 x HI1621 were shown to have significant negative heterosis over the checks UP 2855 and HD 2967. It is advantageous to select the cross combinations which possesses significant negative heterosis in terms of maturity traits while breeding for the higher yield. Present study revaeals F1 VORB/4/D67.2/PARANA 66.270 x PBW 725 exhibited significant negative heterosis for the trait over mid-parent, better parent and check values. Hence, it can be further exploited while breeding for early maturity.

Number of tillers per plant

Relative heterosis for a number of tillers per plant varied from -13.78% to 39.15%. Crosses QLD 65 x HI 1621(36.73%) and QBP 12-11 x HI 1621 (27.17%) exhibited the highest significant positive heterosis over the mid parent and better parent values. In terms of standard heterosis cross

Table 2a: Analysis of Variance table for Combining ability

Source of variation	d. f.	D75H	DM	NTPP	PH	PL	SL	NSPS
Replication	2	12.660	20.959	25.309	257.035	12.586	2.432	10.877
Treatment	48	10.192**	16.418**	13.332**	43.888**	9.068**	0.818**	1.493**
Error	96	2.910	5.834	2.579	18.238	5.124	0.296	0.823

Table 2b: Analysis of Variance table for Combining ability

Source of variation	d. f.	NGPS	GWPS	GW	BYPP	GYPP	HI
Replication	2	43.257	0.002	0.223	1,032.037	170.477	5.255
Treatment	48	86.169**	0.119**	20.243**	376.385**	81.302**	12.152**
Error	96	8.029	0.007	1.122	68.052	9.524	1.898

combination, QLD 65 x HI 1621 followed by HPBW 01 x HI 1621 was observed to be superior heterotic combinations. Number of productive tillers per plant plays an important role while breeding for the increased yield. Higher number of productive tillers helps in attaining increased economic product of the crop. In the present investigation cross combinations Crosses QLD 65 x HI 1621(36.73%) and QBP 12-11 x HI 1621 (27.17%) were adjudged to be the best performers for the trait. Therefore, these hybrids are recommended for further exploitation in breeding programmes for higher yield

Plant height (cm)

Cross combination K 1402 x HI 1621 (-14.95%) followed by K 1402 x PBW 725 (-12.72%) exhibited high estimates of significant negative heterobeltiosis for plant height. Heterobeltiosis for the character was observed in a range of -14.95% to 6.78%. Relative heterosis for the trait was varying from 7.89% to 10.12%. Hybrid QBP 12-11 x HD 3237 (-7.89%) showed significant negative heterosis for the trait. In wheat dwarf plants are more preferrable in comparison to the taller plants as the former possesses higher input responsivenes with better lodging resistance. Our investigation reveals hybrid QBP 12-11 x HD 3237 (-7.89%) to possess significant negative heterosis in terms of plant height. Hence, it should be utilized for the development dwarf lines.

Peduncle length (cm)

For peduncle length range of relative heterosis varied between -11.55% to 12.15%. Cross combination K 1402 x HI 1621 (-11.55%) expressed significant negative relative heterosis and F1 QLD 65 x HI 1621 (-15.76%) was observed to possess the highest heterobeltiosis for the trait. While, the hybrid QLD 75 x PBW 725 (-11.30%) had possessed the highest heterosis over the check HD 2967. Peduncle length is one of the important contributors towards higher grain yield. In the present research experiment cross combination PRL/2*PASTOR*2//FH6-1-7/3/KINGBIRD#1//… x PBW 725 was observed to possess significant positive heterosis over mid parent values, whereas, hybrid VORB/4/D67.2/PARANA 66.270 x HI 1621 exhibited significant positive heterosis over the standard parent UP 2855. Therefore, these crosses could be further utilized for exploitation of heterosis for the concerned trait.

Spike length (cm)

Spike length is an important trait in the purview of obtaining higher yield potential. Relative heterosis for the trait ranged -11.74% to 7.007%. Significant positive heterosis for the trait was exhibited by the cross NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2 *PASTOR/5/… x HD 3237 (7.007%). The hybrid also possessed significant positive heterosis over the check parent UP 2855. Spike length is considered as an important yield attribute in the purview of breeding for increased productivity. Therefore, higher significant positive heterosis is desirable for the trait. In the present investigation cross NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2 *PASTOR/5/… x HD 3237 (7.007%) observed with significant desirable heterosis for the trait and is recommended for utilization in breeding programmes aiming at increased yield levels.

Number of spikelets per spike

In terms of the trait number of spikelets per spike magnitude of relative heterosis was observed from -5.58% to 9.45%. The cross-combination QLD 65 x HD 3237 (9.45%) observed to possess high significant heterosis over both mid parent and better parent values and also over the check UP 2855. Crosses with higher significant positive heterosis

Table 3a: Percent heterosis in F1s over mid parent (MP), better parent (BP) and checks for Days to 75% heading, Days to maturity, Number of tillers per plant and Plant height(cm)

Crosses	Days to 75% heading				Days to maturity				Number of tillers per plant				Plant height (cm)			
QBP 12-11 X HD 3237	-0.38	-0.38	0	-2.61	-1.71	-1.84	-4.36**	-5.09**	13.77	3.51	6.92	8.66	-7.89*	-7.97*	-4.34	-3.66
QBP 12-11 x PBW 725	-3.03 *	-3.76 *	-1.92	-4.48 **	0	-1.53	-1.03	-1.78	26.33**	19.02*	13.95	15.8	-4.33	-4.83	-1.07	-0.37
QBP 12-11 X HI 1621	-0.77	-1.53	-1.15	-3.73 *	-2.63*	-2.63	-5.13**	-5.85**	38.20**	27.17**	28.12**	30.19**	-0.95	-4.6	- 0.84	-0.14
SOKOLL X HD 3237	1.71	1.52	2.3	-0.37	0.79	0.26	-1.54	-2.29	16.72*	10.1	13.74	15.58	-3.25	-5.71	3.09	3.82
SOKOLL X PBW 725	-0.57	-1.13	0.77	-1.87	-1.42	-2.55	-2.05	-2.8	-3.35	-5.45	-9.48	-8.01	-6.77*	-9.53*	-1.09	-0.38
SOKOLL X HI 1621	2.88 *	1.9	2.68	0	1.44	1.04	-0.77	-1.53	21.26**	15.75	16.61	18.51*	2.55	-3.58	5.42	6.17
WH 1182 X HD 3237	3.23 *	2.64	4.21 *	1.49	1.31	0.52	-0.77	-1.53	-3.92	-6.6	-3.51	-1.95	1.34	-0.62	3.13	3.86
WH 1182 XPBW 725	3.20 *	3.01	4.98 **	2.24	0.64	-0.26	0.26	-0.51	13.06	12.01	9.27	11.04	4.27	2.7	5.64	6.39
WH 1182 X HI 1621	3.63 *	2.26	3.83 *	1.12	1.18	0.52	-0.77	-1.53	25.89**	23.89**	24.81**	26.84**	1.05	-0.72	-0.96	-0.26
QLD 75 X HD 3237	4.58 **	4.58 **	4.98 **	2.24	2.36	1.56	0.26	-0.51	-5.82	-14.72*	8.63	10.39	-7.24*	-7.5	-4.01	-3.33
QLD 75 X PBW 725	0.76	0	1.92	-0.75	-0.9	-1.79	-1.28	-2.04	5.97	-7.19	18.21*	20.13*	-3.9	-4.06	-1	-0.3
QLD 75 X HI 1621	4.23 **	3.44 *	3.83 *	1.12	0.92	0.26	-1.03	-1.78	-3.83	-13.88*	9.69	11.47	4.04	0.55	3.75	4.49
PRL/2*PASTOR*2//FH6-1-7/3/KINGBIRD#1//… X HD 3237	-1.54	-2.29	-1.92	-4.48 **	2.13	1.32	-1.54	-2.29	0	-3.09	0.11	1.73	2.38	-0.61	3.14	3.87
PRL/2*PASTOR*2//FH6-1-7/3/KINGBIRD#1//… X PBW 725	-3.05 *	-4.51 **	-2.68	-5.22 **	-3.01*	-5.36**	-4.87**	-5.60**	-6.03	-6.59	-9.48	-8.01	0.62	-1.89	0.91	1.62
PRL/2*PASTOR*2//FH6-1-7/3/KINGBIRD#1//… X HI 1621	-0.78	-0.78	-1.92	-4.48 **	-1.46	-2.37	-4.87**	-5.60**	19.61*	17.34*	18.21*	20.13*	5.08	4.3	1.92	2.64
QLD 65 X HD 3237	1.32	0	3.07	0.37	0.13	-2.02	-0.51	-1.27	20.00**	19.39*	24.60**	26.62**	3.5	0.59	4.39	5.13
QLD 65 X PBW 725	-0.56	-1.12	1.92	-0.75	-2.79*	-3.28*	-1.79	-2.54	9.21	4.69	9.27	11.04	3.75	1.28	4.17	4.91
QLD 65 X HI 1621	0.19	-1.86	1.15	-1.49	-3.35*	-5.30**	-3.85*	-4.58**	39.15**	36.73**	42.71**	45.02**	2.92	2.04	-0.06	0.65
NW 6036 X HD 3237	-0.56	-2.21	1.53	-1.12	1.03	-1.26	0.51	-0.25	17.11*	17.11*	20.98*	22.94**	0.93	0.14	5.56	6.31
NW 6036 X PBW 725	0.19	-0.74	3.07	0.37	-0.63	-1.26	0.51	-0.25	0.16	-3.51	-0.32	1.3	-0.01	-1.22	4.12	4.86
NW 6036 X HI 1621	2.84 *	0.37	4.21 *	1.49	-1.42	-3.53*	-1.79	-2.54	-13.78	-14.85	-12.03	-10.61	-0.9	-5.19	-0.07	0.64
K 1402 X HD 3237	-3.61 *	-4.15 *	-2.68	-5.22 **	-0.26	-0.78	-2.56	-3.31*	22.81**	9.96	13.59	15.43	-6.31*	-11.40**	3.15	3.88
K 1402 X PBW 725	-1.32	-1.5	0.38	-2.24	-1.42	-2.55	-2.05	-2.8	17.65*	9.01	4.37	6.06	-7.32*	-12.72**	1.61	2.33
K 1402 X HI 1621	-1.34	-2.64	-1.15	-3.73 *	-1.97	-2.35	-4.10**	-4.83**	16.29*	5.29	6.07	7.79	-6.90*	-14.95**	-0.99	-0.29
VORB/4/D67.2/PARANA 66.270 X HD 3237	3.41 *	2.63	4.60 **	1.87	3.27*	2.33	1.28	0.51	-13	-15.53*	-7.35	-5.84	-3.42	-6.69	3.87	4.6
VORB/4/D67.2/PARANA 66.270 X PBW 725	-4.51 **	-4.51 **	-2.68	-5.22 **	-5.40**	-6.12**	-5.64**	-6.36**	-10.83	-16.50*	-8.41	-6.93	-5.77	-9.35*	0.91	1.63
VORB/4/D67.2/PARANA 66.270 X HI 1621	1.15	-0.38	1.53	-1.12	-0.78	-1.55	-2.56	-3.31*	-9.92	-13.59	-5.22	-3.68	10.12**	2.68	14.30* *	15.11**
HPBW 01 X HD 3237	2.48	2.28	3.07	0.37	1.31	0.78	-1.03	-1.78	-12.96	-14.51	-8.41	-6.93	-2.23	-4.92	4.42	5.16
HPBW 01 X PBW 725	0.19	-0.38	1.53	-1.12	0.13	-1.02	-0.51	-1.27	-11.81	-16.50*	-10.54	-9.09	-2.27	-5.37	3.92	4.66
HPBW 01 X HI 1621	-1.34	-2.28	-1.53	-4.10 *	-1.7	-2.09	-3.85*	-4.58**	24.39**	20.68*	29.29**	31.39**	-0.95	-7.06	2.07	2.8
NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/…X HD 3237	0.96	0.38	0.77	-1.87	0.66	0.53	-2.31	-3.05*	14	5.77	9.27	11.04	6.83*	4.8	8.75*	9.52*
NAC/TH-AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/…X PBW 725	0.95	-0.38	1.53	-1.12	-0.26	-2.04	-1.54	-2.29	-3.3	-7.01	-10.97	-9.52	1.95	0.45	3.32	4.06
NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/…X HI 1621	2.51	2.32	1.53	-1.12	2.37	2.11	-0.51	-1.27	-1.58	-7.61	-6.92	-5.41	8.72*	6.78	6.6	7.35

***, ** significant at 5% and 1% probability levels, respectively. D75H = Days to 75%**

for number of spikelets per spike could be utilized for the development of high yielding cultivars. Our study reveals cross combination QLD 65 x HD 3237 (9.45%) to possess with substantial positive heterosis over mid-parent, better parent and check values. Therefore, these cross combinations should be preferred in breeding programmes.

Number of grains per spike

The number of grains per spike is an important yield attributing trait which enhances the productive potential of the crop. The cross HPBW 01 x PBW 725 followed by NW 6036 x HI 1621 exhibited significant positive heterosis over the mid parent and better parent values. While the F1 NW 6036 x HI 1621 exhibited the highest significant positive heterosis over the checks. Therefore, these crosses can be further utilized in the breeding programme. Higher number of grains per spike results in overall increase of the yield levels. Here the hybrids HPBW 01 x PBW 725 followed by NW 6036 x HI 1621 high significant positive heterosis for the trait. Thus, these could be further exploited for the trait and in breeding for increased production.

Grain weight per spike (g)

The crosses K 1402 x HD 3237 followed by QLD 75 x HI 1621 expressed high significant positive heterosis over mid parent, better parent and check values for grain weight per spike. Hence, these cross combinations are recommended for further utilization in breeding programme to exploit hybrid vigour. Higher values for grain weight per spike ultimately results in higher yield levels. Therefore, crosses with significantly higher positive heterosis are desirable for developing high yielding cultiuvars. In our study K 1402 x HD 3237 followed by QLD 75 x HI 1621 observed with higher positive heterosis for the concerned character. Hence, these hybrids can further be exploited for higher heterosis for the character.

Thousand grain weight (g)

Thousand grain weight is one of the important indicators of total grain yield, which enhances the overall productivity of the crop. In our present investigation QLD 65 x HD 3237 and SOKOLL x HD 3237 were observed to have higher positive heterosis over the mid parent and better parent, whereas, cross combination SOKOLL x HD 3237 followed by NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/… x HI 1621 were observed for having higher significant positive heterosis over the checks UP 2855 and HD 2967 and could be further exploited for the trait. Thousand grain weight is an important yield indicator which has direct influence on the overall yield. It is desirable to select lines and crosses expressing higher values for the trait in order to increase total output levels. Hybrids QLD 65 x HD 3237 and SOKOLL x HD 3237 were observed with higher positive heterosis for the trait and these are recommended for further utilization in breeding programmes.

Biological yield per plant (g)

For the trait biological yield per plant QBP 12-11 x HI 1621 showed higher significant positive heterosis over the mid parent and better parent and the cross combination PRL/2*PASTOR*2//FH6-1-7/3/KINGBIRD#1//… x HI 1621 exhibited higher significant positive heterosis over the checks. Biological yield is also an important yield attribute and research thrust must be put to develop varities with increased biological yield per plant. In our investigation PRL/2*PASTOR*2//FH6-1-7/3/KINGBIRD#1//… x HI 1621 was observed to be superior cross combination for the character and should be preferred in future breeding programmes for the trait.

Grain yield per plant (g)

Grain yield per plant is the most important trait for consideration while breeding for higher-yielding cultivars. Cross combinations SOKOLL x HI 1621 followed by QBP 12-11 x HI 1621 and NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/… x HD 3237 were observed to have higher positive significant heterosis for the character. Therefore, these combinations should be given preference in terms of breeding for higher yield.

Grain yield per plant is the most important trait for consideration, while breeding for the higher yielding cultivars. The cross combinations showing higher estimates of desirable heterosis for the trait could be further utilized for exploitation and hybrid vigour and to break the yield plateu. In our experiments hybrids SOKOLL x HI 1621, QBP 12-11 x HI 1621 and NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/… x HD 3237 were observed with higher heterosis for the trait and these combinations should be preferred while breeding for the higher yield levels.

Harvest Index (%)

Table 3b: Percent heterosis in F1s over mid parent (MP), better parent (BP) and checks for Peduncle length(cm), spike length(cm), No. of spikelets per spike, No. of grains per spike and Grain weight per spike(g)

Crosses	Peduncle length (cm)				Spike length (cm)				No. of spikelets per spike				No. of grains per spike				Grain weight per spike (g)			
QBP 12-11 X HD 3237	0.28	-0.33	0	-2.67	-7.89*	-7.97*	-4.34	-3.66	-1.84	-2.06	-2.88	-4.21	- 12.30**	- 13.19**	- 11.84**	- 15.38**	-16.09**	- 20.96**	- 16.59**	- 13.01**
QBP 12-11 x PBW 725	-1.92	-3.81	-3.49	-6.07	-3.72	-6.09	-1.89	-3.65	-1.96	-2.09	-2.91	-4.24	4.91	-1.91	-0.39	-4.39	-0.54	-3.59	1.74	6.10
QBP 12-11 X HI 1621	-6.12	- 10.07	-1.47	-4.11	- 11.74**	- 14.43**	-9.48*	- 11.11**	-3.43	-3.84	-3.84	-5.16	-9.59**	- 11.28**	-6.41	- 10.16*	- 14.42**	- 18.71**	-14.22**	-10.54**
SOKOLL X HD 3237	0.43	-2.62	2.75	0	2.96	-0.77	2.36	0.52	5.11	4.87	4.02	2.58	8.41*	7.98	7.44	3.13	3.51	1.45	-1.44	2.78
SOKOLL X PBW 725	-2.08	-6.28	-1.11	-3.76	-2.64	-6.73	-2.56	-4.32	-5.06	-5.19	-5.96	-7.25*	18.37**	12.15**	10.71*	6.27	-12.08**	- 12.92**	-13.74**	-10.05**
SOKOLL X HI 1621	-8.52	- 10.21	-1.63	-4.26	6.33	1.25	7.11	5.18	-1.24	-1.64	-1.64	-3	- 14.66**	- 17.40**	- 12.87**	- 16.36**	-6.99*	- 8.05*	- 10.66**	- 6.84*
WH 1182 X HD 3237	-4.32	-5.49	-3.99	-6.56	1.35	-3.69	-0.66	-2.45	5.06	4.81	3.48	2.06	7.27*	4.18	9.99*	5.58	-7.11*	- 10.20**	-10.27**	-6.43
WH 1182 XPBW 725	-1.12	-3.61	-2.08	-4.7	-3.79	-9.12*	-5.05	-6.76	1.57	1.24	0.13	-1.25	0.65	-7.56	-2.41	-6.33	6.87*	6.40*	6.32	10.87**
WH 1182 X HI 1621	-7.25	- 10.62*	-2.08	-4.7	5.01	-1.39	4.32	2.45	6.66*	5.73	5.73	4.27	-7.53*	-7.56	-2.41	-6.33	7.82**	5.14	5.06	9.56**
QLD 75 X HD 3237	-3.36	-4.87	-2.68	-5.28	4.5	-4.26	-1.25	-3.02	5.19	5.17	3.83	2.4	0.06	-4.79	-5.27	-9.07*	3.07	-1.6	0.95	5.27
QLD 75 X PBW 725	-8.3	- 10.92	-8.86	- 11.30*	-0.08	-8.98*	-4.91	-6.62	-0.15	-0.27	-1.36	-2.71	-5.23	-6.03	- 15.56**	- 18.94**	14.98**	13.00**	15.92**	20.89**
QLD 75 X HI 1621	-4.15	-7.33	1.53	-1.18	4.14	-5.66	-0.21	-2	5.67	4.97	4.97	3.52	14.39**	5.92	11.73**	7.25	25.24**	20.57**	23.70**	29.00**
PRL/2*PASTOR*2//FH6-1-7/3/KINGBIRD#1//… X HD 3237	6.57	6	6.19	3.35	2.81	1.67	7.25	5.32	6.12	4.68	3.35	1.93	-2.24	-7.36	2.97	-1.16	-7.83**	- 11.53**	-10.27**	-6.43
PRL/2*PASTOR*2//FH6-1-7/3/KINGBIRD#1//… X PBW 725	12.15*	10.07	10.27	7.32	-2.58	-3.06	2.27	0.43	1.09	-0.38	-1.47	-2.82	-1.9	- 11.96**	-2.14	-6.06	- 15.05**	- 16.04**	-14.85**	-11.20**
PRL/2*PASTOR*2//FH6-1-7/3/KINGBIRD#1//… X HI 1621	-0.25	-4.52	4.61	1.81	-2.36	-2.49	3.15	1.29	4.03	1.97	1.97	0.57	-3.01	-5.49	5.06	0.85	1.05	- 2.18	-0.79	3.46
QLD 65 X HD 3237	12.08*	6.65	5.69	2.87	-3.41	-5.4	-2.42	-4.17	9.45**	9.33*	8.18*	6.69	17.77**	13.40**	12.83**	8.31*	-3.7	-5.32	-8.61**	-4.7
QLD 65 X PBW 725	10.91*	6.91	3.13	0.37	-8.79**	- 11.22**	-7.25	-8.92*	-0.68	-0.7	-1.74	-3.1	9.18*	6.94	-1.48	-5.43	- 10.99**	- 12.12**	-12.95**	-9.23**
QLD 65 X HI 1621	-7.27	- 15.76**	-7.71	-10.18	-3.79	-6.93	-1.54	-3.31	3.35	2.81	2.81	1.39	-6.84	- 12.74**	-7.95	- 11.64**	- 10.07**	- 10.80**	-13.90**	- 10.21**
NW 6036 X HD 3237	5.38	3.12	2.19	-0.54	-2.34	-4.97	-1.98	-3.74	-0.51	-3.17	1	-0.39	10.34*	5.42	4.89	0.68	- 16.73**	- 17.52**	-21.56**	-18.20**
NW 6036 X PBW 725	10.61*	9.69	5.81	2.98	-6.60*	-9.68*	-5.64	-7.34	-0.82	-3.39	0.77	-0.62	24.54**	22.98**	11.45**	6.98	1.22	-0.8	-1.74	2.47
NW 6036 X HI 1621	-8.27	-14.43**	-6.25	-8.75	-6.05	-9.70**	-4.47	-6.19	4.05	1.9	6.29	4.82	29.21**	20.10**	26.69**	21.61**	8.56**	8.47*	3.16	7.58*

K 1402 X HD 3237	5.37	-0.74	11.27	8.3	-2.58	-3.55	-0.51	-2.3	-0.97	-3.1	-0.04	-1.41	0.38	-2.76	3.2	-0.93	31.50**	29.55**	20.85**	26.03**
K 1402 X PBW 725	3.69	-3.54	8.13	5.23	-6.34	-7.85*	-3.74	-5.47	-5.58	-7.52*	-4.6	-5.92	- 12.95**	- 20.24**	- 15.35**	- 18.75**	9.67**	4.94	3.95	8.40*
K 1402 X HI 1621	- 11.55*	- 12.56 *	-1.98	-4.6	-0.86	-3.06	2.55	0.71	1.81	0.26	3.42	2	3.41	3.1	9.41*	5.03	-1.87	-4.16	-9.01**	-5.11
VORB/4/D67.2/PARA NA 66.270 X HD 3237	1.96	-1.23	4.42	1.62	1.52	-0.14	3	1.15	3.88	1.61	4.91	3.46	11.24***	8.16	7.62	3.31	-0.46	-2.13	-5.53	-1.48
VORB/4/D67.2/PARA NA 66.270 X PBW 725	-2.41	-6.68	-1.35	-3.99	-3.73	-5.89	-1.68	-3.45	-2.75	-4.8	-1.71	-3.06	-2.05	-5	- 10.70*	- 14.28**	18.42**	16.91**	15.80**	20.76**
VORB/4/D67.2/PARA NA 66.270 X HI 1621	5.97	4.11	14.06 *	11.01	0.07	-2.77	2.86	1.01	1.58	-0.02	3.23	1.81	- 4.09***	- 18.77**	- 14.31**	- 17.75**	-0.99	-1.8	-5.21	-1.15
HPBW 01 X HD 3237	4.65	3.57	4.81	2.01	-5.64	-7.24	-4.32	-6.04	1.84	-0.52	2.98	1.57	26.59**	22.71**	22.09**	17.19**	-0.35	-1.41	-8.03*	-4.09
HPBW 01 X PBW 725	2.77	0.36	1.57	-1.15	-0.65	-2.95	1.39	-0.43	4.09	1.77	5.35	3.9	35.97**	32.30**	23.55**	18.60**	3.9	-0.16	-1.11	3.13
HPBW 01 X HI 1621	-3.02	-6.72	2.19	-0.54	1.14	-1.8	3.88	2.01	-3.93	-5.56	-2.24	-3.59	6.5	0.39	5.9	1.66	3.82	1.83	-3.32	0.82
NAC/TH.AC//3*PVN/3 /MIRLO/BUC/4/2*PAS TOR/5/…X HD 3237	3.77	2.19	4.45	1.65	7.01*	5.75	9.08*	7.12	2.27	1.71	0.42	-0.96	9.19*	6.38	11.59**	7.11	12.74**	10.89**	6.95*	11.53**
NAC/TH-AC//3*PVN/3/MIRLO/ BUC/4/2*PASTOR/5/ …X PBW 725	4.3	1.37	3.6	0.83	4.11	2.24	6.81	4.89	-0.62	-1.25	-2.33	-3.68	18.94**	9.56*	14.92**	10.32*	8.12**	6.70*	5.69	10.21**
NAC/TH.AC//3*PVN/3 /MIRLO/BUC/4/2*PAS TOR/5/…X HI 1621	-5.93	-9.09	-0.4	-3.06	-4.36	-6.65	-1.25	-3.02	-1.36	-2.52	-2.52	-3.86	-0.25	-0.53	4.93	0.72	16.55**	15.64**	11.53**	16.31**

Table 3c: Percent heterosis in F1s over mid parent (MP), better parent (BP) and checks for 100 grain weight(g), Biological yield per plant (g), Grain yield per plant(g) and Harvest Index (%)

Crosses	1000 grain weight (g)				Biological yield per plant (g)				Grain yield per plant (g)				Harvest Index (%)			
QBP 12-11 X HD 3237	9.28**	5.91**	5.96**	6.61**	11.21	2.59	9	9.45	28.06**	18.60*	17.46*	20.17*	17.25**	15.92**	9.02*	9.85**
QBP 12-11 x PBW 725	-5.42**	-5.84**	-4.95*	-4.37	18.47**	11.5	13.47*	13.93*	14.27*	3.46	7.72	10.2	-3.58	-7.62*	-5.18	-4.46
QBP 12-11 X HI 1621	-1.94	-2.39	-2.35	-1.75	29.95**	21.41**	25.51**	26.02**	47.59**	37.25**	34.73**	37.83**	13.57**	13.01**	7.35*	8.17*
SOKOLL X HD 3237	17.24**	15.02**	12.23**	12.92**	18.51**	13.05*	20.11**	20.61**	35.91**	28.36**	27.14**	30.06**	15.42**	15.06**	5.75	6.56
SOKOLL X PBW 725	1.33	-0.36	0.59	1.21	0.58	-2.04	-0.31	0.1	-2.33	-9.87	-6.15	-3.99	-1.03	-6.48	-4.01	-3.28
SOKOLL X HI 1621	3.48	2.67	1.78	2.41	21.26**	17.20**	21.15**	21.65**	50.71**	42.94**	40.32**	43.55**	24.26**	21.87**	15.77**	16.65**
WH 1182 X HD 3237	-2.44	-6.01**	-4.80*	-4.22	-2.71	-4.92	1.02	1.44	-5.26	-6.23	-7.13	-4.99	-1.85	-3.66	-8.06*	-7.37*
WH 1182 XPBW 725	0.85	0.69	1.98	2.6	10.9	10.71	12.67	13.13	21.94**	17.77*	22.63**	25.45**	9.87**	6.01	8.81*	9.64**
WH 1182 X HI 1621	-10.54**	-11.49**	-10.36**	-9.80**	11.14	10.09	13.81*	14.28*	30.69**	29.92**	27.54**	30.48**	14.01**	13.75**	8.55*	9.37**
QLD 75 X HD 3237	7.64**	7.38**	1.3	1.92	1.93	-5.28	17.22*	17.70**	-4.48	-14.18*	6.66	9.12	1.3	-2.97	-2.59	-1.85
QLD 75 X PBW 725	11.68**	8.02**	9.04**	9.72**	8.64	-1.01	22.50**	23.01**	11.12	2.1	26.91**	29.83**	1.9	0.79	3.45	4.24
QLD 75 X HI 1621	9.21**	6.57**	5.65*	6.30**	-1.46	-9.57	11.91	12.37	17.03**	4.73	30.18**	33.17**	19.04**	15.84**	16.29**	17.17**
PRL/2*PASTOR*2//FH6 7/3/KINGBIRD#1//… X HD 3237	-13.15**	-19.16**	-11.91**	-11.37**	-2.23	-3.97	2.03	2.45	2.19	1.88	1.51	3.85	5.24	2.52	-0.62	0.13
PRL/2*PASTOR*2//FH6-1-7/3/KINGBIRD#1//… X PBW 725	-0.01	-3.69	4.94*	5.59*	-3.29	-3.62	-1.26	-0.85	-1.15	-3.29	0.7	3.02	2.24	-0.6	2.02	2.8
PRL/2*PASTOR*2//FH6-1-7/3/KINGBIRD#1//… X HI 1621	-7.16**	-11.35**	-3.4	-2.81	23.75**	23.20**	27.36**	27.88**	30.18**	29.22**	28.75**	31.71**	4.53	3.48	0.31	1.07
QLD 65 X HD 3237	16.15**	16.04**	8.93**	9.60**	11.71*	11.63	18.60**	19.09**	15.13*	14.11	15.06*	17.71*	3.73	2.06	-3.08	-2.34
QLD 65 X PBW 725	9.98**	6.03**	7.03**	7.69**	13.73*	11.41	18.19**	18.68**	18.33**	16.46*	21.26**	24.05**	4.45	0.54	3.2	3.98
QLD 65 X HI 1621	1.82	-0.97	-1.83	-1.22	20.36**	18.82**	26.06**	26.58**	25.01**	23.36**	24.38**	27.25**	4.12	4.11	-1.11	-0.35
NW 6036 X HD 3237	11.42**	6.55**	9.60**	10.27**	17.87**	17.34**	25.81**	26.33**	28.56**	28.17**	27.73**	30.67**	9.90**	9.35*	1.53	2.3
NW 6036 X PBW 725	-9.25**	-10.10**	-7.52**	-6.95**	-1.6	-4.1	2.82	3.25	7.33	5.03	9.36	11.87	8.71**	3.52	6.25	7.06*
NW 6036 X HI 1621	-4.20*	-5.93**	-3.24	-2.64	-10.88*	-12.48*	-6.15	-5.77	-2.73	-3.45	-3.79	-1.57	9.32**	8.09*	2.67	3.45
K 1402 X HD 3237	-6.40**	-10.92**	-7.43**	-6.86**	13.83*	7.07	13.76*	14.23*	29.29**	24.62**	23.43**	26.27**	11.77**	8.43*	5.99	6.79
K 1402 X PBW 725	-0.17	-1.6	2.25	2.88	9.92	5.52	7.38	7.83	5.5	-0.7	3.4	5.78	-4.26	-6.54	-4.07	-3.34
K 1402 X HI 1621	-8.15**	-10.26**	-6.74**	-6.17**	8.88	3.74	7.24	7.68	12.7	9.1	7.1	9.56	3.54	2.08	-0.22	0.54
VORB/4/D67.2/PARANA 66.270 X HD 3237	-5.59**	-8.15**	-8.83**	-8.27**	-4.6	-6.36	3.31	3.74	-3.57	-5.21	-2.81	-0.57	7.01*	6.44	-1.11	-0.36
VORB/4/D67.2/PARANA 66.270 X PBW 725	-7.33**	-8.1**	-7.24**	-6.67**	-8.25	-11.81	-2.7	-2.3	-4.45	-5.18	-1.27	1	3.59	-1.33	1.28	2.05
VORB/4/D67.2/PARANA 66.270 X HI 1621	12.20**	12.13**	11.30**	11.98**	-6.58	-9.52	-0.17	0.24	-7.95	-9.91	-7.63	-5.51	-1.51	-2.59	-7.47*	-6.77
HPBW 01 X HD 3237	-2.61	-3	-8.21**	-7.65**	-13.81**	-17.73**	-3.86	-3.46	-13.56*	-17.66*	-9.9	-7.82	1.16	0.37	-6.29	-5.58
HPBW 01 X PBW 725	12.00**	8.50**	9.53**	10.20**	-12.70*	-18.34**	-4.57	-4.18	-13.34*	-15.44*	-7.46	-5.33	-1.18	-5.64	-3.15	-2.42
HPBW 01 X HI 1621	-0.59	-2.85	-3.69	-3.09	8.4	2.14	19.36**	19.86**	21.20**	14.96*	25.81**	28.70**	11.90**	10.95**	5.39	6.19
NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/…X HD 3237	4.54*	-3.5	7.05**	7.71**	26.71**	15.77*	23.00**	23.51**	44.39**	31.78**	30.52**	33.52**	14.81**	14.16**	6.12	6.93
NAC/TH-AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/…X PBW 725	-0.57	-5.05*	5.33*	5.98**	-1.51	-8.22	-6.6	-6.22	-1.71	-12.28	-8.66	-6.56	-0.26	-4.96	-2.45	-1.71
NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/…X HI 1621	6.02**	0.39	11.35**	12.04**	-1.13	-8.54	-5.45	-5.06	-1.42	-9.67	-11.33	-9.29	-0.3	-1.37	-6.3	-5.59

In terms of harvest index, relative heterosis varied from 4.26% to 24.26%. The highest significant positive heterosis for the trait was exhibited by the cross SOKOLL x HI 1621 (24.26%). Cross combination SOKOLL x HI 1621 (21.87%) exhibited high significant heterosis over the better parent and QLD 75 x HI 1621 possessed high significant positive heterosis over the checks.
Harvest index is an important indicator of attainable economic yield. Higher values of harvest index leads to higher production levels. Cross combination SOKOLL x HI 1621 and QLD 75 x HI 1621 were observed with higher positive heterosis for the trait. Hence, theses crosses should be preferred in future breeding programmes.
Our study reveals existence of considerable genetic variability for all the trait studied as the mean squares were significant due to all the cahracters. For almost all the characters (except for spike length) a good amount of heterosis observed among the genotypes. For traits like grain yield per plant six cross combinations were found to exhibit significant positive heterobeltiosis, whereas, eleven crosses were expressing positive heterosis over check UP 2855. These combinations showed a good heterosis for number of tillers per plant and harvest index (%) indicating a probable correlation among the traits. The cross combinations QBP 12-11 x HD 3237 and QBP 12-11 which showed heterosis for early maturity over check UP 2855 were also exhibiting heterosis for grain yield and number of grains. It was also observed in the earlier studies of Jaiswal *et al.* (2018) and Adhikari *et al.* (2020) who observed early maturing types to posess heterosis for grain yield. In terms of number of grains per spike eight crosses exhibited significant positive heterosis, while for grain weight per spike six cross combinations were pbserved to possess significant heterosis Both of theses traits are important contributor to the over all grain yield. Therefore, selection for crosses having heterosis these traits are impotant for increasing overall productivity levels. Devi *et al.* (2013), Kumar *et al.* (2014) and Kalhoro *et al.* (2015) observed heterosis for these traits and also found those crosses to be higher yielding in the further breeding programmes. Our present investigation reveals five crosses which possess heterosis for grain yield to have significant heterosis for these traits. Harvest Index (%) is the measure of the ratio between total grain yield and overall biological yield. It denotes the economic product of the plant, therefore the crosses with higher values of harvest index will be useful for farmers to gain higher economic returns. In our study six cross combinations exhibited heterosis for harvest index(%) were also found to possess high yield per se. In the earlier studies of Mahpara *et al.* (2015) and Ishwal *et al.* (2018) they observed and isolated crosses which were highly hetrotic for harvest index(%) which were having high performance in terms of yield and other characters.
Plant height and peduncle length are important characters which do not directly influence yield but negative heterosis for these charcters are desirable as dwarf plant types in wheat are associated with lodging resistance and higher fertilizer and input responsiveness. Garg *et al.* (2015) , Hussain *et al.* (2019), Younas *et al.* (2020) studied these traits in terms heterosis and found significant heterosis in their lines and found those dwarf types as high nutrient responsive per unit and also high yielding. In the present investigation five out of thirty crosses possessed significant heterobeltiosis for plant height and for crosses were having significant negative hetrosis for peduncle length. Selection for these crosses would be highly rewarding as these also expressed heterosis for higher yield and shown to be high nutrient responsive.

Conclusion

The present investigation depicts that there is a considerable amount of genetic variability present among the parental genotypes, which provides a great scope for utilization of these genotypes for commercial exploitation of heterosis for grain yield and other traits. Cross combination SOKOLL x HI 1621 followed by QBP 12-11 x HI 1621 and NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/… x HD 3237 had exhibited high positive heterosis over mid parent, better parent and both the checks with high *per se* performance and is considered to be the best heterotic combination in relation to grain yield. Therefore, theses hybrids should be preferredfor further utilization in breeding programme. Further, NW 6036 x HI 1621 expressed high *per se* performance with superior heterotic value over the checks for the trait number of grains per spike, which provides a possibility for further exploitation of this cross for improvement in grain yield in future.

References

Adhikari, A., Ibrahim, A. M., Rudd, J. C., Baenziger, P. S., & Sarazin, J. B. (2020). Estimation of heterosis and combining abilities of US winter wheat germplasm for hybrid development in Texas. *Crop Science*, *60*(2), 788-803.

Bilgin, O., Balkan, A., Korkut, K.Z. & Başer, I. (2011). Heterotic and heterobeltiotic potentials of bread wheat (*Triticum aestivum* L.) hybrids for yield and yield components. *Journal of Tekirdag Agricultural Faculty,* 8(2), 133-142.

Borghi, B., & Perenzin, M. (1994). Diallel analysis to predict heterosis and combining ability for grain yield, yield components and bread-making quality in bread wheat (*T. aestivum*). *Theoretical and Applied Genetics*, *89*(7-8): 975-981.

Devi, E.L., Swati, Goel, P., Singh, M. & Jaiswal, J. P. (2013). Heterosis studies for yield and yield contributing traits in bread wheat (*Triticum aestivum* L.). *The Bioscan,* 8(3), 905-909.

El-Nahas, M. M., Mohamed, M. M., & El-Areed, S. R. (2021). Line by Tester Analysis for Estimats Combining Ability in Bread Wheat Under Different Levels of Nitrogen Fertilizer. *Journal of Plant Production*, *12*(2), 125-133.

Pankaj, G., Saharan, R. P., Mamta, G., & Renu, M. (2015). Heterosis studies for grain yield and its components in wheat (Triticum aestivum L. Em. Thell) under normal and drought conditions. *The Bioscan*, *10*(2 Supplement), 721-728.

Gite, V. D., Mali, A. R., Idhol, B. D., & Bagwan, J. H. (2014). Estimation of heterosis for yield and some yield components in bread wheat (*Triticum aestivum* L.). *The Bioscan*, *9*(2): 767-770.

Hussain, S.B., Zahra, S., Bakhsh, A., & Zubair, M. (2019). Assessment of heterosis for morphological and yield donating traits in bread wheat by line x tester analysis. *International Journal of Multidisciplinary Research and Studies*, 2(09), 23-39.

Ibrahim, A. U., Yadav, B., Anusha, R., & Magashi, A. I. (2020). Heterosis studies in durum wheat (Triticum durum L.). *J. Genet. Genom. Plant Breed*, *4*(1), 2-8.

Jaiswal, R., Gaur, S. C., & Jaiswal, S. K. (2018). Heterosis and inbreeding depression for grain yield and yield component traits in bread wheat (Triticum aestivum L.). *Journal of Pharmacognosy and Phytochemistry*, *7*(2), 3586-3594.

Kalhoro, F. A., Rajpar, A. A., Kalhoro, S. A., Mahar, A., Ali, A., Otho, S. A., & Baloch, Z. A. (2015). Heterosis and combing ability in F1 population of hexaploid wheat (Triticum Aestivum L.). *American Journal of Plant Sciences*, *6*(07), 1011.

Kumar, D. I. N. E. S. H., & Kerkhi, S. A. (2014). Heterosis studies for yield component traits and quality in spring wheat (Triticum aestivum L.). *The Bioscan*, *9*(4), 1725-1731.

Mahpara, S., Ali, Z., Farooq, J., Hussain, S., & Bibi, R. (2015). Heterosis and heterobeltiosis analysis for spike and its related attributes in different wheat crosses. *Pakistan Journal of Nutrition*, *14*(7), 396.

Sharif, A. F. S. A. R. I., Bakhsh, A., Arshad, M. U. H. A. M. M. A. D., Haqqani, A. M., & Najma, S. (2001). Identification of genetically superior hybrids in chickpea (Cicer arietinum L.). *Pakistan Journal of Botany*, *33*, 403-409.

Solomon, K. F., Labuschagne, M. T., & Viljoen, C. D. (2007). Estimates of heterosis and association of genetic distance with heterosis in durum wheat under different moisture regimes. *The Journal of Agricultural Science*, *145*(3), 239-248.

Singh, M. A. M. T. A., Devi, E. L., Aglawe, S., Kousar, N., & Behera, C. (2013). Estimation of heterosis in different crosses of bread wheat (Triticum aestivum L.). *The Bioscan*, *8*(4), 1393-1401.

Younas, A., Sadaqat, H. A., Kashif, M., Ahmed, N., & Farooq, M. (2020). Combining ability and heterosis for grain iron biofortification in bread wheat. *Journal of the Science of Food and Agriculture*, *100*(4), 1570-1576.