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ESTIMATION OF HETEROSIS FOR GRAIN YIELD AND ITS CONTRIBUTING TRAITS IN BREAD WHEAT (*TRITICUM AESTIVUM* L.)

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ABSTRACT
Heterosis was studied in a 10 x 10 half diallelmating design, excluding reciprocals for yield and its contributing traits in bread wheat to identify the best heterotic combination. Significant differences were observed among the genotype for all the twelve traits under study. Highest magnitude of standard heterosis was observed in the cross K 9423 x NW 1014 for flag leaf area (82.56) followed by Raj 3765 x NW 1014 for biological yield (62.13) while maximum average heterosis was observed in the cross Unnathalna x HUW 560 (52.78) and K 9423 x NW 1014 (51.86) for grain yield. The cross K 9423 x NW 1014 and Unnathalna x HUW 560 was recognized as the best heterotic crosses which exhibited highest significant and desirable average as well as standard parent heterosis for grain yield and some other important yield contributing traits. Inclusion of lines with good combining ability in a national hybrid wheat programme may offer genetic improvementin breeding for higher yield and its component traits.

INTRODUCTION

Wheat is an important cereal crop of the world and constitutes rich source of carbohydrate and protein. India is considered to be the second largest producer of wheat (Anonymous, 2014). Wheat production during the crop season 2013-2014 is estimated to be around 95.85 million tones, an over 2.3 million tones increase over the production of 93.51 million tones recorded during the preceding year 2012-2013. This year the area is also expected to increase by around one million hectares over that of the 2012-2013 which stood at 29.35 million hectare. To fulfill the projected demand of world population for food grains, it is essential that production and productivity of wheat must be increased. The solution of this problem is only lies in heterosis breeding which can be used as an alternative approaches and providing the way to overcome the yield barriers but the utilization of heterosis largely depends on the direction and magnitude of heterosis. Heterosis studies can also be used for getting information about the increase or decrease in F_1s over the standard variety as well as mid parent. The future scope of hybrid technology in wheat depends on the male sterility systems, floral biology, direction and magnitude of heterosis and its exploitation that may be useful in breaking yield barriers and enhancing the productivity in major wheat growing areas of the country (Singh *et al.,* 2010). Moreover, the study of heterosis helps the breeders in eliminating the low productive cross combinations in F_1s generation itself. The rejection of crosses, which shows no heterosis, would helps the breeder to concentrate the attention on few but high productive crosses. According to Longin *et al.,*(2012),yield due to exploitation of heterosis can be improved ranged from 3.5 to 15% in wheat.Gami *et al.*, (2011) explain that the lines, which perform well in combination, are eventually of great importance to the plant breeders.Study of heterosis for grain yield and its contributing traits in wheat have also been reported by Singh *et al.* (2004), Chowdhry *et al.* (2005), Ashutosh *et al.,* (2011), Singh *et al.,* (2012),Singh *et al.* (2013), Devi *et al.* (2013), Beche *et al.* (2013), Singh *et al.* (2014) and Kumar and Kerkhi (2014).The major objective of the present study was to estimate the heterosis over standard parent (economic heterosis) as well as mid parent (average heterosis) for twelve characters in a half diallel mating design involving ten diverse genotypes of bread wheat.

MATERIALS AND METHODS

Ten genotypes of bread wheat namely, Raj 3765, K 9162, PBW 373, K 9423, K 7903, Unnat-halna, NW 1014, HUW 560, NW 1076 and UP 2425 were sown at Crop Research Centre during*rabi* 2011-2012 for attempting crossing programme in a 10 x 10 diallel fasion excluding reciprocals. In the next crop season rabi 2012-2013, experimental material consisted of 55 genotypes (10 parents and 45 F_1s) were sown in a randomized block design with three replication. Each of the parental lines and crosses were sown by dibbling seeds in two row plot of 2 meter length at specing of 10 cm between plant to plant and row to row specing was 23 cm. All the standard agronomical practices were followed from sowing to till harvest of crop. Observations were recorded on five randomly selected plants in each of three replications for twelve characters, namely days to 50% flowering, days to maturity, plant height (cm), number of productive tillers per plant, flag leaf area (cm^2), spike length (cm), number of spikelets per spike, number of grains per spike, 1000 grain weight (g), biological yield per plant (g), grain yield per plant (g) and harvest index (%).For flag leaf area (cm2), length and the maximum width of flag leaf was measured and the area was calculated using the following formula suggested by Muller (1991) as Flag leaf area = leaf length × maximum leaf width × correction factor (0.74). The mean values of parents and F_{1s} cross combinations were used for the estimation of heterosis over standard parent as well as mid parent. The magnitude of heterosis was estimated by commonly used statistical software (INDOSTAT 7.5).Analysis of variance was performed to test the significance of difference among the genotypes for the characters studied, as suggested by Panse and Sukhatme, (1967). The percent increase or decrease of F_1 hybrids over mid parent as well as standard check was calculated by using the formulae of Fonseca and Patterson (1968).

$$\text{Sandard heterosis}(\%)\ \frac{F1 - SP}{SP}\ \ 100$$

$$\text{Average heterosis}(\%)\ \frac{F1\ \ MP}{MP}\ \ 100$$

F_1 = Mean performance of F_1 hybrid

SP = Mean performance of standard parent

MP = Mean mid-parental value *i.e.* (P1 + P2)/2

Test of significance

The 't' test was manifested to determine whether F_1s means were statistically different from mid parent and better parent means. The heterosis was tested by least significant difference at 5 per cent and at 1 per cent level of significance for error degrees of freedom as follow the formulae suggested by panse and sukhatme(1961).

For testing heterosis over mid parent; SE (diff.) (MP) = 3Me/2r

For testing heterosis over standard check; SE (diff) (SC) = 2Me / r

Where,

Me = Error variance

r = Number of replications

RESULTS AND DISCUSSION

The pedigree and origin of the parental line are given in Table 1. Analysis of variance (Table 2) revealed significant differences due to parents and their F_1s crosses for all the characters under study except days to 50 % flowering in parents and grains per spike in parents and F_1s which possess the good amount of variability present in the parents and F_1s (Table 2) and also the possibilities of identifying the superior hybrid from the study.

In the present investigation, the estimated value of heterosis over standard parent as well as mid parent revealed that none of the crosses showed significant heterosis for all the characters under study. Estimated value of heterosis showed that the degree and direction of heterosis varied not from character to character but also in cross to cross. In the present study, the degree of heterosis was measured as superiority of mean of F_1s cross combination over their respective standard parent as well as mid parental values. Heterosis may be high or low depending upon themean value of the parent in question. Obviously, there may be possibility of getting a cross with high per se performance but with low heterosis, in case the parental performance is alsohigh. On the contrary, there can be a cross with poor per se performance but high percent of heterosis. It means that the choiceof the best cross combination

Table 1: Pedigree and origin of the parental lines are given in the following table:

Genotypes	Species	Parentage	Centre developed
Raj 3765	*T. aestivum*	HD 2402/VL639	R.A.U. Rajasthan
K 9162	*T. aestivum*	K 7827/HD 2204	C.S.A.U. Kanpur
PBW 373	*T. aestivum*	ND/VG1944//KAL/BB/3/YACO'S'/4/VEE#5'S'	P.A.U. Ludhiana
K 9423	*T. aestivum*	HP 1533/KalyanSona/UP 262	C.S.A.U. Kanpur
K 7903	*T. aestivum*	HP 1982/K 816	C.S.A.U. Kanpur
Unnat-halna	*T. aestivum*	-	C.S.A.U. Kanpur
NW 1014	*T. aestivum*	HAHN'S'	N.D.U.A.T. Faizabad
HUW 560	*T. aestivum*	-	B.H.U. Banaras
NW 1076	*T. aestivum*	OPATA/KILL	N.D.U.A.T. Faizabad
UP 2425	*T. aestivum*	HD 2320/UP 2263	G.B.P.U.A.T. Pantnagar

Table 2: Analysis of variance for twelve traits in 10 x 10 parental diallel crosses of bread wheat.

Mean sum of square S.O.V.	D.F.	DTF	DTM	PH	PL	FLA	PT	SL	SPS	GPS	BY	TGW	GY
Replications	02	0.16	1.76	15.68*	0.75	4.12	0.14	0.28	2.17	14.98	11.18	0.31	1.12
Treatments	54	40.69**	13.73**	72.93**	23.17**	123.54**	0.48**	0.80**	10.94**	51.26**	104.14**	13.43**	18.30**
Parents	09	16.518	5.20**	129.42**	30.85**	58.79**	0.66**	1.29**	4.95*	28.11	98.83**	8.62**	17.57**
F_{1s}	44	46.39**	15.26**	58.09**	21.17**	139.02**	0.35**	0.58**	7.84**	17.45	81.65**	10.94**	6.16**
Parents Vs F_1s	01	7.77*	23.28**	217.37**	42.37**	25.24*	4.28**	5.93**	201.21**	1747.15**	1141.02**	166.44**	559.01**
Error	108	1.61	0.82	4.44	0.99	4.48	0.07	0.20	2.26	18.21	7.47	2.20	1.72

Table 3: Promising heterotic crosses for various traits based on mid parent and standard parent in bread wheat

Trait	Average heterosis	Standard heterosis
DTM	K 9162 x K 7903, K 9162 x UP 2425, K 9162 x HUW 560	K9162 x UP 2425, NW 1014 x HUW 560, K 9162 x K 7903
DTF	K 9162 x NW 1076, K 7903 x Unnathalna, Raj 3765 x HUW 560	PBW 373 x K 7903, K 9423 x HUW 560, Raj 3765 x UP 2425
PH	K 9423 x Unnathalna, K 9423 x NW 1076, K 9423 x HUW 560	PBW 373 x K 7903, PBW 373 x NW 1076, K 9162 x PBW 373
PL	NW 1014 x NW 1076, Unnathalna x NW 1076, K 9162 x K 7903	Unnathalna x NW 1076, NW 1014 x NW 1 076, NW 1014 x UP 2425
FLA	K 9423 x NW 1014, K 9423 x UP 2425, Unnathalna x UP 2425	K 9423 x NW 1014, K 9423 x UP 2425, K 7903 x NW 1076
PT	RAJ 3765 x NW 1014, RAJ 3765 x Unnathalna, K 9162 x NW 1014	NW 1076 x UP 2425, K 9423 x NW 1076, K 9423 x UP 2425
SL	K 9162 x UP 2425, K 9162 x NW 1076, PBW 373 x NW 1076	K 7903 x HUW 560, K 7903 x UP 2425, PBW 373 x NW 1076
SPS	NW 1014 x HUW 560, PBW 373 x HUW 560, K 9423 x NW 1076	K 9423 x NW 1076, K 7903 x NW 1076, K 9423 x K7903
GPS	HUW 560 x UP 2425, Unnathalna x UP 2425, PBW 373 x UP 2425	K 9162 x K 7903, K 9162 x K 9423, RAJ 3765 x K7903
TGW	RAJ 3765 x Unnathalna, PBW 373 x Unnathalna, PBW 373 x HUW 560	K 9162 x K 9423, K 9423 x NW 1076, K 9162 x NW 1076
BY	HUW 560 x NW 1076, NW 1014 x HUW 560, K 9162 x PBW 373	Raj 3765 x NW 1014, PBW 373 x UP 2425, K 9162 x K 7903
GY	Unnathalna x HUW 560, K 9423 x NW 1014, K 7903 x HUW 560	K 9423 x NW 1014, Unnathalna x HUW 560, RAJ 3765 x NW 1076

Table 4:Estimation of average and standard heterosis in 45 F_1s cross combination for twelve traits in bread wheat (*Triticum aestivum* L.)

Trait	DTF		DTM		PH		PL		FLA		PT		SL		SPS	
F_1s	MP	SP	MP	SP	MP	SP	MP	SP	MP	SP	MP	SP	MP	SP	MP	SP
A x B	-4.96**	-0.74	0.95*	2.16**	9.92**	18.01**	2.7	14.09**	-1.68	12.07	3.12	-1.98	3.44	-0.37	21.62**	18.71**
A x C	5.05**	7.78**	0.95*	1.44**	1.45	4.49*	3.79	10.62**	27.34**	41.34**	4.55	2.48	4.88	4.23	17.97**	14.25*
A x D	-2.69**	0.37	2.39**	2.64**	-6.14**	8.06**	-54.88	10.51**	11.09**	46.59**	2.64	5.94	9.57**	10.03**	10.94	13.04
A x E	2.65**	7.41**	-2.02**	-0.96	2.29	9.14**	-4.18	10.39**	-7	27.84**	2.24	1.49	3.98	9.30*	21.11**	25.84**
A x F	2.98**	8.89**	-1.07*	0	-3.96*	2.01	-3.97*	20.21**	9.25**	40.38**	15.12**	7.43*	5.02	1	23.61**	15.02*
A x G	-3.61**	-1.11	0.96*	1.20*	-5.49**	7.40**	-18.03**	-0.81	-8.59	11.95	16.36**	10.89**	6.42	-0.27	20.10**	14.59*
A x H	-5.73**	-2.59*	2.26**	2.88**	-5.91**	1.39	-13.66**	-2.54	-3.32	19.95**	3.23	2.97	2.64	4.97	10.88	8.96
A x I	-3.17**	1.85	2.85**	3.84**	-2	6.16**	-9.09**	1.62	-19.90**	-4.54	1.92	4.95	1.57	2.63	4.15	6.65
A x J	-5.26**	-3.33**	1.68**	1.44**	-2.25	1.86	4.77*	25.52**	-0.25	20.55**	-0.73	0.99	6.88*	5.83	-0.3	-0.63
B x C	-3.64**	-1.85	2.38**	3.12**	-4.32*	-0.15	5.64*	10.39**	-1.04	1.91	10.71**	7.43*	10.55**	7.16	18.20**	19.10**
B x D	3.07**	5.56**	-0.95*	-0.48	-7.46**	7.78**	-4.21	11.66**	-20.19**	-1.08	-1.69	0.5	3.74	1.63	22.12**	29.21**
B x F	4.10**	8.15**	-2.49**	-1.208	0.61	8.71**	7.69**	21.82**	-22.38**	0.48	4.79	2.97	-1.46	1.17	15.17**	24.17**
B x G	1.23	6.30**	0.12	1.44**	-4.12*	3.14	-5.91**	15.82**	-11.85**	6.21	10.46**	1.98	8.52*	1.7	21.59**	17.89*
B x H	-5.09**	-3.33**	2.15**	2.64**	-9.16**	4.45*	-8.45**	8.89**	9.19	24.97**	12.86**	6.44	8.91*	-0.6	13.55*	12.78
B x I	3.97**	6.67**	-2.02**	-1.20*	2.68	12.04**	-2.24	8.31**	-20.95**	-8.24	5.76	4.46	6.06	5.86	25.06**	27.79**
B x J	-7.09**	-2.96*	-1.42**	-0.24	-4.87**	4.34*	2.84	12.82**	8.87	21.03**	-0.49	1.49	10.98**	9.43*	16.31**	23.64**
B x K	-2.74**	-1.48	-2.16**	-2.16**	-4.53**	0.77	-13.49**	1.85	-2.91	9.56	1.72	2.48	13.49**	9.60**	14.62*	18.71**
C x D	4.97**	5.56**	1.68**	1.44**	-7.08**	4.18*	-0.26	11.78**	-13.09**	5.14	4	9.41**	6.66*	7.76*	6.65	12.03
C x E	-5.63**	-3.70**	2.03**	2.64**	-4.95**	-1.43	-6.98**	1.04	-24.70**	-4.78	4.16	5.45	-1.04	4.63	19.78**	28.23**
C x F	-5.21**	-2.22	-0.6	0	2.33	5.62**	-13.73**	2.31	-10.32*	5.38	4.94	0	5.56	2.17	10.74	6.53
C x G	6.30**	6.30**	2.64**	2.40**	1.24	6.20**	-16.13**	8.08*8	-5.36	5.5	3.31	0.5	4.73	-1.2	15.72*	14.06
C x H	8.46**	9.26**	-1.08*	-0.96		10.88**	1.13	13.86**	-16.22**	-5.26	7.54**	9.41**	2.35	5.3	27.62**	29.44**
C x I	-4.69**	-2.22	2.15**	2.64**	-9.80**	-0.19	-7.32**	2.31	-6.02	1.67	2.83	7.92*	10.78**	12.63**	7.39	13.35
C x J	5.40**	4.81**	4.83**	4.08**	9.53**	12.16**	-12.60**	10.51*8	-10.178	-1.31	3.1	6.93*	4.75	4.37	20.75**	24.15**
D x E	-5.05**	-2.59*	0.84	1.20*	-15.24**	5.31**	-15.16**	5.31	0.97	48.86**	4.19	10.89**	5.02	12.13**	19.36**	33.81**
D x F	-3.57**	0	2.27**	2.64**	-18.55**	1.2	-11.78**	21.02**	1.47	40.50**	8.37**	8.91**	4.14	1.87	4.05	5.34

on the basis of high heterosis wouldnot necessarily be one which would give the highest per seperformance also. The per se performance being the realized value, and the heterotic response being an estimate, the formers hould be given preference with high percentage of heterosis while making selection of cross combination. The heterosis was estimated over wide adopted and high yielding variety PBW 373, usedas an standard parent and result is presented in Table 4.

Days to flowering: Negative heterotic response in a cross is generally important for the development of short duration wheat varieties. Manifestation of heterosis was found in both positive and negative direction for days to 50 % flowering. The magnitude of average heterosis for days to flowering varied from (-7.09) K 9162 x NW 1076to (8.46) PBW 373 x HUW 560. The best three crosses namelyK 9162 x NW 1076, K 7903 x UnnatHalna and RAJ 3765 x HUW 560showing highestnegative significantheterosis over mid parent. Themagnitude of heterosis for days to flowering over standard parent varied from (-3.70) PBW 373 x K 7903 to (10.37) UH x NW 1076 where the highest negative standardheterosis was showed by PBW 373 x K 7903, K 9423 x HUW 560 and RAJ 3765 x UP 2425.Similar results for the importance of negative heterosis for days to 50 % flowering was reported by Ashutosh *et al.,* (2011),Singh *et al*. (2013), Devi *et al*., (2013) and Kumar and Kerkhi (2014).

Days to maturity

The magnitude of average heterosis for days to maturityranged from (-2.49) K 9162 x K 7903 x (4.83) PBW 373 x UP 2425 where the highest negative heterosis over mid parent was showed by K 9162 x K 7903, K 9162 x UP 2425 and K 9162 x HUW 560. The magnitude of standardheterosis for days to maturityvaried from(-2.16) K9162 x UP 2425 to(4.08) PBW 373 x UP 2425 where the highest negative heterosis over standard parent was showed by K9162 x UP 2425, NW 1014 x HUW 560, K 9162 x K 7903.Negative heterosis for days to maturity has also been reported by Devi *et al*. (2013), Singh *et al*. (2013) and Kumar and Kerkhi (2014).

Plant height

Short statured cultivars of wheat become much more popular

Table 4: Estimation of average and standard heterosis in 45 F_1s cross combination for twelve traits in bread wheat

Trait	DTF		DTM		PH		PL		FLA		PT		SL		SPS	
F_1s	MP	SP	MP	SP	MP	SP	MP	SP	MP	SP	MP	SP	MP	SP	MP	SP
D x G	4.24**	4.81**	0.00	-0.48	-1.62	22.23**	-15.14**	9.35**	37.84**	82.56**	8.21**	10.89**	8.04*	3.03	17.22**	21.45**
D x H	-4.94**	-3.70**	2.28**	2.16**	-14.78**	5.89**	-15.16**	5.31	-11.41**	18.76**	4.63	11.88**	4.83	8.93*	22.68**	30.63**
D x I	-4.49**	-1.48	0.72	0.96	-16.37**	3.91	-0.93	22.98**	25.90**	62.60**	8.76**	19.80**	5.87	8.73*	26.91**	40.36**
D x J	7.41**	7.41**	0.97*	0.00	-9.79**	12.08**	-5.11**	19.98**	35.34**	77.06**	8.18**	17.82**	5.20	5.90	13.06*	21.95**
E x F	-6.34**	-1.48	0.47	1.68**	-5.66**	1.32	-7.32**	27.14**	6.31	53.05**	7.69*	3.96	-4.34	-1.93	4.56	7.97
E x G	-4.90**	-2.96*	-1.55**	-1.20*	-13.48**	4.92*	-16.22**	7.97**	12.52**	55.20**	8.54**	6.93*	-3.26	-3.20	11.31	17.56*
E x H	-4.86**	-2.22	2.14**	2.88**	1.73	11.43**	-2.80	13.97**	6.59	48.75**	8.65**	11.88**	4.56	13.56**	15.66**	25.47**
E x I	-1.59	2.96*	-0.59	0.48	-6.20**	3.80	-0.93	16.17**	24.93**	68.22**	4.90	11.39**	3.13	10.76**	22.84**	38.33**
E x J	-2.19*	-0.74	1.56**	1.44**	-6.60**	0.31	-6.39**	18.36**	3.94	41.70**	4.72	9.90**	6.938	12.66**	7.80	18.44*
F x G	-1.97*	1.11	2.27**	2.64**	-10.70**	8.29**	-9.34**	24.36**	5.14	35.60**	11.23**	2.97	8.06*	-1.53	11.59	5.75
F x H	-0.53	3.33**	0.00	0.72	-4.67*	4.42*	-17.09**	13.74**	11.34**	45.40**	11.73**	8.42*	3.68	3.33	18.38**	15.57*
F x I	4.38**	10.37**	-2.02**	-0.96	2.24	13.13**	1.26	38.91**	17.40**	47.55**	5.68	5.94	4.28	2.67	6.08	7.93
F x J	-0.72	1.85	3.24**	3.12**	-5.53**	0.54	-19.95**	9.82**	30.58**	66.31**	4.50	3.47	7.72*	3.87	23.53**	22.31**
G x H	4.04**	4.81**	-1.80**	-1.92**	-5.88**	14.14**	-12.54**	12.70**	24.70**	55.32**	9.00**	7.92*	1.25	-1.57	29.62**	29.61**
G x I	-4.69**	-2.22	0.96*	1.20*	-8.18**	6.47**	12.64**	34.76**	3.84	24.25**	6.54*	8.91**	5.87	1.63	10.48	15.02*
G x J	5.77**	5.19**	0.00	-0.96	-5.70**	5.46**	1.85	30.02**	6.15	28.79**	9.80**	10.89**	6.52	0.10	12.05	13.60
H x I	1.08	4.44**	-0.36	0.24	-6.88**	2.52	7.20**	19.52**	3.65	25.69**	7.66**	14.85**	1.96	6.60	21.52**	29.99**
H x J	7.58**	7.78**	3.02**	2.40**	6.62**	12.97**	-5.70**	12.70**	12.15*	37.87**	2.82	8.42*	1.02	3.57	15.28*	20.17**
I x J	-3.45**	-1.48	0.96*	0.72	-4.34**	1.90	-10.78**	5.66	-1.92	15.77*	11.16**	20.79**	5.26	6.63	19.88**	29.90**

* Significant at 5 % probability level ** Significant at 1% probability level; DTF- Days to 50 % Flowering, DTM- Days to Maturity, PH- Plant Height, PL- Peduncle Length, FLA- Flag Leaf Area, PT- Productive Tillers, SL- Spike Length, SPS-Spikelets Per Spike, GPS-Grains Per Spike, BY- Biological Yield, GY- Grain Yield, HI- Harvest Index, TGW- Thousand Grain Weight, A = Raj 3765, B = K 9162, C = PBW 373, D = K 9423, E = K 7903, F = UnnatHalna, G = NW 1014, H = HUW 560, I = NW 1076, J = UP 2425

after the green revolution in 1960s which drew the attention and attempts of plant breeders to breed for reduced plant height. The magnitude of average heterosis for plant height varied from (-12.26) K 9423 x Unnat Halnato (10.83) PBW 373 x UP 2425 where the highest negative heterosis over mid parent was showed by K 9423 x UnnatHalna, K 9423 x NW 1076 and K9423 x HUW 560. The magnitude of standard heterosis for plant height varied from (-1.43) PBW 373 x K 7903 to (22.23) K 9423 x NW 1014 where the highest negative heterosis over standard parent was showed by PBW 373 x K 7903, PBW 373 x NW 1076 and K 9162 x PBW 373. This result showed that a significant neglible percent of heterosis for plant height was seen in the present crosses. Negative heterosis for plant height earlier reported byAshutosh *et al.* (2011), Devi *et al.* (2013), Singh *et al.* (2013) and Kumar and Kerkhi (2014).

Peduncle length

The magnitude of heterosis for peduncle length over mid parent varied from (-18.03) RAJ 3765 x NW 1014 to (12.64) NW 1014 x NW 1076 where the highest positive and significant average heterosis was showed by NW 1014 x NW 1076, Unnat Halna x NW 1076 and K 9162 x K 7903. The magnitude of heterosis for peduncle length over standard parent varied from (-2.54) RAJ 3765 x HUW 560 to(38.91) UnnatHalna x NW 1076) where the highest positive heterosis over standard parent was showed by Unnat Halna x NW 1076, NW 1014 x NW 1 076 and NW 1014 x UP 2425 in desirable direction. Positive heterosis for peduncle length was reported by Farooq *et al.* (2005).

Flag leaf area

Positive heterosis for flag leaf area can be exploited as a beneficial trait as it increases the chance of getting healthy and good quality grain and significant in photosynthetic activity. Flag leaf is responsible for more than 70 % photosynthesis and thus is important for grain filling. The magnitude of average heterosis for flag leaf area varied from(-24.70) PBW 373 x K 7903 to(37.84) K 9423 x NW 1014 where the highest positive heterosis over mid parent was showed by K 9423 x NW 1014, K 9423 x UP 2425 and Unnat Halna x UP 2425in desirable direction.The magnitude of standard heterosis for flag leaf area varied from (-8.24) K 9162 x HUW 560 to (82.56) K 9423 x NW 1014 where the highest positive heterosis over standard parent was showed by K 9423 x NW 1014, K 9423 x UP 2425 and K 7903 x NW 1076 in desirable direction. Similar result onpositive heterosis for this trait earlier reported byFarroq *et al.* (2005), Ghulam *et al.* (2006) and Kumar and Kerkhi (2014).

Productive tillers per plant: Higher number of productive tillers per plant are required for getting higher grain yield. The magnitude of average heterosis for productive tillers per plant varied from(-1.69) K9162 x K9423 to (16.36) RAJ 3765 x NW 1014 where the highest positiveheterosis over mid parent was showed by RAJ 3765 x NW 1014, RAJ 3765 x Unnat Halna and K 9162 x NW 1014 whilethe magnitude of standard heterosis for this trait varied from (-1.98) RAJ 3765 x K 9162 to (20.79) NW 1076 x UP 2425 where the highest positiveheterosis overstandard parent was showed by NW 1076 x UP 2425, K 9423 x NW 1076 and K 9423 x UP 2425.These crosses may prove to be the best source for number of tillers per plant, an important yield contributing trait. The same cross combination may be advanced and utilized for single plant selection. Similar result on positive and significant heterosis for productive tillers per plant was also earlier reported by Ashutosh *et al.* (2011),Sngh *et al.* (2013), Gite *et al.* (2014) and Kumar and Kerkhi (2014).

Spike length

Spike length is one of the most important yield contributing trait which contributes towards productivity and should be taken into consideration for selection. The magnitude of average heterosis for spike length varied from (-4.34) K 7903 x Unnat Halna to (13.49) K 9162 x UP 2425 where the highest positive heterosis over mid parent was showed by K 9162 x UP 2425, K 9162 x NW 1076 and PBW 373 x NW 1076. The

Table 5: Estimation of average and standard heterosis in 45 F_1s cross combination for twelve traits in bread wheat

Trait	GPS		BY		TGW		GY		Trait	GPS		BY		TGW		GY	
F_1s	MP	SP	MP	SP	MP	SP	MP	SP	F_1s	MP	SP	MP	SP	MP	SP	MP	SP
A x B	16.43**	15.68*	20.37**	50.06**	4.09	5.40	17.96**	1.17	D x G	18.79**	16.76*	35.03**	44.03**	8.67**	16.28**	51.86**	18.09**
A x C	15.34*	13.09	23.41**	44.74**	12.43**	11.64**	12.78**	6.59	D x H	25.23**	21.34**	24.05**	16.87**	8.22**	13.77**	43.12**	6.78
A x D	10.70	8.28	7.05	24.64**	3.69	6.79*	15.59**	-4.28	D x I	14.38*	18.26**	19.96**	23.88**	10.58**	17.21**	26.78**	0.62
A x E	21.09**	21.51**	17.30**	43.56**	11.78**	11.98**	30.44**	4.37	D x J	21.01**	16.56*	17.42**	34.82**	3.67	13.57**	7.57	-3.92
A x F	16.69*	6.89	1.89	35.22**	15.01**	12.54**	33.20**	10.23*	E x F	13.70*	8.99	-8.66*	10.10	2.89	2.31	24.25**	-8.36
A x G	17.46**	13.44	29.92**	62.13**	2.15	4.82	31.44**	10.36*	E x G	13.18*	14.12*	28.71**	44.95**	6.40*	10.86**	40.90**	5.61
A x H	19.59**	13.82*	8.28	21.65**	1.85	2.60	25.07**	1.07	E x H	16.70**	16.04*	18.70**	18.90**	12.22**	14.82**	49.99**	7.70
A x I	7.45	9.25	2.69	24.67**	5.35	7.06*	32.92**	13.74**	E x I	10.91**	17.49*	30.24**	42.25**	11.41**	14.98**	34.07**	2.65
A x J	10.37	4.42	5.49	40.24**	7.68**	13.24**	13.73**	8.63	E x J	17.25**	15.92*	-5.82	13.74*	-0.21	6.52*	6.58	-7.80
B x C	14.42*	15.93*	36.71**	46.82**	13.34**	15.57**	14.86**	4.83	F x G	17.27**	7.99	2.90	26.51**	0.07	1.94	35.73**	5.46
B x D	20.34**	21.64**	11.678	18.97**	11.98**	18.30**	26.46**	0.62	F x H	24.15**	12.58	33.75**	47.78**	13.62**	13.61**	52.78**	13.90**
B x F	19.26**	23.58**	34.29**	51.06**	10.52**	13.67**	36.69**	4.93	F x I	7.10	4.08	9.47*	30.88**	7.75**	8.68**	31.69**	4.44
B x G	19.76**	13.62	1.65	24.84**	4.20	4.74	33.91**	6.47	F x J	27.11**	14.55*	-9.20*	19.04**	-1.32	3.04	8.04	-3.57
B x H	12.07*	11.90	26.85**	45.75**	9.67**	15.46**	40.42**	13.34**	G x H	22.67**	17.35*	44.64**	48.36**	3.18	8.09*	44.96**	9.81*
B x I	20.98**	19.10**	26.83**	29.93**	7.33**	10.99**	30.15**	0.95	G x I	9.97	12.34	5.39	17.65**	8.44**	14.54**	29.66**	4.40
B x J	10.30	15.75*	33.55**	48.92**	11.51**	16.28**	32.82**	9.34	G x J	20.87**	14.93*	-7.33	14.15*	4.63	14.24**	2.56	-7.22
B x K	14.23*	11.81	-8.51*	12.59*	5.01	13.24**	9.06*	0.62	H x I	16.61**	17.50*	46.94**	45.73**	6.57*	10.57**	39.50**	7.92
C x D	15.88**	15.61*	25.59**	24.52**	-2.63	0.96	21.89**	7.64	H x J	28.66**	20.54**	23.55**	36.81**	3.01	10.54**	16.27**	1.51
C x E	10.54	13.08	13.39**	19.18**	6.14	7.08*	17.13**	0.15	I x J	15.89**	16.11*	6.03	27.01**	4.57	13.12**	14.45**	5.37
C x F	13.84*	6.50	2.03	17.78**	14.72**	13.06**	8.91	-3.89									
C x G	12.32*	10.66	4.50	12.35*	-1.12	2.16	3.20	-7.68									
C x H	18.84**	15.43*	34.85**	28.19**	14.23**	15.87**	21.33**	4.71									
C x I	14.10*	18.25**	14.10**	18.80**	6.42*	8.88**	14.58**	4.34									
C x J	25.67**	21.35**	32.86**	53.68**	-0.05	5.81	12.50**	13.63**									
D x E	17.08**	19.50**	23.88**	29.15**	7.36**	12.26**	43.29**	5.76									
D x F	18.81**	10.88	2.28	17.19**	-1.10	1.11	48.18**	13.44**									

magnitude of standard heterosis for spike length varied from (-3.20) K 7903 x NW 1014 to (13.56) K 7903 x HUW 560 where the highest positive heterosis over standard parent was showed by K 7903 x HUW 560, K 7903 x UP 2425 and PBW 373 x NW 1076.The highest positive and significant heterosis for spike length was earlier reported by Singh *et al*. (2004), Ashutosh *et al*. (2011), Devi *et al*. (2013) and Kumar and Kerkhi (2014).

Spikelets per spike

The magnitude of average heterosis for spikelets per spike varied from (-0.30) RAJ 3765 x UP 2425 to (29.62) NW 1014 x HUW 560 where highest significant heterosis was showed by NW 1014 x HUW 560, PBW 373 x HUW 560 and K 9423 x NW 1076 in desirable direction. The magnitude of heterosis for spikelets per spike over standard parent varied from (-0.63) RAJ 3765 x UP 2425 to (40.36) K 9423 x NW 1076 where highest significant heterosis was showed by K 9423 x NW 1076, K 7903 x NW 1076 and K 9423 x K7903 in desirable direction over standard parent. Similar result for this character was also reported by Ashutosh *et al.,* (2011),Gite *et al.,* (2014) and Kumar and Kerkhi (2014). Exploitation of this trait may contribute to increase the grain yield in wheat breeding programmes.

Grains per spike

The magnitude of average heterosis for grains per spike varied from (7.10) Unnat halna x NW 1076 to (28.66) HUW 560 x UP 2425 where the highest positive heterosis over mid parent was showed by HUW 560 x UP 2425, UnnatHalna x UP 2425 and PBW 373 x UP 2425. The magnitude of standard heterosis for number of grains per spike varied from (4.08) Unnathalna x NW 1076 to (23.58) K 9162 x K 7903 where the highest positive heterosis over standard parent was showed by K 9162 x K 7903, K 9162 x K 9423 and RAJ 3765 x K7903 in desirable direction.Grains per spike is one of the most important character of grain yield thus, positive and significant heterosis for this trait is important. Similar result for this trait was earlier reported byAshutosh *et al.,* (2011) and Kumar and Kerkhi (2014).

1000 grain weight

The magnitude of average heterosis for 1000 grain weight varied from (-2.63) PBW 373 x K 9423 to (15.01) RAJ 3765 x Unnathalna where the highest positive heterosis over mid parent was showed by RAJ 3765 x Unnathalna, PBW 373 x Unnathalna and PBW 373 x HUW. The magnitude of standard heterosis for this trait varied from (0.96) PBW 373 x K 9423 to (18.30) K 9162 x K 9423 where the highest positive heterosis over standard parent was showed by K 9162 x K 9423, K 9423 x NW 1076 and K 9162 x NW 1076 in desirable direction. Positive and significant heterosis for 1000 grain weight was earlier reported by Ashutosh *et al.,* (2011) and Gite *et al*. (2014).

Biological yield

The magnitude of average heterosis for biological yield per plant varied from (-9.20) Unnathalna x UP 2425 to (46.94) HUW 560 x NW 1076 where the highest positive average heterosis was showed by HUW 560 x NW 1076, NW 1014 x HUW 560 and K 9162 x PBW 373. The magnitude of heterosis for this trait over standard parent varied from (10.14) K 7903 x Unnat halna to (62.13) RAJ 3765 x NW 1014 where highest significant heterosis over standard parent was showed by RAJ 3765 x NW 1014, PBW 373 x UP 2425 and K 9162 x K 7903 in desirable direction. Similar result for biological yield per plant was also reported by Desale and Mehta, (2013), Gite *et al*. (2014) and Kumar and Kerkhi (2014).

Grain yield per plant

The magnitude of average heterosis for grain yield per plant varied from (2.56) NW 1014 x UP 2425 to (52.78) Unnat halna x HUW 560 where the highest positive heterosis over mid parent was showed by Unnat halna x HUW 560, K 9423 x NW 1014 and K 7903 x HUW 560. The magnitude of heterosis for grain yield per plant over standard parent varied from (-8.36) K 7903 x Unnat halna to (18.09) K 9423 x NW 1014 where the highest positive heterosis over standard parent was showed by K 9423 x NW 1014, Unnat halna x HUW 560 and RAJ 3765 x NW 1076 in desirable direction. At the time of selection, grain yield received maximum attention of plant breeder for selecting the plants or genotype. Therefore, positive heterosis for grain yield is desirable. Similar results on positive and significant heterosis for grain yield per plant wasearlier reported by Ashutosh *et al*. (2011), Devi *et al*. (2013), Singh *et al*. (2013), Desale and Mehta, (2013), Singh *et al*. (2014), Gite *et al*. (2014) and Kumar and Kerkhi (2014).

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