

Combining Ability Analysis for Yield and Its Component Traits in Rice (*Oryza sativa* L.)

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ABSTRACT

The present investigation was carried out to study general and specific combining ability of 11 parents and 28 hybrids of rice for their yield and component characters. The 28 hybrids derived from 7 lines and 4 testers in $L \times T$ matting design. Analysis of variance for combining ability revealed significant for all the characters. Variance due to SCA were greater than GCA for all the traits indicating preponderance of non-additive gene action for these traits. Among the parents ADT 43, TKM 13, ASD 16 among lines and ADT 37 and Tetep among testers were good general combiners for grain yield per plant and other com-

ponent traits. Based on SCA effects crosses IR 50 \times ADT 37, TKM 13 \times Tetep, ADT 43 \times Tetep, ADT 43 \times IR 64, BPT 5204 \times ADT 37, CR 1009 \times ADT 37, CR 1009 \times IR 64, ASD 16 \times IR 64 and ASD 16 \times IR 36 having positive and desirable SCA effects for yield and some of its component traits merit attention in breeding program for exploitation of hybrid cultivars.

Keywords Rice, Combining ability, $L \times T$ mating design, Gene action.

INTRODUCTION

Rice (*Oryza sativa* L.) is a well known crop that is consumed by most of the world's population. It has a low fat content and high carbohydrate, protein, vitamin, and mineral content. Rice is grown throughout the world in 168 million hectares with the production of 740 million tonnes. In India, rice occupies an area of about 44 million hectares with a production of 159.2 million tonnes. In Tamil Nadu, it is cultivated in an area of 2.1 million hectares, with a production of 9.2 million tonnes. The global population is estimated to increase from 7.7 billion today to 9 billion in 2035. Therefore, there would be an increase in global rice demand from 763 million tons to 850 million tons. However, in the past decade, only a 1% annual increase in rice yield was reported, and this average was the highest among, rice producing countries. Rice consumption continues to increase with the increase in global population (Gaballah *et al.* 2022). Although many methods are in vogue for rice improvement, hybrid breeding to increase rice productivity has gained much importance nowadays.

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Combining ability analysis is a powerful tool to discriminate good as well as poor combiner and selecting out appropriate parental material and type of gene action involved in the inheritance of various traits. Knowledge of type of *gca* effects and their magnitude is of fundamental importance to the plant breeder. The parent involved in the improvement program should possess good combining ability and wide genetic diversity for various economic traits many biometrical techniques are made available to the breeder for choosing desirable parents. With this background, combining ability analysis is one of the powerful tools available to estimate the combining ability effects and aids in selecting the desirable parents. Line \times tester technique (Kempthorne 1957) is useful in deciding the relative ability of female and male lines to produce desirable hybrid combinations.

MATERIALS AND METHODS

The experimental material used in the present investigation consisted of F_1 hybrids of 28 crosses and 11 parental lines viz., IR 50, TKM 13, ADT 43, BPT 5204, CR 1009, ASD 16 and CO 43 (as lines) as well as ADT37, TETEP, IR64 and IR 36 (as testers). Crosses were made following $L \times T$ method. All the lines, testers and cross combinations were grown in Randomized Block Design with three replications at the Plant Breeding Farm, Faculty of Agriculture, Annamalai University, Annamalainagar during July to October 2021 under transplanted condition. Twenty five days old seedlings were transplanted in the field. Each entry was raised in single row of 3 m length spaced 20 cm apart with 15 cm interplant distance. The standard agronomic packages of practices were followed to raise healthy crop. Ten quantitative characters were evaluated viz. days to 50% flowering, plant height (cm), number of productive tillers per plant, panicle length (cm), number of grains per panicle, hundred grain weight (g), grain yield per plant (g), kernel length (mm), kernel breadth (mm) and kernel L/B ratio. About ten random plants per plot were used for measuring traits and mean values obtained were subjected to line \times tester analysis. The standard procedures developed by Kempthorne (1957) were followed to estimate variances of SCA and GCA. Significance test for GCA and SCA effects were performed using t-test.

RESULTS AND DISCUSSION

Analysis of variance due to parents and hybrids for ten characters is presented in (Table 1). All the hybrids showed significance for all the characters. The analysis of variance revealed that variance due to lines were significant for all the traits studied. While, significant differences were present among the testers for all the characters except hundred grain weight. The lines and testers exhibited significance for all the characters. This indicated the presence of general combining ability effects among parents for these traits. The estimates of GCA and SCA variances revealed that the SCA variances were higher for all the characters which indicated the preponderance of non-additive gene action. Preponderance of non-additive variances in the expression of different characters in rice have also been reported by Shehab *et al.* (2023), Balasubramanian and vennila (2024).

The success of any breeding program largely depends on the choice of parents used in hybridization. Gilbert (1958) suggested that parents with good *per se* performance would result in better hybrids (Table 2). The parental lines IR 50 had significant desirable mean value for the grain yield and number of grains per panicle. The TKM 13 showed significantly higher mean value in number of productive tillers. Panicle length, number of grains per panicle, hundred grain weight, grain yield per plant, kernal length and L/B ratio. The line ADT 43 had significant mean value for characters viz., days to 50% flowering, number of productive tillers, panicle length, number of grains per panicle, hundred grain weight, grain yield per plant, kernal length, L/B ratio and the line ASD 16 recorded significant higher mean value for plant height, number of productive tillers, number of grains per panicle, hundred grain weight, grain yield per plant, kernal length. Among the tester ADT 37 had significant mean value for plant height, number of grains per panicle, grain yield per plant, kernal length, L/B ratio, and the tester Tetep days to 50% flowering, plant height, number of productive tillers, panicle length, number of grains per panicle and grain yield per plant. Considering the mean performance of all the parents for different traits IR 50, TKM 13, ADT 43 and ASD 16 can be adjudged as the best parents for grain yield and its component

Table 1. Analysis of variance for combining ability analysis for yield and its component characters in rice. *Significant at 5% level, **significant at 1% level.

| Source of variations | Df. | DFE | PH | NPT | PL | NGPP | HGW | GY/P | KL | KB | L/B ratio |
|----------------------|-----|--------------|--------------|-------------|-------------|---------------|--------------|--------------|-------------|--------------|--------------|
| Replication | 2 | 1.84 | 6.97 | 8.13 | 10.95 | 113.33 | 0.06 | 0.91 | 0.01 | 0.02 | 0.01 |
| Hybrid | 27 | 118.29** | 298.20** | 18.05** | 21.96** | 3313.69** | 0.20** | 56.43** | 0.78** | 0.22** | 0.15** |
| Lines | 6 | 221.80** | 729.67** | 34.01** | 58.83** | 10525.40** | 0.51** | 113.95** | 1.40** | 0.36** | 0.18** |
| Testers | 3 | 268.46** | 412.26** | 9.50** | 22.52** | 3454.49** | 0.13 | 36.00** | 1.57** | 0.45** | 0.07** |
| L × T | 18 | 58.76** | 135.36** | 14.15** | 9.58** | 886.31** | 0.11** | 40.66** | 0.44** | 0.13** | 0.15** |
| Error | 54 | 1.92 | 2.21 | 1.20 | 1.13 | 7.85 | 0.06* | 1.14 | 0.02 | 0.01 | 0.01 |
| GCA | | 1.32 | 3.62 | 0.09 | 0.28 | 53.94 | 0.002 | 0.35 | 0.01 | 0.002 | 0.001 |
| SCA | | 18.94 | 44.38 | 4.32 | 2.82 | 292.82 | 0.02 | 13.17 | 0.14 | 0.04 | 0.05 |
| GCA/SCA | | 0.07 | 0.08 | 0.02 | 0.10 | 0.18 | 0.10 | 0.03 | 0.07 | 0.02 | 0.02 |

DFF - Days to 50 per cent flowering

PL - Panicle length

GY/P - Grain yield per plant

L/B ratio - kernel L/B ratio

PH - Plant height

NGPP - Number of grains per panicle

KL - Kernel length

NPT - Number of productive tillers

HGW - Hundred grain weight

KB - Kernel breadth

characters.

The combining ability studies of parents provide information about selection of better parents for the grain effective breeding. The *gca* effect is due to addi-

tive gene action and is fixable (Sprague and Tatum 1942). The term combining ability is defined as the relative ability of genotype to transmit its desirable characters to its progenies. Among lines, ADT 43 were found to be good general combiners for grain

Table 2. Mean performance of parents for yield and its component characters in rice. *Significant at 5% level, **significant at 1% level.

| Parents | DFE | PH | NPT | PL | NGPP | HGW | GY/P | KL | KB | L/B ratio |
|-----------------|--------------|--------------|--------------|--------------|---------------|-------------|--------------|-------------|-------------|-------------|
| Lines | | | | | | | | | | |
| IR 50 | 94.73 | 123.63 | 17.26 | 20.73 | 118.83** | 2.03 | 24.06** | 6.13 | 2.29 | 2.68 |
| TKM 13 | 90.59 | 112.56 | 22.03** | 21.81* | 116.22** | 2.04* | 23.42* | 6.95* | 2.30 | 3.19* |
| ADT 43 | 69.12** | 103.27 | 22.27** | 22.62** | 115.6** | 2.23** | 24.47** | 7.02** | 2.12 | 3.31** |
| BPT 5204 | 70.98** | 80.49** | 18.36 | 20.09 | 97.21 | 1.80 | 16.73 | 6.93* | 2.17 | 3.19* |
| CR 1009 | 82.26 | 87.06** | 18.59 | 16.17 | 99.82 | 1.67 | 17.40 | 6.22 | 2.17 | 2.87 |
| ASD 16 | 94.02 | 92.57** | 21.41** | 19.68 | 116.56** | 2.13** | 23.97** | 6.94* | 2.36 | 2.94 |
| CO 43 | 76.98** | 84.88** | 17.26 | 19.01 | 95.25 | 1.53 | 20.60 | 6.68 | 2.58** | 2.59 |
| Testers | | | | | | | | | | |
| ADT 37 | 80.78 | 83.57** | 18.68 | 19.57 | 125.79* | 1.33 | 24.53* | 6.76* | 2.12 | 3.19** |
| Tetep | 74.20** | 80.67** | 22.08** | 22.52* | 127.01** | 1.63 | 24.67* | 6.08 | 2.39 | 2.54 |
| IR 64 | 84.46 | 84.94** | 18.9 | 19.9 | 121.58 | 2.27** | 21.50 | 6.16 | 2.45 | 2.51 |
| IR 36 | 88.65 | 122.86 | 17.85 | 20.97 | 105.73 | 2.20** | 20.33 | 6.98** | 2.63** | 2.65 |
| Mean of parents | 82.43 | 96.05 | 19.68 | 20.28 | 112.69 | 1.90 | 21.97 | 6.62 | 2.33 | 2.88 |
| Mean of line | 82.66 | 97.78 | 17.13 | 20.02 | 108.50 | 1.91 | 21.52 | 6.70 | 2.29 | 2.97 |
| Mean of tester | 82.02 | 93.01 | 19.38 | 20.74 | 120.03 | 1.85 | 22.76 | 6.50 | 2.40 | 2.73 |
| SE | 0.80 | 1.05 | 0.59 | 0.62 | 1.88 | 0.14 | 0.61 | 0.08 | 0.06 | 0.07 |
| CD 5% | 2.25 | 2.94 | 1.65 | 1.75 | 5.25 | 0.13 | 1.60 | 0.23 | 0.16 | 0.20 |
| CD 1% | 2.98 | 3.90 | 2.19 | 2.32 | 6.98 | 0.18 | 2.19 | 0.31 | 0.22 | 0.27 |

DFF - Days to 50% flowering

PL - Panicle length

GY/P - Grain yield per plant

L/B ratio - kernel L/B ratio

PH - Plant height

NGPP - Number of grains per panicle

KL - Kernel length

NPT - Number of productive tillers

HGW - Hundred grain weight

KB - Kernel breadth

Table 3. Mean performance of hybrids for yield and its component characters in rice. *Significant at 5% level, ** significant at 1% level.

| | DFP | PH | NPT | PL | NGPP | HGW | GY/P | KL | KB | L/B ratio |
|----------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| IR 50×ADT 37 | 82.03 | 93.53 | 17.58 | 20.75 | 112.24 | 2.50** | 25.12* | 6.31 | 2.32 | 2.78 |
| IR 50×Tetep | 80.93 | 94.22 | 17.23 | 20.58 | 103.03 | 2.17 | 20.07 | 6.89 | 2.34 | 2.99 |
| IR 50×IR 64 | 77.67 | 76.89** | 15.63 | 17.82 | 94.72 | 2.20 | 19.63 | 7.20 | 2.62 | 2.80 |
| IR 50×IR 36 | 80.81 | 100.78 | 17.04 | 20.32 | 113.21 | 2.07 | 25.04* | 7.21 | 2.36 | 2.99 |
| TKM 13×ADT 37 | 77.15 | 92.22 | 15.55 | 24.04* | 116.66 | 2.20 | 25.67** | 6.49 | 2.36 | 2.74 |
| TKM 13×Tetep | 61.13** | 71.72** | 23.26** | 27.42** | 181.90** | 2.83** | 31.64** | 7.8** | 3.09** | 2.59 |
| TKM 13×IR 64 | 65.84** | 74.48** | 20.52 | 24.28* | 158.84** | 2.47** | 25.06* | 7.70 | 2.57 | 3.01 |
| TKM 13×IR 36 | 78.17 | 79.67** | 21.38 | 24.69** | 164.99** | 2.56** | 25.38* | 7.62** | 2.68 | 2.83 |
| ADT 43×ADT 37 | 71.15 | 85.44 | 19.31 | 20.86 | 99.75 | 2.00 | 16.67 | 7.14 | 2.40 | 2.97 |
| ADT 43×Tetep | 60.77** | 68.35** | 24.00** | 28.19** | 183.34** | 2.94** | 32.81** | 7.91** | 3.22** | 2.52 |
| ADT 43×IR 64 | 63.10** | 65.65** | 22.06* | 25.03** | 168.26** | 2.54** | 26.50** | 7.51** | 2.71** | 2.78 |
| ADT 43×IR 36 | 75.03 | 72.11** | 21.43 | 24.52** | 154.16** | 2.39* | 25.13* | 7.56** | 2.47 | 3.11** |
| BPT 5204 × ADT 37 | 74.78 | 94.48 | 20.56 | 20.94 | 104.17 | 2.10 | 22.35 | 6.43 | 2.26 | 2.82 |
| BPT 5204×Tetep | 64.46** | 81.95 | 18.89 | 20.49 | 101.56 | 2.07 | 22.38 | 6.57 | 2.29 | 2.93 |
| BPT 5204×IR 64 | 72.78 | 80.26* | 20.26 | 20.94 | 119.47 | 2.43** | 19.63 | 6.57 | 2.33 | 2.87 |
| BPT 5204×IR 36 | 77.03 | 93.41 | 20.11 | 19.09 | 122.18 | 2.20 | 19.15 | 7.06 | 2.52 | 2.78 |
| CR 1009×ADT 37 | 66.74** | 87.11 | 18.11 | 17.93 | 96.06 | 1.90 | 25.20* | 7.27 | 2.02 | 3.42** |
| CR 1009×Tetep | 69.97 | 88.19 | 15.99 | 19.43 | 109.72 | 2.32 | 18.97 | 6.12 | 2.47 | 2.54 |
| CR 1009×IR 64 | 73.40 | 94.98 | 22.79** | 20.83 | 119.82 | 2.72** | 25.00* | 7.33* | 2.23 | 3.36 |
| CR 1009×IR 36 | 77.69 | 100.35 | 23.96** | 23.77* | 101.01 | 2.73** | 19.87 | 7.20 | 2.28 | 3.15 |
| ASD 16×ADT 37 | 70.37 | 80.58* | 21.85* | 20.65 | 130.64** | 1.73 | 21.47 | 6.64 | 2.28 | 2.94 |
| ASD 16×Tetep | 69.70 | 72.15** | 21.75* | 24.06* | 148.95** | 1.57 | 26.05** | 7.48** | 2.45 | 3.12 |
| ASD 16× IR 64 | 66.83** | 72.05** | 22.54** | 26.26** | 172.81** | 2.00 | 28.70** | 7.57** | 2.89** | 2.7 |
| ASD 16×IR 36 | 63.61** | 77.27** | 22.01* | 26.76** | 175.91** | 2.17 | 30.50** | 7.71** | 2.93** | 2.64 |
| CO 43×ADT 37 | 70.77 | 79.14** | 21.15* | 20.96 | 79.31 | 1.97 | 17.57 | 6.58 | 2.40 | 2.71 |
| CO 43×Tetep | 68.92* | 85.94 | 19.00 | 19.82 | 89.41 | 2.27 | 18.98 | 7.15 | 2.55 | 2.78 |
| CO 43×IR 64 | 67.07** | 92.28 | 19.67 | 19.25 | 86.44 | 1.97 | 19.57 | 6.40 | 2.50 | 2.62 |
| CO 43×IR 36 | 78.69 | 90.11 | 18.65 | 19.29 | 76.32 | 2.17 | 18.86 | 6.94 | 2.51 | 2.82 |
| Mean of cross | 71.66 | 83.76 | 20.08 | 22.13 | 124.46 | 2.25 | 23.32 | 7.08 | 2.50 | 2.87 |
| SE | 0.80 | 1.05 | 0.59 | 0.62 | 1.88 | 0.14 | 0.64 | 0.08 | 0.06 | 0.07 |
| CD 5% | 2.25 | 2.94 | 1.65 | 1.75 | 5.25 | 0.13 | 1.60 | 0.23 | 0.16 | 0.20 |
| CD 1% | 2.98 | 3.90 | 2.19 | 2.32 | 6.98 | 0.18 | 2.19 | 0.31 | 0.22 | 0.27 |

DFP - Days to 50 per cent Flowering
 PL - Panicle Length
 GY/P - Grain yield per plant
 L/B ratio - kernel L/B ratio

PH - Plant Height
 NGPP - Number of grains per
 Panicle
 KL - Kernel Length

NPT - Number of Productive Tillers
 HGW - Hundred grain weight
 KB - Kernel Breadth

yield per plant and (all other characters except L/B ratio) (Table 3), followed by line TKM 13 (all the characters except number of productive tillers), ASD 16 (all the characters except hundred grain weight and L/B ratio). Among the testers, ADT 37 was good general combiner for grain yield per plant and all other characters except L/b ratio followed by tester Tetep for the grain yield per plant and all other characters except number of productive tillers hundred grain weight and kernal length. Good general combiner for various traits were also been reported by Amit

Kumar *et al.* (2021), Rajib Das *et al.* (2023), Akshay Kumar *et al.* (2024).

Genotypes with high *per se* performance and high *gca* effects could be useful in evolving desirable segregants in breeding programmes. Parents with good *per se* performance would give better hybrids Gilbert (1958). Based on both *per se* and *gca* effects, TKM 13 exhibited significant *per se* and *gca* effects for six traits viz., panicle length, number of grins per panicle, hundred grain weight, grain yield

Table 4. Estimates of general combining ability (*gca*) effects for yield and its component characters in rice. *Significant at 5% level, **significant at 1% level.

| Parents | DFF | PH | NPT | PL | NGPP | HGW | GY/P | KL | KB | L/B ratio |
|-----------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Lines | | | | | | | | | | |
| IR 50 | 8.7** | 7.59** | -3.21** | -1.76** | -18.66** | -0.04 | -0.86** | -0.18** | -0.09** | 0.02 |
| TKM 13 | -1.09** | -4.24** | 0.1 | 2.47** | 31.14** | 0.24** | 2.87** | 0.32** | 0.17** | -0.08* |
| ADT 43 | -4.15** | -10.87** | 1.62** | 2.52** | 26.92** | 0.2** | 1.96** | 0.44** | 0.2** | -0.02 |
| BPT 5204 | 0.6 | 3.76** | -0.12 | -1.27** | -12.62** | -0.06 | -2.07** | -0.43** | -0.15** | -0.02 |
| CR 1009 | 0.29 | 8.9** | 0.13 | -1.96** | -17.31** | -0.35** | -1.44** | -0.1* | -0.25** | 0.25** |
| ASD 16 | -4.04** | -8.25** | 1.96** | 2.05** | 32.12** | 0.13 | 4.11** | 0.27** | 0.13** | -0.02 |
| CO 43 | -0.3 | 3.11** | -0.46 | -2.05** | -41.59** | -0.12 | -4.58** | -0.32** | -0.01 | -0.14** |
| Testers | | | | | | | | | | |
| ADT 37 | 1.62** | 3.74** | -0.92** | -1.54** | -19.2** | -0.11* | -1.53** | -0.39** | -0.21** | 0.04 |
| Tetep | -3.68** | -3.4** | -0.07 | 0.58* | 6.96** | 0.04 | 1.67** | 0.05 | 0.13** | -0.09** |
| IR 64 | -2.14** | -4.25** | 0.42 | 0.36 | 7.02** | 0.07 | -0.16 | 0.1** | 0.05* | 0.01 |
| IR 36 | 4.2** | 3.91** | 0.57* | 0.61* | 5.22** | -0.01 | 0.03 | 0.24** | 0.04 | 0.03 |
| SE (<i>gca</i> for line) | 0.40 | 0.42 | 0.31 | 0.30 | 0.80 | 0.07 | 0.30 | 0.04 | 0.02 | 0.03 |
| SE (<i>gca</i> for tester) | 0.30 | 0.32 | 0.23 | 0.23 | 0.61 | 0.05 | 0.23 | 0.03 | 0.02 | 0.02 |

DFF - Days to 50% flowering
 PL - Panicle length
 GY/P - Grain yield per plant
 L/B ratio - Kernel L/B ratio

PH - Plant height
 NGPP - Number of grains per panicle
 KL - Kernel length

NPT - Number of productive tillers
 HGW - Hundred grain weight
 KB - Kernel breadth

per plant, kernal length, L/B ratio. ADT 43 excelled significantly for Days to 50% flowering, number of productive tillers, panicle length, number of grains per panicle, hundred grain weight, grain yield per plant. ASD 16 showed significant *per se* and *gca* effects for plant height, number of productive tillers, number of grins per panicle, hundred grain weight, grain yield per plant, kernal length. In tester ADT 37 showed desirable significant *per se* and *gca* effects for plant height, number of grins per panicle, grain yield per plant, kernal length, L/B ratio. Tetep exhibited desirable mean and *gca* effects for days to 50 percent flowering, plant height, number of productive tillers, panicle length, number of grains per panicle, grain yield per plant. Hence, from the overview of *per se* and *gca* effects, two lines viz., TKM 13, ADT 43 and ASD 16 and two testers viz., ADT 37 and Tetep were found to be the best parents which can be utilized for hybridization program to obtain superior segregants with high yield and good grain quality traits.

Mean values are considered as an important criteria to evaluate the performance of hybrid. To analyze the value of hybrid, *per se* performance is a

useful index Kadambavanasundaram (1980). Table 4 in the present study, the hybrids viz., TKM 13 × Tetep, TKM 13 × IR 64, ADT 43 × Tetep, ADT 43 × IR 64, BPT 5204 × Tetep, CR 1009 × ADT 37, ASD 16 × IR 64, ASD 16 × IR 36, CO 40 × Tetep, CO 43 × IR 64 showed superior mean performance for Days to 50% flowering. The trait plant height had significant mean value for 13 hybrids viz., IR 50 × IR 64, TKM 13 × Tetep, TKM 13 × IR 64, TKM 13 × IR 36, ADT 43 × Tetep, ADT 43 × IR 64, ADT 43 × IR 36, BPT 5204 × IR 64, ASD 16 × ADT 37, ASD 16 × Tetep, ASD 16 × IR 64, ASD 16 × IR 36, CO 43 × ADT 37. The trait number of productive tillers, hybrids TKM 13 × Tetep, ADT 43 × Tetep, ADT 43 × IR 64, CR 1009 × IR 64, CR 1009 × IR 36, ASD 16 × ADT 37, ASD 16 × Tetep, ASD 16 × IR 64, ASD 16 × IR 36, CO 43 × ADT 37 recorded significant mean value. The hybrid viz., TKM 13 × ADT 37, TKM 13 × Tetep, TKM 13 × IR 64, TKM 13 × IR 36, ADT 43 × Tetep, ADT 43 × IR 64, ADT 43 × IR 36, CR 1009 × IR 36, ASD 16 × Tetep, ASD 16 × IR 64, ASD 16 × IR 36. Showed significant higher mean value for panicle length. The trait number of grains per panicle, the crosses TKM 13 × Tetep, TKM 13 × IR 64, TKM 13

Table 5. Estimates of specific combining ability (*sca*) effects for yield and its component characters in rice. *Significant at 5% level, **significant at 1% level.

| Hybrids | DFP | PH | NPT | PL | NGPP | HGW | GY/P | KL | KB | L/B ratio |
|-------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| IR 50 x ADT 37 | 0.05 | -1.56 | 1.63 * | 1.91 ** | 25.64 ** | 0.31 * | 2.68 ** | -0.2 * | 0.12 * | -0.16 * |
| IR 50 x Tetep | 4.25 ** | 6.27 ** | 0.42 | -0.38 | -9.73 ** | -0.1 | -2.56 ** | -0.06 | -0.20 ** | 0.19 ** |
| IR 50 x IR 64 | -0.55 | -10.22 ** | -1.66 * | -0.87 | -18.1 ** | -0.16 | -1.17 | 0.2 * | 0.16 ** | -0.10 |
| IR 50 x IR 36 | -3.75 ** | 5.51 ** | -0.40 | -0.66 | 2.19 | -0.05 | 1.05 | 0.06 | -0.08 | 0.07 |
| TKM 13 x ADT 37 | 4.95 ** | 8.96 ** | -3.70 ** | -1.02 | -19.74 ** | 0.04 | 0.01 | -0.52 ** | -0.11 | -0.09 |
| TKM 13 x Tetep | -5.76 ** | -4.40 ** | 3.15 ** | 2.23 ** | 19.35 ** | 0.15 | 4.78 ** | 0.35 ** | 0.28 ** | -0.12 |
| TKM 13 x IR 64 | -2.60 ** | -0.79 | -0.07 | -0.69 | -3.78 * | -0.11 | -2.46 ** | 0.2 * | -0.15 * | 0.21 ** |
| TKM 13 x IR 36 | 3.40 ** | -3.76 ** | 0.63 | -0.52 | 4.17 * | -0.07 | -2.33 ** | -0.03 | -0.03 | 0.01 |
| ADT 43 x ADT 37 | 2.02 * | 8.81 ** | -1.47 * | -2.24 ** | -32.43 ** | -0.07 | -7.08 ** | 0 | -0.09 | 0.08 |
| ADT 43 x Tetep | -3.06 ** | -1.14 | 2.36 ** | 2.96 ** | 25.01 ** | 0.25 | 7.37 ** | 0.34 ** | 0.39 ** | -0.24 ** |
| ADT 43 x IR 64 | -2.28 ** | -2.99 ** | -0.06 | 0.02 | 9.86 ** | -0.02 | 1.39 * | -0.12 | -0.04 | -0.08 |
| ADT 43 x IR 36 | 3.32 ** | -4.69 ** | -0.84 | -0.74 | -2.44 | -0.15 | -1.67 ** | -0.21 * | -0.26 ** | 0.23 ** |
| BPT 5204 x ADT 37 | 0.90 | 3.21 ** | 1.53 * | 1.61 ** | 11.52 ** | 0.01 | 2.62 ** | 0.17 | 0.12 * | -0.07 |
| BPT 5204 x Tetep | -4.12 ** | -2.17 * | -1.00 | -0.95 | -17.24 ** | -0.04 | -0.54 | -0.13 | -0.19 ** | 0.17 * |
| BPT 5204 x IR 64 | 2.65 ** | -3.02 ** | -0.11 | -0.28 | 0.61 | 0.09 | -1.46 * | -0.19 * | -0.07 | 0.01 |
| BPT 5204 x IR 36 | 0.57 | 1.98 * | -0.42 | -0.38 | 5.11 ** | -0.06 | -0.63 | 0.16 | 0.13 * | -0.11 |
| CR 1009 x ADT 37 | -6.83 ** | -9.29 ** | -1.18 | -0.70 | 8.11 ** | -0.11 | 3.84 ** | 0.68 ** | -0.02 | 0.26 ** |
| CR 1009 x Tetep | 1.70 * | -1.07 | -4.15 ** | -1.32 * | -2.39 | -0.26 | -4.58 ** | -0.91 ** | 0.09 | -0.49 ** |
| CR 1009 x IR 64 | 3.59 ** | 6.57 ** | 2.16 ** | 0.30 | 5.65 ** | 0.11 | 1.28 * | 0.25 ** | -0.07 | 0.23 ** |
| CR 1009 x IR 36 | 1.54 | 3.78 ** | 3.17 ** | 1.72 ** | -11.37 ** | 0.26 | -0.54 | -0.03 | 0.01 | 0.01 |
| ASD 16 x ADT 37 | 1.12 | 1.33 | 0.73 | -1.99 ** | -8.74 ** | -0.32 * | -2.43 ** | -0.32 ** | -0.15 * | 0.05 |
| ASD 16 x Tetep | 5.75 ** | 0.04 | -0.23 | -1.70 ** | -14.58 ** | 0.04 | -3.05 ** | 0.08 | -0.32 ** | 0.35 ** |
| ASD 16 x IR 64 | 1.34 | 0.79 | 0.09 | 1.72 ** | 9.21 ** | 0.25 | 1.43 * | 0.12 | 0.21 ** | -0.16 * |
| ASD 16 x IR 36 | -8.22 ** | -2.15 * | -0.60 | 1.97 ** | 14.11 ** | 0.04 | 4.05 ** | 0.11 | 0.26 ** | -0.24 ** |
| CO 43 x ADT 37 | -2.21 ** | -11.47 ** | 2.46 ** | 2.43 ** | 15.64 ** | 0.13 | 0.35 | 0.2 * | 0.12 * | -0.07 |
| CO 43 x Tetep | 1.24 | 2.47 ** | -0.55 | -0.84 | -0.42 | -0.02 | -1.43 * | 0.33 ** | -0.06 | 0.14 * |
| CO 43 x IR 64 | -2.16 ** | 9.66 ** | -0.36 | -0.19 | -3.45 * | -0.15 | 0.99 | -0.46 ** | -0.04 | -0.12 |
| CO 43 x IR 36 | 3.13 ** | -0.67 | -1.54 * | -1.40 * | -11.77 ** | 0.04 | 0.09 | -0.07 | -0.02 | 0.05 |
| SE (<i>sca</i> effect) | 0.80 | 0.85 | 0.63 | 0.61 | 1.61 | 0.14 | 0.61 | 0.08 | 0.05 | 0.06 |

× IR 36, ADT 43 × Tetep, ADT 43 × IR 64, ADT 43 × IR 36, ASD 16 × ADT 37, ASD 16 × Tetep, ASD 16 × IR 64, ASD 16 × IR 36 recorded significant higher mean value. Hundred grain weight the hybrids IR 50 × ADT 37, TKM 13 × Tetep, TKM 13 × IR 64, TKM 13 × IR 36, ADT 43 × Tetep, ADT 43 × IR 64, ADT 43 × IR 36, BPT 5204 × Tetep, CR 1009 × IR 64, CR 1009 × IR 36 had significant mean value. The trait Grain yield per plant had significant mean value for 14 crosses viz., IR 50 × ADT 37, IR 50 ×

IR 36, TKM 13 × ADT 37, TKM 13 × Tetep, TKM 13 × IR 64, TKM 13 × IR 36, ADT 43 × Tetep, ADT 43 × IR 64, ADT 43 × IR 36, CR 1009 × ADT 37, CR 1009 × IR 64, ASD 16 × Tetep, ASD 16 × IR 64, ASD 16 × IR 36. The kernal length had significant mean value for TKM 13 × Tetep, TKM 13 × IR 36, ADT 43 × Tetep, ADT 43 × IR 64, ADT 43 × IR 36, CR 1009 × IR 64, ASD 16 × Tetep, ASD 16 × IR 64, ASD 16 × IR 36. The kernal breadth TKM 13 × Tetep, ADT 43 × Tetep, ADT 43 × IR 64, ASD 16

× IR 64, ASD 16 × IR 36 showed significant mean value. In L/B ratio the crosses ADT 43 × IR 36, CR 1009 × ADT 37, CR 1009 × IR 64, CR 1009 × IR 36 recorded significant mean value.

Deviation of hybrid performance from the predicted general combining ability effects is known as specific combining ability effects. Generally parents with high *gca* effects will yield superior hybrids and consequently these hybrids throw better segregants in F₂ generation. Low × low combination of *gca* effects can also produce high *sca* effects. The specific combining ability (*sca*) effects of the 28 F₁ crosses for 10 quantitative traits are presented in Table 5. Specific combining ability is the deviation from the performance predicted on the basis of general combining ability (Allard 1956). The crosses with high *gca* effects generally gave high *sca* effects. High *sca* effects were not only produced by high × high but also with high × low or low × high or low × low combination of *gca* effects. All the promising crosses viz. IR 50 × ADT 37 (number of productive tillers, panicle length, number of grains per panicle, hundred grain weight, grain yield per plant, kernal breadth), TKM 13 × Tetep (number of productive tillers, panicle length, number of grains per panicle, grain yield per plant, kernal length, kernal breadth), ADT 43 × Tetep (number of productive tillers, panicle length, number of grains per panicle, grain yield per plant), ADT 43 × IR 64 (number of grains per panicle, grain yield per plant), BPT 5204 × ADT 37 (plant height, number of productive tillers, panicle length, number of grains per panicle, grain yield per plant, kernal breadth), CR 1009 × ADT 37 (number of grains per panicle, grain yield per plant, kernal length, L/B ratio), CR 1009 × IR 64 (days to 50% flowering, plant height, number of productive tillers, number of grains per panicle, grain yield per plant kernal length, L/B ratio), ASD 16 × IR 64 (panicle length, number of grains per panicle, grain yield per plant and kernal breadth) and ASD 16 × IR 36 (panicle length, number of grains per panicle, grain yield per plant and kernal breadth) recorded significant and positive *sca* effects (Table 5). The *gca* effects of parents (ADT 43, TKM 13, ASD 16, ADT 37 and Tetep) are also significant and positive for grain yield per plant. Hence, it may be concluded that the gene action involved in these crosses are of additive type of epistasis. Similar trend

was observed for other traits too. The present findings were also supported Amit Kumar *et al.* (2021), Shiguang Wang *et al.* (2023), Nivedha *et al.* (2024), Shiwani *et al.* (2025).

In the present study, out of 11 parents, ADT 43, TKM 13, ASD 16, ADT 37 AND Tetep were adjudged as good general combiners for grain yield per plant and other yield component traits. Among the hybrids, IR 50 × ADT 37, TKM 13 × Tetep, ADT 43 × Tetep, ADT 43 × IR 64, BPT 5204 × ADT 37, CR 1009 × ADT 37, CR 1009 × IR 64, ASD 16 × IR 64 and ASD 16 × IR 36 were high yielders with positive Significant SCA effect. Parents of these hybrids were good combiners for grain yield per plant and yield component traits. The specific combining ability effects of these hybrids indicated the involvement of additive type epistasis for grain yield and other characters of these promising hybrids. Hence, the present study indicated that good combiners need to be involved in heterosis breeding to exploit additive type of epistasis.

Depending upon the nature of gene actions and the combining abilities of parents and crosses, suitable breeding procedure such as pedigree or heterosis breeding or biparental mating in F₂ and selection in later generation will have to be adopted in selective crosses or for characters in varietal improvement work.

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