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# Analysis of combining ability effects and for yield traits in $F_1$ and $F_2$ generation of in Winter wheat x spring wheat cross combinations (*Triticum aestivum* L.) under rainfed conditions

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**Abstract**
The present investigation was carried out at the research farm of the Division of Plant Breeding & Genetics, SKUAST –Jammu, Chatha. The experimental material of the present study comprised 20 true breeding facultative type winter wheat lines which were evaluated under rainfed conditions in a RBD. The best ten winter wheat lines (Arkaan, Blue boy, China 4435893, Drina, Drina NS 720, Nordersprez, WW12, WW21, WW23 and WW25) used as females and three spring wheat (PBW175, PBW 644 and WH 1080) were used as male parents to develop the experimental material for line x tester mating design. 30$F_{1s}$ and advanced 30$F_2$ seeds along with 13 parents were sown in the Rabi 2016-17 in a RBD under rainfed conditions. Observations were recorded on yield traits. The mean squares for comparisons of parents' *vs* crosses were significant. Combining ability analysis carried over $F_1$ and $F_2$ generation revealed that variance for crosses, testers and partly in lines was significant for almost all the traits. The GCA effects were greater than SCA effects for most of the traits. The compassion of relative magnitude of GCA and SCA variances indicated greater magnitude of GCA variance than SCA variance yield traits indicating the presence of additive gene action for the inheritance of these traits. On the basis of overall ranking of the parents for GCA, the lines Arkaan, Blue boy, Nordersprez, Drina and WW25 and in testers WH1080, PBW 175 revealed desirable significant effect for many traits.).

**Keywords:** Winter wheat, spring wheat, line x tester, combining ability, heterosis

## Introduction
Wheat (*Triticum aestivum* L.), self-pollinated crop of the Poaceae family and of the genus *Triticum*, is the world's largest cereal crop. It is popularly known as 'Stuff of life or King of the cereals' because of the acreage occupied, high productivity and the prominent position it holds in the international food grain trade. Wheat is extensively grown crop in the world. Its cultivation is widespread between 30 to 60 degrees north and between 27 to 40 degrees south of latitude. It is grown below sea level near the Dead Sea and in the Imperial Valley of California and at as high as 5000m altitude of Tibet (Tadesse *et al*. 2016). Wheat (*Triticum* spp.), is the most important cereal crop and occupies prominent position in Indian agriculture after rice (Joshi *et al*. 2007) [16]. India is now the second largest producer of wheat in the world with the production hovering around 106.21 million tonnes in 2020. It is consumed mostly in the form of bread, biscuits, chapatti, Baati, Upma, Dalia etc. The total production of wheat in the world is around 735.9 million metric tons covering an area of about 227.61 million ha with an average productivity of 3289.3 kg ha-1 (FAOSTAT, 2020) [8]. One of the ways by which this can be achieved is by the incorporation of genes from winter wheat (drought tolerant). The reports of Pinthus (1967) [24], in wheat and by Fedak and Fejar (1975) [9] in barley highlighted the importance of winter genotypes in the improvement of spring genotypes. Very little work has been done in this aspect. Subsequently several workers have explored the potential of winter wheats in spring wheat improvement programme (Baric *et al*. 2004; Sharma and Chaudhary, 2009) [3, 9]. Thus, winter x spring wheat hybridization appears to be important for achieving quantum jump in better wheat production in rainfed areas. The success of winter x spring hybridization depends upon the ability of these two physiologically different ecotypes to combine well with each other.

In order to formulate a sound breeding strategy, information on the relative magnitude of genetic variance, combining ability for grain yield and its related traits is essential. Such information is useful for the selection of parental lines having superior performance and isolation of potential combination for their further use in the breeding programmes. The technique of line x tester analysis tends itself to the detailed genetic analysis and identifies superior parents and cross combinations on the basis of the combining ability. Another strategy to overcome the yield plateau is the commercial production of hybrid varieties.

## Materials and Methods

The breeding material, ten winter wheat lines used as females were crossed with three spring wheat lines used as males (Testers) in Line x Tester fashion during 2015-2016 at University Research Farm of Sher-e-Kashmir university of Agricultural Sciences and Technology, Jammu (SKUAST-Jammu) to generate 30 $F_{1s}$. These were advanced in off-season nursery to generate 30 $F_{2s}$. 30 $F_1$ crosses, 30 $F_2$ crosses and 13 Parents (10 lines + 3 testers) were evaluated in Randomized Block Design at the Research Farm of SKUAST Jammu during the Rabi season 2016-17. The observation was recorded on five competent for different traits namely: tillers per plant, spike length, grains per plant, 1000 grain weight, Biological yield per plant, grain yield per plant and harvest index.

Data recorded for various parameters were analyzed to know the significance of differences among genotypes including crosses. The estimates of combining ability were computed by using line × tester analysis (Kempthorne, 1957) [17]. The estimates of general combining ability (GCA) of lines and testers and specific combining ability (SCA) of the hybrids Significance of combining ability effects were determined by using *t* test at 0.05 and 0.01 levels of probability, respectively The distribution of crosses in relation to GCA and SCA effects was worked out by taking significant positive combining ability effects as high, non-significant as average and significant negative as low.

## Results

### Analysis of variance - Parents and $F_1$ Generation crosses

**Yield and yield contributing traits:** Analysis of variance Table (1) revealed highly significant variability all treatments in all traits except harvest Index which was significant at 5% only. The variability among the parents (lines + tester) was also highly significant for all traits. Among lines significant variability was observed for all the traits except harvest index. Among testers significant variability was observed for traits except Grains per plant, 1000 Grain weight and harvest index. The crosses arising from winter x spring wheat derivatives relieved highly significant variability for all traits except harvest index which was significant at 5% only. Significant difference in variability was observed for all the traits except Grain yield and harvest index when parents were compared with the crosses (P *vs* C). Similarly, Comparison of lines with testers revealed significant variability for all traits except Spike length and harvest index.

### Analysis of variance - Parents and $F_2$ Generation crosses

**Yield and Yield contributing traits:** Analysis of variance Table (2) revealed highly significant variability for all treatments for all traits. The variability among the parents (lines and tester) was also significant for all traits. Among lines significant values were observed for all the. Among testers significant values were observed for traits except Grains per plant, 1000 Grain weight and Harvest Index. The crosses arising from winter x spring wheat derivatives relieved highly significant variability for all traits. Significant difference was observed for all yield contributing traits when parents were compared with the crosses (P *vs* C).

**Table 1:** Analysis of variance for yield traits on the basis of $F_1$ generation of crosses in winter x spring wheat derivatives (Line x Tester).

| Sources of variation | D.F | Tillers Per Plant (no.) | Spike Length (cm) | Grains Per Plant (no) | Grain Yield (g) | 1000 Grain Weight (g) | Biological Yield Per Plant (g) | Harvest Index (%) |
|---|---|---|---|---|---|---|---|---|
| Replicates | 2 | 2.39 | 0.05 | 8.43 | 10.53 | 0.57 | 46.08 | 6.53** |
| Treatments | 42 | 82.97** | 5.43** | 77.96** | 325.84** | 219.55** | 574.63** | 142.47* |
| Parents | 12 | 38.94** | 1.38** | 27.99** | 141.65** | 49.29** | 274.64** | 23.91** |
| Parents (Line) | 9 | 28.45** | 1.05** | 25.39** | 138.93** | 48.14** | 197.37** | 25.51 |
| Parents (Testers) | 2 | 67.44** | 3.09** | 2.21 | 195.46** | 1.53 | 726.88** | 9.75 |
| Parents (L vs T) | 1 | 76.41** | 0.94 | 102.91** | 58.49* | 155.18** | 65.56 | 37.83* |
| Parents vs Crosses | | 265.24** | 20.05** | 210.83** | 30.60 | 4620.17* | 184.66* | 1523.67 |
| Crosses | 29 | 94.91** | 6.59** | 94.06** | 412.23** | 138.25** | 712.22*** | 143.89* |
| Error | 84 | 4.92 | 0.30 | 7.47 | 14.32 | 2.04 | 32.22 | 5.41 |

*, ** significant at 5% and 1% level, respectively.

**Table 2:** Analysis of variance for yield traits on the basis of $F_2$ generation of crosses in Winter x spring wheat derivatives (Line x Tester).

| Sources of variation | D.F | Tillers Per Plant (no.) | Spike Length (cm) | Grains Per Plant (no) | Grain Yield (g) | 1000 Grain Weight (g) | Biological Yield Per Plant (g) | Harvest Index (%) |
|---|---|---|---|---|---|---|---|---|
| Replicates | 2 | 2.39 | 0.05 | 8.43 | 10.53 | 0.57 | 46.08 | 6.53** |
| Treatments | 42 | 82.97** | 5.43** | 77.96** | 325.84** | 219.55** | 574.63** | 142.47* |
| Parents | 12 | 38.94** | 1.38** | 27.99*** | 141.65** | 49.29** | 274.64** | 23.91** |
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| Parents vs Crosses | 1 | 265.24** | 20.05** | 210.83** | 30.60 | 4620.17* | 184.66* | 1523.67 |
| Crosses | 29 | 94.91** | 6.59** | 94.06** | 412.23** | 138.25** | 712.22** | 143.89* |
| Error | 84 | 4.92 | 0.30 | 7.47 | 14.32 | 2.04 | 32.22 | 5.41 |

*, ** significant at 5% and 1% level, respectively

**Analysis of variance for combining ability and estimation of components of variance**

**Parents and $F_1$ crosses**

**Yield and Yield contributing traits:** Analysis of variance Table (3) arising from line, tester and line x tester effect for different yield and yield component traits *viz,* tillers per plant, spike length, grains per plant, grain yield per plant, 1000 grain weight and biological yield per plant revealed that variance due to line effects was significant only for tillers per plant, grains per plant and 1000 grain weight, whereas the contribution from tester effect was significant for all the traits, the $F_1$ crosses revealed significant variance as also revealed by significant line x tester effects for all these yield component traits.

**Estimation of components of variance and genetic variance**

Variance combining ability arising from lines, testers and line x testers Table (3) revealed that predominant contribution came from testers and little from the lines. The average contribution from the lines and testers was closer to the magnitude of tester effects. Variance due to line x tester effects was also lower for all the traits.

Magnitude of additive genetic variance ($s^2_A$) was much higher being 56.42, 40.00, 45.46, 329.18, 73.73 and 322.80 as compared to corresponding values of 2.78, 0.28, 5.97, 13.37, 9.22 and 73.48 due to dominance deviations ($s^2_D$) for tillers per plant, spike length, grains per plant, grain yield per plant, 1000 grain weight and biological yield per plant, respectively. Dominance ratio ($s^2_D/s^2_A$) was mainly incomplete for all traits except Biological yield per plant which revealed partial dominance.

**Table 3:** Analysis of variance for combining ability for Yield traits on the basis of $F_1$ generation of cross in Winter x spring wheat derivatives (line x tester)

| Sources of variation | D.F | Tillers Per Plant (no.) | Spike Length (cm) | Grains Per Plant (no) | Grain Yield (g) | 1000 Grain Weight (g) | Biological Yield Per Plant (g) | Harvest Index (%) |
|---|---|---|---|---|---|---|---|---|
| Line Effect | 9 | 41.89 * | 1.97 | 66.84* | 118.96 | 84.54 * | 484.01 | 47.14 |
| Tester Effect | 2 | 1068.31** | 76.55 ** | 834.76 ** | 4952.13** | 1356.94 ** | 5875.13 ** | 1585.87 ** |
| Line * Tester Eff. | 18 | 13.26 ** | 1.14** | 25.37 ** | 54.43** | 29.70** | 252.67 * | 32.05 ** |
| σ2GCA Tester | | 4.11 | 0.19 | 6.60 | 11.63 | 4.64 | 9.17 | 50.20 |
| σ2GCA (Average) | | 28.21 | 2.00 | 22.73 | 129.29 | 36.86 | 161.40 | 41.59 |
| σ2L X T (SCA) | | 2.78 | 0.28 | 5.97 | 13.37 | 9.22 | 73.48 | 8.88 |
| s GCA / SCA | | 10.14 | 7.14 | 3.80 | 9.67 | 3.99 | 2.19 | 4.68 |
| σ2A | | 35.45 | 2.54 | 27.58 | 164.59 | 52.68 | 45.16 | 194.76 |
| σ2 D | | 28.21 | 2.00 | 22.73 | 129.29 | 36.86 | 161.40 | 41.59 |
| σ2 D / s2A | | 2.78 | 0.28 | 5.97 | 13.37 | 9.22 | 73.48 | 8.88 |

*, ** significant at 5% and 1% level, respectively

**Analysis of variance for combining ability in $F_2$ generation**

**Yield and Yield contributing traits:** Variance due to combining ability in the crosses Table (4) was highly significant for all yield and yield component traits *viz* tillers per plant, spike length, grains per plant, grain yield per plant, 1000 grain weight, biological yield per plant and harvest index. The contribution to their significant variance came primarily from variance due to tester effects for all traits. Variance due to line effect was non – significant. The variance due to (line x tester) was significant for all the traits.

**Estimation of components of variance and genetic variance:** Translating the values of combining ability variances due to gca and sca into genetic components it was observed that additive genetic variance ($s^2_A$) were 63.68, 4.32, 50.64, 366.10, 37.14, 215.25 and 68.29 with their corresponding ($s^2_D$) values of 6.52, 0.82, 16.80, 26.10, 25.85, 189.72 and 51.21 for tillers per plant, Spike length, grains per plant, grain yield per plant, 1000 grain weight, biological yield per plant and harvest index respectively. Dominance ratio was incomplete (tillers per plant and grain Yield per plant) nearly complete for biological yield per plant and partial for rest of the traits.

**Table 4:** Analysis of variance for combining ability for yield traits on the basis of $F_2$generation of cross in Winter x Spring wheat derivatives (line x tester).

| Sources of Variation | D.F | Tillers Per Plant(no) | Spike Length(cm) | Grains Per Plant(no) | Grain Yield(g) | 1000 Grain Weight(g) | Biological Yield Per Plant(g) | Harvest Index (%) |
|---|---|---|---|---|---|---|---|---|
| Line Effect | 9 | 14.07 | 1.48 | 37.28 | 97.62 | 40.14 | 464.69 | 68.06 |
| Tester Effect | 2 | 924.88** | 62.00 ** | 709.46 ** | 5280.19 ** | 509.36 ** | 2785.32 * | 938.49 ** |
| Line x Tester Effect | 18 | 18.42** | 2.02 ** | 40.94 ** | 70.52** | 61.27 ** | 477.85** | 119.16** |
| Error | 58 | 2.84 | 0.16 | 2.96 | 11.44 | 4.34 | 63.08 | 4.39 |
| $\sigma^2$ GCA Line | | 1.15 | 0.15 | 3.81 | 9.54 | 4.11 | 45.97 | 7.13 |
| $\sigma^2$GCA Tester | | 30.70 | 2.06 | 23.55 | 175.61 | 16.88 | 91.14 | 31.15 |
| $\sigma^2$GCA (Average) | | 23.88 | 1.62 | 18.99 | 137.29 | 13.93 | 80.72 | 25.61 |
| $\sigma^2$L X T (SCA) | | 4.89 | 0.62 | 12.64 | 19.58 | 19.39 | 142.29 | 38.41 |
| s GCA / SCA | | 4.88 | 2.61 | 1.50 | 7.01 | 0.71 | 0.56 | 0.66 |
| $\sigma^2_A$ | | 63.68 | 4.32 | 50.64 | 366.1 | 37.14 | 215.25 | 68.29 |
| $\sigma^2_D$ | | 6.52 | 0.82 | 16.8 | 26.1 | 25.85 | 189.72 | 51.21 |
| $\sigma^2_{D/S}{}^2_A$ | | 0.102 | 0.189 | 0.33 | 0.07 | 0.69 | 0.88 | 0.74 |

*, ** significant at 5% and 1% level, respectively

**Estimation of GCA, $g_i$ effects and per se performance of parental lines on the basis of $F_1$ generation crosses**

The potential of a line for crossing and generation of transgressive segregants in line x tester mating design in assessed as per its gca effect and per se performance. In the present study parental lines possessing significantly higher gca ($g_i$) values together with them per se performance were identified for each trait. The results there of, are summarized as under:

**Yield components traits**

**Tillers per plant:** Significantly higher ($g_i$) values for this trait were revealed by WW21 and Drina NS 720 (among lines) and PBW175 and WH1080 (among testers). These were rates as good combiners. Significant negative ($g_i$) values (Poor combiners) were recorded in WW23 and Arkaan (among lines) PBW644 (among testers). Rests of the genotypes were average combiners. Highest tillers per plant (per se performance) was recorded in Drina (34.0) followed by WW23, China4435893 and WW12 (30.0 and 30.7) among lines and PBW 175 (28.0) in the testers.

**Spike Length:** Significant positive ($g_i$) values (Good combiners) was recorded in Blue boy and Arkaan (among lines). PBW 175 in the testers. The poor combiners (significant negative $g_i$ values) were WW21, Drina and Drina NS7200 (among lines) and PBW 644 and WH1080 (testers). The rest were average combiners. Based on the mean performance (per se) the lines showing longer spikes were Drina and WW12 (11.04 and 11.22 cm) and the testers was PBW 175 (11.05 cm).

**Grains per Plant:** Lines showing significant positive ($g_{i)}$ values (Good combiners) were Drina NS 720, WW25 and Nordersprez while PBW175 (among testers) was good combiners. Poor combiners (significant negative $g_i$ values) were WW21 and WW12 (among lines) and PBW644 and WH1080 (among testers). Rests of the lines were average combiners. Highest grains per plant (per se performance) were observed in China4435893 (49.3) followed by Blue boy (48.6) in the lines and PBW175 (42.3) in the testers.

**Grain yield per plant:** Significant positive ($g_i$) values (good combiners) were recorded in WW12, Drina NS 720 and Blue boy (among lines) and PBW175 (among testers). Significant negative ($g_i$) values (poor combiners) were recorded in WW23 and Nordersprez (among lines) and PBW 644 and WH1080 (among testers). Rests of the lines were average performers. Highest grain yield per plant (per se performance) was recorded in WW12 and Nordersprez (60.3 to 63.2 g) among the lines, while as the tester PBW175 recorded 65.6 g.

**1000 grain weight:** Highly significant values of ($g_i$) contributing to good performance of parents (lines and testers) in generating high performance cross combinations were revealed by WW23, Arkaan and WW12 (Lines) and PBW175 (testers). Poor significant Performers were Blue boy, China4435893, Drina NS 720 and Nordersprez (among lines), and PBW 644 and WH1080 (among testers). Highest 1000 grain weight (among lines) was revealed by Arkaan and Blue boy (55.5 to 60.4 g), while in the testers the difference for this trait was not much (45.7 to 47.0) with PBW 175 being top. Biological yield per plant: Among lines the genotypes WW12, WW25 and Drina NS7200 revealed significant ($g_i$) values (good performers), while in the testers PBW175 as significantly good performer. Poor performers among lines (significant negative $g_i$ values) where WW21 and Nordersprez, while in the testers the genotypes were PBW 644 and WH1080. Taking into consideration the per se performance of the lines, almost all the genotypes except Arkaan and Blue boy revealed 123.0 to 129 g per plant, whereas among the testers WH 1080 and PBW 175 recorded 138.5 and 129.4 g per plant respectively.

**Harvest Index:** Positive significant ($g_i$) values (good performance) among lines was revealed by Drina and Nordersprez while as among the testers the genotype were PBW 175 and PBW 644.Poor performance (significant negative value) was revealed by WW25 (line) and WH1080 (tester). Rest of the parents were average performers (non – significant $g_i$ values).The variability for this trait based on per se performance, in the testers was 38.00 to 58.0% whereas among the lines it ranged from 35.60 and 50.58% with top performers being Blue boy (50.58%) followed by WW12 (48.89%) and Nordersprez (48.26%).

**Estimation of gca (gi) effects and per se performance of parental lines on the basis of $F_2$ generation crosses**

**Yield contributing traits**

**Tillers per plant:** The good performer among the lines was only Blue boy, while in the tester it was PBW 175. The poor performers were China4435893 and WW23 (among lines) and PBW 644 and WH1080 (among testers). Rests of the parents (lines) were average performers.

**Spike Length:** For this trait the good performers were Arkaan, Blue boy and WW21 (among lines) and PBW 175 (among testers).The poor performers among lines were China4435893, Drina NS 720 and WW25, while in the tester the genotypes were PBW 644 and WH1080. Rests of the parents (among lines) were average performers.

**Grains per plant:** The good performers were Drina NS 720, WW21 and WW25 (among lines) and PBW 175 (among testers). The poor performers were only PBW 644 and WH1080 (among testers). Rests of the lines were average performers.

**Table 5:** Estimates of gca and per se performance on the basis of $F_1$ generation of crosses in Winter x Spring wheat derivatives (Line x Tester)

| Parent | Tillers per plant | | Spike length | | Gain per plant | | Grain yield | | 1000 grain weight | | Biological Yield per Plant | | Harvest index | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | gi | Per se performance | gi | Per se performance | gi | Per se performance | gi | Per se performance | gi | Per se performance | gi | Per se performance | gi | Per se performance |
| **Lines** | | | | | | | | | | | | | | |
| Arkaan | -1.99** | 26.66 | 0.44* | 9.88 | -.12 | 40.0 | -1.81 | 54.10 | 3.49** | 60.46 | -1.74 | 113.10 | 1.10 | 47.86 |
| Blue Boy | -0..32 | 25.33 | 0.57** | 10.16 | -1.67 | 48.66 | 2.59** | 52.00. | -3.59** | 55.50 | -3.18 | 102.86 | 1.58** | 45.67 |
| China4435893 | -0.88 | 30.66 | -0.36 | 10.65 | 0.71 | 49.33 | 1.73 | 44.03 | -3.90** | 52.66 | 1.32 | 123.67 | -0.20 | 50.06 |
| WW 23 | -2.88** | 30.67 | -0.28 | 9.96 | 1.74 | 46.667 | -8.46** | 58.5 | 5.08** | 51.00 | 2.76 | 127.81 | 0.14 | 44.14 |
| Drina NS 720 | 2.46** | 26.66 | -0.37 | 10.00 | 3.63** | 43.00 | 3.12* | 46.066 | -2.97** | 50.13 | 3.92* | 124.33 | -0.75 | 48.26 |
| WW 21 | 4.34** | 26.33 | -0.81** | 9.86 | -5.05** | 46.00 | 2.41 | 51.00 | 0.02 | 50.00 | -13.8** | 125.33 | 1.31** | 49.13 |
| WW25 | 0.46 | 24.00 | 0.27 | 9.27 | 1.86** | 44.00 | -1.09 | 45.9 | 0.30 | 48.63 | 5.98** | 127.47 | -4.75 | 44.90 |
| WW 12 | -1.43 | 30.00 | -0.31 | 11.04 | -2.42 | 46.00 | 3.22* | 63.20 | 2.90** | 48.63 | 11.65** | 129.27 | 0.14 | 43.33 |
| Nordresprez | -0.77 | 26.07 | 0.25 | 10.40 | 3.07 | 43.00 | -2.57** | 60.33 | -1.06 | 47.50 | -8.91** | 125.00 | 2.24** | 41.70 |
| Drina | 1.01 | 34.00 | -0.47** | 11.22 | -1.76 | 46.66 | 0.86 | 59.74 | -0.28 | 47.73 | 2.03 | 129.37 | 3.67 | 48.70 |
| **Testers** | | | | | | | | | | | | | | |
| PBW 175 | 6.89** | 28.00 | 1.84** | 11.05 | 6.02** | 44.00 | 14.82** | 65.66 | 7.76** | 47.03 | 16.14** | 113.10 | 8.34** | 48.70 |
| PBW 644 | -3.31** | 27.00 | 0.99** | 9.27 | -3.83** | 42.33 | -6.80** | 50.90 | -4.05** | 46.90 | -7.45** | 108.13 | 3.37** | 50.66 |
| WH1080 | 3.58** | 19.33 | -0.85** | 9.30 | -2.19** | 46.66 | -8.02 | 52.63 | -3.71** | 45.73 | -8.69* | 138.47 | -4.97 | 47.06. |
| C.D (0.05) Line | 1.48 | | 0.37 | | -1.8 | | 2.52 | | 0.95 | | 3.79 | | 1.55 | |
| C.D (0.05) Testers | 0.81 | | 0.20 | | 1.00 | | 1.38 | | 0.52 | | 2.07 | | 0.85 | |

*,** significant at 0.05, 0.01 respectively

**1000 grain weight:** The good performers among lines were Arkaan, Blue boy and WW23, whereas the poor performance was Drina NS 720, WW21, Nordersprez and Drina. Similarly, among the testers the good performer was PBW 175 while PBW 644 and WH1080 were poor performers. Rests among the lines were average performer.

**Biological yield per plant:** Among the lines the good performers were WW21, WW25 and WW12, while the poor performer was China4435893. Among the testers the good performer was China4435893Among the testers the good performer was PBW 175, while the poor performer were PBW 644 and WH1080. Rests of the genotypes among lines were average Performers.

**Harvest Index:** The good performers among the lines were Nordersprez and Drina, while in the testers it was PBW 175. Poor performers among the lines were China4435893, WW23 and Drina NS 720, while in the testers the genotypes were PBW 644 and WH 1080.

**Estimation of SCA (Specific Combining Ability) effects and per se Performance of $F_1$ and $F_2$generation Crosses**

The performance of the crosses in $F_1$ and $F_2$ generation based on their $s_{ij}$ values (specific combining ability) is highlighted here under together with the per se performance of these cross in the $F_1$ and $F_2$ generations. The significant positive $S_{ij}$ values of the cross shall be highlighted high or good specific combining ability of the parent (line x tester) involved, whereas significant negative $S_{ij}$ values shall be highlighted for poor combining ability of the parent involved.The non – significant $S_{ij}$ values will reveal average specific combining ability of a cross. This generalized derivation shall hold good for all the traits except days to flowering and days to maturity wherein significant negative $S_{ij}$ value will determine good specific combining ability for earliness and reverse for delayed maturity. Accordingly, the cross shall be described on the basis of good, Poor or average specific combining ability only with their per se performance. The research finding on different morphological, yield components.

**$F_1$ generation cross**

**Yield component traits**

**Tillers per plant:** Good specific combining ability was recorded in the cross WW21 x PBW 644 and WW25 x WH 1080 and Drina x WH 1080, whereas Poor specific combining ability was recorded for the cross WW21 X PBW 175. Rests of the cross combinations revealed average specific combining ability. Highest per se performance was recorded in the cross.

**Table 6:** Estimates of GCA and per se performance on the basis of $F_2$ generation of crosses in winter x spring wheat derivatives (Line x Tester)

| Parents | Tillers per plant | | Spike length | | Gain per plant | | Grain yield | | 1000 grain weight | | Biological Yield per Plant | | Harvest index | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $g_i$ | Per se performance | $g_i$ | Per se performance | $g_i$ | Per Se performance | $g_i$ | Per se performance | $g_i$ | Per Se performance | $g_i$ | Per Se performance | $g_i$ | Per Se performance |
| **Lines** | | | | | | | | | | | | | | |
| Arkaan | -0.98 | 26.66 | 0.43** | 9.88 | -0.04 | 40.00 | -2.88* | 54.10 | 1.22* | 60.46 | -0.13 | 113.10 | -0.92 | 47.86 |
| Blue Boy | 1.91** | 25.33 | 0.45** | 10.1 | -0.94 | 48.66 | 0.52 | 52.00 | 1.81** | 55.50 | -3.32 | 102.86 | -0.36 | 45.66 |
| China4435893 | -1.31* | 30.66 | -0.47** | 10.6 | 0.85 | 49.33 | 3.55** | 44.04 | -0.58 | 52.66 | -6.55** | 123.66 | -1.38* | 49.66 |
| WW 23 | -1.98** | 30.66 | 0.20 | 9.96 | 0.05 | 46.66 | -4.86** | 58.56 | 4.35** | 51.00 | 2.35 | 127.81 | -1.94** | 50.06 |
| Drina NS 720 | 0.80 | 26.66 | -0.49** | 10.0 | 4.70** | 43.00 | 2.50* | 46.06 | -2.48** | 50.13 | 3.12 | 124.33 | -2.45** | 44.14 |
| WW 21 | 1.24 | 26.33 | 0.65** | 9.86 | 2.26** | 46.00 | 2.29 | 51.00 | -1.21* | 50.00 | 13.91** | 125.33 | -1.32 | 48.26 |
| WW25 | 0.24 | 24.00 | -0.31* | 9.27 | -0.02 | 44.00 | -3.87** | 45.90 | 0.46 | 49.00 | 6.44** | 127.46 | -0.80 | 49.13 |
| WW 12 | -0.87 | 30.00 | -0.10 | 11.0 | 2.53** | 42.33 | 1.54 | 63.20 | 0.41 | 48.63 | 12.11** | 129.26 | 0.29 | 44.90 |
| Nordersprez | 0.02 | 26.66 | -0.20 | 10.4 | 1.12 | 46.66 | -2.80* | 60.33 | -2.32** | 48.00 | -2.71 | 123.60 | 1.83** | 43.33 |
| Drina | 0.91 | 34.00 | -0.16 | 11.2 | -0.94 | 46.00 | 4.02** | 59.73 | -1.67** | 47.50 | 2.59 | 125.00 | 7.04** | 41.70 |
| Testers | | | | | | | | | | | | | | |
| PBW 175 | 6.41** | 28.00 | 1.66** | 11.0 | 5.61** | 42.33 | 15.25** | 65.66 | 4.75** | 47.03 | 11.07** | 129.36 | 6.37** | 48.70 |
| PBW 644 | -3.26** | 27.00 | -0.85** | 9.27 | -2.89** | 40.63 | 6.35** | 50.90 | -2.61** | 46.90 | -6.46** | 108.13 | -2.24** | 50.66 |
| WH1080 | -3.16** | 19.33 | -0.85** | 9.30 | -2.72** | 41.26 | -8.89** | 52.63 | -2.14** | 45.73 | -4.61** | 138.46 | -4.12** | 47.06 |
| C.D (0.05) line | 1.29 | | 0.26 | | 1.16 | | 2.29 | | 1.18 | | 4.76 | | 1.32 | |
| C. D (0.05) Tester | 0.71 | | 0.14 | | 0.64 | | 1.25 | | | | 1.24 | | 1.44 | |

*,**significant at 0.05, 0.01

**Spike length:** Good specific combining ability for this trait was recorded in the cross. Arkaan x WH 1080, whereas poor specific combining ability was shown by the cross Arkaan x PBW 175, WW21 x WH 1080 and WW12 x PBW 175. Rest of the crosses revealed average specific combining ability. Longest spike length of 12.29 cm was recorded in ww21 x PBW175 followed by blue boy x PBW 175 followed by Blue boy x PBW 175 (11.56 cm). Rest of the crosses had average spike length of 7.35 to 11.50 cm.

**Grain per plant:** Good specific combining ability was recorded in the crosses Arkaan x PBW 644, and WW12 x WH 1080, while as the poor specific combining ability was recorded in the cross Arkaan x WH1080, WW12 x PBW 175 and Drina x WH 1080. Rest of the crosses had average specific combining ability. Highest grains per plant were recorded in Drina x WH1080 (52.0) followed by Nordersprez x PBW 175 (51.0) and China4435893 x PBW 175 (50.4). Rest of the crosses had an average of 33.7 to 48.6.

**Grain Yield:** Crosses showing good specific combining ability were WW21 x WH1080; WW25 x WH 1080 and WW12 x PBW 644 and those with poor specific combining ability were WW21 x PBW 644, WW25 x PBW 644. Rest of the crosses showed average specific combining ability. Highest grain yield per plant was recorded in the cross Drina NS 720x PBW 644 (75.0 g) followed by China4435893 84-40022 x PBW 175 (73.0 g); WW21 x PBW 175 (72.3 g) and Blue boy x PBW 175 (71.1 g). The remaining crosses had a range of 35.5 to 69.6 g.

**1000 grain weight:** Good specific combining ability was revealed by the cross Arkaan x PBW 644, China4435893 x WH1080, Drina NS 720 x WH 1080, WW21 X PBW 175, WW25 x PBW 175, WW12 x WH 1080, Drina x PBW 644; whereas poor specific combining ability was revealed by the cross Arkaan x PBW 175, Drina NS 720 x PBW 175, WW21 x PBW 644 and Drina x PBW 175. The best performing crosses with bolder grains were WW23 x PBW 175, WW21 x PBW 175, WW25 x PBW 175; WW12 x PBW 175 and Drina x PBW 175 (47.0 – 49.0 g/1000seeds). The rest of the crosses had 1000 grain weight of 29.5 to 46.3 g.

**Biological yield per plant:** Crosses with a good specific combining ability were identified as Arkaan x PBW 644, WW23 x WH 1080, WW21 x WH 1080; Blue boy x PBW 175; Nordersprez x PBW 644; whereas those with poor specific combining ability were Arkaan x WH 1080; WW23 x PBW 644; WW21 x PBW 644; WW12 x WH 1080 ; WW12 X PBW 175 and Nordersprez X PBW 644; where as those with poor specific combining ability were Arkaan x WH 1080, WW23 x PBW 644, WW21 x PBW 644; WW12 x WH 1080 and Nordersprez x PBW 175. Rest of the cross had average specific combining ability. Highest biomass per plant was recorded in the cross WW21 x PBW 175 (160.3 g)

**Harvest Index:** Good specific combining ability was recorded in the cross Arkaan x WH 1080; China4435893 x PBW 175; WW23 x PBW 175 and WW25 X WH 1080, while as the poor specific combining ability was revealed by the crosses Arkaan x PBW 644; WW25 x PBW 175 and WW21 x WH 1080. Rest of the crosses revealed average specific combining ability. Highest harvest index of 59.4% was recorded in the cross Nordersprez x PBW175 followed by WW21 x PBW 175 (58.9%) and China4435893 x PBW 175 (54.5%). Rest of the crosses had the range of 29.1 to 51.9%.

**$F_2$ generation crosses**

**Yield component trait**

**Tillers per plant:** Good specific combining ability for more tillers per plant was observed in the crosses Drina NS 720 x WH 1080; WW25 x WH 1080 and Nordersprez x PBW 175; while as poor specific combining ability for less number of tillers per plant was observed in the crosses Blue boy x WH 1080; China4435893 x PBW644 and Drina NS 720x PBW 175. Rest of the crosses had average specific combining ability. Maximum tillers per plant was observed in the crosses Blue boy x PBW 175 and Nordersprez x PBW 175 (33.0) followed by Drina x PBW 175 (32.33). Rest of the cross ranged from 16.60 to 31.00.

**Spike Length:** Good specific combining ability was revealed by the cross Arkaan x WH 1080; Blue boy x PBW 644 and Drina x WH 1080; while as poor specific combining ability was revealed by Arkaan x PBW 175 and WW23 x WH 1080.Rest of the crosses possessed average specific combining ability.Maximum spike length of 12.57 cm was found in the cross WW 21 x PBW 175 followed by WW23 x PBW 1 (12.15 cm). Rest of the crosses had average spike length ranging from 7.90 to 11.81 cm.

**1000 grain weight:** All the cross combinations possessed average specific combining ability. The maximum 1000 grain weight of 49.10 g was found in the cross WW 25 x PBW 175 followed by Nordersprez x PBW 175 (49.0 g) and Drina x PBW 175 (48.06 g). Rest of the cross range from 30.36 to 47.66 g.

**Table 7:** Estimates of sca and per se performance on the basis of $F_1$ generation of crosses in Winter x Spring wheat derivatives (Line x Tester)

| Crosses | Tillers Per Plant | | Spike length | | Grains per Plant | | Grain Yield | | 1000 Grain weight | | Biological yield / Plant | | Harvest Index | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $S_{ij}$ | Per se performance | $S_{ij}$ | Per se performance | $S_{ij}$ | Per se performance | $S_{ij}$ | Per se performance | $S_{ij}$ | Per se performance | $S_{ij}$ | Per se performance | $S_{ij}$ | Per se performance |
| Arkaan x PBW175 | -0.78 | 28.33 | -1.11** | 10.47 | -0.16 | 47.33 | 0.56 | 67.66 | -2.49** | 45.93 | 0.58 | 135.33 | -1.64 | 49.9 |
| Arkaan x PBW 644 | 0.09 | 19.00 | -0.37 | 8.37 | 3.35* | 41.00 | -2.08 | 44.53 | 2.80** | 39.40 | 12.18** | 123.33 | -3.36* | 36.1 |
| Arkaan x WH1080 | 0.69 | 19.33 | 1.48** | 10.36 | -3.19* | 36.10 | -2.64 | 48.33 | -0.31 | 36.63 | -12.75** | 97.1667 | 5.01** | 49.7 |
| B.BOY x PBW175 | 0.56 | 31.33 | -0.16 | 11.56 | 1.16 | 47.10 | -1.53 | 71.10 | -0.94 | 40.40 | 7.36 | 140.66 | -1.12 | 50.5 |
| B.BOY x PBW 644 | 1.09 | 21.66 | 0.19 | 9.08 | -1.43 | 34.67 | 4.23 | 55.33 | 1.28 | 30.80 | -1.21 | 108.50 | 1.26 | 50.9 |
| B.BOY x WH1080 | -1.64 | 18.66 | -0.02 | 8.98 | 0.26 | 38.00 | -2.79 | 47.00 | -0.33 | 29.53 | -6.14 | 102.33 | -0.14 | 45.9 |
| China4435893 x PBW175 | 1.44 | 31.66 | 0.18 | 10.62 | 2.80 | 50.40 | 1.22 | 73.00 | -3.56 | 37.46 | -4.14 | 133.66 | 3.32* | 54.46 |
| China4435893 x PBW 644 | -2.36 | 17.66 | 0.19 | 7.93 | 0.03 | 38.50 | 2.87 | 53.03 | 1.29 | 30.50 | -4.21 | 110.00 | -1.63 | 48.2 |
| China4435893 x WH1080 | 0.91 | 20.66 | 0.04 | 8.27 | -2.11 | 38.00 | -4.10 | 44.87 | 2.28** | 31.83 | 8.36 | 121.33 | -1.69 | 36.9 |
| WW23 x PBW175 | -2.22 | 26.00 | 0.16 | 11.05 | 0.68 | 48.67 | 3.41 | 65.00 | -0.57 | 49.43 | 2.08 | 141.33 | 3.32* | 45.99 |
| WW23 x PBW 644 | 1.98 | 20.00 | 0.02 | 8.43 | -1.17 | 38.33 | -0.14 | 39.83 | 0.04 | 38.23 | -9.32** | 106.33 | -1.63 | 37.45 |
| WW23 x WH1080 | 0.24 | 18.00 | 0.18 | 7.56 | 1.58 | 48.67 | -3.28 | 35.46 | 0.53 | 39.06 | 7.25* | 121.66 | -1.69 | 33.00 |
| Drina NS7200X PBW175 | 0.78 | 34.3 | 0.19 | 10.60 | 0.76 | 38.33 | 1.84 | 75.00 | -6.03** | 35.93 | -4.41 | 136.00 | 0.68 | 55.14 |
| Drina NS720 X PBW 644 | -1.69 | 21.66 | 0.41 | 8.15 | 2.61 | 43.00 | -3.51 | 48.03 | 0.35 | 30.50 | 1.32 | 118.13 | 1.59 | 40.65 |
| Drina NS720 X WH1080 | 0.91 | 24.00 | 0.60 | 8.04 | -3.37 | 52.00 | 1.68 | 52.00 | 5.68** | 36.16 | 3.09 | 118.66 | -2.27 | 43.8 |
| WW21 X PBW175 | -3.11* | 32.33 | 0.17 | 12.29 | -1.23 | 47.7000 | -0.12 | 72.33 | 2.75** | 47.70 | 0.00 | 122.66 | 1.81 | 51.00 |
| WW21 X PBW 644 | 3.42** | 28.66 | 0.63 | 8.65 | 0.85 | 44.00 | -5.14* | 45.70 | -2.97** | 30.16 | -11.00** | 88.06 | -0.14 | 58.9 |
| WW21 X WH1080 | -0.31 | 24.66 | -0.68* | 9.38 | 0.38 | 39.66 | 5.25* | 54.86 | 0.22 | 33.70 | 11.00** | 108.83 | -1.67 | 1.62 |
| WW25 x PBW175 | -1.56 | 30.00 | 0.06 | 11.50 | 0.53 | 41.33 | | 66.23 | 3.87** | 49.10 | -0.81 | 141.66 | -5.79** | 46.7 |
| WW25 x PBW 644 | -1.69 | 19.66 | -0.12 | 7.36 | 1.51 | 33.73 | -4.90* | 42.43 | -1.41 | 32.00 | 1.45 | 120.33 | -0.07 | 35 |
| WW25 x WH1080 | 3.24* | 24.33 | 0.06 | 8.23 | -2.04 | 39.23 | 7.62** | 53.73 | 1.17 | 31.30 | -0.64 | 117.00 | 5.86** | 45.92 |
| WW12 x PBW175 | 1.00 | 30.66 | -0.68 | 10.71 | -4.59** | 40.60 | -1.16 | 72.10 | 0.52 | 49.00 | 12.19** | 160.33 | 2.66 | 44.9 |
| WW12 x PBW 644 | 0.53 | 20.00 | -0.06* | 8.43 | -1.08 | 34.27 | 5.85 | 57.50 | -1.69 | 36.53 | 1.52 | 126.06 | 1.37 | 45.61 |
| WW12 x WH1080 | 1.53 | 17.66 | -0.12 | 7.82 | 5.68** | 42.67 | -4.69* | 45.73 | 2.46** | 34.66 | -13.71** | 109.60 | -4.03** | 41.72 |
| Nordresprez x PBW175 | 2.00 | 32.33 | 0.43 | 11.31 | 0.32 | 51.00 | 0.86 | 68.33 | 3.35 | 46.33 | -12.59 | 115.00 | -1.36 | 59.4 |
| Nordresprez x PBW 644 | -0.80 | 19.33 | -0.32 | 8.88 | 0.17 | 42.33 | -0.56 | 45.30 | 1.84 | 32.00 | 7.01* | 111.00 | 1.69 | 40.8 |
| Nordresprez x WH1080 | 1.90 | 18.66 | 0.08 | 8.46 | -0.17 | 47.67 | -0.30 | 44.33 | -1.51 | 30.00 | 5.58 | 108.33 | -0.32 | 40.9 |
| Drina x PBW175 | 1.89 | 34.00 | 0..32 | 11.32 | -0.15 | 47.67 | -1.24 | 69.66 | -2.40** | 48.00 | -0.25 | 138.26 | -1.86 | 50.38 |
| Drina x PBW 644 | -0.58 | 21.33 | 0.08 | 7.83 | 1.82 | 42.33 | 3.28 | 52.57 | 3.35 | 31.00 | 2.28 | 117.20 | 0.92 | 44.8 |
| Drina x WH1080 | -1.31 | 20.33 | 0.32 | 7.35 | -4.50** | 40.33 | -2.03 | 46.03 | -1.84 | 31.66 | -2.02 | 111.66 | 0.96 | 41.2 |

*,** significant at 0.05, 0.01

**Grain per plant:** The crosses having good specific combining ability were Arkaan x PBW 644, Drina NS 720 x PBW 644, WW21 x WH 1080, WW12 x WH 1080 while as those showing poor specific combining ability were Blue boy x PBW 644, China4435893 84-40022 8440012 x WH 1080, Drina NS 720 x WH 1080 and Drina x PBW 644. Maximum grains per plant were formed in the cross Drina NS 720 x PBW 175 and Nordersprez x PBW 175 (51.66) followed by China4435893 x PBW 175 (50.40); WW25 x PBW 175 (50.33) and Drina x PBW 175 (50.33) and Drina x PBW 175 (50.00). Rest of the crosses had a range of 30.83 to 49.46 g.

**Grain yield per plant:** Crosses showing good specific combining ability were Blue boy x PBW 644; WW25 X WH1080 and WW12 x PBW 644, while as those showing poor specific combining ability were Blue boy x PBW 644; China4435893 x WH1080, Drina NS 720 x PBW 644, WW 25 x PBW 175, WW12 x WH 1080 and Nordersprez x PBW 644. Rest of the crosses had Average specific combining ability. Maximum grain yield was recorded in the cross Drina NS 720 x PBW 175 (77.00 g) followed by the crosses China4435893 x PBW 175 (74.66g); WW 21 x PBW 175 (73.66 g) and WW12 X PBW 175 (73.26 g). Rest of the crosses had a range of 44.30 to 72.43 g.

**Biological yield per plant:** Crosses possessing good specific combining ability were Arkaan x PBW 644, Blue boy x PBW 175; China4435893 x PBW 175 and Drina x WH 1080. Those showing poor specific combining ability were none. Rest of the crosses had average specific combining ability. Maximum biomass (biological yield) of 162.34 g was recorded in the cross WW12 x PBW 175 followed by WW25 x PBW 175 (142.36 g) and Drina x PBW 175 (140.23 g). Rest of the crosses ranged from 88.06 to 139.43.

**Harvest Index:** Crosses showing good specific combining ability were Arkaan x WH 1080; China4435893 x PBW 175; WW23 x PBW 175, WW12 x PBW 175, WW12 x WH 1080, Nordersprez x PBW 644 and those showing poor combining ability were Arkaan x PBW 644, WW25 x PBW 175, Nordersprez x PBW 175 and Drina x PBW 175. Rest of the cross combinations were having average specific combining ability. Maximum harvest index was recorded in the cross China4435893 x PBW 175 (72.09%) followed by WW21 x PBW 175 (59%). For the other crosses it ranged from 30.8 to 58.9%.

## Discussion

Treatment revealed highly significant variance for all the trait *viz*, tillers per plant, spike length, grains per plant, 1000 grain weight, Biological yield per plant, grain yield per plant and harvest index. Variance for parents and crosses was also significant in both $F_1$ and $F_2$ generations. Comparison of crosses *vs* parents revealed significant variances for all the traits except grain yield per plant and harvest index ($F_1$ generation) while as comparison of lines *vs* Tester also revealed significant variance except spike length (both $F_1$ and $F_2$ generation) and harvest index. In bread wheat wide range of variability has been reported for almost all the traits in divergent breeding material (Shoran, 1995) [29]. Combining ability analysis carried over $F_1$ and $F_2$ generations revealed that variance for crosses, testers and partly in line was significant for almost all the traits.

Translating the components of combining ability variance ($^2$gca and $^2$sca) into genetic component, it was observed that $^2{}_A$ (additive genetic variance) was higher in magnitude than variance due to dominance variations ($^2{}_D$) for all the traits. Thus, the inheritance of these traits was predominant under the control of additive gene action. The average degree of dominance was incomplete to partial for almost all the traits except biological yield per plant that revealed nearly complete dominance. Non-additive gene action also played some role in the inheritance of some yield component traits. Lebana *et al*. (1978) [19] suggested that manifestations of GCA effects in some cross combinations results due to concentration of more favorable alleles and their interaction. Some of the desirable cross combination for grain yield and its major components on the basis of SCA effects could be used to generate desirable segregants by adopting bi-parental mating to increase the chances of recombination (Peer, 2004) [23], Singh *et al*. (2012) [32] advocated inter –mating among desirable early generation segregants in bi-parental fashion and the bulking of the best families to produce phenotypically more uniform but genetically buffered populations in autogamous crop species. Desirable segregants could be obtained if additive gene effects exhibited by good combiners and the complementary epistasis in crosses act complementarily. The crossing, involving multiple parents would result in creation of broad-based gene pools that would help to generate tremendous genetic variability after few generations of inter-mating (Webel, 1956) [34]. Singh *et al*. (2012) [32] studied combining ability in wheat and found that best cross combination involved high x low or low x low general combiners for most of the yield component traits. Desale and Mehta (2013) [7], Kumar and Kerkhi (2015) [18], Barot *et al*. (2014) [4] studied combining ability in bread wheat which revealed that the mean squares due to both GCA and SCA were significant for all traits indicating both additive and non-additive genetic variances played a vital role in inheritance of all these traits.

**Table 8:** Estimates of sca and per se performance on the basis of $F_2$ generation of crosses in Winter x Spring wheat derivatives (Line x Tester)

| Crosses | Tillers Per Plant | | Spike length | | Grains per Plant | | Grain Yield | | 1000 Grain weight | | Biological yield / Plant | | Harvest Index | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sij | Per se performance | Sij | Per se performance | Sij | Per se performance | $S_{ij}$ | Per se performance | $S_{ij}$ | Per se performance | $S_{ij}$ | Per se performance | $S_{ij}$ | Per se performance |
| Arkaan x PBW175 | 0.14 | 29.33 | -1.94** | 9.80 | -1.45 | 46.33 | 0.41 | 68.33 | -2.383 | 43.60 | -10.211 | 120.81 | -1.54 | 56.55 |
| Arkaan x PBW 644 | 1.14 | 20.66 | 0.440 | 9.71 | 2.71** | 42.00 | 1.58** | 47.86 | 1.013 | 39.63 | 12.263** | 125.71 | -4.63** | 38 |
| Arkaan x WH1080 | 1.289 | 18.33 | 1.49** | 10.73 | -1.25 | 38.20 | -2.03 | 41.70 | 1.370 | 40.46 | -2.051 | 113.29 | 6.18** | 36.8 |
| B.BOY x PBW175 | 0.92 | 33.00 | -0.203 | 11.56 | 0.30 | 47.20 | 1.15 | 72.43 | -3.072 | 43.50 | 11.592** | 139.43 | 1.81 | 51.9 |
| B.BOY x PBW 644 | 1.92 | 24.33 | 0.68** | 9.98 | -2.38** | 36.00 | 3.988** | 53.66 | 1.258 | 40.46 | -1.254 | 109.05 | -0.31 | 49.2 |
| B.BOY x WH1080 | -2.84* | 19.66 | -0.48 | 8.77 | 2.07 | 40.63 | -5.13** | 42.00 | 1.814 | 41.5 | -10.338 | 101.81 | -1.50 | 41.2 |
| China 84-8440012 x PBW175 | 0.811 | 29.66 | -0.49 | 10.35 | 1.71 | 50.40 | 0.35 | 74.66 | -6.717 | 37.46 | -21.041** | 103.56 | 4.98** | 72.09 |
| China4435893 x PBW 644 | -2.52* | 16.66 | -0.10** | 8.26 | 1.99 | 42.16 | 3.65 | 56.366 | 0.947 | 37.76 | 3.963 | 111.03 | -1.313 | 48.06 |
| China4435893 x WH1080 | 1.711 | 21.00 | 0.59 | 8.93 | -3.71** | 36.63 | -4.00** | 46.17 | 5.770 | 43.06 | 17.079** | 126.00 | -3.6** | 36.6 |
| WW23 x PBW175 | -1.189 | 27.00 | 0.64 | 12.15 | 1.58 | 49.46 | 0.76 | 66.66 | -2.872 | 46.23 | -4.908 | 128.60 | 5.06** | 51.8 |
| WW23 x PBW 644 | 1.478 | 20.00 | 0.46 | 9.50 | -2.04 | 37.33 | 0.53 | 44.83 | 2.691 | 44.43 | -8.571 | 107.40 | -1.46 | 36.62 |
| WW23 x WH1080 | -0.289 | 18.333 | -1.10 | 7.90 | 0.45 | 40.00 | -1.29 | 40.46 | 0.181 | 42.40 | 13.479** | 131.30 | -3.59** | 30.8 |
| Drina NS720 X PBW175 | -2.63* | 28.33 | -0.32 | 10.50 | -0.85 | 51.66 | 3.74 | 77.00 | -6.350 | 35.93 | -4.541 | 129.73 | 4.28** | 59.35s |
| Drina NS720 X PBW 644 | -1.96 | 19.33 | 0.06 | 8.42 | 4.04** | 48.06 | -5.62** | 46.03 | 2.247 | 37.16 | 1.696 | 118.43 | 0.48 | 38.86 |
| Drina NS720X WH1080 | 4.60** | 26.00 | 0.26 | 8.58 | -3.18 | 41.00 | 1.88 | 51.0000 | 4.103 | 39.50 | 2.846 | 121.43 | -4.76 | 30.92 |
| WW21 X PBW175 | -0.41 | 31.00 | 0.60 | 12.57 | -3.27 | 42.30 | 0.61 | 73.6667 | 3.483 | 47.03 | 7.581 | 124.83 | 5.25** | 52.56 |
| WW21 X PBW 644 | 1.58 | 23.33 | -0.79** | 8.70 | 1.16 | 36.90 | -3.74 | 47.7000 | -2.687 | 33.50 | -11.649** | 88.06 | -2.368* | 36.33 |
| WW21 X WH1080 | -1.17 | 20.66 | 0.18 | 9.64 | 3.43 | 40.66 | 3.12 | 52.0333 | -0.797 | 35.86 | 4.068 | 105.63 | -2.88** | 33.93 |
| WW25 x PBW175 | -2.41 | 28.00 | 0.46** | 11.47 | 2.51 | 50.33 | -8.12** | 58.7667 | 3.883 | 49.10 | 4.770 | 142.36 | -7.10** | 40.726 |
| WW25 x PBW 644 | -1.07 | 19.66 | -0.53** | 7.99 | 0.35** | 39.66 | -1.19 | 44.1000 | -2.187 | 35.66 | 1.107** | 121.16 | -1.555** | 37.66 |
| WW25 x WH1080 | 3.48* | 24.33 | 0.07 | 8.57 | -2.87** | 36.60 | 9.31** | 52.0667 | -1.697 | 36.63 | -5.877 | 116.03 | 8.659** | 46.00 |
| WW12 x PBW175 | 0.70* | 30.00 | 0.32** | 11.53 | -6.37 | 38.93 | 0.96 | 73.2667 | 2.494 | 47.66 | 19.076** | 162.34 | 4.411** | 53.33 |
| WW12 x PBW 644 | 1.033 | 20.66 | -0.094 | 8.64 | -0.19 | 36.60 | 4.13 | 54.8333 | -2.742 | 35.06 | 0.304 | 126.03 | 3.354 | 43.66 |
| WW12 x WH1080 | -1.733 | 18.00 | -0.227 | 8.47 | 6.56 | 43.53 | -5.09* | 43.0667 | 0.248 | 38.53 | -19.380** | 108.20 | -7.765** | 30.66 |
| Nordresprez x PBW175 | 2.81* | 33.00 | 0.251 | 11.36 | 2.71 | 51.66 | 2.54 | 70.5000 | 6.561 | 49.00 | -8.797 | 119.65 | -12.16 | 38.3 |
| Nordresprez x PBW 644 | -2.52 | | 18.00 | | 0.056 | | 8.69 | 0.22 | 40.66 | 33.66 | -0.510 | 110.40 | 6.810** | 48.66 |
| Nordresprez x WH1080 | -0.289 | | 20.33 | | -0.307** | | 8.29 | -2.94 | 37.66 | 30.40 | 9.307* | 122.06 | 5.354** | 45.32 |
| Drina x PBW175 | 1.256 | | 32.33 | | 0.663 | | 11.81 | 3.10 | 50.00 | 48.06 | 6.481 | 140.23 | -4.998 | 50.67 |
| Drina x PBW 644 | 0.922 | | 22.33 | | -0.175 | | 8.50 | -4.55 | 33.83 | 36.60 | 2.651 | 118.86 | 1.012 | 48.07 |
| Drina x WH1080 | -2.178 | | 19.33 | | -0.489 | | 8.15 | 1.44 | 40.00 | 30.36 | 9.13** | 108.93 | 3.986 | 49.17 |

*,** significant at 0.05, 0.01

## Conclusion

The material selected (winter and spring wheat) possessed good magnitude of variability for all the traits. Greater magnitude of GCA variance than SCA variance revealed that the traits had predominant role of additive gene action as compared to non-additive gene action. The results were also confirmed from the average degree of dominance that was incomplete to partial for all the traits. Accordingly, for population improvement of wheat for rainfed ecosystem, multiline crossing programme is needed to introgress allelic resources from elite genotypes and the progenies showing better early generation performance are further crossed through bi-parental procedure to increase chances of generation of hidden latent variability in heterozygous polygenic blocks. Use of recurrent selection procedure for the identification of superior transgressive segregants before fixation of alleles in homozygous condition.

## References


1. Baric M, Saracenic H, Keresa S. Analysis of yield components of $F_1$ hybrids of crosses between spring and winter wheat types (*Triticum aestivum* L.). Agri. Conspectus Scientificus, 2004; 69(1):11-15.
2. Barot HG, Patel MS, Sheikh WA, Patel LP, Allam CR. Heterosis and combining ability analysis for yield and its component traits in wheat (*Triticum aestivum* L.). Electron. J Plant Breed, 2014; 5(3): 350-359.

3. Desale CS, Mehta DR. Heterosis and combining ability analysis for grain yield and quality traits in bread wheat (*Triticum aestivum* L.). Elect. J Plant Breed. 2013; 4(3):1205-1213.
4. FAO. Wheat Status, 2020. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source
5. Fedak G, Fejer SO. Yield advantage in $F_1$ hybrids between spring and winter barley. Canadian J Plant Sci. 1975; 55(2):547-553.
6. Joshi AK *et al*. Wheat improvement in India: present status, emerging challenges and future prospects. Euphytica. 2007; 157(3):431-446.
7. Kempthorne O. An introduction to genetic statistics, 1957.
8. Kumar D, Kerkhi SA. Combining ability analysis for yield and some quality traits in spring wheat (*Triticum aestivum* L.). Electron. J Plant Breed., 2015; 6(1):26-36
9. Labana KS, Ram T, Badwal SS, Mehan DK. Combining ability analysis in the Indian mustard Crop Improvement. 1978; 5:137-144.
10. Peer AS. Genetic architecture of yield and its components in a Winter x Springdiallel cross of wheat (*Triticum aestivum* L.), 2004. (Doctoral dissertation).
11. Pinthus MJ. Spread of the root system as indicator for evaluating lodging resistance of wheat 1. Crop Science. 1967; 7(2):107-110.
12. Shoran J. Estimation of variability parameters and path coefficients for certain metric traits in winter wheat (*Triticum aestivum* L. em. Thell.). Indian J Genet. 1995; 55(4):399-405.
13. Singh V, Krishna R, Singh S, Vikram P. Combining ability and heterosis analysis for yield traits in bread wheat (*Triticum aestivum*). Indian J Agri. Sci. 2012; 82(11):254-258.
14. Gebremichael H, Tafese M, Zegeye H, Gebregiorgis A, Gerenfess D, Demsis N, *et al*. Identifying bread wheat lines for high zinc, iron and low phytate concentration. Int. J Agric. Nutr. 2020;2(1):08-12. DOI: 10.33545/26646064.2020.v2.i1a.24
15. Webel DE. Inheritance of quantitative characters in wheat. Iowa State College J Sci. 1956; 30(3):450-51.
16. Tadesse W, Amri A, Ogbonnaya FC, Sanchez-Garcia M, Sohail Q, Baum M *et al*. Wheat. In Genetic and Genomic Resources for Grain Cereals Improvement. Academic Press, 2016, 81-12.