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Research Article

Identification of best heterotic cross combination from diallel crosses for grain yield and other agro-morphological traits in bread wheat (*Triticum aestivum* L.)

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Abstract
Heterosis over better parent for yield and its contributing traits were studied in a 10 x 10 half diallel mating design in bread wheat to identify the best heterotic cross combination. Highest magnitude of heterosis over better parent was observed in the crosses K 9423 x NW 1014 (49.65), UNNAT-HALNA x HUW 560 (48.90) and K 7903 x HUW 560 (48.34) was recognized as the best heterotic crosses for grain yield and six other yield attribute. These individual crosses may be exploited in heterosis breeding programme for the improvement of grain yield and other traits according to the objective of breeding programme. The cross combinations namely UNNAT-HALNA x NW 1076 and Raj 3765 x HUW 560 were heterotic for quality traits such as gluten content, low phenol reaction along with grain yield per plant. These cross combinations may be exploited through heterosis breeding programme for improvement of grain yield with quality traits in bread wheat. Inclusion of lines with good combining ability in a national hybrid wheat programme may offer genetic improvement in breeding for higher yield and its component traits.

Key words
Diallel cross, heterobeltiosis, bread wheat and grain yield

Introduction

Wheat is a highly self pollinated crops, scope for the exploitation of hybrid vigour depends on the direction and magnitude of heterosis, biological feasibility of crop and nature of gene action. It is the second most important staple food crop of the world with the production of 95.91 million tons during 2013-2014 (Anonymous, 2014). But to feed the growing population, the country's wheat requirement by 2030 has been estimated of 100 million metric tons which is a major challenge. To achieve this target, the wheat production has to be increase at the rate of <1 mmt per annum Sharma et al., (2011). Wheat constitutes major staple food of rapidly increasing population of India and plays a most important role in food security and economic stability of the country. Because of its versatility in adaptation and utility of various ways, wheat is grown in more than 44 countries at global level. Heterosis study can also be used for getting information about the increase or decrease of F_1s over better parent (heterobeltiosis). However, selection of superior parents represent the major step in development of high yielding new cultivars and the identification of superior hybrid combinations is another fundamental issue in hybrid breeding. Wheat production can be enhanced through the development of new cultivars having wide genetic base and better performance under various agro-climatic conditions. Heterosis breeding is one of the important tools to take a quantum jump in production and productivity under different agro-climatic conditions Devi et al., (2013). 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. Singh et al., (2004) suggested that especially heterosis over better parent (heterobeltiosis) can be useful for determining true heterotic cross combinations. According to Longin et al., (2012), yield due to exploitation of heterosis can be improved ranged from 3.5 to 15% in wheat. For any successful breeding programme to improve grain yield and its contributing traits, it is essential to know precisely the genetic architecture of these characters. Study of heterosis for grain yield and its contributing traits in wheat have also been reported by Chowdhry et al. (2005), Singh and Sharma (2012), Ashutosh et al., (2011), Singh et al., (2012), Devi et al. (2013), Beche et al. (2013), Singh et al. (2013) and Singh et al. (2014), Kumar and Kerkhi (2014) and Garg et al., (2015). The major objective of the present study was to estimate the heterosis over better parents (heterobeltiosis) for fourteen characters in a half diallel mating design involving ten diverse genotypes of spring wheat. The studies were conducted for identify the best cross combination which may be exploited through heterosis breeding.

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 spacing of 10 cm between plant to plant and row to row spacing 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 fifteenth 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), harvest index (%), gluten content and phenol colour reaction (grading). 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 for these traits were used for the estimation of heterosis over better 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 better parent was calculated by using the formulae of Fonseca and Patterson (1968).

Heterobeltiosis (%) $\frac{F1-BP}{BP} \times 100$

F_1 = Mean performance of F_1 hybrid

BP = Mean performance of better parent

Test of significance: The't' test was manifested to determine whether F_1s means were statistically different from 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 follows the formulae suggested by Panse and Sukhatme (1961).

For testing heterosis over better parent; SE (diff) (BP) = $\sqrt{2VE/r}$

Where,

VE = error variance

r = Number of replications

CD= SE x t value

Data recorded on Phenol colour reaction was not statistically analyzed. Parents and their F_1s were categorized on the bases of colour intensity observed on grains after phenol colour reaction. The colours on the grains after phenol colour reaction were categorized in five groups viz; Black, Dark brown to brown, Light brown, slight colour on the edge and no colour.

Results and discussion

Estimation of heterosis over better parent: Heterosis breeding plays an important role in crop improvement for obtaining higher production and has been exploited in both self as well as cross pollinated crops. In the present study, the degree of heterosis was measured as superiority of mean of F_1s cross combination over their respective better parental values. Heterosis may be high or low depending upon the mean 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 also high. On the contrary, there can be a cross with poor per se performance but high percent of heterosis. It means that the choice of the best cross combination on the basis of high heterosis would not necessarily be one which would give the highest per se performance also. The per se performance being the realized value, and the heterotic response being an estimate, the former should be given preference with high percentage of heterosis while making selection of cross combination. In the present study, the estimated value of heterosis over better parent revealed that none of the crosses showed significant heterosis for all the characters. Estimated value of heterosis showed that the degree and direction of heterosis varied not from character to character but also in cross to cross.

Analysis of variance (table 2) revealed significant variation 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 and also the possibilities of identifying the superior cross combination from the present study.

Manifestation of heterosis was found in both positive and negative direction for days to 50 % flowering. The heterosis over better parent ranged from -8.10 (Raj-3765 x UP 2425) to 7.66 (PBW 373 x HUW 560). Out of 45 crosses, five crosses showed significant and high heterosis over better parent in negative direction for early flowering. The best cross combinations with highly significant and negative values were, Raj-3765 x UP-2425 (-8.10) followed by PBW-373 x UNNAT-HALNA (-8.01), K-9162 x NW-1076 (-7.75), PBW-373 x K-7903 (-7.47) and Raj-3765 x HUW-560 (-7.39). Similar result on the importance of negative heterosis for days to 50 % flowering has been reported by Ashutosh et al., (2011), Beche et al., (2013), Singh et al. (2013), Devi et al., (2013), Kumar and Kerkhi (2014) and Garg et al., (2015). Negative heterotic response in a cross is generally important for the development of short duration wheat varieties.

In days to maturity, magnitude of heterobeltiosis ranged from -3.55 (K 9162 x UP 2425) to 4.08 (PBW 373 x UP 2425) for early maturity. The crosses with highly significant and negative values were K-9162 x UP-2425 (-3.55), K-9162 x K-7903 (-2.60) and K-9162 x HUW-560 (-2.60). Similar result on the negative heterosis for days to maturity was reported by Devi et al., (2013), Singh et al. (2013), Kumar and Kerkhi (2014) and Garg et al., (2015).

A range of heterosis over better parent for plant height was from -18.55 (K 9423 x UNNAT-HALNA) to 9.53 (PBW 373 x UP 2425). The highest significant heterosis in negative direction were observed for the crosses namely, K-9423 x UNNAT-HALNA (-18.55) followed by K-9423 x NW-1076 (-16.37), (-16.15), K-9423 x K-7903 (-15.24), K-9423 x HUW-560 (-14.78), K-9162 x NW-1014 (-13.86), K-7903 x NW-1014 (-13.48), K-9162 x K-9423 (-13.25), NW-1014 x UP-2425 (-13.03), which showed more than 13 % heterosis over better parent for short stature. The present result are in agreement with Ashutosh et al., (2011), Devi et al., (2013), Beche et al., (2013), Singh et al. (2013), Kumar and Kerkhi (2014) and Garg et al., (2015). The heterosis for peduncle length ranged from -25.42 (PBW 373 x UNNAT-HALNA) to 6.15 (HUW 560 x NW 1076). The maximum value of heterosis were observed in only two crosses namely HUW-560 x NW-1076 (6.15) and NW-1014 x NW-1076 (4.57). Similar findings on significant and desirable heterosis for this character have been reported by Farooq et al., (2005).

The heterosis over better parent for flag leaf area was found in the range of -37.73 (PBW 373 x K 7903) to 28.62 (K 9423 x NW 1014). Out of 45 F_1s, 8 crosses showed heterosis in positive direction. The highest significant and desirable heterosis were observed in the crosses namely, K-9423 x NW-1014 (28.62), K-9423 x UP-2425 (24.75), UNNAT-HALNA x UP-2425 (23.19), NW-1014 x HUW-560 (23.11) and Raj-3765 x PBW-373 (15.87) which showed more than 15 % heterobeltiosis. Positive heterosis for flag leaf area has been reported by Farroq et al., (2005), Ghulam et al., (2006) and Kumar and Kerkhi (2014). 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.

Higher number of productive tillers per plant is required for obtaining higher yield. For this character, heterosis over better parent ranged from -8.97 (K 9162 x K 9423) to 15.46 (Raj-3765 x NW 1014). The crosses showed highly significant and positive heterosis were Raj-3765 x NW-1014 (15.46) followed by K-9162 x NW-1014 (12.57) and Raj-3765 x UNNAT-HALNA (11.86). Similar results on significant and desirable heterosis have been reported by Chowdhry et al., (2005), Ashutosh et al., (2011), Singh et al., (2013), Gite et al., (2014), Barot et al., (2014), Kumar and Kerkhi (2014) and Garg et al., (2015). 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.

The magnitude of heterosis for number of spikelets per spike ranged from -5.93 (Raj-3765 x UP 2425) to 26.34 (K 9423 x NW 1076). A total of 19 crosses showed desirable and significant heterobeltiosis. The highest positive and significant value were observed for crosses namely K-9423 x NW-1076 (26.34), NW-1014 x HUW-560 (26.01), PBW-373 x HUW-560 (25.85), K-9162 x HUW-560 (24.25), Raj-3765 x UNNAT-HALNA (22.75) and K-7903 x NW-1076 (21.22) which showed more than 20 % heterosis. The present study are in agreement with 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 programme. The magnitude of heterosis for spike length ranged from -13.15 (K 7903 x NW 1014) to 10.14 (K 9162 x UP 2425). The maximum positive and significant heterosis were observed for crosses namely, K-9162 x UP-2425 (10.41), PBW-373 x NW-1076 (9.00), K-9162 x UNNAT-HALNA (8.34) and Raj-3765 x K-9423 (7.80). Positive heterosis for spike length has been reported by Singh et al., (2004), Ashutosh et al., (2011), Devi et al., (2013) and Kumar and Kerkhi (2014). Spike length is one of the most important yield contributing traits which contributes towards productivity and should be taken into consideration for selection

Heterobeltiosis for number of grains per spike ranged from -2.96 (UNNAT-HALNA x NW 1076) to 27.88 (HUW 560 x UP 2425). Out of 45 F_1s, 17 crosses showed significant and positive heterosis. The crosses namely, HUW-560 x UP-2425 (27.88), UNNAT-HALNA x UP-2425 (23.01), K-9423 x HUW-560 (21.91), PBW-373 x UP-2425 (21.35), NW-1014 x HUW-560 (20.91), UNNAT-HALNA x HUW-560 (19.44), K-9162 x K-9423 (18.52), Raj-3765 x HUW-560 (18.45), NW-1014 x UP-2425 (18.42), K-9162 x K-7903 (18.13), K-

9423 x NW-1014 (17.32), K-9423 x UP-2425 (17.12), Raj-3765 x NW-1014 (16.88), Raj-3765 x K-7903 (16.16), K-9162 x HUW-560 (16.04), PBW-373 x K-9423 (15.61), PBW-373 x HUW-560 (15.43) exhibited highest value of heterosis for number of grains per spike. Similar finding for this trait has been reported by Ashutosh et al., (2011), Kumar and Kerkhi (2014) and Garg et al., (2015). Grains per spike are one of the most important characters of grain yield thus, positive and significant heterosis for this trait is important.

Heterobeltiosis value for biological yield per plant ranged from -15.86 (K 7903 x UNNAT-HALNA) to 34.64 (HUW 560 x NW 1076) The crosses showed highest degree of significant and positive heterosis were HUW-560 x NW-1076 (34.64), K-9162 x K-7903 (31.61), K-9162 x NW-1076 (29.74), K-7903 x NW-1076 (29.08), NW-1014 x HUW-560 (28.98), PBW-373 x HUW-560 (28.19), K-9162 x PBW-373 (27.91), K-9162 x NW-1014 (26.71), K-7903 x NW-1014 (26.02), K-9423 x NW-1014 (25.21), PBW-373 x K-9423 (24.52), Raj-3765 x NW-1014 (20.49), K-9423 x HUW-560 (18.89), K-9423 x K-7903 (17.19), PBW-373 x UP-2425 (17.01), which showed heterosis more than 15 (%). Heterosis for biological yield per plant was earlier reported by Desale and Mehta, (2013), Gite et al., (2014), Kumar and Kerkhi (2014) and Garg et al., (2015).

The range of heterosis over better parent for grain yield per plant varied from -9.62 (K 7903 x UP 2425) to 49.65 (K 9423 x NW 1014). Therefore, positive and significant heterosis for grain yield per plant is desirable. In the selection process, grain yield received maximum attention of a plant breeder. In case of grain yield 28 crosses showed positive and significant heterosis over better parent more than 11 %. Similar results on heterosis for grain yield per plant reported by Ashutosh et al., (2011), Devi et al., (2013), Singh et al., (2013), Desale and Mehta, (2013), Barot et al., (2014), Singh et al. (2014), Gite et al., (2014), Kumar and Kerkhi (2014) and Garg et al., (2015). 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.

The magnitude of heterosis for harvest index ranged from -28.97 (K 9162 x PBW 373) to 29.77 (K 7903 x UNNAT-HALNA). The maximum positive and significant value of heterosis was display by the crosses namely, K-7903 x UNNAT-HALNA (29.77), K-9423 x UNNAT-HALNA (24.48), Raj-3765 x UNNAT-HALNA (23.00), Raj-3765 x NW-1076 (20.76), UNNAT-HALNA x NW-1014 (19.55) and NW-1014 x NW-1076 (17.45). Positive heterosis for harvest index was reported by Singh et al. (2014), Gite et al., (2014), Kumar and Kerkhi (2014) and Garg et al., (2015). The ranged of heterosis over better parent for 1000 grain weight varied from -7.78 (UNNAT-HALNA x UP 2425) to 14.14 (Raj-3765 x UNNAT-HALNA). The significant positive heterosis was display by 18 crosses. The crosses namely, Raj-3765 x UNNAT-HALNA (14.14), PBW-373 x UNNAT-HALNA (13.06), PBW-373 x HUW-560 (12.63), Raj-3765 x PBW-373 (11.64), K-7903 x HUW-560 (11.61), K-9162 x PBW-373 (11.20), K-9162 x NW-1076 (11.14), UNNAT-HALNA x HUW-560 (10.44), K-9162 x K-9423 (10.18) showed highest degree of significant positive heterosis. Similar results for 1000 grain weight were reported by Ashutosh et al., (2011), Gite et al., (2014) and Garg et al., (2015).

The magnitude of heterosis for gluten content ranged from -12.02 (PBW 373 x HUW 560) to 5.96 (K 9162 x NW 1076). Out of 45 F_1s, total numbers of crosses with positive value were 21 out of which only two crosses namely UNNAT HALNA x NW 1076 and Raj 3765 x HUW 560 showed highest degree of significant positive heterosis over better parent. Similar results for gluten content were reported by Kumar and Kerkhi (2014).

On the bases of different grades, the parents and crosses were grouped in different category (table 5). Out of 55 genotypes (10 parental lines and 45 their F_1s), only one cross exhibited black colour and was in the black category; 3 parents and 11 crosses were in dark brown to brown category; 3 parents and 21 crosses were found in light brown category; 2 parents and 12 crosses were found in slight colour on the edge category namely K 9162, PBW 373, RAJ 3765 x PBW 373, RAJ 3765 x NW 1014, K 9162 x PBW 373, K 9162 x K 9423, K 9162 x UNNAT-HALNA, K 9162 x NW 1014, K 9162 x HUW 560, K 9162 x NW 1076, K 9162 x UP 2425, NW 1014 x UP 2425, HUW 560 x NW 1076, HUW 560 x UP 2425 and only two parents namely NW 1014 and HUW 560 were found which do not showed any colour on the grains which might be suitable for chapatti quality which in cross breeding programme. Similar results were also reported by Abrol and Uprety (1970) and Kumar and Kerkhi (2014).

Out of 45 cross combinations, 28 crosses showed positive and significant heterosis over better parent with a range of heterosis from (11.39) PBW-373 x UP-2425 to (49.65) K 9423 x NW 1014 for grain yield per plant (Table 4). Among these crosses, the cross namely, K-9423 x NW-1014 (49.65), UNNAT-HALNA x HUW-560 (48.90), K-7903 x HUW-560 (48.34), K-9423 x UNNAT-HALNA (48.07), K-9423 x HUW-560 (39.37), NW-1014 x HUW-560 (39.17), K-9423 x K-7903 (38.04), K-9162 x NW-1014 (37.35), K-7903 x NW-1014 (33.84), UNNAT-HALNA x NW-1014 (33.65), K-9162 x NW-1076 (32.50), HUW-560 x NW-1076 (31.42), K-9162 x UNNAT-HALNA (29.02), Raj-3765 x NW-1076 (27.77), UNNAT-HALNA x NW-1076 (27.18), K-9162 x K-7903 (27.16), NW-1014 x NW-1076 (27.13), K-7903 x NW-1076 (25.00), Raj-3765 x NW-1014 (23.98), Raj-3765 x UNNAT-HALNA (23.83), K-9423 x NW-1076 (22.53), K-9162 x HUW-560 (22.33), K-9162 x K-9423 (21.94), exhibited more than 20 % heterobeltiosis for grain yield per plant. These crosses may be exploited for heterosis breeding programme. Since these crosses involved low x average, low x low, average x low, average x average, high x average, high x low, high x average gca value of parents and significant sca effects which indicated the role of non additive gene action and response of dominance and dominance x dominance type of gene effect. A high heterotic result for yield might be obtained by exploiting these individual cross for developing hybrids through heterosis breeding programme. On the other hand, the crosses UNNAT-HALNA x NW 1076 and Raj 3765 x HUW 560 were common for gluten content and grain yield per plant and were graded for low phenol reaction. These cross combination may be exploited through heterosis breeding programme for improvement of yield with quality traits in bread wheat. Out of 28 cross combinations, the crosses namely K 9423 x NW 1014, UNNAT-HALNA x HUW 560 and K 7903 x HUW 560 which showed highest significant sca effects, with good per se performance for grain yield may be used in cross breeding programme and might be expected to give trasgressive segregants in F_2 generation as these two crosses having the parents with low x low gca effects.

Conclusion

The improvement in grain yield is the prime objective of any breeding programme and at the time of selection, grain yield received maximum attention of plant breeder for the selection of a genotype, thus from the result of present investigation, it may be concluded that K 9423 x NW 1014, UNNAT-HALNA x HUW 560, K 7903 x HUW 560, K 9423 x UNNAT-HALNA, K 9423 x HUW 560, NW 1014 x HUW 560, K 9423 x K 7903, K 9162 x NW 1014 was recognized as the best heterotic crosses for grain yield and some other yield attribute. These individual crosses may be exploited in heterosis breeding programme for the improvement of grain yield and other traits according to the objective of breeding programme. The cross combinations namely UNNAT-HALNA x NW 1076 and Raj 3765 x HUW 560 were common for gluten content, grain yield per plant and also were graded for low phenol reaction. These cross combination may be exploited through heterosis breeding programme for improvement of grain yield with quality traits in bread wheat.

References

Abrol, Y. P. and Uprety, D. C. 1970. Studies on darkening of whole wheat meal dough. *Current Science,* 40: 421-422.

Anonymous, 2014. Progress Report of All India Coordinated Wheat and Barley Improvement Project, 74pp. Sharma Indu (Ed). Directorate of Wheat Research, Karnal.

Ashutosh, K., Mishra, V. K., Vyas, R. P. and Singh, V. 2011. Heterosis and combining ability analysis in bread wheat (*Triticum aestivum* L.). *Journal of Plant Breeding and Crop Science,* **3 (10):** 209- 217.

Barot, H. G., Patel, M. S., Sheikh W. A., Patel, L. P. and Allam, C. R. 2014. Heterosis and combining ability analysis for yield and its component traits in wheat [*Triticum aestivum* (L.)], *Electronic Journal of Plant Breeding*, 5 (3): 350-359.

Beche, E., Silva, C. L., 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.

Chowdhry, M. A., Muhammad-Sajad and Ashraf, M. I. 2005. Analysis on combining ability of metric traits in bread wheat, (*Triticum aestivum* L.). *Journal of Agricultural Research,* **45 (1):** 11-17.

Desale, C. S. and Mehta, D. R. 2013. Heterosis and combining ability analysis for grain yield and quality traits in bread wheat (*Triticum aestivum* L.). *Electronic Journal of Plant Breeding*, **4 (3):** 1205-1213.

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

Farooq, J., Habib, I. and Khaliq, I. 2005. Diallel analysis to predict utilization of heterosis and heterobeltiosis in yield and yield components of bread wheat. *Indian Journal of Biological Science,* **2 (1)**: 36-42.

Fonseca, S. and Patterson, E. L. 1968. Hybrid vigour in seven parent diallel cross in common winter wheat (*Triticum aestivum* L.). *Crop Sci*ences, **8**: 85-95.

Garg, P., Saharan, R. P., Gupta, M., and Munjal, R. 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)** 721-728.

Ghulam, H., Mohammad, F., Khalil, I. H. and Raziuddin 2006. Heterosis and heterobeltiosis studies for morphological traits in bread wheat. *Sarhad Journal of Agriculture,* **22 (1):** 51-54.

Gite, V. D., Mali, A. R., Idhol, B. D. and 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.

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

Longin, C. F. H., Mühleisen, J., Maurer, H. P., Zhang, H., Gowda, M. and Reif, J. C. 2012. Hybrid breeding in autogamous cereals. *Theoretical and Applied Genetics* 125, 1087–1096.

Muller, J. 1991. Determining leaf surface area by mean of linear measurements in wheat and triticale (brief report). Archiv Fuchtungsforschung. **21 (2):** 121-23.

Panse and Sukhatme 1961. Statistical methods for agricultural workers. ICAR, New Delhi. pp. 228-232.

Panse, V. G. and Sukhatme, P. V. 1967. Statistical Methods of Agricultural Workers. 2nd Endorsement, ICAR Publication, New Delhi, India, pp: 381.

Sharma, I., Shoran, J., Singh, G. and Tyagi, B. S. 2011. Wheat Improvement in India. Souvenir of 50th All India Wheat and Barley Research workers' Meet, p. 11. New Delhi.

Singh, H., Sharma, S. N., Sain, R. S. and Sastry, E. V. D. 2004. Heterosis studies for yield and its components in bread wheat under normal and late-sowing conditions. *SABRAO Journal of Breeding and Genetics*, **6 (1):** 1-11.

Singh, M. K. and Sharma, P. K. 2012. Relationship of heterosis for protein content with yield component trait(s) under normal/heat stress environment in spring wheat. *Crop Improvement*, **39 (1):** 8-17.

Singh, M. N., Sharma, P. K., Tyagi, B. S. and Singh, G. 2014. Heterosis for Yield Component Traits and Protein Content in Bread Wheat under Normal and Heat-stress Environment. *Cereal Research Communications,* **42 (1):** 151–162.

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

Singh, S. K., Chatrash, R. and Mishra, B. 2010. Perspective of hybrid wheat research; A review. *Indian Journal of Agricultural Sciences*, **80 (12):**1013-27.

Singh, V., Krishna, R., Singh, S. and Vikram, P. 2012. Combining ability and heterosis analysis for yield traits in bread wheat (*Triticum aestivum*). *Indian Journal of Agricultural Sciences*, **82 (11):** 916-21.

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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/Kalyan Sona/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 grain yield and some other agro-morphological traits in spring wheat. (*Triticum aestivum* L.).

		Mean Sum of Squares													
SOV	D.F	DTF	DTM	PH	PL	FLA	PT	SL	SPS	GPS	BY	HI	TGW	GY	Glu.
Replications	02	0.16	1.76	15.68*	0.75	4.12	0.14	0.28	2.17	14.98	11.18	0.67	0.31	1.12	0.08
Treatments	54	40.69**	13.73**	72.93**	23.17**	123.54**	0.48**	0.80**	10.94**	51.26**	104.14**	68.34**	13.43**	18.30**	0.38**
Parents	09	16.51	5.20**	129.42**	30.85**	58.79**	0.66**	1.29**	4.95*	28.11	98.83**	140.49**	8.62**	17.57**	0.33
F_{1s}	44	46.39**	15.26**	58.09**	21.17**	139.02**	0.35**	0.58**	7.84**	17.45	81.65**	49.39**	10.94**	6.16**	0.39**
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**	252.55**	166.44**	559.01**	0.24
Error	108	1.61	0.82	4.44	0.99	4.48	0.07	0.20	2.26	18.21	7.47	1.53	2.20	1.72	0.20

Table 3:Twenty two crosses showing maximum heterosis over batter parent (heterobeltiosis) for grain yield per plant in spring wheat (*Triticum aestivum* L.).

Crosses	Heterosis	SCA effect	GCA effect		*Per se value*		Other characters exhibiting significant heterosis in desirable direction.
			P1	P2	F1	BP	
K 9423 x NW 1014	49.65**	4.01**	-0.13	0.09	26.59	17.77	Flag leaf area, Grains per spike, Biological yield per plant, Harvest index, 1000 grain weight
UNNAT-HALNA x HUW 560	48.90**	3.39**	-0.26	-0.11	25.65	17.23	Days to 50 % flowering, Plant height, Grains per spike, Biological yield, 1000 grain weight
K 7903 x HUW 560	48.34**	2.64**	-0.90**	-0.11	24.25	16.35	Days to 50 % flowering, Plant height, Productive tillers, Harvest index, 1000 grain weight
K 9423 x UNNAT-HALNA	48.07**	3.32**	-0.13	-0.26	25.54	17.25	Days to 50 % flowering, Plant height, Harvest index,
K 9423 x HUW 560	39.37**	1.66*	-0.13	-0.11	24.04	17.25	Days to 50 % flowering, Plant height, Spikelets per spike, Grains per spike, Biological yield, Harvest index, 1000 grain weight
NW 1014 x HUW 560	39.17**	2.12**	0.09	-0.11	24.73	17.77	Days to maturity, Plant height, Flag leaf area, spikelets per spike, Grains per spike, Biological yield
K 9423 x K 7903	38.04**	2.23**	-0.13	-0.90**	23.81	17.25	Days to 50 % flowering, Plant height, Spikelets per spike, Grains per spike, Biological yield, Harvest index
K 9162 x NW 1014	37.35 **	2.27**	0.04	0.09	25.52	18.58	Days to 50 % flowering, Plant height, Productive tillers per plant,Biological yield per plant,1000 grain weight
K 7903 x NW 1014	33.84**	1.97**	-0.90**	0.09	23.78	17.77	Days to 50 % flowering, Days to maturity, Plant height, Biological yield
UNNAT-HALNA x NW 1014	33.65**	1.30	-0.26	0.091	23.75	17.77	Days to 50 % flowering, Plant height, Productive tillers per plant*, Harvest index
K 9162 x NW 1076	32.50**	1.73*	0.04	0.22	24.62	18.58	Days to 50 % flowering, Days to maturity, Plant height, Biological yield, 1000 grain weight
HUW 560 x NW 1076	31.42**	1.56*	-0.11	0.22	24.30	18.49	Plant height, Peduncle length, Spikelets per spike, Biological yield
K 9162 x UNNAT-HALNA	29.02**	1.57*	0.04	-0.26	23.97	18.58	Plant height, Productive tillers per plant,Spike length, Spikelets per spike, Harvest index
Raj 3765 x NW 1076	27.77**	2.30**	0.46*	0.22	25.61	20.05	Days to 50 % flowering, Plant height, Harvest index,
UNNAT-HALNA x NW 1076	27.18**	0.93	-0.26	0.22	23.52	18.49	Days to maturity, Plant height,Flag leaf area, Harvest index, Gluten content
K 9162 x K 7903	27.16**	1.87*	0.04	-0.90**	23.63	18.58	Days to maturity,Grains per spike, Biological yield, 1000 grain weight
NW 1014 x NW 1076	27.13**	0.57	0.09	0.22	23.51	18.49	Days to 50 % flowering, Plant height, Peduncle length, Harvest index, 1000 grain weight
K 7903 x NW 1076	25.00**	1.17	-0.90**	0.22	23.11	18.49	Plant height, Flag leaf area, Spikelets per spike, Biological yield, 1000 grain weight
Raj-3765 x NW-1014	23.98**	1.67*	0.46*	0.09	24.85	20.05	Days to 50 % flowering, Plant height, Productive tillers per plant, Spikelets per spike, Grains per spike, Biological yield
Raj 3765 x UNNAT-HALNA	23.83**	2.00**	0.46*	-0.26	24.82	20.05	Days to maturity, Plant height, Productive tillers per plant, Spikelets per spike,Harvest index, 1000 grain weight
K 9423 x NW 1076	22.53**	-0.05	-0.13	0.22	22.66	18.49	Days to 50 % flowering, Plant height, Flag leaf area, Productive tillers, Spikelets per spike, Biological yield , Harvest index, 1000 grain weight

K 9162 x HUW 560	22.33**	0.17	0.04	-0.11	22.73	18.58	Days to maturity, Spikelets per spike, grains per spike, Biological yield, 1000 grain weight
K 9162 x K 9423	21.94**	0.13	0.04	-0.13	22.66	18.58	Days to maturity,Plant height, Spikelets per spike, Grains per spike, Harvest index, 1000 grain weight
K 7903 x UNNAT-HALNA	19.79**	-0.82	-0.90**	-0.26	20.63	17.23	Days to 50 % flowering, Plant height, Peduncle length, Harvest index
Raj 3765 x K 7903	17.24**	1.32	0.46*	-0.90**	23.50	20.05	Days to maturity, Grains per spike, Harvest index, 1000 grain weight
Raj 3765 x K 9162	13.65*	-0.35	0.46*	0.04	22.78	20.05	Days to 50 % flowering, Spikelets per spike, Biological yield
Raj 3765 x HUW 560	13.54*	-0.22	0.46*	-0.11	22.76	20.05	Days to 50 % flowering, Plant height, Grains per spike, Gluten content
PBW 373 x UP 2425	11.39*	2.38**	0.47*	0.12	25.59	22.97	Plant height, Spikelets per spike, Grains per spike, Biological yield, Harvest index

Table 4: Heterosis over better parent (Heterobeltiosis) in 45 crosses combination for fourteenth characters in spring wheat (*Triticum aestivum*. L.)

Crosses	Days to 50 % flowering	Days to maturity	Plant height	Peduncle length	Flag leaf area	Productive tillers/ plant	Spike length	Spikelets\ spike	Grains\ spike	Biological yield/ plant	Grain yield/ plant	Harvest index	1000 grain weight	Gluten content
	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP
Raj 3765 x K 9162	-5.63**	0.71	8.55**	0.82	-8.13	2.06	0.88	16.94*	12.72	11.52**	13.65*	-10.43**	1.42	-2.23
Raj 3765 x PBW 373	2.46*	0.48	-1.42	-2.24	15.87**	2.48	4.23	14.25*	13.09	7.56	6.59	-26.67**	11.64**	-1.85
Raj 3765 x K 9423	-4.58**	1.66**	-13.03**	-10.98**	3.28	-4.04	7.80*	2.68	8.79	-7.37	7.53	-1.20	-0.54	-5.41
Raj 3765 x K 7903	2.11	-2.13**	1.62	-5.85*	-16.41**	-0.97	-1.94	10.27	16.16*	6.69	17.24**	9.55**	10.04**	-3.29
Raj 3765 x UNNAT-HALNA	2.44*	-1.18*	-4.15*	-12.37**	3.98	11.86**	2.26	22.75**	11.24	0.49	23.83**	23.00**	14.14**	-6.96
Raj 3765 x NW 1014	-5.99**	0.24	-11.43**	-23.03**	-8.94	15.46**	0.98	17.98*	16.88*	20.49**	23.98**	-2.39	-1.70	-2.72
Raj 3765 x HUW 560	-7.39**	1.90**	-7.43**	-13.88**	-4.92	-0.48	-0.76	5.94	18.45*	-9.60*	13.54*	3.05	-0.27	10.51*
Raj 3765 x NW 1076	-3.17**	2.85**	-4.06*	-10.20**	-21.74**	-4.50	-0.68	-4.00	1.85	-7.35	27.77**	20.76**	2.32	3.36
Raj 3765 x UP 2425	-8.10**	0.48	-3.91*	-0.73	-1.18	-5.99	6.61	-5.93	8.67	4.22	6.49	-1.07	1.35	1.74
K 9162 x PBW 373	-5.36**	1.65**	-8.16**	1.27	-3.83	7.43*	7.16	17.32*	12.95	27.91**	4.83	-28.97**	11.20**	-0.95
K 9162 x K 9423	1.79	-1.89**	-13.25**	-10.05**	-30.30**	-8.97**	-0.42	17.36**	18.52**	3.66	21.94**	8.92**	10.18**	1.41
K 9162 x K-7903	3.91**	-2.60**	0.00	3.90	-34.30**	0.48	-9.24**	8.81	18.13**	31.61**	27.16**	-7.07**	9.37**	1.92
K 9162 x UNNAT-HALNA	0.00	0.00	-5.13**	-15.57**	-21.33**	8.42*	8.34*	16.13*	10.70	-4.60	29.02**	13.97**	0.77	-0.72
K 9162 x NW 1014	-6.79**	1.18*	-13.86**	-15.50**	1.65	12.57**	5.89	11.09	9.03	26.71**	37.35**	3.80	8.28**	2.01
K 9162 x HUW 560	2.86*	-2.60**	2.30	-3.79	-27.27**	0.96	0.09	24.25**	16.04*	13.21*	22.33**	-3.72	6.79*	0.16
K 9162 x NW 1076	-7.75**	-1.65**	-5.71**	2.20	4.00	2.06	0.88	16.94*	12.72	11.52**	32.50**	-2.86	11.14**	5.96
K 9162 x UP 2425	-5.00**	-3.55**	-7.30**	-19.45**	-8.48	2.48	4.23	14.25*	13.09	7.56	-1.36	14.25**	1.35	3.57
PBW 373 x K 9423	4.40**	1.44**	-16.15**	-9.95**	-25.93**	-4.04	7.80*	2.68	8.79	-7.37	7.64	-14.05**	-5.97*	-1.83
PBW 373 x K 7903	-7.47**	1.42**	-8.22**	-13.83**	-37.73**	-0.97	-1.94	10.27	16.16*	6.69	0.15	-16.37**	5.22	-1.64
PBW 373 x UNNAT-HALNA	-8.01**	-1.18*	-0.76	-25.42**	-21.95**	11.86**	2.26	22.75**	11.24	0.49	-3.89	-18.81**	13.06**	-9.32*
PBW 373 x NW 1014	6.30**	2.40**	-14.53**	-21.21**	-14.19**	15.46**	0.98	17.98*	16.88*	20.49**	-7.68	-16.93**	-4.20	0.99
PBW 373 x HUW 560	7.66**	-1.20*	-10.75**	-17.00**	-24.91**	-0.48	-0.76	5.94	18.45*	-9.60*	4.71	-18.70**	12.63**	-12.02*
PBW 373 x NW 1076	-7.04**	1.66**	-19.67**	-25.42**	-12.63*	-4.50	-0.68	-4.00	1.85	-7.35	4.34	-12.71**	4.06	0.19
PBW 373 x UP 2425	4.81**	4.08**	-9.73**	-19.44**	-17.56**	-5.99	6.61	-5.93	8.67	4.22	11.39*	-26.39**	-5.30	-1.45
K 9423 x K 7903	-6.41**	0.00	-15.24**	-23.23**	-2.66	7.43*	7.16	17.32*	12.95	27.91**	38.04**	5.38*	4.56	-0.92
K 9423 x UNNAT-HALNA	-5.92**	1.42**	-18.55**	-11.78**	-1.01	-8.97**	-0.42	17.36**	18.52**	3.66	48.07**	24.48**	-5.83	-0.81
K 9423 x NW 1014	3.66**	0.00	-1.62	-20.29**	28.62**	0.48	-9.24**	8.81	18.13**	31.61**	49.65**	5.53*	8.30**	5.49
K 9423 x HUW 560	-5.11**	1.91**	-14.78**	-23.23**	-16.33**	8.42*	8.34*	16.13*	10.70	-4.60	39.37**	13.43**	5.96*	1.05
K 9423 x NW 1076	-6.34**	0.00	-16.37**	-10.35**	14.56**	12.57**	5.89	11.09	9.03	26.71**	22.53**	4.52*	9.17**	1.05
K 9423 x UP 2425	6.23**	0.48	-9.79**	-12.54**	24.75**	0.96	0.09	24.25**	16.04*	13.21*	-5.82	-8.88**	1.65	0.00
K 7903 x UNNAT-HALNA	-7.32**	0.47	-18.45**	-7.32**	0.08	-7.66*	5.90	11.29	7.92	29.74**	19.79**	29.77**	0.54	-8.34

Conti…………………

Table 4: Heterosis over better parent (Heterobeltiosis) in 45 crosses combination for fourteenth characters in spring wheat (*Triticum aestivum*. L.)

Crosses	Days to 50 % flowering	Days to maturity	Plant height	Peduncle length	Flag leaf area	Productive tillers/ plant	Spike length	Spikelets\ spike	Grains\ spike	Biological yield/ plant	Grain yield/ plant	Harvest index	1000 Grain weight	Gluten content
	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP
K 7903 x NW 1014	-6.76**	-2.37**	-15.55**	-21.30**	1.48	4.35	-13.15**	3.02	9.10	26.02**	33.84**	4.30	3.97	0.04
K 7903 x HUW 560	-6.05**	1.66**	-10.32**	-16.92**	-2.73	8.13*	1.88	9.95	10.93	7.89	48.34**	12.37**	11.61**	-5.92
K 7903 x NW 1076	-2.11	-0.71	-16.46**	-15.32**	10.00*	1.35	-0.63	21.22**	9.54	29.08**	25.00**	-4.53	9.89**	4.15
K 7903 x UP 2425	-4.63**	0.24	-19.26**	-13.72**	-7.34	2.30	1.08	3.79	10.82	-13.40**	-9.62*	3.54	-4.66	5.96
UNNAT-HALNA x NW 1014	-4.88**	1.42**	-12.84**	-9.34**	0.44	8.90*	5.24	8.87	11.27	-3.32	33.65**	19.55**	-4.40	3.03
UNNAT-HALNA x HUW 560	-2.79*	-0.47	-15.96**	-17.09**	7.70	4.78	-2.30	12.36	19.44**	12.93**	48.90**	-4.29*	10.44**	3.96
UNNAT-HALNA x NW 1076	3.83**	-2.13**	-8.95**	1.26	9.29*	-3.60	-0.64	-2.84	-2.96	0.01	27.18**	5.57*	3.87	9.70*
UNNAT-HALNA x UP 2425	-4.18**	1.90**	-19.08**	-19.95**	23.19**	-3.69	4.63	15.79*	23.01**	-9.36*	-5.47	3.47	-7.78**	-4.93
NW 1014 x HUW 560	3.28**	-2.15**	-8.14**	-17.85**	23.11**	4.31	-6.93	26.01**	20.91**	28.98**	39.17**	-8.25**	1.36	3.07
NW 1014 x NW 1076	-7.04**	0.24	-12.20**	4.57*	1.07	-0.90	-1.64	3.53	4.74	2.29	27.13**	17.45**	7.42*	-2.88
NW 1014 x UP 2425	5.19**	-0.48	-13.03**	0.90	4.76	3.23	0.84	7.54	18.42**	-13.08**	-9.05	3.79	2.25	-0.35
HUW 560 x NW 1076	-0.70	-0.71	-7.35**	6.15*	-0.38	4.50	0.79	17.02**	9.55	34.64**	31.42**	-8.12**	5.68	-3.51
HUW 560 x UP 2425	6.20**	2.15**	3.15	-10.87**	9.28	0.92	-2.08	13.76*	27.88**	4.17	-0.49	-7.93**	-1.07	-4.66
NW 1076 x UP 2425	-6.34**	-0.24	-7.91**	-16.44**	-3.29	9.91**	3.19	16.93**	8.25	-3.30	3.29	6.01**	1.25	5.48

Table 5: Parental lines/crosses appeared in different category with the help of phenol colour reaction.

Category	Parental lines/crosses
Black	K 7903 x HUW 560
Dark brown to brown	K 7903, UNNAT-HALNA, UP 2425, RAJ 3765 x K 7903, RAJ 3765 x UNNAT-HALNA, PBW 373 x UNNAT-HALNA, PBW 373 x NW 1014, K 9423 x UNNAT-HALNA, K 9423 x NW 1014, K 9423 x HUW 560, K 9423 x NW 1076, K 7903 x NW 1076, K 7903 x UP 2425, NW 1076 x UP 2425
Light brown	RAJ 3765, K 9423, NW 1076, RAJ 3765 x K 9162, RAJ 3765 x K 9423, RAJ 3765 x NW 1076, RAJ 3765 x UP 2425, K 9162 x K 7903, PBW 373 x K 9423, PBW 373 x K 7903, PBW 373 x HUW 560, PBW 373 x NW 1076, PBW 373 x UP 2425, K 9423 x K 7903, K 9423 x K 2425, K 7903 x UNNAT-HALNA, K 7903 x NW 1014, UNNAT-HALNA x NW 1014, UNNAT-HALNA x HUW 560, UNNAT-HALNA x UP 2425, NW 1014 x HUW 560, NW 1014 x NW 1076
Slight colour on the edge	K 9162, PBW 373, RAJ 3765 x PBW 373, RAJ 3765 x HUW 560, RAJ 3765 x NW 1014, UNNAT-HALNA x NW 1076, K 9162 x PBW 373, K 9162 x K 9423, K 9162 x UNNAT-HALNA, K 9162 x NW 1014, K 9162 x HUW 560, K 9162 x NW 1076, K 9162 x UP 2425, NW 1014 x UP 2425, HUW 560 x NW 1076, HUW560 x UP 2425
No colour	NW 1014, HUW 560