Int.J.Curr.Microbiol.App.Sci (2017) *6*(10): 1352-1364

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 Volume 6 Number 10 (2017) pp. 1352-1364
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2017.610.159

Heterosis and Inbreeding Depression for Grain Yield and Related Morphophysiological Characters in Wheat (*Triticum aestivum* L.)

Sanjeev Kumar[1*], S.K. Singh[1], Lokendra Singh[1], S.K. Gupta[1], Vishwanath[1], Prashant Yadav[2], P.C. Yadav[1], Y. Pandey[1], Lokendra Singh[1] and Surendra Kumar[1]

[1]Department of genetics and plant breeding, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur-208002 (U.P.), India
[2]ICAR-Indian Agricultural research Institute, New Delhi 110012, India
**Corresponding author*

Keywords

Heterosis, Inbreeding depression, F1 hybrids, F2 population, Wheat, Generations.

Article Info

Accepted:
14 September 2017
Available Online:
10 October 2017

A B S T R A C T

A set of 45 crosses of wheat were generated by crossing 10 lines *viz*., K-9533, K-9162, K9465, K8962, HUW-234, NW-2036, K-9423, K9351, KRL-210 and K-906 following half diallel design. Ten parents, 45F_1 hybrids and 45 F_2 populations using Randomized Block Design with three replications were evaluated for yield and other important morphophysiological characters at Kanpur (UP, India). Significant genetic differences were observed among the parents, F_1 hybrids and F_2 populations for all the characters under study. The cross K9465 x K9351 and K9162 x K906 exhibited higher heterosis over economic parent 'K 9423' along with considerable inbreeding depression indicating that this cross could be suitable for exploitation of hybrid vigour for grain yield. The cross, K9465 x K9351 and K9162 x K906 had stable performance in both generations hence, can be exploited for development of high yielding stable lines and or isolation of desirable segregants. Negative estimates of heterotic effects were observed in some traits may be attributed to inter-allelic interactions.

Introduction

Wheat (*Triticum aestivum* L.) cultivation reaches far back into history. It has been the basic staple food of different civilizations of Europe, West Asia and North Africa. Wheat is a member of *Poaceae* family and one of the most important cereal crops of the world. The majority of the cultivated wheat varieties belong to three main species of the genus *Triticum*. These are the hexaploid (2n=42), *T. aestivum* L. (bread wheat), the tetraploid (2n=28), *T. durum* and the diploid (2n=14), *T. dicoccum* Schrank and *T. monococcum*. Wheat covers an area of about 221.48 million hectares followed by corn 179.91 million hectares and rice 161.03 million hectares (Anonymous, 2014-15). In 2014-15 world production of wheat was 727.85 million metric tons making it the second most-produced cereal after maize (1,013.56 million metric tons) (Anonymous, 2014-15).

Wheat is a major diet component of human due to its ease of converting grain into flour for making edible, palatable and satisfactory foods. It contains minerals, vitamins and fats which makes it highly nutritious. It contains

70% carbohydrates, 22% crude fibers, 12% protein, 12% water 2% fat, and 1.8% minerals (Anonymous 2015). Wheat has relatively high content of niacin and thiamin which are principal component of the special protein called 'glutin'. Wheat proteins are of special significance because glutin provides the framework of spongy cellular texture of bread and baked products.

In India, wheat is the second most important food crop after rice both in terms of area and production. India has become self-sufficient in meeting wheat grain demand of its population at present but substantial increase in wheat production will be required to provide food security to the ever increasing population of our country. The population of India is likely to reach around 1.3 billion by the year 2020. Thus, the target of increasing wheat production by about 35 million tonnes within two decades is a big challenge that cannot be met only by increasing the area under production and improving the production technology until and unless the genetic potential of wheat varieties for different areas and environments is enhanced considerably.

In breeding programme for development of wheat varieties, indigenous and exotic germplasm is the backbone of successful breeding programme for improving yield and yield contributing traits. Nature always favours the plant populations having much variability in terms of adaptation across the years and locations.

It is true that greater plant diversity provides more diverse plants, greater chances of obtaining high heterotic crosses and broad spectrum of variability in segregating generations during genetic improvement. Selection and hybridization techniques are frequently used for improving genetic constitution of a genotype. Selection is usually practiced for pooling favourable genes while hybridization is predominantly utilized to accumulate favourable genes in a genotype for obtaining better performance. For this purpose donors can be identified from available gene pool. The identification of donor parents for important characters through assessment of genetic variation in the available germplasm is required to devise a successful breeding programme.

Materials and Methods

The experiment was conducted at Crop Research Farm, Nawabganj, C. S. Azad University of Agriculture and Technology, Kanpur- 208 002. (U.P.) during *Rabi*, 2012-13. Geographically, this place is located between 25^0 28´ and 26^0 58´ N latitude, 79^0 31´ and 80^0 34´ E longitudes and at an altitude of 126 meter above from mean sea level. This area falls in sub-tropical climatic zone. The soil type is sandy loam. The annual rainfall is about 1270 mm. The climate of district Kanpur is semi-arid with hot summer and cold winter. The experimental material comprised of 45 F_1's developed by crossing 10 lines *viz*., K-9533, K-9162, K9465, K8962, HUW-234, NW-2036, K-9423, K9351, KRL-210 and K-906 following half diallel design (Table 1).

A total of 100 treatments and 10 parents (45 F_1's and 45 F's $_2$) were used for the study of combining ability for eighteen quantitative characters in wheat. Heterosis and inbreeding depression for each trait was worked out by utilizing the overall mean of each hybrid over replications for each trait.

The nature and magnitude of heterosis was computed as per cent increase or decrease of the mean values of F_1 over mid parent, better parent (BP) and standard variety (SV). Significance of heterosis was tested by simple't' test.

Heterosis over mid parent (%)

$$Ht = \frac{\overline{F_1} - \overline{M.P}}{\overline{M.P}} x\ 100$$

Heterosis over better parent (%)

$$Hbt = \frac{\overline{F_1} - \overline{B.P}}{\overline{B.P}} x\ 100$$

Heterosis over standard check variety (%)

$$Ht = \frac{\overline{F_1} - \overline{SV}}{\overline{SV}} X\ 100$$

Where,

Ht = Heterosis
Hbt = Heterobeltiosis
M.P= Mid parent
B.P= Better parent
S.V= Standard Variety

Test of significance

The "t" test was applied to determine whether F_1 hybrid means were statistically different from mid parent and better parent values (Wynne *et al.,* 1970).

$$t_{ij} = \frac{\overline{F_{1\ ij}} - \overline{MP}}{\sqrt{3/2\ \frac{MSE}{r}}}$$

The "t" values for heterobeltiosis and standard heterosis were calculated by the formula as reported by Wynne *et al.,* (1970).

$$t_{ij} = \frac{\overline{F_{1\ ij}} - \overline{BP}}{\sqrt{\frac{2MSE}{r}}}$$

Where,

F_1ij = The mean of the ij_{th} F_1 cross
MP = The mid parent value
BP = The better parent value
EMS = Error mean square.

The value of critical difference (CD) was used for testing the significance of heterosis.

The critical difference (CD) was calculated with the help of following formula:

CD = SEd × t value

Where,

SEd is standard error of the difference of the treatment means to be compared, and is equal to:

$SEd = (2\ Mse/r)^{0.5}$

Where,

MSe= Error mean square obtained from ANOVA table

r = Number of replications

t = Table value of 't' at 5% and 1% level of significance for error degree of freedom.

Inbreeding depression refers to decrease in fitness and vigour due to inbreeding.

The degree of inbreeding is measured by the inbreeding coefficient. Inbreeding depression was estimated when both F_1 and F_2 populations of the same cross were available. It was measured as follows:

$$ID\ (\%) = \frac{\overline{F_1} - \overline{F_2}}{\overline{F_1}} x\ 100$$

Where,

$\bar{F}_1$ = Mean value of F_1 generation
$\bar{F}_2$ = Mean value of F_2 generation

SE for heterobeltiosis, standard heterosis and inbreeding depression = $\sqrt{2Me/r}$

Where,

Me = mean error variance
r = number of replications
Calculated 't' value = difference/SE

The 't' test was applied for testing significance of estimated value at error degree of freedom.

CD = SE x t at error d.f.

Results and Discussion

The degree of heterosis should preferably (Table 2) be measured as superiority of F_1 hybrids over the best parent treated as commercially cultivated variety. The estimate of heterosis over F_1 hybrids in real sense, decides whether the hybrid is worth exploiting or not. Though, the production of hybrid seed is technically feasible, yet the practical approach of this concept needs further exploration and perfection observed that F_2 performance might be a good indication of predicting F_1 hybrids in wheat. On the other hand the inbreeding depression in F_2 generation has expressed the performances of the different crosses in the present investigation. Heterosis was measured as deviation of hybrids from economic parent 'K9423' and exploit the maximum *per se* performance among the cultivars for grain yield. It is to be point out that the experiment for the present study was conducted under optimum fertility and irrigated conditions, hence the appropriate choice of K9423 as economic cultivar in respect of grain yield and other economic traits was made.

Out of 45 combinations the desired heterosis over economic parent was measured in 43 crosses. The heterosis over economic parent (K 9423) varied from -15.30 to 18.66 per cent. The performance for early days to anthesis over economic parent was observed in 31 cross combinations, exhibited significant and negative performance indicated earliness in the crosses. The crosses K9351 x KRL210, K9423 x KRL210, K9162 x HUW234, K9162 x K9351, and NW2036 x KRL210 with negative and significant values were in order of merit for earliness. The highest positive and significant heterosis was recorded in the cross, K9162 x K906 and K9162 x KRL210 over economic parent for lateness. The range of inbreeding depression varied from -12 to 14 per cent out of 45 cross only eight crosses exhibited significant and positive values indicating inbreeding depression in F2 generation. The crosses K9533 x K9351, K9533 x HUW2036, KRL210 x K906, K9533 x K9465 and K9465 x NW2036 were in order of merit for higher inbreeding depression. On the other hand two crosses K9162 x NW2036 and K9423 x K906 were in order of merit with no inbreeding depression.

The negative value of heterosis over economic parent exhibited average specific leaf weight in all the crosses. Out of these sixteen cross combinations showed positive and significant performance indicated towards more dry weight per unit. The crosses, namely, K9162 x K906, K9533 x K9162, K9465 x K9351, K9351 x K906 and K9424 x K906 were in order of merit observed desirable for high specific leaf weight. The inbreeding depression performed significant and positive expression in twenty nine crosses over economic parent. The crosses K8962 x KRL210, NW2036 x K906, HUW234 x K906, K9162 x K8962 and K9423 x K9351 were in order of merit for higher inbreeding depression. Two crosses K9162 x K9465 and K9465 x K9423 showed negatively significant inbreeding depression.

Out of 45 combinations, the desired heterosis over economic parent was measured in 43 crosses. The superiority for leaf angle over economic parent was observed as desirable in 19 cross combinations exhibiting significant and negative performance. The crosses, namely, K9533 x KRL210, K9533 x NW2036, K9533 x K9423, K9162 x K8962 and K8962 x KRL210 were in order of merit observed desirable for low leaf angle. In case of inbreeding depression, only two crosses K9162 x K9465 and HUR234 x NW2036 also showed the significant and negative values in support of heterosis.

The increased percentage over economic parent for chlorophyll florescence in 5 cross (K9162x NW2036, K8962 x K906, K9533 x K9351, K9533 x K9162, K9465 x KRL210) combinations were positive and highly significant while twenty one crosses coined the negative and significant performance exhibited decreased heterosis for this trait ranged from -15.75 to 9.62 On the other hand, the inbreeding depression for chlorophyll florescence performed 9 crosses (K9162 x K8962, K9465 x K9351, K9162 x K9465, K9162 x NW2036, K8962 x HUW234, K8962 x K906, K9533 x HUW234, K9533 x K9465 and K8962 x K9423) manifested positive values over economic parent, exhibited variability from 0.0 to 12.6 per cent. Such type of variability at inbreeding depression indicated that increased percentage of chlorophyll florescence. The heterosis for canopy temperature depression over economic parent was found positive and highly significant in 25 cross showed wheat was cooler in high temperature conditions, while inbreeding depression for this trait over economic parent in 36 crosses showed Positive and highly significant value. Positive and negative expression of values indicated the presence of dominance and recessive genes. Chlorophyll intensity exhibited highest heterosis in the combination HUW234 x K9423, NW2036 x K9351, K9465 x K9351, K9162 x K906 and K9465x K935 in order of merit along with high inbreeding depression value of K8962 x K9423, K8962 x K906, K9533 x KRL210, K9351 x K906 and K8962 x K9351. Therefore, it is assumed that chlorophyll intensity is a partially heritable character from parent to its progenies. Generally it depends upon the climatic condition and affected by environment, so the selection will not be reliable.

The heterosis over economic parent in case of flag leaf area of main shoot, exhibited highly significant and positive impression for 14 cross combinations. The crosses in order of merit were K9351 x K906, K9162 x K906, K9533 x KRL210, K9351 x K906 and K8962 x K935 and positive and significant response of inbreeding depression showed all the 43 crosses. The exploitation in leaf area will be a good precursor for high photosynthesis which will certainly increase the strengthening of seeds and carry over the increase in yield. Desirable heterosis over economic parent was measured in days to physiological maturity.

The superiority of heterosis due to negative and significant performance for early days to physiological maturity over economic parent in 12 crosses (K9162 x HUW234, HUW234 x KRL210, K9162 x K8962, HUW234 x K9351 and K8962 x KRL210 in order of merit) and positive and significant performance for late days to physiological maturity over economic parent in 12 crosses (K9162 x K906, K9162 x KRL210, K9162 x K8962 and K9465 x K9423 in order of merit) along with inbreeding depression values was considerable. Both cases were independently associated for expression of this trait.

Table.1 Feature of parental genotypes used for diallel mating design in wheat (*Triticum aestivum* L.)

Genotype	Pedigree	Year of Release	Average Yield (q/ha)	Production Condition
K9533	HI1077/HUW234	2002	35.0	Irrigated, late sown
K9162	K7827/HD2204	2001	35.0	Irrigated, late sown
K9465	B1153/CB85	1997	20.0	Late sown, rainfed
K8962	K7401/HD2160	1995	19.5	Rained, timely sown
HUW234	HUW-21*2/CPAN1666	1986	35.0	Irrigated, late sown
NW2036	BOW/CROW//BUC/PVN	2002	40.0	Irrigated, late sown
K9423	HP1633/KSONA/UP262	2005	40-45	High fertility, irrigated and very late sown
K9351	K72/K8077//K72	2004	26-36	Rained, timely sown
KRL210	PBW65/2*PASTOR	2009	33.75	Irrigated, timely sown
K906	UP2338/PBW373	2010	35.00	Irrigated, late sown

Table.2 Estimates of heterosis and inbreeding depression in percentage for 18 attributes in 10 x 10 diallel cross of wheat

Hybrid combinations	Days to Anthesis		Specific Leaf Weight		Leaf Angle	
	Heterosis Over EP	Inbreeding depression	Heterosis Over EP	Inbreeding depression	Heterosis Over EP	Inbreeding depression
K9533 x K9162	-1.49	0.76	27.93**	11.88**	-16.56**	19.92**
K9533 x K9465	-0.75	3.01*	-13.24**	1.46	36.59**	3.09*
K9533 x K8962	-1.87	2.66**	-13.87**	2.21	22.67**	1.95
K9533 x HUW234	-1.12	4.53*	-13.24**	-3.65	47.23**	4.06*
K9533 x NW2036	-0.37	0.37	-14.50**	7.41**	-29.28**	4.90
K9533 x K9423	-2.61	0.77	23.50**	6.67**	-27.33**	1.04
K9533 x K9351	-1.87	14.07**	19.70**	0.00	6.05**	3.15**
K9533 x KRL210	-4.85**	1.57	5.57*	7.62**	-31.11**	-5.30
K9533 x K906	-4.85**	0.00	-11.97**	-0.72	-10.01**	4.55**
K9162 x K9465	-6.34**	2.79	-22.10**	-10.57*	-12.41**	-4.17*
K9162 x K8962	-11.57**	0.00	20.33**	13.16**	-20.97**	1.20
K9162 x HUW234	-12.31**	0.85	-17.67**	4.62	44.84**	-0.39
K9162 x NW2036	-10.45**	-12.08**	4.50	7.88**	-13.85**	2.56*
K9162 x K9423	-5.97**	-1.98	9.56**	9.25**	-12.97**	4.99**
K9162 x K9351	-12.31**	3.83	-17.67**	5.38	48.05**	3.62**
K9162 x KRL210	17.54**	-0.32	-15.77**	5.26	66.12**	2.84*
K9162 x K906	18.66**	2.52*	29.83**	10.24**	-14.04**	3.15
K9465 x K8962	-1.49	0.00	-9.44**	11.89**	1.07	3.99
K9465 x HUW234	-1.49	0.76	-18.30**	0.78	61.40**	3.78**
K9465 x NW2036	-9.33**	2.88*	-13.87**	5.15	62.09**	3.50**
K9465 x K9423	-8.58**	1.22	-13.24**	-5.11*	36.84**	5.57**
K9465 x K9351	-4.10**	1.17	24.13**	5.61*	4.91**	8.70**
K9465 x KRL210	-3.73*	-0.39	5.13*	6.63**	46.28**	6.03**
K9465 x K906	-4.10**	1.56*	-14.50**	7.41**	28.78**	11.00**
K8962 x HUW234	-7.46**	0.40	22.23**	6.22**	0.44	4.64**
K8962 x NW2036	-8.58**	0.41	4.50	6.67*	3.65*	3.58
K8962 x K9423	-8.21**	0.00	11.46**	10.23**	-10.77**	-0.92
K8962 x K9351	-8.58**	-1.22	-0.57	10.19**	-18.20**	0.31
K8962 x KRL210	-8.21**	-0.81	7.03**	15.98**	-20.09**	5.36**
K8962 x K906	-6.34**	0.00	-18.30**	-8.53	-13.60**	0.58
HUW234 x NW2036	-1.12	0.00	-15.14**	4.48	-11.78**	-3.21*
HUW234 x K9423	-7.84**	0.81	-13.24**	9.49**	-14.99**	4.15*
HUW234 x K9351	-8.21**	0.00	-9.44**	11.89**	43.77**	2.10
HUW234 x KRL210	-5.60**	7.11	0.70	8.81**	20.47**	1.99
HUW234 x K906	-8.96**	2.05	17.16**	13.51**	27.39**	2.97**
NW2036 x K9423	-7.84**	0.81	-18.30**	-0.78	46.03**	0.00

NW2036 x K9351	-1.49	0.00	22.86**	6.70**	-15.55**	4.10*
NW2036 x KRL210	-11.94**	0.42	-11.34**	10.00*	40.49**	31.82**
NW2036 x K906	-11.94**	-1.27	1.96	15.53**	5.29**	5.08**
K9423 x K9351	-11.94**	3.81	-8.80**	12.50**	-12.97**	11.22**
K9423 x KRL210	-13.06**	-1.29	-10.70**	0.00	22.42**	4.89**
K9423 x K906	-11.57**	-2.11	23.50**	7.18**	-9.57**	14.00*
K9351 x KRL210	-15.30**	0.00	0.06	12.03**	24.87**	7.41**
K9351 x K906	-5.60**	-1.19	24.13**	12.76**	4.97**	5.34**
KRL210 x K906	-2.24	3.05*	-1.84	12.26**	23.93**	5.74*
SE±	**1.38**		**0.127**		**0.87**	

Table.2 Contd.

Hybrid combinations	Chlorophyll Florescence's		Canopy Temperature Depression		Chlorophyll Intensity	
	Heterosis Over EP	Inbreeding depression	Heterosis Over EP	Inbreeding depression	Heterosis Over EP	Inbreeding depression
K9533 x K9162	3.24**	0.00	18.88**	28.24**	11.08**	9.83**
K9533 x K9465	-2.31**	2.84*	-4.90	8.82*	-5.17	10.22**
K9533 x K8962	0.46	0.00	-6.29	25.37**	-1.23	13.88**
K9533 x HUW234	-1.85*	3.30**	-8.39*	23.66**	3.20*	9.23**
K9533 x NW2036	0.93	0.00	-0.70	12.68**	4.19	6.54**
K9533 x K9423	0.93	0.00	33.57**	17.28**	21.84**	8.42**
K9533 x K9351	4.17**	0.00	31.47**	18.09**	6.73**	10.69**
K9533 x KRL210	-9.26**	0.00	0.70	17.36**	10.84	16.96**
K9533 x K906	-1.39	0.00	9.09**	14.74**	6.65**	13.16**
K9162 x K9465	-0.46	8.84**	-6.78*	22.73**	12.89*	11.27**
K9162 x K8962	-0.93	12.62**	33.78**	15.32**	16.83**	8.71**
K9162 x HUW234	-6.02**	0.00	-11.89**	29.37**	4.27**	11.26**
K9162 x NW2036	9.26**	8.05**	-6.99*	21.80*	6.40*	0.00
K9162 x K9423	-3.70**	0.00	-2.10	10.71*	13.14	12.26**
K9162 x K9351	-12.96**	0.00	-11.89**	50.00**	-20.03**	7.19**
K9162 x KRL210	-9.72**	0.00	-6.99*	0.00	-15.60*	7.00**
K9162 x K906	-7.41**	0.0	78.32**	16.08**	24.38**	10.50**
K9465 x K8962	-15.74**	0.00	-9.79**	20.93**	2.13**	8.68**
K9465 x HUW234	-2.31**	0.00	-7.69*	37.88**	-20.53*	-0.10
K9465 x NW2036	-6.48**	0.00	-8.39*	25.19**	1.48*	8.25**
K9465 x K9423	-2.78**	0.00	-5.59	31.85**	3.12	10.43**
K9465 x K9351	-3.70**	10.10**	75.52**	6.37**	29.97**	11.18**
K9465 x KRL210	1.85*	0.00	18.18**	10.65**	19.05**	11.10**
K9465 x K906	-9.26**	0.00	-4.90	8.82	-13.14	9.74**
K8962 x HUW234	-0.46	6.05**	36.99**	7.10*	10.10**	8.72**
K8962 x NW2036	-5.09**	0.00	32.17**	1.59	4.68**	12.47**
K8962 x K9423	-0.93	2.80*	60.14**	6.11*	20.85**	18.75**
K8962 x K9351	-6.94**	0.00	-10.49**	17.97*	-19.62**	14.40**
K8962 x KRL210	-9.26**	0.00	-8.39*	19.08**	10.51*	12.41**
K8962 x K906	5.09**	3.96**	56.64**	15.18**	20.03**	17.44**
HUW234 x NW2036	-0.46	0.00	56.64**	11.16**	17.16**	12.12**
HUW234 x K9423	-1.85*	0.00	56.64**	11.61*	46.22**	11.96**
HUW234 x K9351	0.00	0.00	57.90**	10.54**	10.43**	11.00**
HUW234 x KRL210	-0.93	0.00	48.95**	0.00	16.26**	0.00
HUW234 x K906	-0.46	0.00	59.44**	0.00	6.65**	12.47**
NW2036 x K9423	-1.39	0.00	18.04**	5.21*	1.23**	12.98**
NW2036 x K9351	-1.39	0.00	-8.25*	7.77	37.60*	11.40**
NW2036 x KRL210	-1.39	0.00	-6.99*	54.14**	-24.47*	6.20*
NW2036 x K906	-1.85*	0.00	51.75**	7.37**	11.49**	10.75**
K9423 x K9351	0.93	0.00	57.34**	4.89	21.26**	1.02
K9423 x KRL210	-0.46	0.00	61.96**	4.58*	22.74**	10.37**
K9423 x K906	1.39	0.00	69.23**	4.96*	22.82**	13.90**
K9351 x KRL210	-2.31**	0.00	32.87**	4.74	13.79**	14.29**
K9351 x K906	0.00	0.00	56.64**	11.61**	-0.66**	14.88**
KRL210 x K906	-1.85*	0.00	10.49**	0.00	22.50**	13.47**
SE±	**0.0059**		**0.153**		**0.33**	

Table.2 Contd.

Hybrid combinations	Flag Leaf Area		Days to Physiological Maturity		Plant Height	
	Heterosis Over EP	Inbreeding depression	Heterosis Over EP	Inbreeding depression	Heterosis Over EP	Inbreeding depression
K9533 x K9162	9.30**	10.32**	1.10	3.81*	17.82**	4.04**

K9533 x K9465	-5.37**	16.95**	0.55	0.82	6.61**	2.88**
K9533 x K8962	-10.59**	11.75**	-1.93**	1.97**	11.92**	3.62**
K9533 x HUW234	-18.02**	14.94**	0.00	3.03*	13.18**	3.37**
K9533 x NW2036	-4.13*	13.66**	-1.93**	0.56	0.71	4.06**
K9533 x K9423	-4.12*	14.27*	-0.83	0.00	0.26	1.51
K9533 x K9351	-2.92	10.74*	0.55	1.10	13.53**	3.26**
K9533 x KRL210	4.08*	10.81**	-2.20**	-0.28	-2.75**	3.56*
K9533 x K906	-4.03*	9.74**	2.48**	0.00	11.21**	2.51*
K9162 x K9465	10.33**	10.66**	0.28	3.02*	1.89*	3.01**
K9162 x K8962	3.78	8.01**	-3.31**	1.42	9.56**	4.56**
K9162 x HUW234	-6.46**	12.28*	-4.96**	0.00	3.07**	4.89**
K9162 x NW2036	1.24	9.57**	0.00	3.03*	12.67**	3.81**
K9162 x K9423	-2.78	14.12**	0.00	0.28	15.22**	3.79**
K9162 x K9351	-21.20**	24.28**	-2.20**	-0.56	0.83	4.33**
K9162 x KRL210	-34.28**	12.21**	7.16**	2.06*	-2.20**	5.03*
K9162 x K906	12.54**	9.49**	9.64**	1.26	16.92**	3.80**
K9465 x K8962	-10.58**	4.42*	1.93**	2.16**	36.11**	1.13
K9465 x HUW234	-34.41**	6.26	2.48**	1.34	-2.83**	9.96**
K9465 x NW2036	-19.19**	5.89**	0.55	2.74*	21.95**	4.97**
K9465 x K9423	-3.22	10.66**	2.48**	2.15	19.08**	5.52**
K9465 x K9351	-4.72*	15.68**	0.28	0.00	-2.48**	4.24**
K9465 x KRL210	5.80**	14.81*	1.38	1.63	9.83**	3.01**
K9465 x K906	-25.70**	4.89	1.65*	0.00	21.60**	1.10
K8962 x HUW234	4.01*	12.03**	-0.55	1.66*	32.61**	4.45**
K8962 x NW2036	3.07	7.43*	1.38	0.00	36.51**	2.45**
K8962 x K9423	4.33*	7.13**	-1.65*	1.12	17.86**	3.54**
K8962 x K9351	-7.53**	12.98**	-0.55	1.94*	13.49**	2.56*
K8962 x KRL210	3.15	8.45**	-2.20**	1.69*	14.40**	3.16**
K8962 x K906	-0.17	4.72**	-1.93**	1.12*	20.38**	3.56**
HUW234 x NW2036	12.23**	7.56*	2.20**	0.81	15.38**	2.90**
HUW234 x K9423	-6.72**	9.27**	1.93**	2.43**	23.52**	2.48**
HUW234 x K9351	4.72*	7.38**	-2.48**	1.13	8.50**	3.95**
HUW234 x KRL210	4.28*	7.34**	-4.96**	0.00	5.70**	4.17**
HUW234 x K906	-2.74	16.14**	-0.28	2.21*	7.47**	2.67*
NW2036 x K9423	-38.39**	9.59**	1.10	1.63	19.67**	4.17*
NW2036 x K9351	4.49*	15.65**	1.93**	-0.27	13.65**	5.37**
NW2036 x KRL210	-24.25**	8.06*	-0.55	-0.28	-0.04	4.64**
NW2036 x K906	-4.04*	10.85**	-1.93**	1.40	1.26	5.09**
K9423 x K9351	3.79	9.37**	-0.55	0.00	-3.19**	4.19**
K9423 x KRL210	-4.63*	9.85*	0.28	0.82	9.05**	3.35**
K9423 x K906	9.09**	12.57**	0.83	0.82	0.08	3.73**
K9351 x KRL210	3.87*	4.80*	1.38	1.63*	13.14**	3.27**
K9351 x K906	19.65**	10.06**	1.65*	0.27	-3.46**	6.23**
KRL210 x K906	-4.08*	4.68*	3.31**	0.80	4.68**	2.10*
SE±	**0.47**		**0.83**		**0.65**	

Table.2 Contd.

Hybrid combinations	Spike Length		No. of Spikelets Spike -1		Spike Density	
	Heterosis Over EP	Inbreeding depression	Heterosis Over EP	Inbreeding depression	Heterosis Over EP	Inbreeding depression
K9533 x K9162	16.35**	12.42**	5.81**	8.16*	-9.22**	-5.00*
K9533 x K9465	-3.42	14.17**	1.41	7.59**	5.09**	-7.59*
K9533 x K8962	23.19**	13.58**	5.49**	9.08**	-14.31**	-5.14
K9533 x HUW234	22.05**	12.15**	-3.30**	5.19**	-20.91**	-8.00*
K9533 x NW2036	-2.66	13.67**	-9.73**	9.57**	-7.15**	-4.59*
K9533 x K9423	17.87**	7.10*	-2.04*	6.57	-16.92**	-0.50
K9533 x K9351	34.14**	10.15**	-3.61**	10.59**	-28.06**	0.76
K9533 x KRL210	-9.35**	18.04**	9.73**	7.01**	21.18**	-13.28**
K9533 x K906	29.43**	7.17*	-8.16**	8.55**	-29.02**	1.55
K9162 x K9465	4.41*	15.37**	-27.79**	7.39**	-30.95**	-9.76**
K9162 x K8962	27.76**	0.00	5.34**	7.60**	-17.61**	-6.34*
K9162 x HUW234	-2.74	14.03**	4.71**	7.80**	7.70**	-7.28*
K9162 x NW2036	39.24**	15.54**	5.18**	8.81**	-24.35**	-7.82**
K9162 x K9423	17.64**	20.30**	1.26	9.46**	-13.89**	-13.58**
K9162 x K9351	30.72**	16.06**	1.10	8.54**	-22.70**	-8.90**
K9162 x KRL210	17.41**	7.42*	-18.84**	2.13	-30.81**	-5.57*
K9162 x K906	-2.36	17.68**	-10.05**	2.09	-7.98**	-18.98**

K9465 x K8962	40.23**	12.72**	1.41	8.36**	-27.65**	-4.94**
K9465 x HUW234	-13.42**	18.23**	-8.48**	7.03*	5.64**	-13.67**
K9465 x NW2036	7.22**	16.67**	0.78	9.03**	-6.05**	-9.08**
K9465 x K9423	8.90**	18.51**	0.31	4.54**	-7.98**	-17.34**
K9465 x K9351	15.97**	6.23*	0.31	4.69**	-13.48**	-1.59
K9465 x KRL210	21.48**	16.90**	-3.30**	6.49**	-20.50**	-12.63**
K9465 x K906	-11.18**	13.10**	5.81**	11.28**	19.12**	-2.19
K8962 x HUW234	30.04**	10.82**	-3.30**	8.60**	-25.72**	-2.41
K8962 x NW2036	20.15**	10.09**	9.26**	9.91**	-9.08**	-0.15
K8962 x K9423	22.43**	14.29**	9.89**	10.71**	-10.18**	-3.98
K8962 x K9351	8.75**	14.34**	5.97**	11.56**	-2.61	-3.25
K8962 x KRL210	10.30**	15.44**	8.48**	11.00**	-1.65	-5.17*
K8962 x K906	10.34**	11.47**	5.65**	7.43**	-4.26*	-4.60
HUW234 x NW2036	8.97**	12.56**	-4.24**	10.16**	-12.10**	-2.82
HUW234 x K9423	11.25**	16.37**	-3.45**	9.59**	-13.20**	-8.08**
HUW234 x K9351	8.37**	0.00	0.94	11.66**	-7.02**	1.18
HUW234 x KRL210	9.73**	13.03**	-2.98**	0.00	-11.55**	-7.31*
HUW234 x K906	17.95**	7.48**	6.44**	0.00	-9.90**	-1.22
NW2036 x K9423	-14.11**	14.12**	-17.74**	11.07**	-4.26*	-3.59
NW2036 x K9351	0.30	7.28*	5.97**	7.26*	5.64**	0.00
NW2036 x KRL210	-11.33**	21.05**	-13.50**	5.81**	-2.48	-19.32**
NW2036 x K906	-2.66	14.84**	-17.27**	5.12**	-14.99**	-11.49*
K9423 x K9351	6.54**	14.17**	-3.61**	9.12**	-9.63**	-5.94*
K9423 x KRL210	7.53**	11.78**	5.34**	8.05**	-2.06	-4.21
K9423 x K906	17.95**	12.89**	0.78	0.00	-14.58**	-5.96**
K9351 x KRL210	6.54**	10.71**	6.75**	12.94**	0.28	2.74
K9351 x K906	10.57**	13.27**	5.49**	10.57**	-4.40*	-2.73
KRL210 x K906	7.38**	14.94**	6.12**	7.54**	-1.10	-8.62*
SE±	**0.17**		**0.204**		**0.045**	

Table.2 Contd.

Hybrid combinations	**No. of Productive Tillers Plant -1**		**No. of Grains Spike -1**		**1000 Grain Weight**	
	Heterosis Over EP	**Inbreeding depression**	**Heterosis Over EP**	**Inbreeding depression**	**Heterosis Over EP**	**Inbreeding depression**
K9533 x K9162	-1.60	24.10**	21.42**	7.72**	6.01**	3.44**
K9533 x K9465	-14.05**	53.10**	1.38	14.28**	-4.63**	10.51**
K9533 x K8962	-18.79**	27.74**	-4.85**	11.94**	-1.16**	6.92**
K9533 x HUW234	-15.23**	23.78**	-1.58	10.14**	-18.02**	6.27**
K9533 x NW2036	-21.16**	25.56**	11.38**	10.15**	-0.20	4.17**
K9533 x K9423	-24.13**	45.31**	24.45**	9.66**	-7.44**	7.30**
K9533 x K9351	-15.83**	26.76**	22.36**	9.24**	10.09**	5.42**
K9533 x KRL210	-1.60	23.49**	16.52**	8.47**	1.80**	7.54**
K9533 x K906	-1.01	24.55**	14.20**	8.42**	-6.04**	4.00**
K9162 x K9465	10.25**	24.73**	-2.50**	5.97**	3.60**	7.82**
K9162 x K8962	-14.64**	25.69**	19.43**	5.97**	12.60**	4.60**
K9162 x HUW234	-18.20**	24.64**	13.96**	8.47**	4.37**	6.35**
K9162 x NW2036	-21.75**	21.21*	16.14**	9.29**	2.80**	6.09**
K9162 x K9423	-22.35**	30.53**	20.13**	6.46**	4.37**	7.03**
K9162 x K9351	-9.90**	41.45**	-3.57**	10.33**	-10.32**	7.19**
K9162 x KRL210	-19.38**	53.68**	-16.91**	6.66**	-8.63**	8.69**
K9162 x K906	-3.97	24.07**	16.59**	6.36**	13.66**	7.73**
K9465 x K8962	-18.20**	16.67**	-2.87**	1.15	-8.64**	7.41**
K9465 x HUW234	-23.53**	8.53	-12.83**	9.28**	-13.81**	6.78**
K9465 x NW2036	-17.01**	29.29**	6.01**	8.26**	7.69**	4.36**
K9465 x K9423	11.44**	17.02**	9.13**	5.38**	7.82**	3.44**
K9465 x K9351	12.63**	18.95**	12.06**	6.91**	14.88**	3.43**
K9465 x KRL210	-2.79	21.95**	14.89**	7.00**	3.94**	3.90**
K9465 x K906	-8.71*	50.65**	-16.69**	6.50**	-4.35**	7.49**
K8962 x HUW234	-2.19	25.45**	3.60**	6.60**	2.53**	5.57**
K8962 x NW2036	-17.01**	29.29**	19.19**	5.01**	12.67**	3.26**
K8962 x K9423	-15.23**	20.28**	9.22**	2.82*	0.04	6.82**
K8962 x K9351	-16.42**	27.66**	-1.17	9.05**	0.10	6.12**
K8962 x KRL210	-19.38**	19.85*	3.48**	5.77**	2.35**	6.64**
K8962 x K906	-5.16	24.37**	20.53**	6.02**	2.41**	4.95**
HUW234 x NW2036	-23.53**	22.48**	3.61**	8.51**	-5.03**	7.33**
HUW234 x K9423	-14.05**	31.72**	11.28**	4.47**	-3.33**	3.38**
HUW234 x K9351	-2.19	22.42**	3.13**	7.83**	17.73**	5.66**

HUW234 x KRL210	-6.94	17.83**	3.34**	4.80**	0.10	5.38**
HUW234 x K906	-4.56	0.00	3.25**	7.54**	11.52**	3.45**
NW2036 x K9423	-6.94	19.75**	5.59**	5.04**	-5.06**	6.59**
NW2036 x K9351	-18.79**	24.09**	16.64**	4.71**	17.77**	5.50**
NW2036 x KRL210	-12.86**	38.10**	-14.79**	5.99**	-7.81**	5.45**
NW2036 x K906	-16.42**	29.08**	1.46	2.66**	11.06**	5.68**
K9423 x K9351	-19.98**	28.89**	9.29**	7.90**	0.51	8.70**
K9423 x KRL210	-15.23**	15.38**	8.49**	4.89**	8.17**	4.09**
K9423 x K906	-2.79	19.51**	9.99**	6.60**	10.06**	1.17
K9351 x KRL210	-1.60	23.49**	13.24**	6.19**	3.57**	5.09**
K9351 x K906	-18.79**	17.52*	16.91**	5.59**	11.97**	2.32
KRL210 x K906	2.55	18.50**	20.75**	5.46**	10.52**	5.87*
SE±	**0.20**		**0.32**		**0.11**	

Table.2 Contd.

Hybrid combinations	Grain Yield Plant -1		Biological Yield Plant -1		Harvest Index	
	Heterosis Over EP	Inbreeding depression	Heterosis Over EP	Inbreeding depression	Heterosis Over EP	Inbreeding depression
K9533 x K9162	-5.06**	21.01**	12.04**	9.853**	-15.25**	12.396**
K9533 x K9465	-33.72**	50.93**	2.65	10.915**	-35.42**	44.927**
K9533 x K8962	-24.09**	23.94**	14.68**	11.494**	-33.81**	14.044**
K9533 x HUW234	-28.90**	20.57**	28.03**	12.355**	-44.45**	9.257
K9533 x NW2036	-8.71**	17.03**	1.01	5.220**	-9.63**	12.427**
K9533 x K9423	0.61	23.43**	7.60**	12.864**	-6.48**	12.172**
K9533 x K9351	0.82	16.74**	13.86**	13.459**	-11.44**	3.801**
K9533 x KRL210	-4.89**	22.74**	8.26**	17.352**	-12.07**	6.477
K9533 x K906	-11.55**	15.76**	27.70**	11.742**	-30.70**	4.538
K9162 x K9465	-10.80**	19.23**	21.44**	4.613	-26.49**	15.372**
K9162 x K8962	1.64	14.42**	15.01**	7.736**	-11.62**	7.242**
K9162 x HUW234	-29.96**	36.24**	10.56**	8.644**	-36.65**	30.133**
K9162 x NW2036	-8.37**	15.29**	14.02**	9.971**	-19.60**	5.845
K9162 x K9423	-8.37**	26.14**	16.33**	11.756**	-21.23**	16.303**
K9162 x K9351	-33.72**	45.82**	1.17	8.958**	-34.49**	40.479**
K9162 x KRL210	-35.77**	62.39**	-0.97**	7.820**	-35.14**	59.212**
K9162 x K906	14.14**	14.22**	22.10**	12.146**	-6.51**	2.373
K9465 x K8962	-17.49**	16.98**	10.40**	8.507**	-25.27**	9.239**
K9465 x HUW234	-34.95**	39.81**	0.84	14.183**	-35.48**	29.909**
K9465 x NW2036	-22.48**	26.22**	12.54**	12.445**	-31.11**	15.672**
K9465 x K9423	-15.72**	20.71**	39.56**	9.091**	-39.61**	12.760**
K9465 x K9351	25.83**	16.05**	29.02**	5.875**	-2.44	10.839**
K9465 x KRL210	-0.07	16.48**	16.99**	8.873**	-14.56**	8.372**
K9465 x K906	-24.94**	28.17**	11.88**	9.720**	-32.90**	20.447**
K8962 x HUW234	-12.85**	20.78**	0.84	9.804**	-13.55**	12.192**
K8962 x NW2036	-4.68**	21.25**	41.04**	7.827**	-32.41**	14.572**
K8962 x K9423	-3.69**	21.43**	34.62**	6.120**	-28.36**	16.401**
K8962 x K9351	-14.35**	19.43**	45.38**	12.161**	-41.08**	8.235**
K8962 x KRL210	-3.35**	12.65**	27.20**	11.269**	-24.02**	1.464
K8962 x K906	-5.16**	24.53**	30.00**	9.886**	-27.05**	16.248**
HUW234 x NW2036	-11.38**	24.09**	36.76**	5.663**	-35.18**	19.448**
HUW234 x K9423	-7.21**	13.51**	28.52**	11.154**	-27.79**	2.623**
HUW234 x K9351	-4.30**	19.35**	39.56**	8.383**	-31.43**	11.973**
HUW234 x KRL210	1.06	23.19**	45.66**	9.615**	-30.61**	15.050**
HUW234 x K906	-3.31**	22.90**	11.06**	10.831**	-12.94**	13.503**
NW2036 x K9423	-25.25**	28.38**	25.89**	10.471**	-40.61**	20.016**
NW2036 x K9351	5.64**	18.69**	6.77**	0.000**	-1.07	9.613**
NW2036 x KRL210	-35.63**	34.29**	6.94**	10.478**	-39.80**	26.590**
NW2036 x K906	-1.84	20.61**	16.99**	8.732**	-16.10**	13.008**
K9423 x K9351	-3.59**	21.23**	36.60**	10.012**	-29.43**	12.447**
K9423 x KRL210	-4.44**	22.17**	0.68	9.165**	-5.09**	14.302**
K9423 x K906	-2.08*	10.75*	0.84	8.660**	-2.90*	2.278
K9351 x KRL210	-5.71**	8.70**	22.43**	10.498**	-22.97**	-2.037
K9351 x K906	-4.71**	10.15**	29.84**	6.091**	-26.61**	4.313*
KRL210 x K906	-11.72**	11.96*	11.88**	11.046**	-21.09**	1.025
SE±	**0.096**		**0.32**		**0.66**	

*Significant at 5 per cent level; ** Significant at 1 per cent level.

Out of 45 combinations, the desired heterosis over economic parent was measured in 39 crosses. The superiority for plant height over economic parent was observed as desirable in 6 cross (K9351 x K906, K9423 x K9351, K9465 x HUW234, K9533 x KRL210, K9465 x K9391 and K9162 x KRL210) combinations exhibiting significant and negative performance. Similarly, in case of inbreeding depression, all the crosses also showed the significant and positive values in support of heterosis. Thus, the selection procedure to be made depended on the basis of heterosis in respect of plant height.

The increased percentage over economic parent for spike length in 34 cross combinations were positive and highly significant while five crosses coined the negative and significant performance exhibited decreased heterosis. The trait ranged from -14.11 to 40.23 on the other hand, the inbreeding depression for length of spike per plant performed better in 43 crosses manifested positive values over economic parent, exhibited variability from -0.00 to 21.05 per cent. Such type of variability indicated that increased percentage of length of spike per plant.

The positive value of heterosis over economic parent exhibited average number of spikelets per spike among them 18 cross combinations (K9465 x K8962, K9162 x NW2036, K9533 x K9351, K9162 x K9351 and K8962 x HUW234 in order to merit) showed positive and significant performance indicated towards high spikelets. The inbreeding depression performed significant and positive expression in the 39 crosses.

The negative value of heterosis over economic parent exhibited average spike density in all the crosses out of these 6 cross (K9533 x KRL210, K9465 x K906, K9162 x HUW234, NW2036 x K9351, K9465 x HUW234 and K9533 x K9465) combinations showed positive and significant performance indicated towards high density. The inbreeding depression performed negative and significant expression in all the 42 crosses except three crosses (K9351 x KRL210, HUW234 x K9351 and K9533 x K906) showed positive and significant performance.

The negative value of heterosis over economic parent exhibited average number of tillers per plant in all the crosses out of these only three cross combinations (K9465 x K9351, K9465 x K9423 and K9162 x K9465) showed positive and significant performance indicated towards high tillering. The inbreeding depression performed significant and positive expression in all the 42 crosses. The positive value of heterosis over economic parent exhibited average number of grain per spike, 32 cross (K9533 x K9423, K9533 x K9351, K9533 x K9162, KRL210 x K906, K8962 x K906 in order of merit) combinations showed positive and significant performance indicated towards more number of grains per spike. The inbreeding depression performed significant and positive expression in all the 44 crosses. The positive value of heterosis over economic parent exhibited average 1000-grain weight, 12 cross (NW2036 x K9351, HUW234 x K9351, K9465 x K9351, K9162 x K6465 and k9162 x K8962 in order of merit) combinations showed positive and significant performance indicated towards increase grain weight. The inbreeding depression performed significant and positive expression in all the 45 crosses.

In present study, the inbreeding depression for grain yield per plant executed significant and positive expression in all the crosses (Table 2) followed by heterosis values only 2 crosses (K9465 x K9351 and K9162 x K906) manifested positive heterosis over economic parent, exhibited variability from -35.77 to 25.83 per cent. Thus, the increased percentage of grain yield is assumed to be desirable for the consideration to enhance the yield. The heterosis over economic parent for biological yield per plant exhibited positive performance in all the, 37 combinations except 6 non-significant heterosis was observed in various crosses. The inbreeding depression exhibited significant and positive performance in all 43 crosses combinations, which indicated the prevalence of additive gene effects due to genetic variability in the populations.

The heterosis in these crosses also resulted due to general combining ability effects pointing out the role of interaction between additive x additive or non-additive x non additive gene interaction. Similarly these heterotic crosses over economic parent also exhibited desirable heterosis for one or more yield components. Considering the presence of high magnitude of heterosis for grain yield coupled with significant inbreeding depression in crosses, heterosis` breeding may be useful for enhancement of grain yield. Some suitable devices conferring cross pollination like cytoplasmic male sterility or self-incompatibility may be helpful in commercial production of hybrid seed in this crop.

References

Anonymous, 2013-14. Indicates the 4th advance estimates from the Directorate of Economics and Statistics (DES), New Delhi.

Anonymous, 2014-15. United States Department of Agriculture, Foreign Agriculture Service. www.fas.usda.gov

Anonymous, 2015. Wheat 101: Nutrition facts and health effects, Authority nutrition an evidence based approach.

Attia, S., A.A.; EI-Hameid, N.R.A.; Haiba, A.A.A. 2013. Heterosis, combining ability analysis of some bred wheat crosses and the genetic relationship among the included studied cultivars. Journal of Applied science research., 13 (9) : 6394-6403.

Beche, E., Silva C L, da Pagliosa E S, Capelin M A, Franke J, Matei G and Benin G. 2013. Hybrid performance and heterosis in early segregant populations of Brazilian spring wheat. *Australian Journal of Crop Science* 7(1):51-57.

Boris, P., and Francois, T. 2015. Can current crop models be used in the phenotyping era for predicting the genetic variability of yield of plants subjected to drought or high temperature., *Journal of Experimental Botany*. 65(21):6179-6189.

Jaiswal, K. K., Praveen, Pandey. Shailesh, Marker and Anurag, P. J. 2010. Heterosis studies for improvement in yield potential of wheat (*Triticum aestivum* L.). *AAB-Bioflux*., 2 (3): 273-278.

Jogendra Singh. Garg, D. K. and Raje, R. S. 2007. Heterosis for yield and associated traits in bread wheat [*Triticum aestivum* (L.) em. Thell.]. *Indian J. of Genet.*, 67 (2): 215-216.

Joshi, S. K., Sharma, S. N., Singhania, D. L. and Sain, R. S. 2003. Hybrid vigor over environments in a ten-parent diallel cross in common wheat. *SABRAO J. of Breeding and Genetics*., 35 (2): 81-91.

Kalimullah, 2011. Heterosis of certain important yield components in the population of wheat (*Triticum aestivum* L.) crosses. *Electronic J. of Plant Breeding*., 2 (2): 239-243.

Koumber, R.M., and El-Gammaal A.A. 2012. Inheritance and gene action for yield and its attributes in three bread wheat crosses (*Triticum aestivum* L.). *World J. of Agril. Sci*. 8(2):156-162.

Kumar, A. A., and Raghavaiah, P. 2005. Heterosis for quality and yield traits in wheat (*T. aestivum* L.) *Crop. Res. Hisar.*, 30 (1): 50-53.

Kumar, V., and Maloo, S. R. 2011. Heterosis and combining ability studies for yield components and grain protein content in bread wheat *Triticum aestivum* (L.). *Indian J. of Genet.*, 71 (4): 363-366.
Lokendra Singh, Singh P., Daya Ram, Brahm Singh and Jitendra Kumar 2008. Heterosis and inbreeding depression for yield components and quality parameters in wheat (*Triticum aestivum* L.). *Prog. Rese*., 3 (2): 157-159.
Shull, 1914. What is heterosis? *Genetics.*, 33,439-446
Singh, H., Sharma, S.N. and Sain, R.S. 2004. Heterosis studies for yield and its components in bread wheat over environments. *Hereditas.*, 141 (2): 106-114.
Singh, R. C., 2003. Role of heterosis and inbreeding depression in the inheritance of grain yield and its components in wheat (*Triticum aestivum* L.). *Annals of Agri, Bio, Research*., 8 (1): 25-28.
Vanpariya, L. G., Chovatia, V. P. and Mehta, D. R. 2006. Heterosis for grain yield and its attributes in bread wheat (*Triticum aestivum* L.). *National J. of Pl.Improvement.*, 8 (2): 100-102.
Youchun, Li., Peng, Junhua and Liu, Zhongqi 1997. Heterosis and combining ability for plant height and its components in hybrid wheat with *Triticum timopheevi* cytoplasm. *Euphytica*, 95 (3): 337-345

How to cite this article:

Sanjeev Kumar, S.K. Singh, Lokendra Singh, S.K. Gupta, Vishwanath, Yadav Prashant, P.C. Yadav, Y. Pandey, Lokendra Singh and Surendra Kumar. 2017. Heterosis and Inbreeding Depression for Grain Yield and Related Morphophysiological Characters in Wheat (*Triticum aestivum* L.). *Int.J.Curr.Microbiol.App.Sci.* 6(10): 1352-1364.
doi: https://doi.org/10.20546/ijcmas.2017.610.159