# THE IMPACT OF NUCLEAR-PLASMA GENE INTERACTION GOVERNING HETEROSIS IN WHEAT (*TRITICUM AESTIVUM* L.)

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**Abstract :** The present investigation consists of 28 genotypes of wheat, which were procured from Wheat Breeding Programme, Directorate of Research, Sam Higginbottom Institute of Agriculture, Technology and Sciences, (Deemed to be University), Allahabad, UP, India. The experiment was conducted during *Rabi* 2008-10 in RBD having three replications. The data were recorded on twelve characters to study the variability, heterosis and contribution of plasma gene determining the heterosis. The significant mean sum of squares for all the 12 characters indicated the presence of substantial amount of variability. *Per se* performance for grain yield and its components depicted that genotypes GIANT-3, AAI-347 and RAJ-4026 was found to be best for introduction of male sterility either through chemical hybridizing agent (CHA) or through transfer of ms gene from the wild sources or alien genes through biotechnological techniques in hybrid breeding programme in wheat. This hybrid showed highest positive significant heterobeltiosis (hb) and economic heterosis (he) values for grain yield per plant, number of grains per spike, number of effective tillers per plant and biological yield due to plasma gene effect in reciprocal crosses. The highest heterobeltiosis (hb) and economic heterosis (he) value for grain yield per plant was depicted by direct cross GIANT-3 x AAI-347 and reciprocal cross PBW-343 x GIANT-3.

**Keywords:** Heterosis, male sterility, nuclear gene, plasma gene, wheat.

## INTRODUCTION

Wheat is predominantly, a self-pollinated crop. Its population being characterized by homozygous balance. Presence of heterosis is an indication of the crosses, which are likely to give productive transgressive segregants. The direction and magnitude of heterosis and gene action give an indication of the genetic control of the characters. Estimation of heterosis over better parent may be useful in identifying true heterotic cross combinations. In this way, the objective of present investigation was to identify heterotic combinations, which should be statistically superior to the ruling variety of the region and should exhibit at least 20% standard heterosis. The major break through has been achieved in wheat production in the past decades; however, the pace of increase in productivity at present is far below the rate at which population is growing. Hence there is an urgent need to break the yield barrier in wheat and evolve the varieties that have the yield potential of 8 tonnes/hectares.

An interaction between cytoplasm and nuclear genes affecting the inheritance of male sterility in flax (*Linum usitatissimum* L.) was reported first by workers in England in the 1920s in crosses between procumbent and tall plants and later by a worker in Poland using *Linum floccosum.*

Cytoplasmic effects have been observed in the expression of male sterility**,** heading date, plant height, biomass and grain yield and seed viability. Through the use of cytoplasmic substitution lines of wheat (*Triticum spp.* and *Aegilops* spp.) identified **'**nuclear-cytoplasmic' hybrids that exhibited heterosis for grain yield. A phenomenon akin to nuclear-cytoplasmic heterosis was reported by Robertson and Frey (1984) isopopulation of oats (*Avena sativa* L.) in a $BC_2$ cytoplasmic isopopulation of oats (*Avena sativa* L.). A. Dehdari and Rizai (2006**)** Nuclear and cytoplasmic inheritance Salt tolerance in bread wheat plants based on iron contents and Biological yield.

## MATERIAL AND METHOD

During the winter of 2008-09 seven genotypes of bread wheat, viz., GIANT-3, AAI-2, HD-2733, PBW-524, PBW-343, RAJ-4026 and AAI-347 were crossed in all possible combinations including reciprocals on the basis of full diallel mating design fashion. The resulting 7 parents, 20 $F_1$s and 20 reciprocals were evaluated in winter 2009-10 in a randomized block design with three replications under normal sown irrigated condition. Each plot consisted of single row of 2 meter length spaced at 25 cm. Plant to plant distance was kept at 5 cm. Non-experimental rows were provided all around the experimental material to avoid any possible border effects. The data were collected on the five randomly selected plant from each row for twelve characters, viz., Days to 50% flowering, days to maturity, plant height, number of productive tillers per plant, flag leaf length, flag leaf width, spike length, number of grains per spike, test weight, biological weight, harvest index and grain yield per plant. Heterosis over better parent (BP) and standard variety (SV) was calculated as per standard procedures. GIANT-3, HD – 2733, PBW – 343 was kept as standard variety of bread wheat for the present investigation.

## RESULT AND DISCUSSION

The analysis of variance (Table 1) due to parents, $F_{1s}$, reciprocals, parents V/s $F_{1s}$, parent v/s reciprocals and parent v/s $F_{1s}$ + reciprocals were significant for all the characters. Analysis of variance revealed that the mean sum of squares due to parents and their direct and reciprocal crosses showed significant differences for all the characters studied. This indicates relatively high magnitude of genetic variability among parent and their direct and reciprocal crosses.

A perusal of mean value (Table 2) of yield and yield contributing characters revealed that among the parents AAI-347 (18.91) and GIANT-3 (17.82) exhibited maximum value of grain yield per plant and their hybrids (crosses) among the direct crosses GIANT-3 x AAI-347 (24.70) exhibited more number of grains per plant and for contributing traits viz number of grain yield per spike (12.50), test weight (43.64), harvest index (44.09), plant height (86.50), days to 50% flowering (79.00), days to maturity (116.50).

Among the reciprocal crosses PBW-343 x GIANT-3 (20.99) shows highest grain yield per plant and for contributing traits *viz.* grain yield per spike (82.50), test weight (46.95), plant height (92.00), days to flowering (78.00), days to maturity (117.50), flag leaf width (1.57), and harvest index (42.96).

The crosses showing heterosis for grain yield per plant were not heterotic for all characters. This implied that heterosis is a complex character like yield can be registered by single or several characters.

The range of heterosis, number of economic (in parenthesis) and number of crosses showing significant economic heterosis over BP and SV for all the twelve characters have been presented in Table 3. Maximum heterosis for grain yield per plant over BP and SV was observed to be 30.61% and 47.75% respectively. Heterosis for grain yield has been reported by Ansari *et al.* (2005), Farooq *et al* (2007) and Hussain *et al*. (2007). In the present study also heterosis observed in grain yield was maximum next only to number of tillers per plant.

A close perusal of Table 4. Showed that by and large, heterosis for number of grains per spike and that for harvest index was independently associated with heterosis for grain yield per plant. This was perhaps due to antagonistic association of these two characters. Harvest index produced heterotic effects in almost all the crosses. Other important characters contributing to yield heterosis in present study were 1000-grain weight, biological yield per plant, spike length and number of grains per spike. Through some direct and reciprocal crosses, it was found that heterosis *i.e.* relative heterosis (ha), heterobeltiosis (hb) and economic heterosis (he) for the trait effective number of tillers per plant exhibit significant improvement and they were at par with each other. This proves that the trait number of tillers per plant is influenced by nuclear-plasma gene interaction. In the present study most of the traits did not show consistent nuclear- cytoplasmic effect across mating. However, some traits like number of effective tillers per plant, flag leaf length, flag leaf width, test weight, biological yield and harvest index exhibit significant improvement in both direct and reciprocal crosses thus showing nuclear-plasma gene interaction.

It was observed that high yielding pure line PBW-343 (14.63 g/plant), HD-2733 (16.57 g/plant) did not produce high heterotic response for grain yield. Similar results were also reported by Darrel and Charles. Contrary to this finding however, Sharma and Singh observed that higher the mean performance of the parents, greater was the heterotic expression.

*Per se* performance for grain yield and its components depicted that genotypes GIANT-3, AAI-347 and RAJ-4026 was found to be best for introduction of male sterility either through chemical hybridizing agent (CHA) or through transfer of ms gene from the wild sources or alien genes through biotechnological techniques in hybrid breeding programme in wheat. This hybrid showed highest positive significant heterobeltiosis (hb) and economic heterosis (he) values for grain yield per plant, number of grains per spike, number of effective tillers per plant and biological yield due to plasma gene effect in reciprocal crosses. The highest heterobeltiosis (hb) and economic heterosis (he) value for grain yield per plant was depicted by direct cross GIANT-3 x AAI-347 and reciprocal cross PBW-343 x GIANT-3.

**Table 1**. Analysis Of Variance For Different Quantitative Characters In Wheat

| Sr. no. | Character | | Source of variance | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Replication | Genotypes | Parents | $F_1$ | P vs $F_1$ | Reciprocal | P vs Reciprocal | F1 vs Reciprocal | Parent vs F1+reciprocal | Error | Total |
| | | | df[1] | df[27] | df[6] | df[9] | df[1] | df[9] | df[1] | df[1] | df[1] | df[27] | df[54] |
| 1 | Days to 50% Flowering | MEAN SUM OF SQUARE | 0.02 | 27.05** | 77.31** | 15.34** | 22.03* | 8.71* | 25.57* | 28.67* | 21.37* | 3.21 | 14.84 |
| 2 | Days to Maturity | | 0.29 | 12.46** | 33.24** | 7.53** | 19.24** | 2.97** | 27.54** | 30.28** | 29.22** | 0.76 | 6.49 |
| 3 | Effective tillers per plant | | 0.32 | 39.67** | 13.30** | 9.43** | 75.25** | 84.23** | 95.56** | 81.47** | 107.17** | 1.57 | 20.24 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | **Flag leaf length** | | 11.38 | 25.45** | 58.33** | 17.66** | 30.07** | 13.38** | 13.98* | 14.77* | 17.61* | 2.89 | 14.12 |
| 5 | **Flag leaf width** | | 0.002 | 0.13** | 0.20** | 0.08** | 0.45** | 0.10** | 0.27** | 0.23** | 0.45** | 0.02 | 0.07 |
| 6 | **Plant height** | | 0.19 | 66.46** | 90.99** | 75.94** | 28.95** | 44.17** | 93.70* | 100.17* | 90.88** | 13.50 | 39.23 |
| 7 | **Spike length** | | 1.02 | 3.89** | 5.72** | 2.59** | 12.24** | 3.11** | 5.85** | 6.42** | 11.02** | 0.52 | 2.18 |
| 8 | **Grains per spike** | | 0.29 | 431.12** | 719.47** | 200.40** | 753.33** | 371.24** | 734.88** | 245.02** | 503.13** | 4.14 | 213.53 |
| 9 | **Test weight** | | 13.39 | 45.004** | 55.28** | 9.96* | 55.70** | 76.49** | 37.54** | 32.17** | 58.15** | 3.34 | 23.97 |
| 10 | **Biological yield (g)** | | 0.83 | 157.64** | 214.13** | 163.34** | 4.41* | 126.44** | 161.65** | 136.82** | 69.08** | 0.95 | 77.82 |
| 11 | **Harvest index** | | 3.01 | 16.93** | 47.07** | 6.73** | 46.99** | 5.06* | 26.13** | 25.58** | 26.19** | 1.86 | 9.28 |
| 12 | **Grain yield per plant** | | 0.89 | 27.90** | 14.11** | 38.77** | 12.09** | 26.74** | 9.03** | 51.03** | 10.07** | 0.501 | 13.950 |

**Table 2.** Mean Performances For Different Quantitative Characters In Wheat

| Sr. no. | Genotype | Days to 50% Flowering | Days to Maturity | Effective tillers per plant | Flag leaf length (cm) | Flag leaf width (cm) | Plant height (cm) | Spike length (cm) | Number of grains per spike | Test weight (g) | Biological yield (g) | Harvest index (%) | Grain yield per plant (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **GIANT-3×AAI-347** | 79.00 | 116.50 | 11.34 | 26.19 | 2.32 | 86.50 | 13.15 | 72.50 | 43.64 | 56.02 | 44.09 | 24.70 |
| 2 | **GIANT-3×PBW- 524** | 74.00 | 120.00 | 14.37 | 34.60 | 2.55 | 92.67 | 12.25 | 81.50 | 45.14 | 42.16 | 39.83 | 16.80 |
| 3 | **GIANT-3×RAJ-4026** | 74.50 | 114.50 | 13.11 | 36.00 | 2.48 | 99.87 | 12.50 | 79.00 | 46.54 | 42.59 | 44.05 | 18.76 |
| 4 | **GIANT-3×PBW- 343** | 78.00 | 116.50 | 10.95 | 32.10 | 2.41 | 104.75 | 12.90 | 69.00 | 46.45 | 51.07 | 43.94 | 22.71 |
| 5 | **GIANT-3×HD- 2733** | 80.50 | 120.50 | 8.25 | 27.45 | 2.02 | 96.25 | 11.85 | 59.00 | 44.95 | 38.91 | 40.25 | 15.66 |
| 6 | **AAI-2×AAI-347** | 73.50 | 118.00 | 8.00 | 32.59 | 2.62 | 92.84 | 14.04 | 69.00 | 48.89 | 29.72 | 40.67 | 12.08 |
| 7 | **AAI-2×HD-2733** | 80.00 | 115.50 | 7.92 | 30.00 | 2.43 | 85.54 | 11.15 | 65.00 | 43.50 | 33.17 | 41.23 | 13.67 |
| 8 | **AAI-2×PBW- 524** | 74.50 | 115.50 | 11.84 | 32.00 | 2.10 | 88.95 | 9.90 | 52.50 | 43.55 | 31.65 | 40.24 | 13.74 |
| 9 | **AAI-2×PBW- 343** | 80.00 | 116.50 | 10.79 | 30.85 | 2.51 | 90.45 | 11.08 | 53.00 | 46.30 | 34.81 | 40.46 | 14.08 |
| 10 | **AAI-2×RAJ-4026** | 77.50 | 117.50 | 11.35 | 30.40 | 2.54 | 87.83 | 13.00 | 73.00 | 40.84 | 29.78 | 39.67 | 11.82 |
| 11 | **GIANT-3** | 76.00 | 116.50 | 5.70 | 37.82 | 2.76 | 92.09 | 13.80 | 97.00 | 50.80 | 59.94 | 29.73 | 17.82 |
| 12 | **AAI- 347** | 78.00 | 115.00 | 8.33 | 34.70 | 2.22 | 97.70 | 11.54 | 59.00 | 55.05 | 43.90 | 43.14 | 18.91 |
| 13 | **PBW-524** | 72.00 | 109.50 | 13.00 | 29.50 | 1.97 | 77.47 | 9.25 | 41.50 | 39.00 | 27.17 | 43.34 | 11.78 |
| 14 | **RAJ- 4026** | 75.00 | 112.00 | 8.28 | 25.29 | 1.94 | 94.00 | 9.25 | 43.00 | 44.89 | 35.86 | 35.58 | 12.76 |
| 15 | **PBW- 343** | 88.00 | 120.50 | 7.39 | 24.50 | 2.01 | 95.90 | 10.90 | 55.50 | 45.44 | 35.64 | 41.03 | 14.63 |
| 16 | **HD-2733** | 87.00 | 120.50 | 5.59 | 23.50 | 1.88 | 89.90 | 9.80 | 47.00 | 51.25 | 40.85 | 40.57 | 16.57 |
| 17 | **AAI-2** | 75.50 | 115.00 | 6.10 | 29.89 | 2.38 | 87.77 | 12.19 | 61.50 | 46.64 | 34.67 | 39.99 | 13.87 |
| 18 | **AAI-347×GIANT-3** | 77.00 | 118.50 | 9.79 | 25.93 | 2.51 | 88.00 | 11.88 | 63.00 | 41.25 | 44.40 | 39.89 | 17.72 |
| 19 | **PBW-** | 75.50 | 118.50 | 28.25 | 33.60 | 2.25 | 86.18 | 11.21 | 86.50 | 56.94 | 40.04 | 40.17 | 16.08 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **524×GIANT-3** | | | | | | | | | | | | |
| **20** | **RAJ-4026×GIANT-3** | 77.50 | 119.00 | 8.78 | 32.60 | 2.50 | 96.42 | 11.59 | 84.50 | 52.14 | 39.75 | 41.77 | 16.60 |
| **21** | **PBW-343×GIANT-3** | 78.00 | 117.50 | 14.46 | 32.10 | 2.47 | 92.00 | 12.84 | 82.50 | 46.95 | 48.86 | 42.96 | 20.99 |
| **22** | **HD-2733×GIANT-3** | 81.00 | 116.00 | 5.09 | 27.25 | 1.87 | 80.75 | 10.20 | 53.50 | 38.84 | 36.72 | 39.17 | 14.38 |
| **23** | **AAI-347×AAI-2** | 75.50 | 116.50 | 7.77 | 31.10 | 2.65 | 95.68 | 13.39 | 76.00 | 51.04 | 24.76 | 39.98 | 9.90 |
| **24** | **HD- 2733× AAI- 2** | 79.00 | 117.50 | 6.97 | 26.94 | 2.20 | 86.45 | 9.85 | 54.50 | 45.19 | 29.80 | 39.72 | 11.84 |
| **25** | **PBW-524×AAI- 2** | 75.00 | 115.50 | 10.62 | 30.90 | 2.47 | 87.33 | 12.70 | 74.00 | 40.20 | 27.13 | 38.01 | 10.31 |
| **26** | **PBW-343×AAI- 2** | 76.50 | 116.50 | 10.005 | 30.39 | 2.40 | 90.25 | 13.30 | 89.00 | 42.39 | 32.68 | 39.11 | 12.78 |
| **27** | **RAJ-4026×AAI-2** | 80.50 | 118.50 | 10.03 | 29.31 | 2.15 | 90.95 | 11.05 | 59.50 | 39.50 | 28.77 | 37.64 | 10.84 |
| **28** | **CHECK (HUW-510)** | 69.00 | 115 | 9.67 | 26.50 | 2.04 | 81.2 | 10.12 | 49.71 | 48.5 | 42.86 | 43.07 | 18.46 |
| **Grand Mean** | | **77.722** | **116.815** | **10.155** | **30.284** | **2.324** | **90.910** | **11.728** | **66.704** | **45.832** | **37.813** | **40.234** | **15.257** |
| **Range** | **MAX** | 88.00 | 120.50 | 28.25 | 37.82 | 2.76 | 104.75 | 14.04 | 97.00 | 56.94 | 59.94 | 44.09 | 24.70 |
| | **MIN** | 69.00 | 109.50 | 5.09 | 23.50 | 1.87 | 77.47 | 9.25 | 41.5 | 38.84 | 24.76 | 29.73 | 9.90 |
| **CD (5%)** | | 3.68 | 1.78 | 2.57 | 3.49 | 0.30 | 7.55 | 1.48 | 4.18 | 3.75 | 2.005 | 2.80 | 1.45 |
| **SE** | | 0.524 | 0.347 | 0.612 | 0.511 | 0.037 | 0.852 | 0.201 | 1.989 | 0.666 | 1.200 | 0.414 | 0.508 |

**Table 3.** Range of Heterosis, Number of Economic Crosses (In Parenthesis) And Significant Economic Crosses For Twelve Quantitative Characters In Bread Wheat

| **S.N.** | **Characters** | **Range of Heterosis (%) (Due to nuclear gene)** | | **Range of Heterosis (%) (Due to plasma gene)** | |
|---|---|---|---|---|---|
| | | **BP** | **SV** | **BP** | **SV** |
| 1. | Days to 50% Flowering | -11.36 – 2.65 | -13.07 – 6.62 | -13.07 – 6.62 | 8.69 – 17.39 |
| 2. | Days to Maturity | -11.36 – 2.65 | -3.73 – 3.04 | -3.73 – 3.04 | -3.73- 3.04 |
| 3. | Plant height | -11.46 – 9.24 | -12.32 – 2.58 | -12.32 – 2.58 | -0.55 – 18.74 |
| 4. | Flag leaf width | -26.63 – 10.04 | -32.07 – 11.30 | -32.07 – 11.30 | -8.34 – 29.90 |
| 5. | Flag leaf length | -30.76 – 7.02 | -31.46 – 3.34 | -31.46 – 3.34 | 1.66 – 26.79 |
| 6. | Spike length | -18.85 – 15.16 | -2.17 – 38.73 | -26.09 – 9.84 | -2.67 – 32.31 |
| 7. | Effective tillers per plant | -4.08 – 58.27 | 18.27 – 55.41 | -18.27 – 55.41 | -47.36 – 92.14 |
| 8. | Number of grains per spike | 5.69 – 18.70 | -35.05 – 44.72 | -35.05 – 44.72 | 7.62 – 79.04 |
| 9. | Test weight | -20.71 – (-0.75) | -25.07 – 12.11 | -25.07 – 12.11 | -19.91 – 17.40 |
| 10. | Biological yield | -35.09 – (-2.33) | -49.61 – (-8.32) | -43.61– (-8.32) | -42.23 – 14.00 |
| 11. | Harvest index | -8.09 – 23.80 | -12.30 – 17.38 | -12.30 – 17.38 | -12.60–(-0.25) |
| 12. | Grain yield per plant | -36.11 – 30.61 | -47.66 – 47.75 | -47.66 – 47.75 | -41.28 – 32.65 |

**Table 4.** Relationship Of Heterosis For Grain Yield With Economic Heterosis In Other Character In Bread Wheat

| Crosses showing signicant positive heterosis | Grain yield per plant | Spike length | Tillers per plant | Number of grains per spike | Test weight | Biological yield | Harvest Index |
|---|---|---|---|---|---|---|---|
| **Due to nuclear gene** | | | | | | | |
| GIANT-3 x AAI-347 | 33.80** | 29.94** | 17.26 | 45.84** | -10.02* | 30.70** | 2.37** |
| GIANT-3 x PBW-343 | 23.02** | 27.47** | 13.24** | 38.80** | -4.22 | 5.13* | 2.02** |
| GIANT-3 x RAJ-4026 | 1.63 | 23.51** | 35.57* | 58.92** | -4.04 | -0.62 | 2.27* |
| **Due to plasma gene** | | | | | | | |
| PBW-343 x GIANT-3 | 32.65** | 26.87** | 49.53** | 65.96** | -3.20 | 14.00 | -0.25 |
| AAI-347 x GIANT-3 | 4.00 | 17.39* | 1.24 | 26.73** | -14.95* | 3.59 | -7.38* |
| RAJ-4026 x GIANT-3 | 1.07 | 14.52 | -9.20 | 69.92** | 7.50 | -7.25 | -3.02 |

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