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# Analysis of Combining Ability for Yield and Yield Components in Paddy using Line × Tester design under South Eastern Rajasthan

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**ABSTRACT: The line × tester is the most widely used mating design for hybrid development. Line × tester analysis which involves 'l' lines and 't' testers is an extension of the analysis of two factor factorial experiment introduced by Fisher and Yates. Line × tester experiment was conducted to evaluate the performance of 21 hybrids along with 7 lines and 3 testers in rice. The results of the analysis of variance revealed that all genotypes were quite significant for all parameters, indicating that the treatments utilised in this study differed significantly. The results revealed that all of the traits were extremely significant for parents, cross, and parent vs. cross, with the exception of the number of panicles per plant for parent vs. cross. Overall, testers played a bigger role in the expression of most yield components than lines and line-tester interaction. Combining ability analysis is one of the most useful strategies for determining appropriate parents and cross combinations for heterosis exploitation. Combining ability study revealed that both general and specialized combining ability differences were essential for all of the characters, confirming the importance of both additive and non-additive genetic components for such traits. The four lines P-1121, P-1592 and P-1612 and tester P-2511 were identified as best combiners for yield attributing and quality traits on the basis of mean performance and combining ability effects. Similarly, the six crosses viz., P-1592 × P-2511, P-1121 × P-2511, P-1121 × Mahi Sugandha, Pratap-1 × P-2511, P-1612 × P-2511 and Basmati-370 × P-2511 were found the most promising crosses for yield attributing and quality traits. The observed hybrid combinations might be exploited in future hybrid development programmes to exploit heterosis.**

**Keywords:** Combining ability, gene action, line × tester, superior hybrid.

## INTRODUCTION

Rice has a significant role in the Indian economy. Rice is essential for the survival of half of the world's population and two-thirds of Indians. Rice is cultivated on 161.1 million hectares across the world, with a total production of 751.9 million tonnes and a productivity of 4429 kg/ha (Anonymous, 2016). On India it is cultivated in varied agro-climatic condition in an area of 43.79 million hectares with the production of 112.91 million tonnes and average productivity of 2578 kg/ha (Anonymous, 2020). There is an urgent need to increase rice production to meet the requirements of ever-growing population. Rice plant is divided into four parts i.e., root, tiller, leaf and inflorescence. Rice has fibrous root system consisting of seminal, lateral and nodal roots. Lateral roots are produced from seminal root and nodal roots develop on the higher nodes which helps the plant to absorb food material from surrounding water. The stem of rice is erect, cylindrical and hollow. It consists of solid node and hollow internode. 100 g of rice gives about 300 calories of energy. The average Indian citizen's calorie needs is 1500 calories. Cooked unenriched long-grain white rice is composed of 68% water, 28% carbohydrates, 3% protein, 0.28% fat, 0.4 mg niacin, 0.4 mg pantothenic acid, 33 mg phosphorus, 26 mg potassium, 1 mg calcium, 8 mg magnesium and 0.2 mg iron. Traditional rice varieties content various minerals viz., iron (1.34-3.36 mg), zinc (2.22-3.72 mg), calcium (18.32-24.07 mg), and phosphorus (225.25-248.41 mg). Amylose and total starch content ranged from 12.51 to 24.64 per cent and 68.31 to 75.64 per cent respectively. Insoluble, soluble and total dietary fibre ranged from 4.34 to 9.79, 0.12 to 0.62, and 4.46 to 10.40 g per 100 g respectively USDA (2021) and Muttagi and Ravindra (2020).

Hybrid rice technology is a practical and cost-effective method of increasing rice yields. Hybrid rice has a yield that is at least 20% higher than inbred rice, and it is expected that hybrid rice technology will play a vital role in guaranteeing global food security in the next decades. When selecting parents for superior hybrid production, determining the relative importance of general combining ability and specialized combining ability for quantitative variables character affecting yield and its components is extremely useful. General combining ability (GCA) and specialized combining ability (SCA) both aid in the identification of superior parents and hybrids. The information gathered will aid in assessing the amount of heterosis present in F1 hybrids. The heterosis and combining ability of the rice crop development programme reveal the type of gene activity involved, which aids in the selection of appropriate breeding methodology and parameters Kour *et al.* (2019); Suvathipriya and Kalaimagal (2018). The proper selection of suitable parental lines and subsequent superior crossings are critical to the success of hybrid seed breeding. India's export earnings (Basmati and Non-Basmati) increased by 87 percent to 17.72 million tonne (MT) in 2020-21, up from 9.49 MT in 2019-20. In terms of Rupees, India's rice export grew by 44 per cent to Rs 65298 crore in 2020-21 from Rs 45379 crore in the previous year. In 2020-21, India's non-Basmati rice exports were worth Rs 35448 crore, with Basmati Rice exports coming in second at Rs 29,849 crore (APEDA-2022). Combining ability analysis is one of the most useful strategies for determining appropriate parents and cross combinations for heterosis exploitation (Sprague and Tatum 1942).

## MATERIALS AND METHODS

The research was carried out at Agriculture Research Station, Ummedganj, Kota. The experimental material comprised of seven lines viz., P-1592, P-1121, Pratap-1, Surabhi, P-1612, Basmati-370 and Pakistan Basmati with three testers viz., Mahi Sugandha, P-2511 and P-1509. Using the LT mating design, a total of twenty-one crossings were attempted. During Kharif 2020, 29-days old seedlings of 21 hybrids and their ten parents were planted in the main field in a randomized block design with three replications. Row to row and plant to plant distances were 20 cm and 10 cm, respectively. All recommended agronomical practices were followed to raise the ideal crop stand. The observations were recorded on morpho-physiological and quality traits like days to 75% maturity, number of panicles/ plant, number of spikelets/panicle, hulling percent, milling percent, HRR (%), kernel length after cooking (mm), amylose (%) and grain yield/plant (g). Observations were recorded on ten randomly selected competitive plants of each genotype in each replication for all traits except for days to 75% maturity. This observation was recorded on whole plot basis. The mean value data of each trait over ten plants were subjected to statistical analysis using line × tester analysis by Kempthorne (1957) and genetic components of each parameter following Singh and Chaudhary (1985). Significance test for GCA and SCA effects were performed using t-test.

## RESULTS AND DISCUSSION

The analysis of variance (Table 1) revealed that for all parameters, all genotypes were highly significant, indicating that the treatments utilized in this study were considerably different from one another. The mean sums of squares (MSS) of the treatments were further split into parent, cross and parent vs. cross. The results revealed that all of the attributes were extremely important for parents, cross, and parent vs. cross, with the exception of the number of panicles per plant for parent vs. cross. Similarly, the mean sum of squares for crosses was again portioned into lines, testers and line × tester components. For all of the qualities studied, the variation associated to lines was shown to be substantial. For all qualities except HRR percent, the variation due to testers was shown to be significant. The variance due to line × tester was recorded highly significant for all the characters except hulling%, milling%, and amylose%. The results are in akin with the findings of Budhlakoti *et al.* (2020); Ambikabathy *et al.* (2019); Thalapati *et al.* (2015); Kumari *et al.* (2014).

**Table 1: Analysis of variance (mean sum of square) and other parameters for different characters in rice.**

| Source | d.f. | Days to 75% maturity | No. of panicles/ plant | No. of spikelets/ panicle | Hulling (%) | Milling (%) | HRR (%) | Kernel length after cooking (mm) | Amylose (%) | Grain yield/ plant (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| Replications | 2 | 2.45 | 1.73 | 236.04 | 1.38 | 5.92 | 0.10 | 0.60 | 1.05 | 5.24 |
| Treatments | 30 | 46.75** | 15.47** | 1841.60** | 4.93** | 10.91** | 18.41** | 10.72** | 2.71** | 49.66** |
| Parents | 9 | 15.96** | 25.25** | 1773.20** | 3.23** | 8.10** | 4.63** | 15.08** | 2.87** | 50.24** |
| Parents vs. crosses | 1 | 69.98** | 3.88 | 907.21** | 27.09** | 128.83** | 203.91** | 8.07** | 5.77* | 79.53** |
| Crosses | 20 | 59.45** | 11.64** | 1919.08** | 4.59** | 6.27** | 15.33** | 8.88** | 2.48** | 47.90** |
| Lines | 6 | 60.52** | 24.26** | 4656.39** | 8.32** | 16.32** | 47.01** | 7.84** | 3.90** | 83.81** |
| Testers | 2 | 27.12** | 13.95** | 2097.59** | 14.32** | 5.32** | 0.90 | 47.54** | 3.93* | 176.12** |
| Lines × Testers | 12 | 64.30** | 4.96** | 520.67** | 1.10 | 1.41 | 1.90* | 2.96** | 1.53 | 8.58** |
| Error | 60 | 8.06 | 0.74 | 111.71 | 2.53 | 3.77 | 1.30 | 2.13 | 0.20 | 3.15 |
| gca line | | 19.06 | 13.21 | 1985.88 | 11.79 | 1.55 | -0.40 | 45.41 | 3.73 | 172.97 |
| gca tester | | 56.24 | 4.22 | 408.96 | -1.43 | -2.36 | 0.60 | 0.83 | 1.33 | 5.43 |
| sca | | 18.74 | 1.40 | 136.32 | -0.47 | -0.78 | 0.20 | 0.27 | 0.44 | 1.81 |
| Contributions of lines | | 30.54 | 62.49 | 72.79 | 54.33 | 77.98 | 91.97 | 26.46 | 47.13 | 52.48 |
| Contributions of testers | | 4.56 | 11.97 | 10.93 | 31.18 | 8.47 | 0.59 | 53.49 | 15.85 | 36.76 |
| Contributions of L×T | | 64.90 | 25.53 | 16.27 | 14.47 | 13.54 | 7.43 | 20.03 | 37.00 | 10.74 |

*, ** Significant at 5% and 1% level of significance, respectively

Line tester analysis is useful for calculating various forms of gene actions and offers information on the general combining ability (gca) and specific combining ability (sca) effects of parents and crosses, respectively. General combining ability is the average performance of a line in a series of cross combinations. Parents with a significant GCA effect in the desired direction, a non-significant GCA effect in the desired direction, and a significant GCA effect in the undesired direction were classified as good, average, and poor general combiner, respectively, for seed yield and its contributing traits. similarly, crosses were classified as good, average, and poor specific combiner, respectively. All the observation showed both variance like GCA variance and SCA variance which revealed that the both type of gene action governing the traits concerned. The heterosis breeding could be rewarding for improving these traits. The maximum contribution of females (lines) was recorded for HRR% followed by milling% and number of spikelets per panicle. Maximum contribution of male (testers) in normal condition was recorded for kernel length after cooking followed by grain yield per plant and hulling%. Proportional contribution of lines × testers was found maximum for days to 75% maturity followed by amylose% and number of panicles per plant. For illustrating genetic worth of parents for hybridization programme, the general combing ability effects of 10 parents (7 line + 3 testers) for nine characters are consolidated below (Table 2).

**Table 2: Estimation of general combining ability effects of lines and testers for different characters in rice.**

| Parents | Days to 75% maturity | No. of panicles/ plant | No. of spikelets/ panicle | Hulling (%) | Milling (%) | HRR (%) | Kernel length after cooking (mm) | Amylose (%) | Grain yield/ plant (g) |
|---|---|---|---|---|---|---|---|---|---|
| **Lines** | | | | | | | | | |
| P-1592 | -1.33 | 2.37** | 8.39* | 0.90* | -0.35 | -0.45 | -0.05 | -0.08 | 3.71** |
| P-1121 | -3.55* | 2.56** | 19.21** | 2.04** | -2.80** | 3.67** | 1.70** | -0.47** | 2.69** |
| Pratap-1 | 2.11 | 0.93** | -8.31* | 0.08 | 0.23 | -2.49** | -0.72 | 0.95** | 0.56 |
| Surabhi | -4.33** | -0.59* | 13.20** | 0.61** | 1.04* | 1.96** | 0.33 | 0.41** | -1.66** |
| P-1612 | -0.77 | 0.66* | 23.18** | 0.82** | 1.19* | 1.93** | 0.45 | 0.28 | 2.04** |
| Basmati-370 | -0.55 | -2.06** | 1.95 | -0.02 | 0.14 | 1.55* | -0.82 | 0.01 | -3.24** |
| Pakistan Basmati | 1.33 | -1.87** | -43.83** | 0.53** | 0.54 | 1.17 | -0.88 | -1.09** | -4.12** |
| **Testers** | | | | | | | | | |
| Mahi Sugandha | 1.27* | -0.31 | -9.84** | 0.13** | 0.09 | -0.23 | -1.15** | -0.36** | -1.57** |
| P-2511 | -0.34 | 0.92** | 10.13** | 0.75** | 0.45 | 0.15 | 0.55 | 0.11 | 3.34** |
| P-1509 | -0.92 | -0.61** | -0.29 | -0.88** | -0.54 | 0.08 | 1.70** | 0.47** | -1.76** |

*, ** Significant at 5% and 1% level of significance, respectively

The two lines P-1121 and Surabhi recorded negatively significant for days to 75% maturity. Four lines viz., P-1592, P-1121, Pratap-1 and P-1612 and tester P-2511 recorded positively significant for number of panicles per plant. Four lines viz., P-1592, P-1121, Surabhi and P-1612 and tester P-2511 recorded positively significant for number of spikelets per panicle. Five lines viz., P-1592, P-1121, Surabhi, P-1612 and Pakistan Basmati and two testers Mahi Sugandha and P-2511 recorded significantly positive for hulling %. Two lines viz., Surabhi and P-1612 recorded significantly positive for milling%. Four lines viz., P-1121, Surabhi, P-1612 and Basmati-370 recorded positively significant for HRR%. The line P-1121 and tester P-1509 recorded positively significant for kernel length after cooking. Two lines Pratap-1 and Surabhi and tester P-1509 recorded significantly positive for amylose percent. Three lines viz., P-1592, P-1121 and P-1612 and tester P-2511 recorded positive significant for grain yield per plant. Similar results were also reported by Parimala *et al.* (2018); Singh *et al.* (2020) in rice.

The assessment and comprehension of the effect of non-additive gene action for each parameter is referred to as specific combining ability (Table 3) of crosses. Non-additive gene action of any parameter serves as a guide for selecting a favourable cross combination. As a result, a large SCA impact is beneficial to a successful hybrid development programme. The results revealed that five hybrid combinations, namely P-1592 × P-2511, P-1121 × Mahi Sugandha, P-1121 × P-2511, P-1121 × P-1509 and Pratap-1 × P-2511 had a substantial and favourable SCA effect on grain yield per plant out of twenty-one hybrid combinations. Similarly, for days to 75% maturity three combinations viz., P-1121 × P-1509, Pratap-1 × P-2511 and Pakistan Basmati × P-2511 possessed significant and negative SCA, which were desirable for early variety. Cross combination P-1592 × Mahi Sugandha, P-1592 × P-2511, P-1121 × P-2511, Surabhi × P-2511, Basmati-370 × P-2511 and Basmati-370 × P-1509 were showed significant positive SCA effect for number of panicles/ plant. In case of number of spikelets/ panicle positively significant value of SCA effects were observed in crosses viz., P-1592 × Mahi Sugandha, P-1592 × P-2511, P-1121 × Mahi Sugandha, P-1121 × P-1509, Pratap-1 × P-2511, P-1612 × P-2511 and Basmati-370 × P-2511 whereas for hulling per cent eight hybrids showed positive significant SCA effect viz.,P-1592 × P-1509, P-1121 × P-2511, Surabhi × Mahi Sugandha, Surabhi × P-1509, Basmati-370 × Mahi Sugandha, Basmati-370 × P-2511, Pakistan Basmati × P-2511 and Pakistan Basmati × P-1509. Hybrid P-1121 × Mahi Sugandha were showed significantly positive SCA effect for milling percent whereas hybrid P-1121 × P-2511 was showed positively significant SCA effect for kernel length after cooking. Hybrid combinations, P-1121 × Mahi Sugandha, Pratap-1 × P-2511, Basmati-370 × Mahi Sugandha and Pakistan Basmati × P-2511 were showed significant positive SCA effect for amylose content. The results are in akin with the findings of Kirubha *et al.* (2019); Ambikabathy *et al.* (2019); Patil and Mehta (2014).

**Table 3: Estimation of specific combining ability effects of hybrids for different characters in rice.**

| Sr. No. | Hybrids | Days to 75% maturity | No. of panicles/ plant | No. of spikelets/ panicle | Hulling (%) | Milling (%) | HRR | Kernel length after cooking (mm) | Amylose (%) | Grain yield/ plant (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | P-1592 × Mahi Sugandha | -2.04 | 1.60** | 15.49* | -0.49** | -0.41 | -0.84 | -0.14 | -0.05 | 1.18 |
| 2. | P-1592 × P-2511 | 3.23 | 2.08* | 13.24* | -0.26** | 0.10 | 0.84 | -0.69 | 0.002 | 2.55* |
| 3. | P-1592 × P-1509 | -1.19 | -2.05** | -15.70* | 0.75** | 0.31 | 0.002 | 0.84 | 0.05 | 0.37 |
| 4. | P-1121 × Mahi Sugandha | 1.39 | -0.80 | 26.15** | -0.28** | 1.24* | -0.67 | -1.02 | 0.81** | 2.34* |
| 5. | P-1121 × P-2511 | 3.01 | 2.54** | 5.86 | 1.00** | 0.98 | 0.78 | 2.35* | -0.52* | 3.51** |
| 6. | P-1121 × P-1509 | -4.41** | 0.83 | 20.29** | -0.72** | -1.04 | -0.11 | 0.09 | -0.29 | 2.01* |
| 7. | Pratap-1 × Mahi Sugandha | -1.49 | 0.85 | -3.74 | 0.04 | 0.03 | -0.81 | -0.01 | -1.10 | 1.54 |
| 8. | Pratap-1 × P-2511 | -6.20** | -0.62 | 25.49** | -0.20* | -0.005 | 0.37 | 0.50 | 0.65* | 2.63* |
| 9. | Pratap-1 × P-1509 | 7.69** | -0.23 | -1.74 | 0.16* | -0.02 | 0.44 | 0.52 | 0.44 | -3.17** |
| 10. | Surabhi × Mahi Sugandha | 0.61 | -0.23 | 5.85 | 0.50** | -0.15 | 0.75 | 0.46 | 0.39 | -0.13 |
| 11. | Surabhi × P-2511 | 2.23 | 1.33* | -2.65 | -0.85** | -0.88 | -0.35 | -0.43 | 0.18 | 0.39 |
| 12. | Surabhi × P-1509 | -2.85 | -1.09* | -3.20 | 0.36** | 1.04 | -0.40 | -0.02 | -0.57* | -0.26 |
| 13. | P-1612 × Mahi Sugandha | -1.60 | -1.02* | -0.56 | 0.16* | 0.07 | 0.33 | 0.07 | -0.04 | -1.46 |
| 14. | P-1612 × P-2511 | 2.68 | 0.52 | 24.86** | 0.05 | 0.23 | -0.04 | 1.39 | 0.03 | 1.28 |
| 15. | P-1612 × P-1509 | -1.07 | 0.49 | -4.29 | -0.21** | 0.15 | -0.29 | -1.46 | 0.01 | 1.74 |
| 16. | Basmati-370 × Mahi Sugandha | 0.17 | -0.09 | -1.33 | 0.41** | 0.81 | 0.38 | 0.11 | 0.72** | -0.25 |
| 17. | Basmati-370 × P-2511 | 2.12 | 1.60** | 28.21** | 0.15* | -0.23 | 1.12 | 0.64 | 1.04 | 1.16 |
| 18. | Basmati-370 × P-1509 | -2.30 | 1.69** | 9.55 | -0.56** | -0.58 | 0.73 | -0.75 | 0.31 | -0.91 |
| 19. | Pakistan Basmati × Mahi Sugandha | 2.95 | -0.31 | 10.45 | -0.33** | -0.40 | 0.85 | 0.53 | -0.73** | 0.55 |
| 20. | Pakistan Basmati × P-2511 | -7.09** | -0.05 | -5.55 | 0.12* | 0.27 | -0.48 | -1.33 | 0.68* | -0.77 |
| 21. | Pakistan Basmati × P-1509 | 4.14* | 0.36 | -4.89 | 0.21** | 0.13 | -0.36 | 0.79 | 0.05 | 0.21 |

*, ** Significant at 5% and 1% level of significance, respectively

## CONCLUSION

Distinct parents were found as good general combiners for different traits, according to the findings. The findings revealed a strong relationship between the mean performance of the parents and their GCA impacts. On the basis of mean performance and combining ability impacts, the lines P-1121, P-1592, and P-1612, as well as the tester P-2511, were chosen as the top combiners for yield and quality attributes. Similarly, the crosses viz., P-1592 × P-2511, P-1121 × P-2511, P-1121 × Mahi Sugandha, Pratap-1 × P-2511, P-1612 × P-2511 and Basmati-370 × P-2511 were found the most promising crosses for yield attributing and quality traits. Good × good, good × poor, poor × good and poor × poor paternal combinations would have produced the crosses with the best specific combination for grain yield per plant. The identified hybrid combinations could be used for exploitation of heterosis in further hybrid development program. The magnitude of gene action and combining ability effects of parents and hybrids in present investigation showed that heterosis breeding will be useful for developing superior hybrids whereas pedigree method will be useful for improvement of parental lines.

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**Conflict of Interest.** None.

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