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## Original Research Article

# Assessment the Heterosis and Combining Ability for Grain Yield Components and Heat Tolerance Traits in Bread Wheat

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**A B S T R A C T**

The experimental material comprised 8 varieties, their 28 $F_1$'s and two check varieties Raj 4037 and Raj 4079. All genotypes were evaluated in randomized block design with three replications in three different environments *i.e.* normal sown ($E_1$), late sown ($E_2$) and very late sown ($E_3$). Among the crosses PBW 343 x Raj 4238, Raj 3765 x Raj 4238, GW 173 x Raj 4238, HI 1544 x GW 366 and PBW 343 x GW 366 was showed significant economic heterosis in all the environments and pool, indicating their utility for different environments. Among these, most of the crosses also exhibited significant economic heterosis for one or more components and heat tolerant characters. The crosses PBW 343 x Raj 4238, Raj 3765 x Raj 4238, GW 173 x Raj 4238, HI 1544 x GW 366, PBW 343 x GW 366, Raj 3765 x DBW 17 and Raj 4120 x DBW 17 in all the three environments and pool, depicted high economic heterosis along with at least one good general combiner parent and high SCA effects in pool. These crosses may be exploited through identifying transgressive segregants in segregating generations.

## Introduction

Wheat (*Triticum aestivum* em. Thell) is the most widely consumed cereal crop worldwide. Approximately 40% of wheat areas in the temperate environments face terminal heat stress, which cover 36 million ha (Reynolds *et al.*, 2001). Heat stress or high temperature during crop growing period restricts wheat production and productivity, particularly at germination and grain filling stage (Monu Kumar *et al.*, 2013). The optimum temperature required for growth and development of wheat is in the range 18-24ºC and even short periods (5-6 days) of exposure of wheat crops to temperatures of 28-32ºC may result up to 20 percent decrease in yield (Rane *et al.*, 2007). It is reported that between 2020-2050 between 26-51% of Indo Gangnetic Plain may be transformed by climate changes to a heat-stressed, sub-optimal wheat production zone (Ortiz *et al.*, 2008). A number of high temperature stress-related traits have received considerable attention, in particular membrane thermostability (Saadalla *et al.*, 1990), canopy temperature depression (Blum *et al.*, 1982), heat susceptibility index for thousand grain weight (Paliwal *et al.*, 2012).

The present investigation was undertaken to understanding the genetic control of these traits would aid in choosing parents for heat tolerance breeding programmes.

## Materials and Methods

The experimental materials comprised of 8 varieties, their 28 $F_1$'s and two check varieties *viz.,* Raj 4079 and Raj 4037. The 28 $F_1$'s were obtained by crossing 8 varieties in diallel fashion (without reciprocal). The varieties were selected on the basis of their origin, adaptability, diversity and morpho-physiological characters *viz*., earliness, high yield potential and heat tolerance. All the 38 genotypes were grown in a randomized block design with three replications in three different environments. Each genotype was accommodated in one row plot of 3 meter length. Row to row and plant to plant distances were 22.5 cm and 10 cm, respectively. The experiment was conducted under irrigated conditions. Recommended crop production and protection practices were followed to raise the successful crop. Observations were recorded on days to heading, days to maturity, plant height, number of effective tillers per plant, emergence of flag leaf, spike length, number of spikelets per main spike, length of awns, number of grains per spike, flag leaf area, Test weight, biological yield per plant, grain yield per plant, harvest index, heat injury, leaf canopy temperature, proline content, chlorophyll content, chlorophyll stability index and protein content in all the three environments.

## Results and Discussion

The analysis of variance revealed significant differences between parents for all the characters in all the three environments except for days to heading in $E_1$ and $E_2$, days to maturity in $E_1$, $E_2$ and $E_3$, plant height in $E_1$, number of effective tillers per plant in $E_2$ and $E_3$, emergence of flag leaf in $E_1$, $E_2$ and $E_3$, spike length in $E_3$, length of awns in $E_3$, grain yield per plant and harvest index in $E_2$ and Leaf canopy temperature in $E_1$ and $E_2$. Significant differences among parents for the concern characters suggested presence of considerable amount of genetic variation in the materials. Similarly, Mean squares due to hybrids were also significant for all the characters in all the three environments except for days to heading in $E_1$ and $E_2$, days to maturity in $E_1$, $E_2$ and $E_3$, plant height in $E_1$ and $E_2$, emergence of flag leaf in $E_1$ and $E_3$ and harvest index in $E_1$ and $E_2$. Significant differences among hybrids for the concern characters suggested presence of considerable amount of genetic variation in the materials. The existence of average heterosis was evident from significance of parent v/s hybrids comparison for all the characters except days to heading in $E_1$ and $E_2$, days to maturity in $E_1$, plant height in $E_1$, number of effective tillers per plant in $E_2$, emergence of flag leaf in $E_1$ and $E_2$, spike length, number of spikelets per main spike, length of awns, flag leaf area, test weight, grain yield per plant and leaf canopy temperature in $E_1$, $E_2$ and $E_3$, biological yield per plant in $E_1$ and $E_3$ and harvest index in $E_1$ and $E_2$. This indicated that between parents and between hybrids difference was significant and average heterosis existed for these characters in these environments.

Significant heterosis was observed for all the characters in all the environments. Among twenty-eight crosses 7, 6, 5 and 9 crosses in $E_1$, $E_2$, $E_3$ and pool, respectively, exhibited significant positive heterosis for grain yield per plant. Significant heterobeltiosis for grain yield per plant were recorded for 4, 5, 3 and 6 crosses in $E_1$, $E_2$, $E_3$ and pool, respectively. One cross GW 173 x Raj 4238 exhibited significant heterobeltiosis for grain yield per plant in all the three environments and pool. Most of these crosses also depicted high heterobeltiosis for one or more yield components and heat tolerance characters. In the present investigation, expression of economic heterosis, in general, was variable for different characters in different environments. Among the crosses PBW 343 x Raj 4238, Raj 3765 x Raj 4238, GW 173 x Raj 4238, HI 1544 x GW 366 and PBW 343 x GW 366 was showed significant economic heterosis in all the environments and pool, indicating their utility for different environments. Among these, most of the crosses also exhibited significant economic heterosis for one or more components and heat tolerant characters. Similar results were also reported by Desale and Mehta, 2013 and Lal *et al.,* 2013.

The analysis of variance for combining ability indicated significant difference for GCA and SCA was significant for most of the characters in all the three environments suggested difference between parents for GCA and between hybrids for SCA. Over the environment mean square due to GCA x E and SCA x E were significant for proline content, chlorophyll content, chlorophyll stability index and heat injury. Combining ability studies revealed that $\sigma^2$ gca was higher than their respective $\sigma^2$ sca for all the characters except number of grains per spike, chlorophyll content, heat injury and protein content in grain, indicated that additive type of gene action played role in the expression of all these traits. However, higher magnitude of sca variances revealed predominance of non-additive gene action in the inheritance of traits. The estimates of general combining ability effects indicated that parents Raj 4238 and HI 1544 (in $E_3$) were good general combiners for grain yield per plant and most of components along with heat tolerance characters.

The SCA effects for grain yield per plant were significantly positive for 10 crosses in pool. The 8, 9 and 5 crosses each in $E_1$, $E_2$ and $E_3$ respectively had significantly positive SCA**.** Four cross *viz.,* GW 173 x Raj 4238, Raj 3765 x Raj 4238, PBW 343 x GW 366 and PBW 343 x Raj 4238 was significant and positive SCA effects in all three environments and pool. The maximum SCA in pool was recorded for PBW 343 x Raj 4238 followed by PBW 343 x GW 366, Raj 3765 x Raj 4238, GW 173 x Raj 4238 and HI 1544 x GW 366. All these crosses were also having significant SCA effects for one or more components and heat tolerant characters indicate their genetic worth for these characters in respective environments. The crosses PBW 343 x Raj 4238, Raj 3765 x Raj 4238, GW 173 x Raj 4238, HI 1544 x GW 366, PBW 343 x GW 366, Raj 3765 x DBW 17 and Raj 4120 x DBW 17 in all the three environments and pool, and Raj 4120 x GW 173 in $E_1$, $E_2$ and pool depicted high economic heterosis along with at least one good general combiner parent and high SCA effects in pool.

In present investigation, hybrids PBW 343 x Raj 4238, Raj 3765 x Raj 4238, GW 173 x Raj 4238, HI 1544 x GW 366, PBW 343 x GW 366, Raj 3765 x DBW 17 and Raj 4120 x DBW 17 in all the three environments and pool, and Raj 4120 x GW 173 in $E_1$, $E_2$ and pool depicted high economic heterosis along with at least one good general combiner parent and high SCA effects. These crosses may be exploited by identifying transgressive segregants in segregating generations. The hybrids PBW 343 x GW 366 in ($E_1$, $E_3$ and pool) Raj 4120 x GW 173 **(**in $E_1$, $E_2$ and pool) and Raj 4120 x DBW 17 **(**in $E_3$) had high economic heterosis for grain yield per plant but both the parents were poor combiners along with significant SCA effects. Therefore, possibility of transgressive segregants is very low as the high economic heterosis might be due to the presence of dominance and dominance based epistasis (Singh and Chatrath, 1997) (Table 1–4).

**Table.1** Mean square for different characters

| SN | Characters | Env | Source | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Rep [2] | Genotype [35] | Parent [7] | F1 [27] | P vs F1 [1] | Error [70] |
| 1 | Days to heading | 1 | 13.86 | 4.14 | 6.71 | 3.29 | 9.05 | 8.48 |
| | | 2 | 29.45* | 8.74 | 6.00 | 9.67 | 2.71 | 7.50 |
| | | 3 | 30.58** | 11.36** | 15.50* | 9.80* | 24.38* | 5.75 |
| 2 | Days to maturity | 1 | 0.23 | 8.97 | 21.95 | 3.72 | 59.92 | 24.95 |
| | | 2 | 35.01 | 19.27 | 17.24 | 17.40 | 83.82* | 12.98 |
| | | 3 | 88.04** | 20.46* | 14.45 | 15.42 | 198.61** | 11.75 |
| 3 | Plant Height (cm) | 1 | 46.22 | 25.70 | 22.93 | 25.37 | 54.15 | 19.11 |
| | | 2 | 23.38 | 23.88* | 34.28* | 18.79 | 88.25* | 14.09 |
| | | 3 | 10.55 | 37.83** | 62.84** | 25.83** | 186.73** | 10.10 |
| 4 | Number of effective tillers per plant | 1 | 0.68 | 5.68** | 4.52** | 5.28** | 24.53** | 0.53 |
| | | 2 | 0.83 | 3.51** | 0.68 | 4.35** | 0.60 | 0.69 |
| | | 3 | 1.14 | 2.78** | 0.39 | 3.35** | 4.19* | 0.94 |
| 5 | Emergence of flag leaf | 1 | 16.75 | 6.03 | 9.02 | 5.30 | 4.67 | 6.46 |
| | | 2 | 35.45** | 5.49* | 4.71 | 5.66* | 6.22 | 3.16 |
| | | 3 | 107.37** | 10.06* | 9.99 | 8.14 | 62.33** | 5.44 |
| 6 | Spike length (cm) | 1 | 4.75* | 3.25** | 4.92** | 2.94** | 0.00 | 1.02 |
| | | 2 | 1.23 | 1.88** | 2.34** | 1.84** | 0.01 | 0.71 |
| | | 3 | 1.39 | 1.07* | 0.07 | 1.36** | 0.11 | 0.58 |
| 7 | Number of spikelets per main spike | 1 | 2.23 | 3.37** | 3.30** | 3.51** | 0.00 | 0.80 |
| | | 2 | 2.23 | 4.50** | 4.53** | 4.66** | 0.01 | 0.76 |
| | | 3 | 0.62 | 4.64** | 4.46** | 4.86** | 0.00 | 0.34 |
| 8 | Length of awns (cm) | 1 | 5.64** | 3.25** | 4.92** | 2.94** | 0.00 | 1.02 |
| | | 2 | 1.14 | 1.88** | 2.34** | 1.84** | 0.01 | 0.71 |
| | | 3 | 2.72* | 1.07* | 0.07 | 1.36** | 0.11 | 0.58 |
| 9 | Number of grains per spike | 1 | 16.82 | 43.30** | 55.07** | 38.49** | 90.73* | 16.46 |
| | | 2 | 14.09 | 47.29** | 63.75** | 40.50** | 115.23** | 13.15 |
| | | 3 | 36.43* | 56.30** | 78.08** | 42.27** | 282.81** | 10.25 |
| 10 | Flag leaf area ($cm^2$) | 1 | 232.35** | 31.96** | 36.41** | 31.98** | 0.11 | 5.02 |
| | | 2 | 353.90** | 29.92** | 37.42** | 29.08** | 0.06 | 4.53 |
| | | 3 | 103.75** | 27.36** | 34.53** | 26.51** | 0.05 | 4.14 |
| 11 | Test Weight (g) | 1 | 17.55** | 18.60** | 13.57** | 20.14** | 12.17 | 3.24 |
| | | 2 | 27.22** | 17.86** | 15.15** | 18.93** | 8.11 | 2.70 |
| | | 3 | 6.16 | 13.98** | 12.51** | 14.57** | 8.46 | 2.92 |
| 12 | Biological yield per plant (g) | 1 | 24.45 | 156.34** | 72.25** | 182.99** | 25.34 | 17.62 |
| | | 2 | 19.52 | 150.55** | 51.23** | 180.12** | 47.63* | 10.51 |
| | | 3 | 142.77** | 113.74** | 31.04* | 138.18** | 32.88 | 14.26 |
| 13 | Grain yield per plant (g) | 1 | 22.65** | 18.96** | 7.29* | 22.65** | 0.88 | 2.59 |
| | | 2 | 6.80* | 15.24** | 3.35 | 18.89** | 0.02 | 1.60 |
| | | 3 | 10.13** | 8.65** | 3.49* | 10.27** | 0.99 | 1.31 |
| 14 | Harvest index (%) | 1 | 56.31* | 23.57* | 57.49** | 15.25 | 10.51 | 14.61 |
| | | 2 | 86.10* | 21.13 | 20.84 | 21.02 | 26.16 | 22.15 |
| | | 3 | 312.01** | 23.46** | 45.22** | 16.23** | 66.24** | 6.32 |
| 15 | Heat Injury (%) | 1 | 3.13 | 131.51** | 131.80** | 135.73** | 15.60** | 1.20 |
| | | 2 | 0.91 | 114.13** | 103.26** | 120.58** | 16.03** | 1.84 |
| | | 3 | 1.48 | 135.81** | 122.47** | 143.36** | 25.32** | 2.61 |
| 16 | Leaf canopy Temperature | 1 | 1.33 | 0.96* | 0.82 | 1.03* | 0.14 | 0.55 |

| SN | Characters | Env | Source | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Rep [2] | Genotype [35] | Parent [7] | F1 [27] | P vs F1 [1] | Error [70] |
| | (˚C) | | | | | | | |
| | | 2 | 3.34** | 1.05* | 0.91 | 1.12* | 0.14 | 0.59 |
| | | 3 | 6.11** | 1.23** | 1.36* | 1.25** | 0.00 | 0.61 |
| 17 | Proline content (µg) | 1 | 0.09 | 33.73** | 28.35** | 35.27** | 29.81** | 0.30 |
| | | 2 | 0.92** | 26.01** | 29.12** | 26.08** | 2.38** | 0.10 |
| | | 3 | 0.16 | 37.05** | 37.45** | 36.41** | 51.44** | 0.45 |
| 18 | Chlorophyll Content (µg/g) | 1 | 0.00 | 0.37** | 0.43** | 0.35** | 0.61** | 0.00 |
| | | 2 | 0.00 | 0.41** | 0.33** | 0.41** | 0.71** | 0.00 |
| | | 3 | 0.00 | 0.35** | 0.32** | 0.35** | 0.49** | 0.00 |
| 19 | Chlorophyll stability index | 1 | 0.12 | 32.60** | 40.08** | 30.37** | 40.38** | 0.29 |
| | | 2 | 0.88 | 27.29** | 31.70** | 26.20** | 25.78** | 0.38 |
| | | 3 | 0.13 | 18.92** | 14.23** | 20.05** | 21.09** | 0.23 |
| 20 | Protein content (%) | 1 | 0.32* | 0.95** | 0.60** | 1.05** | 0.61** | 0.08 |
| | | 2 | 0.30* | 0.93** | 0.55** | 1.04** | 0.56** | 0.08 |
| | | 3 | 0.13** | 1.04** | 0.63** | 1.16** | 0.63** | 0.03 |

*,** Significant at 5 and 1 percent respectively

**Table.2** Promising hybrids identified on the basis of *Per se* performance, economic heterosis with their SCA effect and component characters showing significant desired heterosis over environments for grain yield per plant

| S.N. | Hybrids | *Per se* performance of grain yield per plant (g) | Economic heterosis (%) | SCA effects | Significant economic heterosis for other traits in desired direction |
|---|---|---|---|---|---|
| 1. | PBW 343 x Raj 4238 | 17.86 | 58.27** | 3.60** | BY, GY, CSI, PCT |
| 2. | Raj 3765 x Raj 4238 | 17.71 | 56.88** | 3.04** | ET, BY, GY, CSI, |
| 3. | GW 173 x Raj 4238 | 17.14 | 51.82** | 2.38** | BY, GY, PC, CC, CSI, H, |
| 4. | HI 1544 x GW 366 | 16.32 | 44.62** | 2.28** | SS, BY, GY, PC, CC, CSI, H |
| 5. | PBW 343 x GW 366 | 16.19 | 43.46** | 3.04** | TW, BY,GY, CSI, PCT |
| 6. | Raj 3765 x DBW 17 | 15.72 | 39.32** | 1.51** | BY, GY, |
| 7. | Raj 4120 x GW 173 | 15.22 | 34.88** | 2.01** | BY,GY, CSI, |
| 8. | Raj 4120 x DBW 17 | 15.10 | 33.76** | 1.52** | SS, GY, PCT |
| ET: | No. of effective tillers per plant | SS: | No. of spikelets per main spike | TW: | Test weight |
| BY: | Biological yield per plant | GY: | Grain yield per plant | H: | Heat injury |
| PC: | Proline content | CC: | Chlorophyll content | CSI: | Chlorophyll stability index |
| PCT: | Protein content | | | | |

**Table.3** Extent of heterosis for grain yield per plant (g)

| SN. | Crosses | Heterosis | | | | Heterobeltiosis | | | | Economic heterosis | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $E_1$ | $E_2$ | $E_3$ | Pool | $E_1$ | $E_2$ | $E_3$ | Pool | $E_1$ | $E_2$ | $E_3$ | Pool |
| 1. | HI 1544 x Raj 4120 | -3.17 | -6.80 | -13.77* | -7.13 | | | | | 32.23** | 22.69* | 11.37 | 23.46** |
| 2. | HI 1544 x GW 173 | -4.19 | 4.00 | 1.24 | -0.04 | | | | | 20.03* | 29.37** | 24.96* | 24.44** |
| 3. | HI 1544 x Raj 3765 | -3.56 | 0.70 | -0.83 | -1.45 | | | | | 32.03** | 35.87** | 20.58* | 30.21** |
| 4. | HI 1544 x PBW 343 | -13.69* | -20.17** | -12.24 | -15.53** | | | | | 11.09 | 1.97 | | 4.97 |
| 5. | HI 1544 x GW 366 | 1.99 | 7.32 | 26.55** | 9.91** | | 7.03 | 17.58* | 4.43 | 36.48** | 47.61** | 53.03** | 44.62** |
| 6. | HI 1544 x Raj 4238 | -8.78 | -9.39 | -14.32* | -10.46** | | | | | 21.26* | 20.21* | 12.28 | 18.50** |
| 7. | HI 1544 x DBW 17 | -20.83** | -22.46** | -14.83* | -19.88** | | | | | 6.51 | 4.71 | 3.91 | 5.22 |
| 8. | Raj 4120 x GW 173 | 19.23** | 23.38** | -6.70 | 13.40** | 8.78 | 16.25* | | 5.88 | 39.85** | 45.71** | 14.22 | 34.88** |
| 9. | Raj 4120 x Raj 3765 | 0.00 | 4.00 | -6.15 | -0.24 | | 1.40 | | | 28.91** | 33.78** | 13.16 | 26.27** |
| 10. | Raj 4120 x PBW 343 | -20.78** | -20.77** | -22.22** | -21.14** | | | | | | | | |
| 11. | Raj 4120 x GW 366 | -30.27** | -32.74** | -36.60** | -32.74** | | | | | | | | |
| 12. | Raj 4120 x Raj 4238 | -1.42 | -8.54 | -23.75** | -9.93* | | | | | 23.18* | 15.59 | | 14.21* |
| 13. | Raj 4120 x DBW 17 | 8.86 | 8.27 | -0.08 | 6.34 | 7.15 | 5.48 | | 5.00 | 37.76** | 39.39** | 20.91* | 33.76** |
| 14. | GW 173 x Raj 3765 | 6.32 | 4.09 | -9.91 | 1.31 | | | | | 25.07* | 26.36** | 3.47 | 19.68** |
| 15. | GW 173 x PBW 343 | 17.63* | 20.47** | 10.31 | 16.69** | 14.07 | 17.05* | 0.88 | 16.46** | 28.74** | 37.57** | 17.73 | 28.69** |
| 16. | GW 173 x GW 366 | -17.79* | -20.25** | -6.48 | -15.69** | | | | | | | 6.80 | |
| 17. | GW 173 x Raj 4238 | 29.90** | 30.76** | 23.18** | 28.28** | 21.70** | 22.25** | 16.07* | 20.30** | 47.66** | 55.78** | 53.14** | 51.82** |
| 18. | GW 173 x DBW 17 | 0.95 | -5.08 | -8.34 | -3.57 | | | | | 16.37 | 15.32 | 5.67 | 13.14* |
| 19. | Raj 3765 x PBW 343 | -40.72** | -42.37** | -34.94** | -39.91** | | | | | | | | |
| 20. | Raj 3765 x GW 366 | 1.78 | 1.68 | 2.41 | 1.90 | | | 1.81 | 1.46 | 28.42** | 36.82** | 15.06 | 27.59** |
| 21. | Raj 3765 x Raj 4238 | 25.74** | 25.88** | 20.92** | 24.52** | 21.89** | 23.73** | 12.24 | 24.31** | 57.55** | 63.24** | 48.10** | 56.88** |
| 22. | Raj 3765 x DBW 17 | 14.53* | 11.28 | 6.72 | 11.49** | 12.44 | 11.19 | 6.32 | 10.78* | 45.33** | 46.93** | 21.05* | 39.32** |
| 23. | PBW 343 x GW 366 | 23.03** | 17.01** | 28.74** | 22.24** | 17.91* | 8.63 | 20.12* | 15.07** | 45.13** | 49.02** | 34.17** | 43.46** |
| 24. | PBW 343 x Raj 4238 | 37.02** | 33.98** | 29.33** | 33.98** | 32.23** | 28.78** | 12.08 | 25.41** | 60.45** | 64.10** | 47.88** | 58.27** |
| 25. | PBW 343 x DBW 17 | 11.38 | 6.52 | 14.51 | 10.43* | 6.16 | 0.63 | 5.91 | 4.15 | 32.20** | 32.98** | 20.58* | 29.33** |
| 26. | GW 366 x Raj 4238 | 4.17 | -1.09 | -8.37 | -0.94 | 3.44 | | | | 27.31** | 30.86** | 11.62 | 24.26** |
| 27. | GW 366 x DBW 17 | 5.75 | 4.00 | 3.87 | 4.66 | 5.13 | 2.09 | 2.89 | 4.45 | 30.92** | 40.04** | 17.14 | 30.22** |
| 28. | Raj 4238 x DBW 17 | 3.06 | -0.67 | -2.36 | 0.35 | 1.74 | | | | 26.70** | 28.92** | 19.99 | 25.63** |

*, ** Significant at 5% and 1% respectively.

**Table.4** GCA effects, SCA effects and stability of economic heterotic crosses of grain yield per plant

| Crosses | Economic heterosis | | | | SCA Effects | | | | GCA effects | | | | Stability |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pool | $E_1$ | $E_2$ | $E_3$ | Pool | $E_1$ | $E_2$ | $E_3$ | Pool | |
| PBW 343 x Raj 4238 | + | + | + | + | + | + | + | + | L x H | L x H | L x H | L x H | bi > 1 |
| Raj 3765 x Raj 4238 | + | + | + | + | + | + | + | + | M x H | M x H | L x H | M x H | bi > 1 |
| GW 173 x Raj 4238 | + | + | + | + | + | + | + | + | L x H | L x H | M x H | L x H | bi = 1 |
| HI 1544 x GW 366 | + | + | + | + | | + | + | + | M x L | L x M | H x L | M x L | bi < 1 |
| PBW 343 x GW 366 | + | + | + | + | + | + | + | + | L x L | L x M | L x L | L x L | bi > 1 |
| Raj 3765 x DBW 17 | + | + | + | + | + | + | | + | M x M | M x M | L x L | L x M | bi > 1 |
| Raj 4120 x GW 173 | + | + | + | + | + | + | | + | L x L | L x L | L x M | L x L | bi > 1 |
| Raj 4120 x DBW 17 | + | + | + | + | + | + | | + | L x M | L x M | L x L | L x M | bi > 1 |

+ = Significant positive value
H: High GCA, M: Medium GCA, L: Low GCA

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