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Combining Ability and Gene Action in Hybrid Rice

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ABSTRACT

A study of combining ability was conducted on 24 hybrids along with the 11 parents (3CMS female lines and 8 male lines) to know the pattern of inheritance of some morphological traits for selecting superior genotypes. The experiment was carried out according to line x tester mating design, during 2015-16. Analysis of Variance (ANOVA) for combining ability revealed significant differences among treatments, parents, crosses and line x tester interactions. Among lines plant height, grain length and grain breadth were showed significant differences out of sixteen characters. Among testers number of unproductive tillers per plant, flag leaf width, 1000 grain wt, length-breadth ratio were showed significant differences. Variances of SCA were higher than GCA in traits like days to 50% flowering, number of productive tillers per plant, number of unproductive tillers per plant, flag leaf length, flag leaf width, 1000 grain wt and grain length-breadth ratio which indicated these traits are governed by Non-additive gene effect. The proportional contribution of lines and testers were more than the interactions of the line X tester revealed the higher estimates of GCA variance that is additive gene action among the testers and lines were used. Among crosses IR 58025A x RNR 21301, JMS 13A x RNR 2604 and IR 58025A x RNR 21218 were identified as good specific combinations for grain yield and all other traits related to yield.

Key words: *grain length, grain breadth, High GCA - Additive and High SCA - Non-Additive.*

INTRODUCTION

India has the largest acreage under rice at 43.38 M. ha. with annual production of 104.32 MT in the year 2015-16 as per Agricultural Statistics Division, Directorate of Economics & Statistics, Department of Agriculture & Cooperation. Spectacular growth in rice production was achieved since 1960s through the adoption of semi-dwarf varieties coupled with green revolution that made the country self-sufficient in rice during 1980s. However, the productivity has come to stagnation since last two decades and efforts have failed to give tangible results to break the genetic yield barrier in rice. Results of the hybrid rice commercialization program in the China look promising. Following China's success in the commercialization of hybrid rice.

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India was one of the countries to start applied strategic research programme on hybrid rice. The hybrid rice program in India was launched in 1989 through a systematic, goal-oriented, and time-bound network project with financial support from the Indian Council of Agricultural Research (ICAR).

Successful development of rice hybrids by utilizing the cytoplasmic genetic male sterility and fertility restoration system mainly depends on the availability of stable male sterile lines. The choice of suitable parents with desirable alleles, which on crossing could produce heterotic hybrids, is also important. Combining ability of the parents provides useful information on their selection for better performance of hybrids besides elucidating the nature and magnitude of gene action in the inheritance of a particular character. The line × tester analysis of combining ability proposed by Kempthorne (1957) is the most commonly used method to find out the general and specific combiners and to study the nature of gene action governing the inheritance of different characters.

MATERIALS AND METHODS

The present material comprised 3 CMS lines viz., IR 58025A, IR 68897A and JMS 13A were crossed with 8 Rajendra Nagar genotypes in line x tester design during Rabi 2014-15. The resultant 24 hybrids along with 3 CMS parents, 8 male parents and check DRRH-3 were evaluated in randomized block design with three replications at Rice Research Centre, Agriculture Research Institute, PJTSAU, Hyderabad during Kharif 2015-16. Each genotype was planted in two rows of two meters length with a spacing of 20 x 15 cm spacing. All the necessary recommended package of practices were followed to raise the good crop. The data was recorded from average of 5 randomly selected plants from each replication for quantitative characters viz., days to 50% flowering, plant height, panicle length, Panicle weight, productive tillers per plant, unproductive tillers per plant, flag leaf length, flag leaf width, number of filled grains per panicle, spikelet fertility, grain yield per plant, productivity per day, 1000 grain weight, grain length, grain breadth and length-breadth ratio. The general reference for data collection was standard evaluation system for rice[1,13]. To estimate significant differences among hybrids and parents, the mean value of each character were subjected to Analysis of Variance (ANOVA) as suggested by Steel and Torrie[10].

RESULTS AND DISCUSSION

The analysis of variance for combining ability revealed significant difference between the treatments for all the characters. Significant differences were also recorded for replications for certain characters such as flag leaf width, grain yield per plant, productivity/day/ha.

General combining ability is associated with additive gene action, while specific combining ability is due to non-additive gene action i.e. dominance and epistasis. In the present investigation, it was found that SCA variances were higher than GCA for eight characters and GCA variances were higher than SCA for remaining characters which indicated the predominance of non-additive gene action and additive gene action. It is evident from different studies, the predominance of non-additive gene action over the additive component, which is ideal for exploitation through heterosis breeding.

A comparison of the magnitude of variance components due to GCA and SCA confirmed the nature of gene action in controlling the expression of traits. The ratio of GCA and SCA variance was less than unity indicating the predominant role of non-additive gene action for most of the characters under study except plant height, panicle length, panicle weight, spikelet fertility, filled grains per panicle, grain yield per plant, productivity/day and grain breadth showing both additive and non-additive gene action the contribution of lines was recorded high for four traits like panicle length, number of productive tillers per plant, grain length and grain breadth, while the contribution of testers was high for six traits *viz.,* plant height, panicle weight, spikelet fertility%, filled grains per panicle, grain yield per plant and productivity/day.

The contribution of line × tester interaction was high for remaining six characters (days to 50% flowering, number of unproductive tillers per plant, flag leaf length, flag leaf width, 1000 grain weight and length-breadth ratio), most of the traits being important in determining the potentiality of the hybrids.

Days to 50% flowering:

For days to 50% flowering, the GCA effects of testers ranged from -2.85 (IR 68897B) to 2.65 (IR 58025B). Among the testers IR 68897B (-2.85) had exhibited significant negative GCA effect while IR 58025B (2.65) showed significant positive GCA effect. The GCA effects of the lines for days to 50% flowering ranged from -1.56 (RNR 21615) to 1.78 (RNR 21304). Among the 8 lines RNR 21304 (1.78) showed significant positive GCA effect and none of them showed significant negative GCA effect. With respect to days to 50 per cent flowering, early flowering (i.e., significant negative GCA) effect is desirable. In hybrids SCA effects for days to 50% flowering, the SCA effects ranged from -5.31 (JMS 13A x RNR 21604) to 6.35 (IR 58025A × RNR 21615).

Plant height:

For plant height, the GCA effects of testers ranged from -6.71 (IR 68897B) to 3.77 (JMS 13B). Among the testers, JMS 13B and IR 58025B showed significant positive GCA effects while IR 68897B showed significant negative GCA effects. The GCA effects of lines for plant height ranged from -6.04 (RNR 21288) to 8.41 (RNR 21604). Among the 8 lines, three lines viz., RNR 21288 (-6.04), RNR 21301 (-1.87) and MTU 1010 (-1.37) showed significant negative GCA effects while only one line RNR 21604 (8.41) showed significant positive GCA effects. However desirable were those exhibiting significant negative GCA effects.

For plant height the SCA effects ranged from -7.88 (JMS 13A × RNR 21288) to 6.62 (IR 58025A × RNR 21288). Out of the 24 hybrids studied, five hybrids showed significant negative SCA effects while another five hybrids showed significant positive SCA effects. The five hybrids viz., JMS 13A × RNR 21288(-7.88), IR 58025A × RNR 15048(-4.05), IR 58025A × RNR 21615(-3.94), IR 68897A × RNR 21304 (-3.18) and JMS 13A × RNR 21301 (-2.72) exhibited desirable significant negative SCA effects, resulted in short statured hybrids.

Panicle length:

For panicle length the GCA effects of testers ranged from -1.83 (IR 68897B) to 1.74 (IR 58025B). Among the testers IR 58025B (1.74) showed significant positive while IR 68897B (-1.83) showed negative GCA effects. The GCA effects of lines for panicle length ranged from -2.75 (RNR 15048) to 1.87 (RNR 21218). Among the 8 lines, three lines viz., RNR 21218 (1.87), RNR 21301 (1.36) and showed significant positive GCA effect while, three lines viz., RNR 15048 (-2.75), RNR 21288(-1.97) and RNR 21615(-0.75) showed significant negative GCA effect.

The SCA effects for panicle length ranged from -3.19 (IR 58025A ×RNR 21301) to 3.14 (JMS 13A × RNR 21301). Out of the24 hybrids studied, three hybrids showed significant positive SCA effects while other two hybrids showed significant negative SCA effects. The hybrids JMS 13A x RNR 21301 (3.14), IR 58025A x RNR 15048 (2.59) and IR 58025A x MTU 1010 (1.93) showed significant positive SCA effects for panicle length are desirable.

Panicle weight:

For panicle weight the GCA effects of testers ranged from -1.00 (IR 68897B) to 0.71 (IR 58025B). Among the testers, IR 58025B (0.71) and JMS 13B (0.29) were showed significant positive GCA effect and IR 68897B (-1.00) showed significant negative GCA effect. The GCA effects of lines for panicle weight ranged from -0.74 (RNR 15048) to 0.47 (RNR 21615). Among the 8 lines, four lines viz., RNR 21615 (0.47), RNR 21288 (0.29), RNR 21301 (0.28) and RNR 21218 (0.19) showed significant positive GCA effects while four other lines viz., RNR 15048 (-0.74), RNR 21304 (-0.33), RNR 21604 (0.1) and MTU 1010 (-0.06) showed significant negative GCA effects.

For panicle weight the SCA effects ranged from -0.84 (IR 58025A ×RNR 21304) to 0.73 (IR 68897A × RNR 15048). Out of the 24 hybrids studied, 7 hybrids showed significant positive SCA effects while another 8 hybrids showed significant negative SCA effects. The hybrids IR 68897A x RNR 15048 (0.73), JMS 13A x RNR 21304 (0.68), IR 58025A x RNR 21288 (0.51), IR 58025A x RNR 21615 (0.45), IR 58025A x RNR 21301 (0.41), JMS 13A x MTU 1010 (0.33) and IR 68897A x RNR 21304 (0.16) showed significant positive SCA effects for panicle weight.

Number of productive tillers per plant:

For number of productive tillers per plant the GCA effects of testers ranged from -1.58 (IR 68897B) to 0.88 (JMS 13B). Among the testers JMS 13B (0.88) and IR 58025B (0.71) showed significant positive GCA effect while IR 68897B (-1.58) showed significant negative GCA effect. For number of productive tillers per plant the GCA effects of lines ranged from -2.24 (RNR 21615) to 2.65 (RNR 21301). Among the 8 lines studied, two lines viz., RNR 21301 (2.65) and RNR 21218 (0.99) showed significant positive GCA effect and three lines viz., RNR 21615 (-2.24), RNR 21604 (-0.90) and RNR 15048 (-0.90) showed significant negative GCA effects.

For number of productive tillers per plant the SCA effects ranged from -2.93 (IR 58025A × RNR 21615) to 2.24 (JMS 13A × RNR 21615). Out of 24 hybrids, six hybrids showed significant negative SCA effects while five others showed significant positive SCA effects. The hybrids JMS 13A x RNR 21615 (2.24), IR 58025A x RNR 21301 (1.85), JMS 13A x RNR 21304 (1.80), IR 58025A x MTU 1010 (1.29) and IR 58025A x RNR 21604 (1.07) showed significant positive SCA effects and such hybrids are desirable.

Number of unproductive tillers per plant:

For number of unproductive tillers per plant the GCA effects of testers ranged from -0.13 (IR 58025B) to 0.13 (IR 68897B). Among the testers IR 58025B (-0.13) showed significant negative GCA effect, while IR 68897B (0.13) showed significant positive GCA effect. For number of unproductive tillers per plant the GCA effects of lines ranged from -0.61 (RNR 21615) to 0.50 (RNR 21301). Among the 8 lines studied, four lines viz., RNR 21615 (-0.61), RNR 21304 (-0.28), MTU 1010 (-0.17) and RNR 15048 (-0.17) showed significant negative and four lines viz., RNR 21301 (0.50), RNR 21604 (0.39), RNR 21218 (0.17) and RNR 21288 (0.17) showed significant positive GCA effects. With respect to number of unproductive tillers per plant, parents exhibiting significant negative GCA effects are desirable.

For number of unproductive tillers per plant the SCA effects ranged from -1.21 (IR 58025A × RNR 21301) to 0.90 (IR 58025A × RNR 21604). Out of 24 hybrids, nine showed significant negative SCA effects while, ten others showed significant positive SCA effects. Among the hybrids IR 58025A x RNR 21301 (-1.21), IR 58025A x RNR 21288 (0.88), IR 68897A x RNR 21604 (-0.68), IR 68897A x RNR 21304 (-0.68), JMS 13A x RNR 15048 (-0.67), IR 58025A x MTU 1010 (-0.54), IR 68897A x RNR 21615 (-0.35), JMS 13A x RNR21604 (-0.22) and JMS 13A x RNR 21615 (-0.22) showed significant negative SCA effects and such hybrids are desirable.

Flag leaf length:

For flag leaf length the GCA effects of testers ranged from -2.19 (JMS 13B) to 2.15 (IR 58025B). Among the testers, IR 58025B (2.15) showed significant positive GCA effect, while, JMS 13B (-2.19) showed significant negative GCA effect. The GCA effects of lines for flag leaf length ranged from -2.15 (RNR 15048) to 2.85 (RNR 21615). Among the eight lines studied, three lines viz., RNR 21615 (2.85), RNR 21218 (1.63) and RNR 21301 (1.30) showed significant positive GCA effects while, four lines viz., RNR 15048 (-2.15), RNR 21304 (-1.65), RNR 21288 (-1.04) and MTU 1010 (-0.92) showed significant negative GCA effects.

For flag leaf length the SCA effects ranged from -5.48 (JMS 13A × RNR 15048) to 5.52 (IR 58025A × RNR 15048). Out of 24 hybrids, 4 hybrids showed significant negative SCA effects while, 4 others showed significant

positive SCA effects. The hybrids, IR 58025A x RNR 15048 (5.52), JMS 13A x RNR 21304 (3.69), JMS 13A x RNR 21288 (3.41) and IR 68897A x RNR 21615 (1.96) showed significant positive SCA effects and such hybrids are desirable.

Flag leaf width:

For flag leaf width the GCA effects of testers ranged from -0.14 (IR 68897B) to 0.04 (JMS 13B). Among the testers, IR 58025B (0.10) showed significant positive GCA effect, while, IR 68897B (-0.14) showed significant negative GCA effect. The GCA effects of lines for flag leaf width ranged from -0.17 (MTU 1010) to 0.14 (RNR 15048). Among the 8lines studied, three lines viz., RNR 15048 (0.14), RNR 21301 (0.12) and RNR 21604 (0.11) showed significant positive GCA effects while, two lines viz., MTU 1010 (-0.17) and RNR 21304 (-0.13) showed significant negative GCA effects.

For flag leaf width the SCA effects ranged from -0.54 (IR 58025A × RNR 21304) to 0.42 (JMS 13A × RNR 21304). Out of 24 hybrids, 5 hybrids showed significant negative SCA effects while, 4 others showed significant positive SCA effects. The hybrids, JMS 13A x RNR 21304 (0.42), IR 58025A x MTU 1010 (0.37), JMS 13A x RNR 21604 (0.18) and JMS 13A x RNR 21288 (0.16) showed significant positive SCA effects and such hybrids are desirable.

Spikelet fertility (%):

For spikelet fertility % the GCA effects of testers ranged from -10.3 (IR 68897B) to 5.50 (JMS 13B). Among the testers, IR 68897B (-10.30) showed negative GCA effects and JMS 13B (5.50) and IR 58025B (4.81) showed significant positive GCA effects. The GCA effects of lines for spikelet fertility % ranged from -3.80 (RNR 21304) to 2.00 (RNR 21218). Among the 8 lines, four lines viz., RNR 21218 (2.00), RNR 21288 (1.88), RNR 21301 (1.61) and RNR 21604 (1.24) showed significant positive GCA effect while three lines viz., RNR 21304 (-3.80), RNR 21615 (-1.89) and RNR 15048 (-1.75) showed significant negative GCA effect.

The SCA effects for spikelet fertility % ranged from -3.63 (IR 58025A × RNR 21301) to 4.14 (IR 68897A × RNR 15048). Out of 24 hybrids studied, eight hybrids showed significant positive SCA effects while seven others showed significant negative SCA effects. The hybrids IR 68897A x RNR 15048 (4.14), JMS 13A x RNR 21301 (4.04), IR 68897A x RNR 21304 (3.38), IR 58025A x RNR 21218 (3.36), IR 58025A x RNR 21288 (2.79), IR 58025A x RNR 21604 (2.42), JMS 13A x RNR 21615 (1.65) and JMS 13A x MTU 1010 (1.60) showed significant positive SCA effects and such hybrids are desirable.

Number of filled grains per panicle:

For number of filled grains per panicle the GCA effects of testers ranged from -68.65 (IR 68897B) to 47.89 (JMS 13B). Among the testers, IR 68897B (68.65) showed significant negative GCA effect, while, IR 58025B (20.76) and JMS 13B (47.89) showed significant positive GCA effect. The GCA effects of lines for number of filled grains per panicle ranged from -31.39 (RNR 15048) to 28.39 (RNR 21615). Among the eight lines studied, three lines viz., RNR 21615 (28.39), RNR 21218 (23.61) and RNR 21604 (6.99) showed significant positive GCA effects while, three lines viz., RNR 15048 (-31.39), RNR 21304 (18.50) and RNR 21288 (-7.28) showed significant negative GCA effects.

The SCA effects for number of filled grains per panicle ranged from 49.67 (JMS 13A × RNR 21301) to 78.57 (IR 58025A × RNR 21615). Out of 24 hybrids, 8 hybrids showed significant positive SCA effects while 11 hybrids showed significant negative SCA effects. The hybrids, IR 58025A x RNR 21615 (78.57), JMS 13A x RNR 21218 (65.89), IR 58025A x RNR 21301 (57.79), JMS 13A x RNR 21604 (49.56), IR 68897A x RNR 15048 (34.43), IR 58025A x RNR 21288 (22.90), IR 68897A x RNR 21304 (22.54) and IR 68897A x RNR 21288 (10.65) showed significant positive SCA effects and such hybrids are desirable.

Grain yield per plant:

For grain yield per plant the GCA effects of testers ranged from -7.32 (IR 68897B) to 5.63

(JMS 13B).Among the testers, JMS 13B (5.63) and IR 58025B (1.69) showed significant positive GCA effect while, IR 68897B (-7.32) showed significant negative GCA effect.The GCA effects of lines for grain yield per plant ranged from -6.07 (RNR 15048) to 6.04 (RNR 21301).Among the eight lines studied, three lines viz., RNR 21301 (6.04), RNR 21218 (5.12) and RNR 21604 (2.68) showed significant positive GCA effects while, four lines viz., RNR 15048 (-6.07), RNR 21615 (-3.55), RNR 21304 (-3.46) and MTU 1010 (-0.79) showed significant negative GCA effects.

The SCA effects for grain yield per plant ranged from -4.43 (JMS 13A ×RNR 15048) to 10.52 (IR 58025A × RNR 21301). Out of 24 hybrids, 8 hybrids showed significant positive SCA effects while, 12 hybrids showed significant negative SCA effects. The hybrids, IR 58025A x RNR 21301 (10.52), IR 68897A x RNR 15048 (6.60), JMS 13A x RNR 21604 (6.41), JMS 13A x RNR 21218 (3.85), IR 68897A x RNR 21304 (3.52), IR 68897A x RNR 21615 (2.9), IR 58025A x RNR 21288 (2.32) and JMS 13A x RNR 21615 (1.25) showed significant positive SCA effects and such hybrids are desirable.

Productivity per day:

For productivity per day the GCA effects of testers ranged from -20.07 (IR 68897B) to 16.23 (JMS 13B).Among the testers, JMS 13B (16.23) and IR 58025B (3.83) showed significant positive GCA effect while, IR 68897B (-20.07) showed significant negative GCA effect. The GCA effects of lines for productivity per day ranged from -17.55 (RNR 15048) to 15.79 (RNR 21301).Among the eight lines studied, three lines viz., RNR 21301 (15.79), RNR 21218(14.90) and RNR 21604 (9.25) showed significant positive GCA effects while, four lines viz., RNR 15048 (-17.55), RNR 21304 (-10.57), RNR 21615 (-9.50) and MTU 1010 (-3.08) showed significant negative GCA effects.

The SCA effects for productivity per day ranged from -16.56 (IR 68897A × RNR 21301) to 29.31 (IR 58025A × RNR 21301).Out of 24 hybrids, 8 hybrids showed significant positive SCA effects while 11 hybrids showed significant negative SCA effects. The hybrids, IR 58025A x RNR 21301 (29.31), JMS 13A x RNR 21604 (21.13), IR 68897A x RNR 15048 (18.87), JMS 13A x RNR 21218 (10.80), IR 68897A x RNR 21304 (10.46), IR 58025A x RNR 21288 (8.47), IR 68897A x RNR 21615 (8.07) and JMS 13A x RNR 21615 (5.32) showed significant positive SCA effects and such hybrids are desirable.

1000 grain weight:

For 1000 grain weight the GCA effects of testers ranged from -1.39 (IR 68897B) to 0.77 (JMS 13B).Among the testers, JMS 13B (0.77) and IR 58025B (0.63) showed significant positive GCA effect while, IR 68897B (-1.39) showed significant negative GCA effect. The GCA effects of lines for 1000 grain weight ranged from -3.65 (RNR 15048) to 1.23(RNR 21304). Among the eight lines studied, seven lines viz., RNR 21304 (1.23), MTU 1010 (1.06), RNR 21218(0.44), RNR 21301 (0.29), RNR 21604 (0.24), RNR 21288 (0.20) and RNR 21615 (0.19) showed significant positive GCA effects while, only one line RNR 15048(-3.65) showed significant negative GCA effects.

The SCA effects for 1000 grain weight ranged from -3.22 (JMS 13A × RNR 21288) to 2.94 (IR 68897A × RNR 15048).Out of 24 hybrids, 10 hybrids showed significant positive SCA effects while,11 hybrids showed significant negative SCA effects. The hybrids, IR 68897A x RNR 15048(2.94), IR 58025A x RNR 21218 (2.70), JMS 13A x RNR 21615 (2.49), IR 68897A x RNR 21288 (2.28), JMS 13A x RNR 21301 (2.23), IR 58025A x RNR 21304 (1.69), IR 58025A x RNR 21288 (0.94), IR 58025A x RNR 21604(0.81), IR 58025A x MTU 1010 (0.80) and JMS 13A x RNR 21604 (0.32) showed significant positive SCA effects and such hybrids are desirable.

Grain length:

For grain length the GCA effects of testers ranged from -0.35 (IR 68897B) to 0.18 (IR 58025B).Among the testers, IR 58025B (0.18) and JMS 13B (0.17) showed significant positive GCA effect, while, IR 68897B (-0.35) showed significant negative GCA effect. The

GCA effects of lines for grain length ranged from -0.42 (RNR 15048) to 0.71 (RNR 21604).Among the eight lines studied, two lines viz., RNR 21604(0.71) and RNR 21304 (0.35) showed significant positive GCA effects while, five other lines viz., RNR 15048 (-0.42), RNR 21288 (-0.39), RNR 21218 (-0.12), RNR 21301 (0.10) and RNR 21615(-0.09) showed significant negative GCA effects.

The SCA effects for grain length ranged from -0.52 (IR 58025A ×RNR 21301) to 0.72 (JMS 13A × RNR 21301).Out of 24 hybrids, 10 hybrids showed significant positive SCA effects while, 7 hybrids showed significant negative SCA effects. The hybrids, JMS 13A x RNR 21301 (0.72), IR 58025A x RNR 21218 (0.46), IR 58025A x RNR 21604 (0.37), IR 68897A x RNR 21604 (0.29), IR 68897A x RNR 21288 (0.20), IR 68897A x RNR 15048 (0.20), JMS 13A x RNR 15048 (0.17), JMS 13A x RNR 21615 (0.16), IR 58025A x RNR 21304 (0.15) and IR 58025A x RNR 21288 (0.15) showed significant positive SCA effects and such hybrids are desirable.

Grain breadth:

For grain breadth the GCA effects of testers ranged from -0.07 (IR 68897B) to 0.10 (JMS 13B). Among the testers, IR 68897B (-0.07) and IR 58025B (-0.03) showed significant negative GCA effect while, JMS 13B (0.10) showed significant positive GCA effect. The GCA effects of lines for grain breadth ranged from -0.29 (RNR 15048) to 0.11 (RNR 21604).Among the eight lines studied, two lines viz., RNR 15048(0.29) and RNR 21288 (-0.07) showed significant negative GCA effects while, five other lines viz., RNR 21604 (0.11), RNR 21615 (0.08), RNR 21218 (0.10), RNR 21304 (0.05) and MTU 1010 (0.05) showed significant positive GCA effects. However, parents showing significant negative GCA effects are desirable.

The SCA effects for grain breadth ranged from -0.17 (JMS 13A × RNR 21304) to 0.16 (IR 58025A × RNR 21304).Out of 24 hybrids, 6 hybrids showed significant negative SCA effects while, 6 others showed significant positive SCA effects. The hybrids, JMS 13A x RNR 21304 (-0.17), IR 58025A x RNR 21218 (-0.11), IR 58025A x RNR 15048 (-0.11), IR 68897A x RNR 21615 (-0.10), JMS 13A x RNR 21604 (-0.09) and JMS 13A x RNR 21288 (-0.06), showed significant negative SCA effects and such hybrids are desirable.

Grain length-breadth ratio:

For grain length-breadth ratio GCA effects of testers ranged from 0.11 (JMS 13B) to 0.15 (IR 58025B).Among the testers, IR 58025B (0.15) showed significant positive GCA effect, while, JMS 13B (-0.11) and IR 68897B (-0.04) showed significant negative GCA effect. The GCA effects of lines for grain length-breadth ratio ranged from 0.23 (RNR 21218) to 0.42 (RNR 15048). Among the eight lines studied, three lines viz., RNR 15048 (0.42), RNR 21604 (0.12) and RNR 21304 (0.06), showed significant positive GCA effects while, four other lines viz., RNR 21218 (-0.23), RNR 21615 (-0.21), RNR 21288 (-0.06) and MTU 1010 (-0.07) showed significant negative GCA effects.

The SCA effects for grain length-breadth ratio ranged from -0.40 (JMS 13A ×RNR 21218) to 0.40 (IR 58025A × RNR 21218). Out of 24 hybrids, 9 hybrids showed significant positive SCA effects while, 7 hybrids showed significant negative SCA effects. The hybrids, IR 58025A x RNR 21218 (0.40), JMS 13A x RNR 21301 (0.23), JMS 13A x RNR 21304 (0.22), IR 58025A x RNR 21604 (0.20), IR 68897A x RNR 21615 (0.17), IR 68897A x MTU 1010 (0.17), JMS 13A x RNR 21615 (0.16), IR 58025A x RNR 15048 (0.13) and JMS 13A x RNR 21604 (0.12) showed significant positive SCA effects and such hybrids are desirable.

The overall study of SCA effects of different traits, in the present investigation reveals that SCA effects and per se performance of the crosses were not closely related. The crosses with high per se performance need not be the one with high SCA effects and vice versa. An ideal combination to be explored is one where high magnitude of SCA is present, in addition to high GCA effect in both or at least one of the parents. Similar results were reported by

Banumathy *et al.*[2], Hariprasanna *et al.*[5], Dalvi and Patel[3], Salgotra *et al.*[8], Saidaiah *et al.*[7], Tiwari *et al.*[12], Thakare *et al.*[11], Dorosti and Monajjem[4], Kumari Priyanka *et al.*[6] and Srijan[9]. It is not necessary that the parents involved in the cross combinations should have high GCA effects to get significant SCA effects. The reason ascribed is due to positive interaction between nuclear and cytoplasmic genes appear to be important that the interaction between nuclear genes alone. The GCA effects of the parents revealed that, the tester JMS 13B was the best general combiner for grain yield per plant, number of productive tillers per plant, spikelet fertility%, number of filled grains per panicle, productivity per day, 1000 grain weight. Among the lines, RNR 21301 is best for grain yield per plant, plant height, panicle length, panicle weight, number of productive tillers per plant, flag leaf length, flag leaf width, spikelet fertility, productivity per day, 1000 grain weight. RNR 21218 is superior in grain yield per plant, days to 50% flowering, panicle length, panicle weight, number of productive tillers per plant, flag leaf length, spikelet fertility, number of filled grains per panicle, productivity per day, 1000 grain weight and grain breadth. And RNR 21604 is best for grain yield per plant, days to 50% flowering, flag leaf width, spikelet fertility, number of filled grains per panicle, productivity per day, 1000 grain weight, grain length and length-breadth ratio. It was observed in certain instances that the lines and testers with good per se performance have not been good general combiners and vice versa, thus the association between per se performance and GCA effects was evident in the present study indicated the effectiveness of choice of parents based on per se performance alone was not appropriate for predicting the combining ability of the parents.

Among the crosses, the three best specific combiners identified based on SCA effects and corresponding mean performance being IR 58025A x RNR 21301, for grain yield per plant, panicle weight, number of productive tillers per plant, number of unproductive tillers per plant, number of filled grains per panicle and productivity per day. JMS 13A x RNR 21218 is best specific cross for grain yield per plant, flag leaf length, number of filled grains per panicle, productivity per day. And finally JMS 13A x RNR 21604 is having high SCA for grain yield per plant, Days to 50% flowering number of unproductive tillers per plant, flag leaf width, number of filled grains per panicle, productivity per day, 1000 grain weight, grain breadth and length-breath ratio.

Table 1: Analysis of variance (Mean squares) for combining ability (L X T) for yield and yield components in rice

Source of Variation	Degrees of freedom	Days to 50% flowering	Plant height	Panicle length	Panicle weight	No. of productive tillers per plant	No. of unproductive tillers per plant	Flag leaf length	Flag leaf width
Replicates	2	1.35	8.07	2.12	0.01	0.04	0.04	1.07	0.08*
Treatments	34	36.75**	179.81**	15.74**	2.00**	11.02**	1.38**	31.95**	0.27**
Parents	10	28.76**	214.19**	6.63**	0.92**	2.09**	1.47**	26.05**	0.32**
Crosses	23	41.47**	148.73**	20.37**	2.54**	15.13**	1.39**	34.59**	0.21**
Lines	7	17.46	148.64*	24.68	1.40	19.60	1.24	27.94	0.12
Testers	2	182.18*	814.20**	76.46**	19.19**	45.29*	0.38	112.70*	0.37
Lines × Testers	14	33.37**	53.71**	10.21**	0.73**	8.58**	1.61**	26.75**	0.24**
Parents *vs* Crosses	1	8.04	550.81**	0.21	0.62**	5.91**	0.13*	30.30**	1.14**
Error	46	5.74	4.43	2.46	0.01	0.74	0.04	2.00	0.02

(Cont.)

Source of Variation	Degrees of freedom	Spikelet fertility %	No. of filled grains per panicle	Grain yield per plant	Productivity per day	1000-grain weight	Grain length	Grain breadth	Length breadth ratio
Replicates	2	1.78	77.10	2.36**	22.19*	0.01	0.00	0.00	0.02
Treatments	34	176.69**	13299**	135.16**	1081.26**	29.68**	1.43**	0.10**	0.42**
Parents	10	47.47**	15122**	11.66**	62.08**	56.34**	2.95**	0.10**	0.72**
Crosses	23	196.74**	13048.22**	193.72**	1565.06**	19.28**	0.84**	0.09**	0.28**
Lines	7	42.81	3621.43	169.43	1384.77	21.02	1.26*	0.16**	0.39
Testers	2	1916.09**	89252.27**	1056.70**	8171.16**	34.97	2.24*	0.20*	0.45
Lines × Testers	14	28.08**	6875.35**	82.59**	711.480**	16.17**	0.42**	0.04**	0.20**
Parents *vs* Crosses	1	1007.8**	846.48**	23.11**	145.68**	2.51**	0.01	0.13**	0.53**
Error	46	1.731	48.87	0.37	5.23	0.03	0.02	0.00	0.00

**** Significant at 1% level of significance; * Significant at 5 % level of significance**

Table 2: Estimates of general and specific combining ability effects for days to 50% flowering, plant height, panicle length and panicle weight

Parent/Cross	Days to 50% flowering	Plant height	Panicle length	Panicle weight
Testers				
JMS 13B	0.19	3.77 **	0.09	0.29**
IR 58025B	2.65**	2.94**	1.74**	0.71**
IR 68897B	-2.85**	-6.71**	-1.83**	-1.00**
SE(Testers) (gi)	0.49	0.41	0.31	0.02
SE (gi-gj)	0.69	0.58	0.44	0.03
Lines				
RNR21615	-1.56	0.85	-0.75**	0.47**
RNR21604	-1.11	8.41**	0.62	-0.1**
RNR21304	1.78*	-1.26	1.05	-0.33**
RNR21218	-1.44	0.63	1.87**	0.19**
RNR 21301	1.22	-1.87**	1.36*	0.28**
RNR 21288	-0.89	-6.04**	-1.97**	0.29**
MTU 1010	1.44	-1.368**	0.58	-0.06**
RNR 15048	0.56	0.63	-2.75**	-0.74**
SE(Lines) (gi)	0.79	0.67	0.51	0.04
SE (gi-gj)	1.12	0.94	0.72	0.05
Crosses				
JMS 13A x RNR21615	-3.19*	4.9**	0.25	-0.12
JMS 13A x RNR21604	-5.31**	2.01	-0.42	-0.11
JMS 13A x RNR 21304	2.47	0.67	0.45	0.68**
JMS 13A x RNR21218	0.694	-0.88	0.63	-0.04
JMS 13A x RNR21301	2.028	-2.72*	3.14**	-0.22**
JMS 13A x RNR21288	1.80	-7.88**	-1.53	-0.05
JMS 13A x MTU 1010	1.14	-1.55	-0.75	0.33**
JMS 13A x RNR 15048	0.36	5.45**	-1.75*	-0.49**
IR 58025A x RNR 21615	6.35**	-3.94**	-1.41	0.45**
IR 58025A x RNR 21604	3.24*	-2.16	0.23	0.04
IR 58025A x RNR 21304	-1.99	2.51*	0.19	-0.84**
IR 58025A x RNR 21218	0.24	1.62	-1.5	0.1
IR 58025A x RNR 21301	-0.76	-0.88	-3.19**	0.41**
IR 58025A x RNR 21288	-4.32**	6.62**	1.15	0.51**
IR 58025A x MTU 1010	-1.65	0.29	1.93*	-0.43**
IR 58025A x RNR 15048	-1.1	-4.05**	2.59**	-0.23**
IR 68897A x RNR 21615	-3.15*	-0.958	1.16	-0.33**
IR 68897A x RNR 21604	2.07	0.15	0.19	0.06
IR 68897A x RNR 21304	-0.49	-3.18**	-0.64	0.16*
IR 68897A x RNR 21218	-0.93	-0.74	0.87	-0.06
IR 68897A x RNR 21301	-1.26	3.6**	0.05	-0.2**
IR 68897A x RNR 21288	2.51	1.26	0.38	-0.46**
IR 68897A x MTU 1010	0.51	1.26	-1.17	0.10
IR 68897A x RNR 15048	0.74	-1.40	-0.84	0.73**
SE (Sij)	1.37	1.16	0.88	0.06
SE (Sij-Sik)	3.37	2.83	2.16	0.15
SE (Sij-Skl)	1.94	1.64	1.25	0.09

**** Significant at 1% level of significance; * Significant at 5 % level of significance**

Table 3: Estimates of general and specific combining ability effects for number of productive tillers, number of unproductive tillers, flag leaf length and flag leaf breadth

Parent/Cross	Productive tiller per plant	Unproductive tillers per plant	Flag leaf length	Flag leaf width
Testers				
JMS 13B	0.88**	0.00	-2.19**	0.04
IR 58025B	0.71**	-0.13**	2.15**	0.1**
IR 68897B	-1.58**	0.13**	0.04	-0.14**
SE(Testers) (gi)	0.17	0.04	0.27	0.03
SE (gi-gj)	0.24	0.05	0.38	0.04
Lines				
RNR 21615	-2.24**	-0.61**	2.85**	-0.03
RNR21604	-0.90**	0.39**	-0.04	0.11**

RNR21304	-0.46	-0.28**	-1.65**	-0.13**
RNR21218	0.99**	0.17**	1.63**	-0.03
RNR21301	2.65**	0.50**	1.3*	0.12**
RNR21288	0.32	0.17**	-1.04**	-0.01
MTU 1010	0.54	-0.17**	-0.92**	-0.17**
RNR 15048	-0.90**	-0.17**	-2.15**	0.14**
SE(Lines) (gi)	0.27	0.06	0.44	0.04
SE (gi-gj)	0.39	0.08	0.62	0.06
Crosses				
JMS 13A x RNR 21615	2.24**	-0.22*	-2.48**	-0.15*
JMS 13A x RNR21604	-0.1	-0.22*	1.08	0.18*
JMS 13A x RNR21304	1.8**	0.11	3.69**	0.42**
JMS 13A x RNR21218	0.68	0.00	-0.59	0.12
JMS 13A x RNR21301	-1.32**	0.67**	1.41	0.00
JMS 13A x RNR21288	-1.65**	0.00	3.41**	0.16*
JMS 13A x MTU 1010	-1.54**	0.33**	-1.04	-0.47**
JMS 13A x RNR 15048	-0.1	-0.67**	-5.48**	-0.02
IR 58025A x RNR 21615	-2.93**	0.57**	0.52	0.12
IR 58025A x RNR 21604	1.07*	0.90**	0.08	0.02
IR 58025A x RNR 21304	-2.38**	0.57**	-3.65**	-0.54**
IR 58025A x RNR 21218	-0.15	0.13	0.74	0.02
IR 58025A x RNR 21301	1.85**	-1.21**	-0.92	0.08
IR 58025A x RNR 21288	0.85	-0.88**	-2.59**	-0.2*
IR 58025A x MTU 1010	1.29**	-0.54**	0.3	0.37**
IR 58025A x RNR 15048	0.40	0.46**	5.52**	0.12
IR 68897A x RNR21615	0.69	-0.35**	1.96*	0.03
IR 68897A x RNR 21604	-0.97*	-0.68**	-1.15	-0.21**
IR 68897A x RNR 21304	0.58	-0.68**	-0.04	0.13
IR 68897A x RNR 21218	-0.53	-0.13	-0.15	0.09
IR 68897A x RNR 21301	-0.53	0.54**	-0.49	-0.08
IR 68897A x RNR 21288	0.81	0.88**	-0.82	0.04
IR 68897A x MTU 1010	0.25	0.21*	0.74	0.11
IR 68897A x RNR 15048	-0.31	0.21*	-0.04	0.11
SE (Sij)	0.48	0.10	0.76	0.07
SE (Sij-Sik)	1.16	0.24	1.87	0.18
SE (Sij-Skl)	0.67	0.14	1.08	0.10

**** Significant at 1% level of significance; * Significant at 5 % level of significance**

Table 4: Estimates of general and specific combining ability effects for spikelet Fertility %, number of filled grains per panicle, grain yield per plant and productivity per day

Parent/Cross	Spikelet fertility %	No. of filled grains per panicle	Grain yield per plant	Productivity per day
Testers				
JMS 13B	5.50**	47.89**	5.63**	16.23**
IR 58025B	4.81**	20.76**	1.69**	3.83**
IR 68897B	-10.3**	-68.65**	-7.32**	-20.07**
SE(Testers) (gi)	0.27	1.35	0.12	0.43
SE (gi-gj)	0.38	1.91	0.18	0.61
Lines				
RNR 21615	-1.89**	28.39*	-3.55**	-9.50**
RNR 21604	1.24*	6.99**	2.68**	9.25**
RNR 21304	-3.80**	-18.5**	-3.46**	-10.57**
RNR 21218	2.00**	23.61*	5.12**	14.90**
RNR 21301	1.61**	2.5	6.04**	15.79**
RNR 21288	1.88**	-7.28**	0.03	0.75
MTU 1010	0.71	-4.28	-0.79**	-3.08**
RNR 15048	-1.75**	-31.39**	-6.07**	-17.55**
SE(Lines) (gi)	0.43	2.21	0.20	0.70
SE (gi-gj)	0.61	3.12	0.29	0.99
Crosses				
JMS 13A x RNR 21615	1.65*	-42.56**	1.25**	5.32**
JMS 13A x RNR21604	0.56	49.56	6.41**	21.13**
JMS 13A x RNR 21304	-1.9*	2.00	-1.15**	-4.73**
JMS 13A x RNR 21218	-0.62	65.89**	3.85**	10.80**

JMS 13A x RNR 21301	4.04**	-49.67**	-4.19**	-12.75**
JMS 13A x RNR 21288	-2.2**	-33.56**	-2.19**	-7.48**
JMS 13A x MTU 1010	1.6*	7.45	0.45	0.45
JMS 13A x RNR 15048	-3.14**	0.89	-4.43**	-12.74**
IR 58025A x RNR 21615	-0.89	78.57**	-4.14**	-13.39**
IR 58025A x RNR 21604	2.42**	-48.65**	-3.19**	-10.25**
IR 58025A x RNR 21304	-1.48	-24.54**	-2.37**	-5.74**
IR 58025A x RNR 21218	3.36**	-40.65**	-0.01	-0.35
IR 58025A x RNR 21301	-3.63**	57.79**	10.52**	29.31**
IR 58025A x RNR 21288	2.79**	22.90**	2.32**	8.47**
IR 58025A x MTU 1010	-1.56*	-10.1*	-0.96**	-1.93
IR 58025A x RNR 15048	-1.01	-35.32**	-2.17**	-6.12**
IR 68897A x RNR 21615	-0.76	-36.01**	2.9**	8.07**
IR 68897A x RNR 21604	-2.98**	-0.9	-3.23**	-10.87**
IR 68897A x RNR 21304	3.38**	22.54**	3.52**	10.46**
IR 68897A x RNR 21218	-2.74**	-25.24**	-3.84**	-10.45**
IR 68897A x RNR 21301	-0.41	-8.13*	-6.33**	-16.56**

** **Significant at 1% level of significance ; * Significant at 5 % level of significance**

Table 5: Estimates of general and specific combining ability effects for 1000 grain weight, grain breadth and length-breadth ratio

Parent/Cross	1000 grain weight	Grain length	Grain breadth	Length-breadth ratio
Testers				
JMS 13B	0.77**	0.17**	0.10**	-0.11*
IR 58025B	0.63**	0.18**	-0.03**	0.15**
IR 68897B	-1.39**	-0.35**	-0.07**	-0.04*
SE(Testers) (gi)	0.03	0.03	0.01	0.02
SE (gi-gj)	0.05	0.04	0.02	0.02
Lines				
RNR 21615	0.19**	-0.09*	0.08**	-0.21**
RNR 21604	0.24**	0.71**	0.11**	0.12**
RNR 21304	1.23**	0.35**	0.05**	0.06*
RNR 21218	0.44**	-0.12**	0.1**	-0.23**
RNR 21301	0.29**	-0.1*	-0.02	-0.03
RNR21288	0.2**	-0.39**	-0.07**	-0.06*
MTU 1010	1.06**	0.05	0.05**	-0.07*
RNR 15048	-3.65**	-0.42**	-0.29**	0.42**
SE(Lines) (gi)	0.06	0.04	0.02	0.03
SE (gi-gj)	0.08	0.06	0.03	0.04
Crosses				
JMS 13A x RNR 21615	2.49**	0.16*	-0.04	0.16**
JMS 13A xRNR 21604	0.32**	-0.08	-0.09**	0.12*
JMS 13A x RNR 21304	0.03	-0.2*	-0.17**	0.22**
JMS 13A x RNR 21218	-2.18**	-0.43**	0.13**	-0.4**
JMS 13A x RNR 21301	2.23**	0.72**	0.06	0.23**
JMS 13A x RNR 21288	-3.22**	-0.34**	-0.06*	-0.06
JMS 13A x MTU 1010	0.18	-0.02	0.09**	-0.17**
JMS 13A x RNR 15048	0.15	0.17*	0.07*	-0.12*
IR 58025A x RNR 21615	-1.83**	-0.16*	0.14**	-0.33**
IR 58025A x RNR 21604	0.81**	0.37**	-0.02	0.2**
IR 58025A x RNR 21304	1.69**	0.15*	0.16**	-0.24**
IR 58025A x RNR 21218	2.7**	0.46**	-0.11**	0.40**
IR 58025A x RNR 21301	-2.01**	-0.52**	-0.04	-0.19**
IR 58025A x RNR 21288	0.94**	0.15*	0.02	0.04
IR 58025A x MTU 1010	0.8**	-0.08	-0.03	0.00
IR 58025A x RNR 15048	-3.09**	-0.37**	-0.11**	0.13*
IR 68897A x RNR 21615	-0.67**	-0.01	-0.1**	0.17**
IR 68897A x RNR 21604	-1.13**	0.29**	0.1**	-0.31**
IR 68897A x RNR 21304	-1.17**	0.04	0.01	0.02
IR 68897A x RNR 21218	-0.52**	-0.04	-0.02	-0.01
IR 68897A x RNR 21301	-0.21*	-0.20**	-0.02	-0.05
IR 68897A x RNR 21288	2.28**	0.2*	0.04	0.02
IR 68897A x MTU 1010	-0.98**	0.11	-0.06	0.17**
IR 68897A x RNR 15048	2.94**	0.20**	0.04	-0.01

SE (Sij)	0.10	0.07	0.03	0.05
SE (Sij-Sik)	0.24	0.18	0.04	0.12
SE (Sij-Skl)	0.14	0.10	0.07	0.07

Table 6: Best crosses with high *sca* effects, *per se* performance and *gca* effects of parents for grain yield and its component traits

Character/Cross	Mean	GCA effects		SCA
	Performance	Female parent	Male parent	Effects
Days to 50% flowering				
JMS 13A x RNR 21604	81.00	0.19	-1.11**	-5.31**
IR 58025A x RNR 21288	84.67	2.65**	-0.89**	-4.32**
JMS 13A x RNR 21615	82.67	0.19	-1.56**	-3.19*
IR 68897A x RNR 21615	79.67	-2.85**	-1.56**	-3.15*
Plant height				
JMS 13A x RNR 21288	83.33	3.77**	-6.04**	-7.88**
IR 58025A x RNR 15048	93.00	2.94**	0.63	-4.05**
IR 58025A x RNR 21615	93.33	2.94**	0.85	-3.94**
IR 68897A x RNR 21304	82.33	-6.71**	-1.26**	-3.18**
JMS 13A x RNR 21301	92.67	3.77**	-1.87**	-2.72*
Panicle length				
JMS 13A X RNR 21301	27.33	0.09	1.36*	3.14**
IR 58025A X RNR 15048	24.33	1.74**	-2.75**	2.59**
IR 58025A X MTU 1010	27.00	1.74**	0.58	1.93*
IR 68897A X RNR 21615	21.33	-1.83**	-0.75**	1.16
IR 58025A X RNR 21288	23.67	-1.74**	-1.97**	1.15
Panicle weight				
IR 68897A x RNR 15048	1.97	-1.00**	-0.74**	0.73**
JMS 13A x RNR 21304	3.63	0.29**	-0.33**	0.68**
IR 58025A X RNR 21288	4.50	0.71**	0.29**	0.51**
IR 58025A X RNR 21615	4.61	0.71**	0.47**	0.45**
IR 58025A X RNR 21301	4.39	0.71**	0.28**	0.41**
No. of productive tillers per plant				
JMS 13A X RNR 21615	12.33	0.88**	-2.24**	2.24**
IR 58025A X RNR 21301	16.67	0.70**	2.65**	1.85**
JMS 13A X RNR 21304	13.67	0.88**	-0.46**	1.8**
IR 58025A X MTU 1010	14.00	0.70**	0.54**	1.29**
IR 58025A X RNR 21604	12.33	0.70**	-0.90**	1.07*
No. of unproductive tillers per plant				
IR 58025A x RNR 21301	1.00	-0.13**	0.50**	-1.21**
IR 58025A x RNR21288	1.00	-0.13**	0.17**	-0.88**
IR 68897A x RNR 21604	1.67	0.13**	0.39**	-0.68**
IR 68897A x RNR 21304	1.00	0.13**	-0.28**	-0.68**
JMS 13A x RNR 15048	1.00	0.00	-0.17**	-0.67**
Flag leaf length				
IR 58025A X RNR 15048	39.33	2.15**	-2.15**	5.52**
JMS 13A x RNR 21304	33.67	-2.19**	-1.65**	3.69**
JMS 13A x RNR 21288	34.00	-2.19**	-1.04**	3.41**
IR 68897A x RNR 21615	38.67	0.04	2.85**	1.96*
JMS 13A x RNR 21301	34.33	-2.19**	1.30**	1.41
Flag leaf width				
JMS 13A X RNR 21304	2.00	0.04**	-0.13**	0.42**
IR 58025A X MTU 1010	1.97	0.10**	-0.17**	0.37**
Spikelet fertility %				
IR 68897A X RNR 15048	74.70	-10.31**	-1.75**	4.14**
JMS 13A x RNR 21301	93.76	5.50**	1.61**	4.04**
IR 68897A x RNR 21304	71.88	-10.31**	-3.80**	3.38**
IR 58025A x RNR 21218	92.78	4.81**	2.00**	3.36**
IR 58025A x RNR 21604	91.08	4.81**	1.24*	2.42**
Filled grains per panicle				
IR 58025A X RNR 21615	306.33	20.76**	28.39**	78.57**
JMS 13A x RNR 21218	316.00	47.89**	23.61*	65.89**
IR 58025A x RNR 21301	259.67	20.76**	2.50	57.79**
JMS 13A x RNR 21604	283.00	47.89**	-18.50**	49.56**
IR 68897A x RNR 15048	113.00	-68.65**	-31.39**	34.43**

Grain yield per plant				
IR 58025A x RNR 21301	36.36	1.69**	6.04**	10.52**
IR 68897A x RNR 15048	11.33	-7.32**	-6.07**	6.60**
JMS 13A x RNR 21604	32.83	5.63**	2.68**	6.41**
JMS 13A x RNR 21218	32.70	5.63**	5.12**	3.85**
IR 68897A x RNR 21304	10.86	-7.32**	-3.46**	3.52**
Productivity per day				
IR 58025A x RNR 21301	100.22	3.83**	15.79**	29.31**
JMS 13A x RNR 21604	97.89	16.23**	9.25**	21.13**
IR 68897A x RNR 15048	32.53	-20.07**	-17.55**	18.87**
JMS 13A x RNR 21218	93.22	16.23**	14.90**	10.80**
1000-grain weight				
IR 68897A x RNR 15048	14.24	-1.40**	-3.65**	2.94**
IR 58025A x RNR 21218	20.10	0.63**	0.44**	2.70**
JMS 13A x RNR 21615	19.79	0.77**	0.19**	2.49**
IR 68897A x RNR 21288	17.43	-1.40**	0.20**	2.28**
JMS 13A x RNR 21301	19.61	0.77**	0.29**	2.23**
Grain length				
JMS 13A x RNR 21301	8.98	0.17**	-0.10**	0.72**
IR 58025A x RNR 21218	8.71	0.18**	-0.12**	0.46**
IR 58025A x RNR 21604	8.25	0.18**	0.71**	0.37**
IR 68897A x RNR 15048	7.62	-0.35**	-0.42**	0.20**
Grain breadth				
JMS 13A x RNR 21304	2.03	0.10**	0.05**	-0.17**
IR 58025A x RNR 15048	1.60	-0.03**	-0.30**	-0.11**
IR 58025A x RNR 21218	2.00	-0.03**	0.10**	-0.11**
Length-breadth ratio				
IR 58025A x RNR 21218	4.34	0.15**	-0.23**	0.40**
JMS 13A x RNR 21301	4.11	-0.11**	-0.03**	0.23**
JMS 13A x RNR 21304	4.19	-0.11**	0.06**	0.22**
IR 58025A x RNR 21604	4.48	0.15**	0.12**	0.20**
IR 68897A x RNR 21615	3.94	-0.04**	-0.21**	0.17**

**** Significant at 1% level of significance; * Significant at 5 % level of significance**

Table 7: Estimates of general and specific combining ability variances and proportionate gene action in rice for the characters under study

Character	Source of variation			Nature of gene action	Degree of dominance
	σ^2gca	σ^2sca	σ^2gca/ σ^2sca		$\sqrt{\sigma^2}$sca/ $\sigma^2$2gca
Days to 50% flowering	5.71	9.2	0.62	Non-additive	0.90
Plant height	28.93	16.57	1.75	Additive	0.54
Panicle length	2.92	2.63	1.11	Additive	0.67
Panicle weight	0.62	0.24	2.58	Additive	0.44
Number of productive tillers per plant	1.93	2.63	0.73	Non-additive	0.83
Number of unproductive tillers per plant	0.047	0.53**	0.089	Non-additive	2.37
Flag leaf length	4.16	8.34	0.49	Non-additive	1.00
Flag leaf width	0.01	0.07	0.14	Non-additive	1.87
Spikelet fertility %	59.26	8.80	6.74	Additive	0.27
Filled grains per panicle	2811.70	2277.15	1.23	Additive	0.64
Grain yield per plant	37.13	27.41	1.35	Additive	0.61
Productivity per day	289.31**	235.70	1.23	Additive	0.64
1000-grain weight	1.70	5.38	0.32	Non-additive	1.26
Grain length	0.11	0.14	0.79	Non-additive	0.80
Grain breadth	0.01	0.01	1.00	Both	0.71
Length-breadth ratio	0.03	0.06	0.5	Non-additive	1.00

Table 8: Proportional contribution of lines, testers and their interactions to total variance

S.No.	Character	Contribution		
		Line %	Tester %	Line × Tester %
1	Days to 50% flowering	12.81	38.20	48.98
2	Plant height	30.42	47.60	21.98
3	Panicle length	36.87	32.64	30.49
4	Panicle weight	16.76	65.71	17.53
5	Number of productive tillers per plant	39.44	26.04	34.52
6	Number of unproductive tillers per plant	27.08	2.34	70.57
7	Flag leaf length	24.59	28.33	47.08
8	Flag leaf width	16.97	15.14	67.89
9	Spikelet fertility %	6.62	84.69	6.89
10	Filled grains per panicle	6.62	84.69	8.69
11	Grain yield per plant	8.45	59.48	32.07
12	Productivity per day	26.93	45.40	27.67
13	1000-grain weight	33.18	15.78	51.05
14	Grain length	45.96	23.34	30.71
15	Grain breadth	55.06	19.29	25.65
16	Length-breadth ratio	42.43	14.18	43.39

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