Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

**E-ISSN:** 2278-4136
**P-ISSN:** 2349-8234
JPP 2018; SP4: 443-448

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**(Special Issue- 4)**
**International Conference on Food Security and Sustainable Agriculture**
**(Thailand on 21-24 December, 2018)**

# Studies on mean performance and combining ability analysis for yield and its contributing traits in rice (*Oryza sativa*) under natural saline condition

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**Abstract**
Combining ability analysis for yield and grain quality traits was carried out in rice through Line× Tester analysis. Twenty one hybrids were evolved by crossing 7 lines with 4 testers. Success of any plant breeding programme depends on choice of appropriate genotypes as parents in the hybridization programme combining ability studies of the parents were effective in indents tying better parents and provides information which helps in the selection of better parent for effective breeding programme. Combining ability also provides information on geneaction. General combining ability effects registered maximum *gca*. L1 (ITA132) for kernal breadth, L2 (OM1327-14), L3 for kernel L/B ration and T3 (CO47) for number of productive tillers per plant, kernel length, kernel L/B ratio and 100 grain weight were judged as best parents. The crosses L3 × T1, L3 × T3 and L7 × T3 were best specific combiner were recorded maximum sea values for most of the economic traits.

**Keywords:** Mean performance and Combining ability effects

## Introduction
The potentiality of the hybrids have been well demonstrated in China, Korea and Japan. Some selected hybrids have given an yield increase of more than 30% over the existing hybrids with fairly high yield levels (Yuan, 1994). Further improvement in parental lines will give a steady increase in hybrid yield (Ikehashi *et al*, 1994). Introgression of genes between these genetically distinct varieties was greatly hampered in the past due to problem of hybrid sterility, but it has now become feasible with identification of wide compatibility genes (Ikehashi and Araki, 1984).
Breeding methods to improve a genetic traits are largely determined by the combining ability and nature of gene action. Among the different methods suggested for studying combining ability, Line X Tester is an important one to find out the combining ability of the parents and hybrids with rapidity and confidence (Singh and Chaudhary, 1985). The present investigation was undertaken with the objective of studying the combining ability of rice cultivars for yield and physical quality characters

## Materials and Methods
The present investigation was carried at Plant Breeding Farm, Faculty of Agriculture, Annamalai University during 2015. The experimental materials consisted of seven lines and three testers. The lines are L1 – ITA132, L2 – 0M1327-14, L3 – IR58190-40-3- 1-2, L 4 – BR802 -78-2-1-2, L5 – RP 1678-69-39-4, L6 – IR 60823-78-1 -2-3-1-2, L7 – IR 58125-96-2-3-3 and the testers are T1 – ADT36, T 2 – ADT 45, T 3 – Co 47.
The seven lines and three testers were crossed in a Line x Tester manner resulting in twenty one hybrids. The seeds of male and female parents were sown (two rows each) separately. The spacing adopted was 20 cm between rows and 15 cm plants. Recommended cultural practices were followed. The panicles were covered with butter paper cover immediately after emergency from the boot leaf. In crossing block, crosses were effected in Line x Tester fashion using the seven lines and three testers to get twenty one hybrids. The one third of the tip of the spikelets in the panicle of lines were clipped off using scissors during early morning hours (7-

00 to 8.00 A.M) and the immature spikelets were removed. Then the panicle was covered with butter paper cover. At the time of anther dehiscence, panicle from desired male parent was collected and inserted through the top of the cover and brushed over the clipped off spikelets of line to effect pollination. The crossed seeds of the twenty one hybrid combinations were collected and cleaned carefully.

**Table 1:** Details of parents used in the study

| S. No. | Parents | Origin | Remarks |
|---|---|---|---|
| 1 | ITA132 | IRRI, Philippines | Dwarf, coarse and bold |
| 2 | OM 1327-14 | IRRI, Philippines | Dwarf, coarse and medium |
| 3 | IR 58190-40-2-1-2 | IRRI, Philippines | Semi dwarf, coarse and medium |
| 4 | BR 802-78-2-1-2 | IRRI, Philippines | Dwarf, coarse and medium |
| 5 | RP 1678-69-39-4 | IRRI, Philippines | Dwarf, coarse and medium |
| 6 | IR 60823-78-1-2-3-1-2 | IRRI, Philippines | Dwarf, medium and slender |
| 7 | IR 58125-96-2-3-3 | IRRI, Philippines | Dwarf, coarse and medium |
| 8 | ADT 36 | TRRI, Aduthurai India | Semi dwarf, medium and slender |
| 9 | ADT 45 | TRRI, Aduthurai India | Semi dwarf, coarse and medium |
| 10 | Co 47 | TNAU, Coimbatore India | Tall, medium and slender |

Twenty one hybrids and their ten parents were transplanted in rows with spacing of 20 cm between rows and 15 cm between plants. In each cross, twenty plants were maintained. A randomized block design replicated three times. A recommended fertilizer schedule was followed along with the recommended cultural operations and plant protection measures. The observations were made on randomly selected ten plants for parents and hybrids for recording the following metric traits plant height. Number of productive tillers per plant, panicle length, number of filled grains/panicle, kernel length, kernel breath, kernel L/B ratio, 100 grain weight and grain yield per plant. The combining ability variance analysis was based on method developed by Kempthorne (1957).

**Results and Discussion**

The mean values of seven lines and three testers for different biometrical traits are given in table-2. The mean performance of lines for plant height ranged from 85.85 cm (L5) to 90.64 cm (L3). All the lines had lower values than grand mean. Among the testers, T2 (96.90) was the dwarfish and T3 (100.17) was the tallest. None of the testers was shorter in height than the grand mean (91.28 cm). The range of productive tillers was from 14.55 (L6) to 19.11 (L3) for lines and from 17.41 (T1) to 20.52 (T3) in testers. The lines L3 and the testers T1, T2, and T3 registered positive deviation from grand mean (16.81). The line L1 had the maximum panicle length 25.83 cm, while L4 had the least with 14.40 cm. Among the testers, T3 exhibited highest mean value (24.27 cm) and T2 had lowest value (21.10 cm). Out of seven lines and three testers, only three lines and one tester proved lengthy panicle than grand mean (21.81)

The number of filled grains per panicle in lines exhibited mean values ranging from 125.67 (L6) to 131.90 (L3). The lines L1 and L3 showedincreased grain number than grand mean (130.22). Among the testers, T3 had the maximum mean number of grains (138.53) followed by T2 (132.03). Only these two testers showed significantly higher values than grand mean. The line L 6 had the maximum kernel length 5.87 mm while L4 had the least with 5.48 mm. Among the testers, T3 had highest mean value (6.13 mm) and T2 had lowest value (5.51 mm). Out of seven lines and three testers only three lines and one tester showed higher values than grand mean.

The Kernel breadth in lines exhibited mean values ranging from 1.24 mm (L5) to 1.99 mm (L7). The lines L7, L4, and L2 showed increased kernel breadth than grand mean (1.75 mm). Among testers T3 had the maximum kernel breadth (1.99 mm) followed by T1 (1.96 mm). Only these two testers showed significantly higher values than grand mean. The L/B ratio of lines ranged from 2.52 (L5) to 3.45 (L3). Out of seven lines, three lines registered significantly positive deviation from grand man. The Tester T2 with 3.33 and T1 with 2.87 had highest and lowest L/B ratio respectively. Among the testers T2 and T3 registered significantly positive deviation from grand mean. (3.01).

The line L1 had maximum grain weight of 2.68 g followed by L3 with 2.55g and L7 with 2.53 g while the other lines showed non-significant values. Among the testers, 100 grain weight ranged from 2.28 (T1) to 2.84 (T3). The testers T2 and T3 had significantly higher mean values than grand mean (2.52 g). The grain yield of lines ranged from 32.97g (L 6) to 34.17g (L2). Out of seven lines, none of the lines registered significant positive deviation from grand mean. The tester T3 with 41.77g and T 1 with 34.70g had highest and lowest grain yields respectively. Out of three testers only two T2 and T3 significant surpassed the grand mean (34.84g).

The general combining ability effects (gca) for lines as well as testers for various quantitative traits are furnished.

**Plant Height;** The general combining ability effects of lines varied from -1.47 (L4) to 1.77 (L6) of which L2, L3. L4 and L5 registered negative effects. The gca effects of testers ranged from - 1.20 (T1) to 2.21 (T3), except T3, all other testers exhibited non-significant negative effects.

**Number of Productive tillers/plant;** The lines L2 (-1.39) and L7 (1.80) had lowest and highest significant gca effects respectively, while the testers had a range of - 0.68 (T1) to 0.95 (T3). Positive and significant gca effects were observed in one entry each in lines and testers. The lines L1 and L2 and the tester T1 alone registered significantly negative effects.

**Panicle length:** Among the lines, the range of gca effects was from - 0.63 (L6) to 0.39 (L7). The lines L1, L3, L4, L6 and the testers T1 had negative effects. The minimum gca effects was noticed in T1 (-0.69) while the maximum was in T3 (0.60). All other parents showed positive non-significant.

**Number of filled grains per panicle:** The line L6 recorded the highest gca effect (1.84). Whereas, L4 showed the lowest effect (-1.20). The genotype L3, L5 and L6 among lines, among testers T3 alone exhibited positive non-significant gca effects. Whereas, the lines L1, L2, L4 and L7 and testers T1 and T2 showed non-significant negative effects.

**Kernel length:** The lines had a range of -0.10 (L1) to 0.06 (L5) *gca* effects, of which L1 among lines, T1, T2 among testers noticed significantly negative *gca* effects. The *gca* effects of testers varied from -0.21 (T1) to 0.39 (T3). The tester T3 alone recorded significantly positive *gca* effect.

**Kernel breath:** The lines L3 (-0.17) and L5 (0.18) had lowest and highest *gca* effects respectively. While the testers had a range from -0.06 (T2) to 0.07 (T3). Positive and significant *gca* effects were observed in L5 and L6 among lines, T3 in testers. The line L1, L 2, and L3 and the tester T2 alone registered significantly negative effects.

**Kernel L /B ratio:** The lines had a range of -0.26 (L5) to 0.36 (L3) *gca* effects respectively. While the testers had a range -0.11 (T1) to 0.12 (T3). Positive and significant *gca* effects were observed in L2 and L3 among lines, T3 in testers. The lines L5 and L6 and the tester T1 alone registered significantly negative effects.

**100 grain weight:** The lines had a range of -0.02 (L3), to 0.03 (L5) *gca* effects, of which non-significant positive effects were observed in L5, L6 and L7. The*gca* effect of testers varied from -0.18 (T1) to 0.31 (T3). The tester T3 alone recorded significantly positive effect. Remaining testers recorded significantly negative effects.

**Grain yield per plant:** Among the lines, highest *gca* effect (1.92) was noticed in L7, while L2 recorded lowest value (-1.35). The line L7 alone registered positive and significant *gca* effect. Among the testers, none of the tester registered either positive (or) negative significant *gca* effects.

The mean values of the twenty one hybrids for different characters are given in tables. A brief account of the hybrids performance is presented below character wise (Table 3). The hybrid L2xT1 was the shortest (92.27 cm) and L7xT3 was the tallest (102.31 cm). Out of twenty one hybrids studied, eleven hybrids were shorter in height when compared to grand mean (96 48 cm). The maximum productive tillers (23.12) were produced by the hybrid L7xT3 while L2xT1 produced minimum tillers (17.82) per plant. The hybrids L1xT3, L3XT3, L4xT2, L5xT3, L6xT2, L6xT3, L7xT1, L7xT2 and L7xT3 deviated on positive side from the grand mean (20.02). The longest panicle (28.57cm) was recorded in the hybrid L5xT3. Apart from this nine more hybrids *viz.*, L1xT3, L2xT2, L3xT2, L3xT3, L4xT3, L5xT2, L6xT3, L7xT2 and L7xT3 also registered high positive values than the grand mean (27.32 cm). The shortest panicle (25.13 cm) was observed in the hybrid L6xT1. The hybrids L6xT3 and L3xT1 had the extreme mean filled grains per panicle of 150.40 and 140.73 respectively. Higher mean values than over all mean (144.74) was observed in nine out of twenty-one hybrids.

For kernel length the hybrid L7xT3 and L7xT2 had the extreme mean kernel length of 6.71 mm and 5.75 mm respectively. Higher mean values than over all mean (6.08 mm) was observed in seven out of twenty-one hybrids. The maximum kernel breadth (2.28 mm) was produced by the hybrid L6xT1, while L3xT2 produced minimum breadth (1.73 mm). The hybrids L1xT3, L2xT3, L4xT3, L5xT1, L5xT2, L5xT3, L6xT1, L6xT3 and L7xT3 deviated on positive side from the grand mean (1.98 mm). The highest L/B ratio (3.43) was recorded in the hybrid L3xT2, apart from this, nine more hybrids *viz.,* L1xT2, L1xT3, L2xT1, L2xT2, L2xT3, L3xT1,L3xT3, L4xT3and L7xT3 also registered high positive values than the grand mean (3.09). The lowest (2.55) was observed in the hybrid L6xT1. The mean 100 grain weight of hybrids ranged from 2.34g (L4xT1) to 2.93g (L1xT3). The hybrids of which registered significantly positive values than the grand mean (2.60g) were L1xT3, L2xT3, L3xT3, L4xT3, L5xT3, L6xT3 and L7xT3. The hybrid L7xT3 (40.87g) was the highest grain yielder, whereas, the lowest yield was recorded by the hybrid combination L2xT2 (33.20g). The other hybrids which exhibited higher grain yield. than the grand mean (36.83g) are L2xT3 (37.07g), L3xT1 (39.67g), L3xT2 (37.37g), L3xT3 (36.93g), L4xT1 (37.23g), L4xT2 (37.47g), L5xT2 (38.83g), L5xT3 (36.93g), L6xT1 (37.00g) and L7xT1 (39.73g).

The specific combining ability effects of hybrids are presented (Table 4). The sca effects for different characters are furnished below.

**Plant Height:** Nine out of twenty one cross combinations had non-significant negative sca effects. Only one hybrid L3xT1 (-3.67) recorded highest negative effect. Eleven out of twenty one showed positive effects, L1xT1 (3.90) showed highest significant positive effect(10).

**Number of productive tillers per plant:** The sca effects for this trait varied from -1.30 (L2xT3) to 1.43 (L2xT2). Only two hybrids had significantly positive sca effects. The hybrid combinations L1xT3, L3xT1, L3xT3, L4xT1, L4xT2, L6xT1, L6xT2, L7xT2 and L7xT3 showed non-significant positive effects.

**Panicle length:** The lowest and highest sca effects were noticed in the crosses L2xL3 (-0.93) and L6xT3 (1.01) respectively, non-significant positive effects were observed in ten out of twenty-one hybrid combinations.

**Number of filled grains per panicle:** Eleven out of twenty-one hybrids recorded non-significant positive sca effects. Remaining hybrids showed non-significant negative effects. The highest positive effect was realized in L6xT3 (2.49), while the lowest value in L3xT1 (-3.31).

**Kernel length:** The lowest and highest sca effects were noticed in the crosses L1xT3 (-0.19) and L7xT3 (0.21) respectively. The combinations L1xT2, L6xT3 and L7xT3, showed significantly positive sea effects and L1xT3, L2xT3 and L7xT2 showed significantly negative effects.

**Kernel breath:** Three out of twenty-one hybrids exhibited significant sca effects. Maximum positive and significant sca effect recorded by L6xT1 (0.12). Six out of twenty-one hybrids recorded non-significant positive effect.

**Kernel L / B ratio:** Nine out of twenty-one combination exhibited significant sca effects. Maximum positive and significant sca effect recorded by L6xT2 (0.15). Six combinations registered non-significant positive effects and four combinations showed significantly positive effects.

**100 grain weight:** All the twenty one cross combinations showed non-significant sca effects for 100 grain weight.

**Grain yield per plant:** Eleven cross combinations recorded non-significantly positive effects for this trait. The highest sca effect (2.22) was observed in L5xT2, followed by L3xT1 (1.95) and L7xT3, (1.93) the lowest sca effect -2.82) was noticed in (L7xT1).

In formulating programme for genetic improvement of yield in crops like rice (*Oryza sativa* L), the primary problem met with in the choice of idea parents possessing good combining ability. In addition, the knowledge on genetics of various economic characters is also important. It is essential to identity the parents, as well as crosses which could be exploited in order to bring out further genetic improvement in economic characters. Several biometrical techniques such as dialed analysis (Comstock and Robinson, 1952 and Griffing, 1956b) [2] and Line x Tester analysis (Kempthorne 1957) are available to estimate the combining ability of parents and hybrids.

Line × Tester analysis generally preferred because it admits to evaluate large number of parents when compared to other methods such as dialedanalysis. Present study is an attempt to find out magnitude of heterosis in cross combinations and make use of Line x Tester analysis to estimate the combining ability.

Singh *et al.* (1983) opined that the parents with high order of performance would be of greater significance in breeding programmes. In the present investigation, all the lines showed short in plant height L3 recoded superior performance for six traits viz., number of productive tillers per plant, panicle length, number of filled grains per panicle, kernel L/B ratio and 100 grain weight. L1 for panicle length, number of filled grains per panicle, kernel L/B ratio, and 100 grain weight.L7 for number of productive tillers per plant, kernel breadth and 100 grain weight and L2 for panicle length and kernel breadth. Among the testers, T3 recorded superior performance for all traits, T2 recorded superior performance for five traits viz., plant height, number of productive tillersper plant, number of filled grains per panicle, kernel L/B ratio, 100 grain weight and grain yield per plant. T1 registered for number of productivetillers per plant and kernel breadth. In general the parents L1, L3,T2 and T3 possessed good expression for most of the yield componenttraits. Hence, these parents were adjudged as best and could be utilizedin future breeding programmes.

Combining ability is one of the important parameters commonly used by plant breeders to evaluate the genetic potential of the materials handled. Dhillon (1975) [3] pointed out that the combining ability gives useful information on the choice of parents in terms of expected performance of the hybrids and their progenies. The *gca* effect is considered as intrinsic genetic value of the parent for a trait which is due to additive gene effect and it is fixable (Sinmonds, 1979) [14]. Singh and Nanda (1976) [15] suggested to select atleast one parent with high *gca* effect as a selection index for parental evaluation.

The general combining ability effects of the parents in the present study has brought to light that the parents with high *gca* effects for different trait. Among the lines, L5 had significant positive *gca* effects for kernel breadth only, L6 posses good *gca* effects for kernel L/B ratio. Besides, L7 was found to posses significant *gca* effects for number of productive tillers per plant and grain yield per plant. Among the testers, T3 posses desirable genes for number of productive tillers per plant, kernel length, kernel L/B ratio and 100 grain weight.

From the above, it could be inferred that none of the parents had favourable genes for all the characters studied. However T3 had favorable genes for number of productive tillers per plant, kernel length, kernel L/B ratio and 100 grain weight. Therefore, multiple crossing among these parents would be desirable, to get superior recombinants with all the desirable character along with grain yield (Panwar *et al*., 1985) [12]. The results were in agreement with findings of Hossain *et al*., (2009) [8] and Rashid *et al*., 2007 [13].

It is useful to select hybrids with non-significant sea effects along with parents possessing significant *gca* effects for recombination breeding or heterosis breeding as reported by Nadarajan (1986) [11]. When considering sea effects for selection of superior hybrids, one cross showed negative significant sea effect for plant height in desired direction. For number of productive tillers per plant/two crosses (L2xT2 and L5xT3) showed positive and significant sea effects. Three crosses (L1xT2, L6xT3, and L7xT3) showed significantly positive *sca* effects for kernel length. One cross (L6xT2) for kernel breadth showed significantly negative sea effects. Four crosses (L3xT3, L5xT1, L6xT2 and L7xT3) showed significantly positive sea effect for kernel L/B ratio.

Diwakar and Singh (1993) [4] and Amarnath and Subrahmanyam (1992) [1] found out that cross involving high general combiners generally gave high sea effects. In the present study, the hybrid L3xT3 for kernel L/B ratio showed superior sea effects with high combination of *gca* effects of parents. High sea effects were not only produced by high x high but also with high x low (or) low x high combinations of *gca* effects as observed in the hybrids, L5xT3 (number of productive tillers per plant), L6xT3 and L7xT3 (kernel length) L6xT2 (kernel breadth), L7xT3 (kernel L/B ratio). Such potential crosses from good x poor combinations have been attributed to interaction between dominant alleles from good combiner and recessive alleles from poor combiner Dubey (1975) [5]. Singh (1988) [6] also obtained high sea effect involving at least one good general combiner. The consistent relationship between gca and sea effects might be due to complex interaction of genes as suggested by Matzinger and Kempthorne (1956) [10] and Hayman (1958) [7].

The superior specific combining hybrids were obtained from parents involving all kinds of combinations (high x high, high x low}. Therefore, the specific combining ability of the hybrids was not always dependent on the general combining ability of the parents involved.

**Table 2:** Mean performance of parents for various yield and its component characters

| | **Plant height (cm)** | **No. of Productive tillers / plant** | **Panicle Length** | **No. of filled grains / panicle** | **Kernel length (mm)** | **Kernel breadth (mm)** | **Kernel L/B ratio** | **100 grain weight (gm)** | **Grain yield / plant (gm)** |
|---|---|---|---|---|---|---|---|---|---|
| Lines<br>$L_1$ | 87.54 | 15.52 | 25.83 | 131.27 | 5.60 | 1.64 | 3.42 | 2.68 | 33.13 |
| $L_2$ | 89.40 | 15.55 | 23.47 | 129.13 | 5.61 | 1.84 | 3.04 | 2.49 | 34.17 |
| $L_3$ | 90.64 | 19.11 | 23.43 | 131.90 | 5.69 | 1.65 | 3.45 | 2.55 | 33.47 |
| $L_4$ | 86.32 | 15.17 | 14.40 | 129.93 | 5.48 | 1.85 | 2.95 | 2.48 | 34.13 |
| $L_5$ | 85.85 | 15.35 | 21.50 | 129.90 | 5.79 | 1.24 | 2.52 | 2.45 | 33.73 |
| $L_6$ | 87.91 | 14.55 | 21.33 | 125.67 | 5.87 | 1.71 | 2.74 | 2.37 | 32.97 |
| $L_7$ | 89.31 | 16.50 | 21.63 | 127.00 | 5.58 | 1.99 | 2.76 | 2.53 | 33.83 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tester $T_1$ | 98.73 | 17.41 | 21.17 | 126.80 | 5.64 | 1.96 | 2.87 | 2.28 | 34.70 |
| $T_2$ | 96.90 | 18.32 | 21.10 | 132.03 | 5.51 | 1.65 | 3.33 | 2.55 | 36.47 |
| $T_3$ | 100.17 | 20.52 | 24.27 | 138.58 | 6.31 | 1.99 | 3.07 | 2.84 | 41.77 |
| Grand mean of parents | 91.28 | 16.81 | 21.81 | 130.22 | 5.69 | 1.75 | 3.01 | 2.52 | 34.84 |

**Table 3:** Mean performance of Hybrids for various yield and its component characters

| | **Plant height (cm)** | **No. of Productive tillers / plant** | **Panicle Length** | **No. of filled grains / panicle** | **Kernel length (mm)** | **Kernel breadth (mm)** | **Kernel L/B ratio** | **100 grain weight (gm)** | **Grain yield / plant (gm)** |
|---|---|---|---|---|---|---|---|---|---|
| $L_1$× $T_1$ | 99.46 | 18.36 | 27.03 | 143.50 | 5.81 | 1.93 | 3.01 | 2.38 | 36.37 |
| $L_1$× $T_2$ | 93.94 | 18.57 | 26.70 | 145.77 | 5.94 | 1.85 | 3.20 | 2.44 | 36.50 |
| $L_1$× $T_3$ | 96.87 | 20.78 | 27.77 | 144.17 | 6.18 | 1.99 | 3.15 | 2.93 | 36.40 |
| $L_2$× $T_1$ | 92.27 | 17.82 | 27.17 | 145.27 | 5.86 | 1.86 | 3.15 | 2.41 | 36.20 |
| $L_2$× $T_2$ | 97.26 | 19.79 | 28.27 | 144.07 | 5.99 | 1.83 | 3.27 | 2.46 | 33.20 |
| $L_2$× $T_3$ | 95.79 | 18.28 | 27.23 | 143.17 | 6.27 | 1.99 | 3.15 | 2.90 | 37.07 |
| $L_3$× $T_1$ | 95.51 | 19.80 | 26.50 | 140.73 | 5.86 | 1.82 | 3.22 | 2.44 | 39.67 |
| $L_3$× $T_2$ | 97.84 | 18.64 | 27.73 | 146.97 | 5.96 | 1.73 | 3.43 | 2.38 | 37.37 |
| $L_3$× $T_3$ | 99.77 | 20.82 | 27.57 | 148.20 | 6.54 | 1.90 | 3.70 | 2.91 | 36.93 |
| $L_4$× $T_1$ | 94.18 | 19.59 | 26.63 | 144.47 | 5.91 | 1.92 | 3.07 | 2.34 | 37.23 |
| $L_4$× $T_2$ | 93.01 | 20.37 | 26.93 | 141.07 | 5.91 | 1.94 | 3.04 | 2.48 | 37.47 |
| $L_4$× $T_3$ | 97.83 | 19.84 | 27.97 | 145.07 | 6.38 | 2.02 | 3.22 | 2.91 | 35.87 |
| $L_5$× $T_1$ | 95.60 | 19.06 | 27.03 | 142.80 | 5.98 | 2.11 | 2.82 | 2.47 | 33.80 |
| $L_5$× $T_2$ | 95.33 | 18.86 | 27.50 | 147.73 | 5.88 | 2.16 | 2.72 | 2.52 | 38.83 |
| $L_5$× $T_3$ | 97.61 | 22.43 | 28.57 | 144.73 | 6.55 | 2.21 | 2.96 | 2.91 | 36.93 |
| $L_6$× $T_1$ | 98.35 | 19.98 | 25.13 | 146.10 | 5.83 | 2.28 | 2.55 | 2.48 | 37.00 |
| $L_6$× $T_2$ | 95.81 | 20.40 | 26.63 | 143.23 | 5.85 | 1.96 | 2.98 | 2.45 | 35.40 |
| $L_6$× $T_3$ | 100.58 | 21.51 | 28.30 | 150.40 | 6.70 | 2.23 | 3.00 | 2.91 | 35.03 |
| $L_7$× $T_1$ | 95.60 | 20.72 | 26.97 | 141.50 | 5.87 | 1.94 | 3.01 | 2.42 | 35.67 |
| $L_7$× $T_2$ | 94.58 | 21.61 | 28.07 | 143.83 | 5.75 | 1.95 | 2.94 | 2.52 | 39.73 |
| $L_7$× $T_3$ | 102.31 | 23.12 | 28.10 | 146.73 | 6.71 | 2.02 | 3.32 | 2.89 | 40.87 |
| Grand mean of hybrids | 96.48 | 20.02 | 27.32 | 144.74 | 6.08 | 1.98 | 3.09 | 2.60 | 36.83 |

**Table 4:** General combining ability (GCA) of Parents

| | **Plant height (cm)** | **No. of Productive tillers / plant** | **Panicle Length** | **No. of filled grains / panicle** | **Kernel length (mm)** | **Kernel breadth (mm)** | **Kernel L/B ratio** | **100 grain weight (gm)** | **Grain yield / plant (gm)** |
|---|---|---|---|---|---|---|---|---|---|
| Lines $L_1$ | 0.28 | -0.78* | -0.16 | -0.26 | -0.10* | -0.06** | 0.08 | -0.01 | -0.41 |
| $L_2$ | -1.37 | -1.39** | 0.23 | -0.57 | -0.04 | -0.09** | 0.10** | -0.01 | -1.35* |
| $L_3$ | -0.10 | -0.26 | -0.06 | 0.56 | 0.04 | -0.17** | 0.36** | -0.02 | 1.15 |
| $L_4$ | -1.47 | -0.09 | -0.15 | -1.20 | -0.02 | -0.02 | 0.02 | -0.02 | 0.02 |
| $L_5$ | -0.13 | 0.10 | 0.38 | 0.35 | 0.06 | 0.18** | -0.26** | 0.03 | -0.31 |
| $L_6$ | 1.77 | 0.61 | -0.63 | 1.84 | 0.04 | 0.17** | -0.25** | 0.01 | -1.02 |
| $L_7$ | 1.02 | 1.80** | 0.39 | -0.72 | 0.03 | -0.01 | -0.00 | 0.01 | 1.92** |
| Tester $T_1$ | -1.20 | -0.68** | -0.69 | -1.26 | -0.21** | -0.00 | -0.11** | -0.18** | -0.27 |
| $T_2$ | -1.01 | -0.27 | 0.08 | -0.07 | -0.19** | -0.06** | -0.01 | -0.13** | 0.09 |
| $T_3$ | 2.21** | 0.95** | 0.60 | 1.33 | 0.39** | 0.07** | 0.12** | 0.31** | 0.18 |

* - Significant at 5% level ** - Significant at 1% level

**Table 5:** Specific combining ability (SCA) of Hybrids

| | **Plant height** | **No. of Productive tillers / plant** | **Panicle Length** | **No. of filled grains / panicle** | **Kernel length** | **Kernel breadth** | **Kernel L/B ratio** | **100 grain weight** | **Grain yield / plant** |
|---|---|---|---|---|---|---|---|---|---|
| $L_1$× $T_1$ | 3.90* | -0.19 | 0.55 | 0.28 | 0.04 | 0.01 | 0.00 | -0.02 | 0.22 |
| $L_1$× $T_2$ | -1.81 | -0.40 | -0.55 | 1.36 | 0.15* | -0.00 | 0.09 | -0.01 | -0.02 |
| $L_1$× $T_3$ | -2.09 | 0.59 | -0.00 | -1.64 | -0.19* | 0.00 | -0.09 | 0.03 | -0.20 |
| $L_2$× $T_1$ | -1.65 | -0.13 | 0.30 | 2.36 | 0.03 | -0.03 | 0.08 | -0.00 | 0.98 |
| $L_2$× $T_2$ | 3.17 | 1.43* | 0.63 | -0.03 | 0.13 | 0.00 | 0.09 | 0.01 | -2.38* |
| $L_2$× $T_3$ | -1.52 | -1.30* | -0.93 | -2.33 | -0.16* | 0.03 | -0.16** | -0.01 | 1.40 |
| $L_3$× $T_1$ | -3.67* | 0.73 | -0.08 | -3.31 | -0.05 | 0.00 | -0.12* | 0.04 | 1.95 |
| $L_3$× $T_2$ | 2.48 | -0.85 | 0.39 | 1.74 | 0.03 | -0.02 | -0.01 | -0.06 | -0.72 |
| $L_3$× $T_3$ | 1.19 | 0.11 | -0.30 | 1.57 | 0.02 | 0.02 | 0.13* | 0.02 | -1.23 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $L_4$× $T_1$ | 0.37 | 0.34 | 0.14 | 2.19 | 0.05 | -0.04 | 0.08 | -0.06 | 0.65 |
| $L_4$× $T_2$ | -0.99 | 0.70 | -0.33 | -2.40 | 0.03 | 0.05 | -0.07 | 0.03 | 0.52 |
| $L_4$× $T_3$ | 0.62 | -1.04 | 0.18 | 0.20 | -0.08 | -0.01 | -0.01 | 0.02 | -1.17 |
| $L_5$× $T_1$ | 0.45 | -0.37 | 0.02 | -1.03 | 0.05 | -0.04 | 0.10* | 0.01 | -2.45* |
| $L_5$× $T_2$ | 0.49 | -0.99 | -0.28 | 2.72 | -0.07 | 0.06* | -0.10* | 0.02 | 2.22 |
| $L_5$× $T_3$ | -0.94 | 1.36* | 0.26 | -1.68 | 0.02 | -0.02 | 0.00 | -0.04 | 0.23 |
| $L_6$× $T_1$ | 1.30 | 0.04 | -0.87 | 0.78 | -0.09 | 0.12** | -0.18** | 0.04 | 1.46 |
| $L_6$× $T_2$ | -1.43 | 0.04 | -0.14 | -3.27 | -0.09 | -0.13** | 0.15** | -0.03 | -0.50 |
| $L_6$× $T_3$ | 0.13 | -0.07 | 1.01 | 2.49 | 0.18* | 0.01 | 0.03 | -0.01 | -0.96 |
| $L_7$× $T_1$ | -0.70 | -0.42 | -0.06 | -1.27 | -0.03 | -0.02 | 0.04 | -0.01 | -2.82* |
| $L_7$× $T_2$ | -1.90 | 0.06 | 0.27 | -0.12 | -0.18* | 0.05 | -0.14** | 0.04 | 0.88 |
| $L_7$× $T_3$ | 2.61 | 0.35 | -0.22 | 1.38 | 0.21** | -0.02 | 0.11** | -0.03 | 1.93 |

* - Significant at 5% level ** - Significant at 1% level

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