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# Heterotic implications for yield and quality traits in rice (*Oryza sativa* L.)

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**Abstract**
Forty two rice first filial crosses were generated during rabi 2018-19 period utilizing seven lines and six testers adopting line x tester crossing fashion to get a hold of yield superiority hybrids with blast tolerance. The heterotic components were investigated for yield and quality traits on test hybrids. The results signified the greater heterotic vigour for yield and its component traits while the quality traits particularly length breadth ratio, length elongation ratio breadth elongation ratio and amylase content adjudged to express lower level of heterosis. Thirty five crosses exhibited significantly positive value for relative heterosis while twenty four hybrids showed positive and significant heterobeltiosis. The cross involving White Ponni (128.73 to 157.16), IR 20 (102.85 to 133.32) and CO 50 (95.80 to 125.49) as female parent witnessed to perform extremely superior for yield among the lines deployed. Considering yield and its component traits, the crosses *viz.*, White ponnix Thuyamalli, Whiteponnix Chandaikar, ADT 38 x ADT39, IR 20 xThuyamalli, IR 20 x ADT 39, ACK14072 xSivappumalli, CR 1009 sub 1 x ADT 39, ADT 38 xThuyamalli can be consistently exploited for evolution of great performing rice varieties.

**Keywords:** Rice, heterosis and quality traits

## Introduction
Rice (*Oryza sativa* L., 2n=24), an important cereal food crop for the Asiatic countries besides triggering a significant calorific requirement of 80 per cent among the Asians. It was reported that a range of 9.0 to 186 per cent heterotic benefits could be obtained in grain yield but prevalence always existed in hybrid seed production had impeded the adoption of this phenomenon. Population foundation of India projected the country's population during 2030 as 1546 and 1824 million by the end of 2050 subjugating the existing population of 1234 million (CRRI-Vision 2050). Though the country have sustained in rice yield, yet the yield is often challenged by major pests and diseases. The most devastating fungal disease of rice is Rice blast caused by *Magnaporthe oryzae* as it infects the rice plant in all growth stages and causes reduction in yield up to 10 to 30 per cent. The rapid growth of population and greater challenge by biotic stresses eventually suggested the essentiality of activities to reach a production target of more than 120 million tonnes during 2020. An experiment was laid out wherein thirteen rice parents were deployed to generate forty two rice crosses and thereby selection in heterozygous population for identifying high yielding progenies with inbuilt tolerance to major rice diseases. Further, in the present study the extent of heterosis was assessed to identify superior cross combinations on the basis of grain yield traits for future utilization in crop improvement programmes.

## Materials and Methods
The present study was conducted during Rabi 2018-19 at B block farm of Agricultural College and Research Institute, Killikulam. Forty two hybrids generated utilizing seven lines and six testers were evaluated in a randomized block design under two replications. The exhaustive details of parental rice genotypes were provided in table 1.Twenty five days old seedlings were transplanted with a spacing of 20 cm between rows and 20cm between plants under recommended dose of fertilizers *i.e.*, 120N: 40 P2O5:40 K2O per hectare along with necessary plant protection measures to raise a good crop. Observations were recorded for yield characters such as plant height (cm),number of productive tillers, panicle length (cm),number of grains per panicle, days for 50 per cent flowering and single plant yield (gm) including quality characters such as 1000 grain weight (gm), milling per cent), head rice recovery, grain length (mm),grain breadth (mm), LB ratio, length after cooking, breadth after cooking, linear elongation ratio, breadth elongation ratio, gelatinization temperature, gel consistency and amylase content.

The data recorded on ten randomly selected plants of each replication and the mean data was subjected to statistical analysis. The estimates of relative heterosis (hi) and heterobeltiosis (hii) was estimated and interpreted.

**Results and Discussion**

The mean values and heterosis expressed as percent increase or decrease in the mean value of $F_1$ hybrid over mid parent (H1) and better parent(H2) are presented in table 2 and 3. Heterosis in negative direction is preferred for some traits such as plant height and in days to 50 per cent flowering which is helpful in developing semi dwarf earliness plants (Sahu *et al.,* (2017) [3] and as such negative heterosis for trait plant height over better parent was in the range from -0.49(CO-50X ADT -39) to -57.91 (CR 1009 sub 1 x Chandaikar) besides sixteen crosses are superior out of forty two crosses evaluated. Further, in respect of days to 50 per cent flowering negative heterosis over better parent was in range of -7.89 (IR 20 xNorungan) to -39.47 (TP10106 x ADT 39) and two crosses expressed superiority over better parent whereas the mid parental heterotic values interpreted that twelve crosses showed superiority for days to 50 per cent flowering. Considering the cross combinations which exhibits significant superiority for both earliness and reduced plant height construed to involve parents ACK 14072, CR 1009 sub 1, Norungan and Sivappumalli.

Twelve crosses performed superiorly than the better parent with maximum significant value of 156.66 (White Ponni x Thuyamalli) to minimum significant per cent of 28.80 heterosis (IR 20 x Sivappumalli) over mid parent from 165.05 (White ponni x Thuyamalli) to 0.89 (TP10106 x Chandaikar) for number of productive tillers per plant. Significantly maximum value of 47.82 per cent (White Ponni x Thuyamalli) and a minimum significant value of 13.10 per cent (White Ponni x TPS 3) was registered only in six crosses whereas number of grains per panicle, the significant better parent heterotic value ranged from 122.55 (White ponni x Chandaikar) to 13.23 (CO 50 x Norungan) in 26 hybrids. Further, number of grains per panicle also construed significant mid parent heterotic value for 30 crosses. For single plant yield, heterobeltiosis was registered significant value for 22 crosses with the maximum significant value of 163.70 (White Ponni x Norungan) to the minimum significant value of 15.31 (ADT 38 X TPS 3). (Shukla *et al.,* 2020) [4] interpreted the interaction of alleles under repulsive phase among the contributing traits favour simultaneous increased in the expression of yield as realized among the crosses ADT 38X ADT39, ADT 38 x Thuyamalli, IR 20 x Thuyamalli, IR 20 x ADT 39, White ponni x Thuyamalli, White ponni x Chandaikar, White ponni x TPS 3, ACK 14072 x Shivapumalliand TP 10106 x Thuyamalli.

**Table 1:** Details of parental rice genotypes

| SI. No. | Varieties | Pedigree | Duration |
|---|---|---|---|
| **Lines** | | | |
| L1 | ADT 38 | IR 1529680/IR.4432-52/ IR.7963-30 | 135 days |
| L2 | IR 20 | IR 262 X TKM 6 | 130-135 |
| L3 | ACK 14072 | - | 135-140 |
| L4 | CO 50 | CO 43 / ADT 38 | 130-135 |
| L5 | CR 1009 SUB 1 | Pankaj/Jagannath2 | 155-160 |
| L6 | White ponni | Taichung 65/2/Mayang Ebos-80 | 135-140 |
| L7 | TP 10106 | --- | NNN- |
| **Testers** | | | |
| T1 | Thuyamalli | Traditional variety | 135-140 |
| T2 | Chandaikar | Land race, drought tolerant | 135-145 |
| T3 | Norungan | Land race, drought tolerant | 135-145 |
| T4 | Sivappumalli | Land race,drought tolerant | 135-145 |
| T5 | ADT 39 | IR 8/ IR 20 | 120-125 |
| T6 | TPS 3 | RP31-492/LMN | 135-140 |

**Table 2a:** Mean performance of certain quantitative traits in parents

| Parents | Plant height | No. of productive tillers | Panicle length | No. of grains per panicle | Days to 50% flowering | Single plant yield | 100 grain weight |
|---|---|---|---|---|---|---|---|
| ADT 38 | 80.91 | 14.05 | 21.51 | 76.39 | 70.33 | 47.49 | 22.13 |
| IR 20 | 96.15 | 14.89 | 21.45 | 105.74 | 103.66 | 22.53 | 20.39 |
| ACK 14072 | 80.97 | 15.01 | 18.41 | 132.88 | 101.66 | 32.76 | 18.62 |
| CO-50 | 89.59 | 15.39 | 22.80 | 119.27 | 96.66 | 32.36 | 23.06 |
| CR 1009 SUB 1 | 53.92 | 15.47 | 16.65 | 83.93 | 126.00 | 25.80 | 22.49 |
| WHITE PONNI | 127.59 | 20.02 | 22.58 | 172.29 | 109.00 | 57.91 | 17.64 |
| TP10106 | 103.40 | 13.89 | 22.84 | 83.14 | 63.33 | 24.77 | 23.03 |
| THUYAMALLI | 95.63 | 14.49 | 22.59 | 145.34 | 91.33 | 41.88 | 22.34 |
| CHANDIKAR | 70.93 | 15.55 | 18.78 | 96.17 | 82.66 | 32.81 | 22.32 |
| NORUNGAN | 121.26 | 13.26 | 22.50 | 105.74 | 105.66 | 23.45 | 23.03 |
| SIVAPUMALLI | 146.93 | 11.45 | 25.69 | 119.15 | 112.66 | 18.36 | 22.01 |
| ADT 39 | 92.32 | 15.24 | 23.59 | 95.94 | 112.33 | 51.80 | 17.85 |
| TPS 3 | 98.80 | 15.05 | 22.61 | 92.48 | 105.66 | 31.47 | 21.96 |

**Table 2b:** Mean performance of certain qualitative traits in parents

| Parents | Milling percent | HRR | Grain length | Grain breadth | LB ratio | LAC | BAC | LER | BER | Gelatinization temp | Gel consistency | Amylose content |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ADT 38 | 73.95 | 66.7 | 4.67 | 1.91 | 2.45 | 5.62 | 2.40 | 1.20 | 1.25 | 3.23 | 96.23 | 30.92 |
| IR 20 | 77.84 | 65.43 | 3.87 | 1.81 | 2.13 | 5.63 | 2.28 | 1.45 | 1.25 | 2.25 | 91.94 | 24.53 |
| ACK 14072 | 78.53 | 74.16 | 5.12 | 1.88 | 2.72 | 5.95 | 2.38 | 1.16 | 1.26 | 2.76 | 65.48 | 23.10 |
| CO-50 | 63.79 | 53.05 | 5.32 | 2.30 | 2.31 | 6.23 | 2.63 | 1.17 | 1.14 | 3.92 | 66.86 | 36.98 |
| CR 1009 SUB 1 | 64.54 | 54.56 | 4.80 | 1.82 | 2.64 | 5.57 | 2.19 | 1.16 | 1.20 | 4.49 | 82.45 | 21.52 |
| WHITE PONNI | 84.04 | 78.86 | 5.61 | 1.87 | 2.99 | 6.38 | 2.44 | 1.13 | 1.30 | 3.33 | 91.76 | 22.34 |
| TP10106 | 73.95 | 72.03 | 5.56 | 1.93 | 2.89 | 6.16 | 2.34 | 1.11 | 1.21 | 1.77 | 92.45 | 22.17 |
| THUYAMALLI | 62.05 | 61.57 | 3.91 | 2.13 | 1.83 | 4.69 | 2.51 | 1.20 | 1.18 | 4.29 | 96.19 | 32.39 |
| CHANDIKAR | 69.47 | 66.18 | 4.22 | 1.86 | 2.27 | 5.29 | 2.33 | 1.25 | 1.25 | 3.61 | 95.16 | 29.26 |
| NORUNGAN | 72.81 | 67.42 | 5.27 | 1.82 | 2.90 | 6.08 | 2.38 | 1.15 | 1.31 | 3.11 | 90.31 | 33.32 |
| SIVAPUMALLI | 75.32 | 71.48 | 4.71 | 2.21 | 2.13 | 5.60 | 2.63 | 1.18 | 1.19 | 3.17 | 41.19 | 18.67 |
| ADT 39 | 66.39 | 63.76 | 4.42 | 2.15 | 2.06 | 5.39 | 2.73 | 1.21 | 1.27 | 3.78 | 93.58 | 26.57 |
| TPS 3 | 67.46 | 62.19 | 4.70 | 2.03 | 2.31 | 5.57 | 2.54 | 1.18 | 1.25 | 1.79 | 53.42 | 18.21 |

**Table 3a:** Heterosis for plant height, number of productive tillers, panicle length and number of grains per panicle

| Cross combination | Plant height | | | Number of productive tillers | | | Panicle length | | | Number of grains per panicle | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | μ | $H_1$ | $H_2$ | μ | $H_1$ | $H_2$ | μ | $H_1$ | $H_2$ | μ | $H_1$ | $H_2$ |
| ADT 38 x Thuyamalli | 72.31 | 18.08 ** | -24.39 ** | 31.08 | 117.75 ** | 114.47 ** | 21.60 | -2.06 | -4.41 | 179.67 | 62.06 ** | 23.62 ** |
| ADT 38 xChandaikar | 82.67 | 8.88 | 2.16 | 14.00 | -5.44 | -9.99 | 20.02 | -2.06 | -6.93 | 106.37 | 23.28 ** | 10.60 |
| ADT 38 x Norungan | 88.00 | -12.95 ** | -27.43 ** | 13.53 | -0.92 | -3.72 | 20.50 | -6.84 * | -8.89 * | 131.33 | 44.22 ** | 24.20 ** |
| ADT 38 x Sivappumalli | 84.67 | -25.68 ** | -42.38 ** | 12.43 | -2.51 | -11.55 | 19.30 | -18.24 ** | -24.90 ** | 117.00 | 19.67 ** | -1.80 |
| ADT 38 x ADT 39 | 79.57 | 8.14 | -13.81 ** | 30.31 | 106.92 ** | 98.86 ** | 23.64 | 4.85 | 0.23 | 177.87 | 106.43 ** | 85.39 ** |
| ADT 38 x TPS 3 | 90.53 | 0.75 | -8.37 | 12.93 | -11.14 | -14.08 | 20.77 | -5.87 | -8.17 * | 174.75 | 106.96 ** | 88.95 ** |
| IR 20 x Thuyamalli | 103.57 | 17.29 ** | 8.29 | 35.70 | 142.01 ** | 137.84 ** | 28.56 | 39.29 ** | 26.41 ** | 193.67 | 39.22 ** | 33.25 ** |
| IR 20 xChandaikar | 108.63 | 43.03 ** | 34.16 ** | 14.57 | -4.68 | -6.34 | 21.40 | 15.05 ** | 13.93 ** | 195.71 | 70.88 ** | 47.28 ** |
| IR 20 xNorungan | 112.14 | 10.90 ** | -7.53 | 12.18 | -13.81 | -18.83 * | 17.61 | -13.92 ** | -21.73 ** | 188.00 | 57.57 ** | 41.48 ** |
| IR 20 xSivappumalli | 133.32 | 17.00 ** | -9.26 ** | 19.33 | 46.13 ** | 28.80 ** | 18.27 | -17.15 ** | -28.88 ** | 204.67 | 62.41 ** | 54.02 ** |
| IR 20 x ADT 39 | 102.85 | 18.70 ** | 11.40 * | 33.49 | 121.40 ** | 119.70 ** | 27.59 | 31.36 ** | 16.96 ** | 254.67 | 122.59 ** | 91.65 ** |
| IR 20 x TPS 3 | 107.95 | 20.09 ** | 9.25 | 14.47 | -3.76 | -3.90 | 23.90 | 16.50 ** | 5.69 | 192.33 | 70.68 ** | 44.74 ** |
| ACK 14072xThuyamalli | 90.63 | -5.49 | -5.74 | 15.23 | 3.69 | 2.31 | 18.41 | -16.39 ** | -18.51 ** | 137.00 | 9.13 * | -5.74 |
| ACK 14072 x Chandaikar | 89.33 | 6.93 | -7.09 | 12.43 | -18.32 * | -20.06 * | 18.57 | -7.67 * | -13.41 ** | 142.17 | 40.82 ** | 34.45 ** |
| ACK 14072 x Norungan | 91.56 | -15.78 ** | -24.50 ** | 13.13 | -6.69 | -11.80 | 20.47 | -6.86 * | -9.04 * | 155.90 | 47.44 ** | 47.44 ** |
| ACK 14072 xSivappumalli | 89.55 | -26.32 ** | -39.06 ** | 13.17 | -0.03 | -11.57 | 22.53 | -4.41 | -12.30 ** | 173.83 | 54.59 ** | 45.89 ** |
| ACK 14072 x ADT 39 | 84.80 | -10.01 * | -11.80 * | 13.33 | -11.50 | -12.53 | 21.55 | -4.32 | -8.66 * | 175.00 | 73.54 ** | 65.50 ** |
| ACK 14072 xTPS 3 | 99.23 | 1.80 | 0.43 | 15.23 | 1.75 | 1.20 | 20.48 | -7.04 * | -9.43 ** | 180.20 | 81.82 ** | 70.42 ** |
| CO 50 x Thuyamalli | 97.51 | 5.28 | 1.96 | 14.63 | -2.09 | -4.96 | 22.52 | -0.80 | -1.26 | 171.21 | 29.40 ** | 17.80 ** |
| CO 50 x Chandaikar | 105.32 | 31.22 ** | 17.55 ** | 15.70 | 1.45 | 0.94 | 21.43 | 3.07 | -6.02 | 115.10 | 6.85 | -3.50 |
| CO 50 xNorungan | 95.80 | -9.13 * | -21.00 ** | 13.97 | -2.52 | -9.29 | 22.61 | -0.21 | -0.88 | 135.05 | 20.04 ** | 13.23 * |
| CO 50 x Sivappumalli | 125.49 | 6.11 | -14.59 ** | 23.00 | 71.34 ** | 49.38 ** | 22.67 | -6.53 * | -11.78 ** | 153.33 | 28.62 ** | 28.55 ** |
| CO 50 x ADT 39 | 91.87 | 1.00 | -0.49 | 15.03 | -1.87 | -2.36 | 23.33 | 0.58 | -1.09 | 169.59 | 57.60 ** | 42.18 ** |
| CO 50 x TPS 3 | 97.13 | 3.11 | -1.70 | 14.13 | -7.17 | -8.21 | 20.40 | -10.17 ** | -10.55 ** | 151.23 | 42.83 ** | 26.79 ** |
| CR 1009 SUB 1 xThuyamalli | 85.80 | -23.13 ** | -32.76 ** | 32.53 | 88.49 ** | 62.45 ** | 18.83 | -16.64 ** | -16.67 ** | 172.20 | 8.43 * | -0.05 |
| CR 1009 SUB 1 x Chandaikar | 53.71 | -45.89 ** | -57.91 ** | 14.86 | -16.49 ** | -25.82 ** | 15.64 | -24.36 ** | -30.72 ** | 83.45 | -37.83 ** | -51.56 ** |
| CR1009 SUB 1 x Norungan | 83.95 | -32.53 ** | -34.21 ** | 14.93 | -10.27 | -25.43 ** | 15.99 | -29.04 ** | -29.17 ** | 79.56 | -42.77 ** | -53.82 ** |
| CR 1009 SUB 1x Sivappumalli | 84.20 | -38.66 ** | -42.70 ** | 11.61 | -26.21 ** | -42.01 ** | 17.48 | -27.58 ** | -31.97 ** | 97.01 | -33.42 ** | -43.69 ** |
| CR 1009 sub 1x ADT 39 | 88.39 | -19.61 ** | -30.72 ** | 15.78 | -10.50 | -21.19 ** | 19.75 | -14.45 ** | -16.28 ** | 83.33 | -37.87 ** | -51.64 ** |
| CR 1009 SUB 1 x TPS 3 | 79.56 | -29.71 ** | -37.64 ** | 15.87 | -9.54 | -20.77 ** | 20.52 | -9.20 ** | -9.27 * | 99.17 | -25.09 ** | -42.44 ** |
| White Ponni xThuyamalli | 143.62 | 92.05 ** | 50.17 ** | 39.71 | 165.05 ** | 156.66 ** | 33.40 | 70.22 ** | 47.82 ** | 216.33 | 88.71 ** | 48.85 ** |
| White Ponni x Chandaikar | 129.43 | 107.33 ** | 82.47 ** | 21.99 | 41.73 ** | 41.36 ** | 23.50 | 32.66 ** | 25.13 ** | 214.03 | 137.67 ** | 122.55 ** |
| White Ponni x Norungan | 157.16 | 79.41 ** | 29.60 ** | 21.11 | 46.96 ** | 36.45 ** | 21.39 | 9.29 * | -4.92 | 183.30 | 93.28 ** | 73.35 ** |
| White Ponni x Sivappumalli | 137.93 | 37.34 ** | -6.13 | 17.00 | 26.28 ** | 9.87 | 23.69 | 11.89 ** | -7.80 * | 173.80 | 71.16 ** | 45.86 ** |
| White Ponni xADT 39 | 135.65 | 85.51 ** | 46.93 ** | 16.67 | 8.52 | 7.71 | 24.51 | 21.84 ** | 3.91 | 183.33 | 103.85 ** | 91.09 ** |
| White Ponni x TPS 3 | 128.73 | 68.57 ** | 30.29 ** | 22.60 | 48.07 ** | 46.06 ** | 25.58 | 30.28 ** | 13.10 ** | 188.33 | 113.51 ** | 103.64 ** |
| TP10106 xThuyamalli | 99.69 | 0.17 | -3.60 | 32.53 | 129.19 ** | 124.47 ** | 22.73 | 0.04 | -0.50 | 92.94 | -18.64 ** | -36.05 ** |
| TP10106 xChandaikar | 79.79 | -8.46 | -22.84 ** | 14.86 | 0.89 | -4.48 | 20.68 | -0.62 | -9.44 ** | 93.83 | 4.65 | -2.44 |
| TP10106 xNorungan | 118.38 | 5.38 | -2.38 | 14.93 | 9.98 | 7.46 | 20.50 | -9.56 ** | -10.23 ** | 91.25 | -3.38 | -13.70 * |
| TP10106 xSivappumalli | 127.82 | 2.12 | -13.01 ** | 11.61 | -8.36 | -16.43 | 25.42 | 4.74 | -1.08 | 97.41 | -3.70 | -18.25 ** |
| TP10106 x ADT 39 | 96.35 | -1.55 | -6.82 | 10.79 | -25.97 ** | -29.24 ** | 20.50 | -11.70 ** | -13.10 ** | 83.78 | -6.43 | -12.67 * |
| TP10106 x TPS 3 | 93.45 | -7.57 | -9.63 * | 12.92 | -10.72 | -14.15 | 20.65 | -9.14 ** | -9.59 ** | 89.70 | 2.15 | -3.01 |

**Table 3b:** Heterosis for days to 50 percent flowering, single plant yield, 1000 grain weight and milling percent

| Cross combination | Days to 50% flowering | | | Single plant yield (g) | | | 1000 Grain weight | | | Milling percent | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | μ | $H_1$ | $H_2$ | μ | $H_1$ | $H_2$ | μ | $H_1$ | $H_2$ | μ | $H_1$ | $H_2$ |
| ADT 38 x Thuyamalli | 103.33 | 27.84 ** | 19.97 | 19.97 | 19.97 | -2.79 | 19.97 | -10.22 ** | -10.64 ** | 61.40 | -9.71 ** | -16.97 ** |
| ADT 38 xChandaikar | 76.67 | 0.22 | 21.50 | 21.50 | 21.50 | -21.08 ** | 21.50 | -3.29 | -3.70 | 71.97 | 0.35 | -2.68 |
| ADT 38 x Norungan | 82.33 | -6.44 | 17.46 | 17.46 | 17.46 | -17.39 ** | 17.46 | -22.67 ** | -24.18 ** | 76.73 | 4.56 ** | 3.75 * |
| ADT 38 x Sivappumalli | 89.00 | -2.73 | 21.47 | 21.47 | 21.47 | -7.08 | 21.47 | -2.74 | -3.01 | 71.77 | -3.84 * | -4.72 * |
| ADT 38 x ADT 39 | 89.00 | -2.55 | 19.23 | 19.23 | 19.23 | -8.76 | 19.23 | -3.80 | -13.10 ** | 70.90 | 1.04 | -4.12 * |
| ADT 38 x TPS 3 | 80.67 | -8.33 * | 20.73 | 20.73 | 20.73 | 15.31 ** | 20.73 | -5.96 ** | -6.33 ** | 67.97 | -3.87 * | -8.09 ** |
| IR 20 x Thuyamalli | 96.67 | 0.17 | 27.27 | 27.27 | 27.27 | 22.87 ** | 27.27 | 33.11 ** | 22.03 ** | 65.40 | -6.96 ** | -16.72 ** |
| IR 20 xChandaikar | 92.67 | 0.54 | 21.10 | 21.10 | 21.10 | 15.49 * | 21.10 | 3.05 | -5.48 * | 79.33 | 7.20 ** | 1.02 |
| IR 20 xNorungan | 97.33 | -6.11 | 17.91 | 17.91 | 17.91 | 46.08 ** | 17.91 | -14.03 ** | -22.26 ** | 77.00 | 1.76 | -1.95 |
| IR 20 xSivappumalli | 107.33 | 0.16 | 22.03 | 22.03 | 22.03 | 21.06 ** | 22.03 | 8.44 ** | 0.11 | 61.90 | -19.53 ** | -21.18 ** |
| IR 20 x ADT 39 | 88.33 | -17.45 ** | 25.22 | 25.22 | 25.22 | 15.91 ** | 25.22 | 38.25 ** | 35.38 ** | 84.00 | 15.93 ** | 6.97 ** |
| IR 20 x TPS 3 | 111.67 | 7.72 * | 20.27 | 20.27 | 20.27 | 45.78 ** | 20.27 | -0.13 | -7.71 ** | 74.13 | 1.56 | -5.60 ** |
| ACK 14072xThuyamalli | 101.00 | 3.59 | 17.06 | 17.06 | 17.06 | -2.38 | 17.06 | -20.14 ** | -23.63 ** | 74.16 | 6.02 ** | -4.73 ** |
| ACK 14072 x Chandaikar | 96.67 | 3.76 | 17.95 | 17.95 | 17.95 | 11.99 | 17.95 | -15.95 ** | -19.59 ** | 78.88 | 7.09 ** | 1.34 |
| ACK 14072 x Norungan | 98.67 | -5.73 | 16.78 | 16.78 | 16.78 | 69.55 ** | 16.78 | -22.70 ** | -27.13 ** | 78.21 | 3.83 * | 0.48 |
| ACK 14072 xSivappumalli | 94.67 | -12.48 ** | 22.50 | 22.50 | 22.50 | 112.75 ** | 22.50 | 6.13 ** | 2.23 | 77.18 | 0.78 | -0.85 |
| ACK 14072 x ADT 39 | 85.33 | -20.99 ** | 17.91 | 17.91 | 17.91 | -15.52 ** | 17.91 | -6.35 ** | -12.18 ** | 74.20 | 2.89 | -4.68 ** |
| ACK 14072 xTPS 3 | 104.33 | -0.32 | 20.23 | 20.23 | 20.23 | 70.50 ** | 20.23 | -4.45 * | -7.86 ** | 77.67 | 6.91 ** | -0.22 |
| CO 50 x Thuyamalli | 88.33 | -6.03 | 22.33 | 22.33 | 22.33 | 32.42 ** | 22.33 | -1.65 | -3.19 | 62.93 | 0.02 | -1.34 |
| CO 50 x Chandaikar | 90.67 | 1.12 | 19.87 | 19.87 | 19.87 | 30.81 ** | 19.87 | -12.46 ** | -13.87 ** | 61.13 | -8.25 ** | -12.01 ** |
| CO 50 xNorungan | 106.33 | 5.11 | 22.43 | 22.43 | 22.43 | 48.02 ** | 22.43 | -2.68 | -2.75 | 67.00 | -1.90 | -7.98 ** |
| CO 50 x Sivappumalli | 113.67 | 8.60 ** | 23.27 | 23.27 | 23.27 | 53.45 ** | 23.27 | 3.23 | 0.87 | 75.40 | 8.40 ** | 0.11 |
| CO 50 x ADT 39 | 99.33 | -4.94 | 22.40 | 22.40 | 22.40 | -1.04 | 22.40 | 9.48 ** | -2.89 | 64.05 | -1.60 | -3.52 |
| CO 50 x TPS 3 | 103.33 | 2.14 | 21.73 | 21.73 | 21.73 | 61.59 ** | 21.73 | -3.46 | -5.78 ** | 69.80 | 6.36 ** | 3.47 |
| CR 1009 SUB 1 xThuyamalli | 103.33 | 3.16 | 24.28 | 24.28 | 24.28 | -32.81 ** | 24.28 | 21.41 ** | 8.65 ** | 66.77 | -8.60 ** | -20.55 ** |
| CR 1009 SUB 1 x Chandaikar | 114.33 | 19.30 ** | 21.50 | 21.50 | 21.50 | -36.03 ** | 21.50 | 7.56 ** | -3.70 | 69.32 | -9.70 ** | -17.52 ** |
| CR1009 SUB 1 x Norungan | 86.00 | -19.88 ** | 23.13 | 23.13 | 23.13 | -20.62 ** | 23.13 | 13.73 ** | 0.43 | 65.54 | -16.44 ** | -22.02 ** |
| CR 1009 SUB 1x Sivappumalli | 86.00 | -22.41 ** | 20.93 | 20.93 | 20.93 | -8.22 * | 20.93 | 5.56 * | -4.91 * | 68.79 | -13.67 ** | -18.15 ** |
| CR 1009 sub 1x ADT 39 | 108.00 | -2.41 | 24.32 | 24.32 | 24.32 | -17.05 ** | 24.32 | 37.00 ** | 36.20 ** | 68.50 | -8.93 ** | -18.50 ** |
| CR 1009 SUB 1 x TPS 3 | 98.33 | -8.39 ** | 25.59 | 25.59 | 25.59 | -9.40 * | 25.59 | 29.20 ** | 16.51 ** | 72.76 | -3.95 * | -13.43 ** |
| White Ponni xThuyamalli | 103.33 | -4.91 | 26.96 | 26.96 | 26.96 | 54.53 ** | 26.96 | 20.26 ** | 19.86 ** | 83.46 | 31.84 ** | 29.30 ** |
| White Ponni x Chandaikar | 110.33 | 5.75 | 15.53 | 15.53 | 15.53 | 75.20 ** | 15.53 | -30.68 ** | -30.94 ** | 86.33 | 28.83 ** | 24.26 ** |
| White Ponni x Norungan | 99.33 | -14.24 ** | 14.90 | 14.90 | 14.90 | 163.70 ** | 14.90 | -34.56 ** | -35.33 ** | 83.91 | 22.18 ** | 15.25 ** |
| White Ponni x Sivappumalli | 113.00 | -5.31 | 19.62 | 19.62 | 19.62 | 107.96 ** | 19.62 | -11.84 ** | -12.79 ** | 84.73 | 21.16 ** | 12.49 ** |
| White Ponni xADT 39 | 109.00 | -8.53 ** | 15.68 | 15.68 | 15.68 | 31.06 ** | 15.68 | -22.27 ** | -30.29 ** | 83.21 | 27.10 ** | 25.34 ** |
| White Ponni x TPS 3 | 113.33 | -2.16 | 18.60 | 18.60 | 18.60 | 82.89 ** | 18.60 | -16.32 ** | -17.31 ** | 82.17 | 24.49 ** | 21.80 ** |
| TP10106 xThuyamalli | 74.33 | -3.88 | 25.69 | 25.69 | 25.69 | -97.75 | 25.69 | 13.22 ** | 11.54 ** | 71.46 | 5.08 ** | -3.38 |
| TP10106 xChandaikar | 73.33 | 0.46 | 24.61 | 24.61 | 24.61 | -3.14 | 24.61 | 8.54 ** | 6.88 ** | 71.14 | -0.81 | -3.81 * |
| TP10106 xNorungan | 67.00 | -20.71 ** | 27.29 | 27.29 | 27.29 | 16.39 | 27.29 | 18.49 ** | 18.48 ** | 74.23 | 1.16 | 0.38 |
| TP10106 xSivappumalli | 81.33 | -7.58 * | 20.69 | 20.69 | 20.69 | 32.42 ** | 20.69 | -8.11 ** | -10.15 ** | 74.21 | -0.57 | -1.47 |
| TP10106 x ADT 39 | 68.00 | -22.58 ** | 21.37 | 21.37 | 21.37 | -49.56 ** | 21.37 | 4.53 * | -7.22 ** | 71.95 | 2.54 | -2.70 |
| TP10106 x TPS 3 | 68.00 | -19.53 ** | 22.30 | 22.30 | 22.30 | -33.20 ** | 22.30 | 20.26 ** | -3.17 | 75.86 | 7.28 ** | 2.57 |

**Table 3c:** Heterosis for head rice recovery, grain length, grain breadth and LB ratio

| Cross combination | HRR | | | Grain length | | | Grain breadth | | | LB ratio | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | μ | $H_1$ | $H_2$ | μ | $H_1$ | $H_2$ | μ | $H_1$ | $H_2$ | μ | $H_1$ | $H_2$ |
| ADT 38 x Thuyamalli | 57.40 | -10.57 ** | -14.06 ** | 5.32 | 23.99 ** | 13.83 ** | 1.68 | -17.04 ** | -21.37 ** | 3.40 | 58.75 ** | 38.78 ** |
| ADT 38 xChandaikar | 64.22 | -3.41 | -3.84 | 4.80 | 7.91 ** | 2.64 | 1.53 | -18.80 ** | -19.86 ** | 3.15 | 33.38 ** | 28.57 ** |
| ADT 38 x Norungan | 61.97 | -7.66 * | -8.10 * | 4.97 | -0.17 | -5.82 * | 1.80 | -3.74 | -5.92 | 2.76 | 3.24 | -4.82 |
| ADT 38 x Sivappumalli | 64.43 | -6.80 * | -9.86 ** | 5.62 | 19.63 ** | 19.17 ** | 1.93 | -6.62 | -12.95 * | 2.93 | 27.80 ** | 19.46 * |
| ADT 38 x ADT 39 | 63.57 | -2.62 | -4.83 | 5.61 | 23.18 ** | 19.89 ** | 1.97 | -3.20 | -8.53 | 2.89 | 28.01 ** | 17.82 * |
| ADT 38 x TPS 3 | 61.23 | -5.05 | -8.32 * | 5.65 | 20.47 ** | 20.13 ** | 1.89 | -3.97 | -6.73 | 3.00 | 25.73 ** | 22.31 ** |
| IR 20 x Thuyamalli | 62.80 | -7.47 * | -15.33 ** | 4.54 | 0.59 | -11.32 ** | 1.38 | -31.12 ** | -35.26 ** | 3.31 | 45.18 ** | 21.39 ** |
| IR 20 xChandaikar | 70.00 | -0.25 | -5.62 | 3.76 | -19.44 ** | -26.55 ** | 1.80 | -4.01 | -4.43 | 2.11 | -15.73 * | -22.74 ** |
| IR 20 xNorungan | 66.79 | -5.66 * | -9.95 ** | 4.03 | -22.48 ** | -23.58 ** | 1.54 | -16.73 ** | -17.91 ** | 2.62 | -7.05 | -9.87 |
| IR 20 xSivappumalli | 56.13 | -22.92 ** | -24.31 ** | 3.95 | -19.62 ** | -22.84 ** | 1.44 | -29.48 ** | -34.79 ** | 2.75 | 13.25 | 0.86 |
| IR 20 x ADT 39 | 78.20 | 13.39 ** | 5.44 | 4.30 | -9.95 ** | -16.07 ** | 2.30 | 14.14 * | 6.98 | 1.88 | -21.31 ** | -30.93 ** |
| IR 20 x TPS 3 | 74.20 | 8.83 ** | 0.04 | 4.47 | -8.96 ** | -12.69 ** | 1.80 | -7.76 | -11.17 | 2.48 | -1.52 | -8.92 |
| ACK 14072xThuyamalli | 68.77 | 8.29 ** | 5.09 | 4.69 | 20.38 ** | 19.86 ** | 1.68 | -14.84 ** | -21.22 ** | 2.79 | 40.55 ** | 30.58 ** |
| ACK 14072 x Chandaikar | 75.67 | 14.98 ** | 14.32 ** | 4.83 | 19.39 ** | 14.53 ** | 1.75 | -5.07 | -6.26 | 2.77 | 25.47 ** | 21.70 * |
| ACK 14072 x Norungan | 72.23 | 8.74 ** | 7.13 * | 4.61 | 0.84 | -12.52 ** | 1.31 | -28.27 ** | -28.47 ** | 3.54 | 40.61 ** | 22.04 ** |
| ACK 14072 xSivappumalli | 72.67 | 6.15 * | 1.66 | 4.70 | 9.43 ** | -0.28 | 1.63 | -18.94 ** | -26.20 ** | 2.90 | 35.78 ** | 35.57 ** |
| ACK 14072 x ADT 39 | 73.77 | 14.19 ** | 12.74 ** | 4.93 | 18.75 ** | 11.37 ** | 1.70 | -14.29 * | -20.93 ** | 2.91 | 38.52 ** | 36.04 ** |
| ACK 14072 xTPS 3 | 65.70 | 2.96 | 0.41 | 5.40 | 25.87 ** | 14.81 ** | 1.87 | -2.77 | -7.88 | 2.91 | 30.54 ** | 25.47 ** |
| CO 50 x Thuyamalli | 53.27 | -7.06 * | -13.49 ** | 4.00 | -13.40 ** | -24.87 ** | 2.06 | -7.14 | -10.43 | 1.95 | -6.02 | -15.83 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO 50 x Chandaikar | 52.37 | -12.17 ** | -20.88 ** | 4.10 | -14.05 ** | -22.93 ** | 1.86 | -10.49 * | -18.99 ** | 2.21 | -3.56 | -4.46 |
| CO 50 xNorungan | 61.29 | 1.74 | -9.10 ** | 4.46 | -15.86 ** | -16.23 ** | 1.64 | -20.68 ** | -28.84 ** | 2.72 | 4.34 | -6.20 |
| CO 50 x Sivappumalli | 63.37 | 1.76 | -11.35 ** | 4.26 | -15.15 ** | -19.99 ** | 2.03 | -9.90 * | -11.59 * | 2.10 | -5.40 | -9.21 |
| CO 50 x ADT 39 | 54.98 | -5.87 | -13.78 ** | 4.81 | -1.30 | -9.59 ** | 1.69 | -23.90 ** | -26.38 ** | 2.84 | 29.93 ** | 22.73 * |
| CO 50 x TPS 3 | 60.20 | 4.47 | -3.20 | 4.93 | -1.56 | -7.27 ** | 1.90 | -12.24 * | -17.39 ** | 2.62 | 13.09 | 13.09 |
| CR 1009 SUB 1 xThuyamalli | 63.56 | -9.48 ** | -19.40 ** | 4.75 | -0.25 | -15.38 ** | 1.77 | -11.96 * | -17.32 ** | 2.69 | 11.33 | -10.24 |
| CR 1009 SUB 1 x Chandaikar | 62.17 | -14.28 ** | -21.17 ** | 4.70 | -4.41 | -16.27 ** | 2.22 | 18.54 ** | 18.12 ** | 2.12 | -19.49 ** | -29.18 ** |
| CR1009 SUB 1 x Norungan | 59.34 | -18.87 ** | -24.75 ** | 4.50 | -17.33 ** | -19.83 ** | 1.77 | -4.59 | -5.86 | 2.56 | -13.17 * | -14.48 * |
| CR 1009 SUB 1x Sivappumalli | 65.57 | -12.78 ** | -16.86 ** | 4.31 | -16.53 ** | -23.22 ** | 1.74 | -14.91 ** | -21.39 ** | 2.48 | -3.32 | -17.26 * |
| CR 1009 sub 1x ADT 39 | 65.82 | -7.71 ** | -16.55 ** | 4.57 | -8.96 ** | -18.59 ** | 2.27 | 12.58 * | 5.43 | 2.02 | -20.05 ** | -32.52 ** |
| CR 1009 SUB 1 x TPS 3 | 66.65 | -5.49 | -15.49 ** | 3.77 | -26.98 ** | -32.90 ** | 1.72 | -11.95 * | -15.27 * | 2.19 | -17.39 * | -26.73 ** |
| White Ponni xThuyamalli | 81.17 | 39.79 ** | 31.83 ** | 4.95 | 13.65 ** | 3.05 | 2.34 | 18.01 ** | 9.36 | 2.12 | -5.07 | -19.57 * |
| White Ponni x Chandaikar | 79.15 | 31.09 ** | 19.58 ** | 4.83 | 7.09 ** | 0.55 | 2.41 | 30.92 ** | 29.52 ** | 2.01 | -18.32 * | -23.99 ** |
| White Ponni x Norungan | 79.37 | 30.12 ** | 17.71 ** | 3.82 | -24.21 ** | -27.56 ** | 1.85 | 1.19 | 1.09 | 2.07 | -25.20 ** | -28.59 ** |
| White Ponni x Sivappumalli | 78.69 | 24.86 ** | 10.08 ** | 4.67 | -1.96 | -2.91 | 1.98 | -2.06 | -10.69 | 2.38 | -0.07 | -9.72 |
| White Ponni xADT 39 | 78.64 | 32.91 ** | 23.32 ** | 4.27 | -7.44 ** | -11.10 ** | 2.14 | 7.72 | -0.47 | 2.03 | -13.62 | -23.11 ** |
| White Ponni x TPS 3 | 76.87 | 31.68 ** | 23.61 ** | 4.51 | -5.22 * | -6.24 * | 2.13 | 10.38 | 4.76 | 2.13 | -14.19 | -19.44 * |
| TP10106 xThuyamalli | 65.76 | -1.56 | -8.70 ** | 4.51 | -4.82 | -18.98 ** | 2.09 | 2.54 | -2.34 | 2.18 | -7.69 | -24.57 ** |
| TP10106 xChandaikar | 73.13 | 5.82 * | 1.53 | 4.87 | -0.54 | -12.57 ** | 2.34 | 23.09 ** | 20.86 ** | 2.08 | -19.43 ** | -28.03 ** |
| TP10106 xNorungan | 66.97 | -3.96 | -7.03 * | 4.77 | -12.05 ** | -14.37 ** | 2.12 | 12.59 * | 9.48 | 2.26 | -21.86 ** | -22.04 ** |
| TP10106 xSivappumalli | 69.62 | -2.98 | -3.35 | 4.56 | -11.28 ** | -18.08 ** | 1.71 | -17.36 ** | -22.59 ** | 2.66 | 5.98 | -7.96 |
| TP10106 x ADT 39 | 69.80 | 2.80 | -3.10 | 2.76 | -44.70 ** | -50.36 ** | 1.86 | -8.90 | -13.49 * | 1.49 | -39.93 ** | -48.56 ** |
| TP10106 x TPS 3 | 71.52 | 6.56 * | -0.72 | 2.51 | -51.12 ** | -54.91 ** | 1.80 | -9.17 | -11.33 | 1.40 | -46.09 ** | -51.44 ** |

**Table 3d:** Heterosis for LAC, BAC, LER and BER

| Cross combination | LAC | | | BAC | | | LER | | | BER | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | μ | $H_1$ | $H_2$ | μ | $H_1$ | $H_2$ | μ | $H_1$ | $H_2$ | μ | $H_1$ | $H_2$ |
| ADT 38 xThuyamalli | 6.47 | 25.40 ** | 15.07 ** | 2.10 | -14.38 ** | -16.31 ** | 1.21 | 0.97 | 0.83 | 1.29 | 6.30 | 3.19 |
| ADT 38 xChandaikar | 5.97 | 9.38 ** | 6.17 * | 2.21 | -6.62 | -7.92 | 1.24 | 1.08 | -1.06 | 1.45 | 15.27 ** | 15.12 ** |
| ADT 38 x Norungan | 5.98 | 2.16 | -1.75 | 2.18 | -8.77 | -9.03 | 1.20 | 2.12 | 0.00 | 1.21 | -5.33 | -7.38 |
| ADT 38 x Sivappumalli | 6.33 | 12.74 ** | 12.57 ** | 2.42 | -3.90 | -8.22 | 1.13 | -5.72 * | -6.37 * | 1.26 | 2.86 | 0.27 |
| ADT 38 x ADT 39 | 6.95 | 26.27 ** | 23.72 ** | 2.44 | -4.87 | -10.62 * | 1.24 | 2.75 | 2.19 | 1.25 | -0.92 | -1.57 |
| ADT 38 x TPS 3 | 6.64 | 18.58 ** | 18.09 ** | 2.59 | 4.65 | 1.70 | 1.18 | -1.26 | -1.94 | 1.37 | 9.04 * | 9.04 |
| IR 20 x Thuyamalli | 5.49 | 3.07 | -7.84 ** | 1.72 | -29.88 ** | -31.70 ** | 1.21 | 2.26 | 0.56 | 1.25 | 1.91 | -1.58 |
| IR 20 xChandaikar | 4.97 | -11.65 ** | -16.57 ** | 2.13 | -9.68 * | -10.63 | 1.32 | 9.24 ** | 5.04 | 1.19 | -5.94 | -6.32 |
| IR 20 xNorungan | 5.07 | -15.73 ** | -16.65 ** | 1.87 | -21.73 ** | -21.79 ** | 1.26 | 8.93 ** | 8.62 * | 1.21 | -6.34 | -7.89 |
| IR 20 xSivappumalli | 4.74 | -17.91 ** | -20.32 ** | 1.96 | -21.78 ** | -25.54 ** | 1.20 | 2.27 | 1.12 | 1.36 | 10.45 * | 7.11 |
| IR 20 x ADT 39 | 4.97 | -12.46 ** | -16.57 ** | 2.79 | 9.26 * | 2.32 | 1.16 | -2.66 | -4.93 | 1.22 | -3.81 | -3.94 |
| IR 20 x TPS 3 | 5.13 | -10.93 ** | -13.77 ** | 2.30 | -6.77 | -9.70 | 1.15 | -2.27 | -3.37 | 1.27 | 1.06 | 0.53 |
| ACK 14072xThuyamalli | 5.63 | 9.04 ** | -0.06 | 2.21 | -7.85 | -12.07 * | 1.20 | -9.66 ** | -17.62 ** | 1.31 | 7.80 | 4.51 |
| ACK 14072 x Chandaikar | 5.63 | 3.14 | 0.00 | 2.30 | -0.51 | -1.57 | 1.17 | -14.00 ** | -19.91 ** | 1.31 | 4.51 | 4.51 |
| ACK 14072 x Norungan | 5.89 | 0.51 | -3.23 | 1.90 | -18.63 ** | -20.39 ** | 1.28 | -1.92 | -12.13 ** | 1.45 | 12.73 ** | 10.43 * |
| ACK 14072 xSivappumalli | 5.38 | -4.18 | -4.44 | 2.24 | -8.94 | -15.04 ** | 1.15 | -13.24 ** | -21.28 ** | 1.37 | 12.26 ** | 9.28 |
| ACK 14072 x ADT 39 | 5.92 | 7.44 ** | 5.15 | 2.18 | -13.16 ** | -20.27 ** | 1.20 | -10.22 ** | -17.62 ** | 1.28 | 1.58 | 1.05 |
| ACK 14072 xTPS 3 | 4.94 | -9.49 ** | -20.65 ** | 2.47 | -4.15 | -6.33 | 1.24 | 4.36 | 3.06 | 1.20 | 3.15 | 1.69 |
| CO 50 x Thuyamalli | 5.11 | -11.34 ** | -18.03 ** | 2.20 | -11.41 * | -16.46 ** | 1.25 | 2.75 | -0.80 | 1.18 | -1.80 | -6.10 |
| CO 50 x Chandaikar | 5.41 | -12.15 ** | -13.16 ** | 2.07 | -17.40 ** | -21.27 ** | 1.21 | 4.45 | 3.70 | 1.27 | 3.12 | -3.31 |
| CO 50 xNorungan | 5.17 | -12.62 ** | -17.01 ** | 2.33 | -11.45 ** | -11.50 * | 1.22 | 3.25 | 2.53 | 1.15 | -1.57 | -3.36 |
| CO 50 x Sivappumalli | 5.56 | -4.33 | -10.75 ** | 2.13 | -20.45 ** | -21.86 ** | 1.16 | -3.07 | -4.93 | 1.26 | 4.28 | -0.79 |
| CO 50 x ADT 39 | 5.79 | -1.84 | -7.01 * | 2.47 | -4.57 | -6.20 | 1.17 | -0.42 | -1.12 | 1.31 | 8.89 | 4.26 |
| CO 50 x TPS 3 | 5.78 | 4.46 | -9.35 ** | 2.33 | -5.99 | -7.29 | 1.22 | 4.14 | 1.39 | 1.32 | 6.17 | 1.02 |
| CR 1009 SUB 1 xThuyamalli | 5.58 | -4.37 | -12.54 ** | 2.57 | 7.61 | 5.18 | 1.19 | -0.84 | -5.57 | 1.16 | -9.23 * | -10.97 * |
| CR 1009 SUB 1 x Chandaikar | 5.40 | -13.37 ** | -15.36 ** | 2.26 | -6.42 | -7.50 | 1.20 | 4.80 | 4.05 | 1.28 | -2.17 | -2.29 |
| CR1009 SUB 1 x Norungan | 4.90 | -18.22 ** | -23.20 ** | 2.10 | -17.19 ** | -20.23 ** | 1.14 | -2.15 | -4.21 | 1.21 | -3.34 | -7.65 |
| CR 1009 SUB 1x Sivappumalli | 5.58 | -5.27 * | -12.59 ** | 2.81 | 8.76 * | 3.05 | 1.22 | 3.68 | 0.27 | 1.25 | -3.23 | -4.59 |
| CR 1009 sub 1x ADT 39 | 4.66 | -22.03 ** | -26.96 ** | 2.13 | -14.44 ** | -16.12 ** | 1.24 | 6.74 * | 4.49 | 1.24 | -3.13 | -5.10 |
| CR 1009 SUB 1 x TPS 3 | 5.94 | 15.69 ** | 6.58 * | 2.77 | 17.85 ** | 10.34 | 1.20 | 1.69 | 0.00 | 1.19 | -0.14 | -1.11 |
| White Ponni xThuyamalli | 5.51 | 1.47 | -1.08 | 2.71 | 19.59 ** | 16.00 ** | 1.14 | -5.66 * | -9.28 ** | 1.12 | -8.67 | -10.61 * |
| White Ponni x Chandaikar | 4.64 | -20.45 ** | -23.82 ** | 2.44 | 6.40 | 2.09 | 1.21 | 4.61 | 4.31 | 1.32 | 5.04 | 0.76 |
| White Ponni x Norungan | 5.45 | -2.51 | -2.80 | 2.60 | 7.80 | -1.26 | 1.17 | -0.57 | -1.69 | 1.32 | 10.31 * | 9.70 |
| White Ponni x Sivappumalli | 5.44 | -0.76 | -2.33 | 2.59 | 5.21 | -5.13 | 1.27 | 7.15 * | 4.66 | 1.22 | -1.62 | -4.20 |
| White Ponni xADT 39 | 5.65 | 1.47 | 1.44 | 2.47 | 4.43 | -2.75 | 1.26 | 7.10 * | 5.90 | 1.16 | -5.29 | -7.18 |
| White Ponni x TPS 3 | 5.29 | -2.58 | -14.22 ** | 2.28 | -6.18 | -9.42 | 1.17 | 1.59 | -2.22 | 1.09 | -8.64 | -9.89 |
| TP10106 xThuyamalli | 5.60 | -2.18 | -9.14 ** | 2.69 | 15.12 ** | 14.96 ** | 1.16 | -2.25 | -7.96 * | 1.15 | -6.61 | -8.22 |
| TP10106 xChandaikar | 5.72 | -6.64 ** | -7.24 * | 2.13 | -9.73 * | -10.61 | 1.20 | 6.04 * | 4.05 | 1.02 | -19.15 ** | -22.14 ** |
| TP10106 xNorungan | 5.64 | -4.22 | -8.59 ** | 2.31 | -7.30 | -12.52 * | 1.24 | 7.69 ** | 4.21 | 1.35 | 12.07 * | 10.99 * |
| TP10106 xSivappumalli | 3.65 | -36.85 ** | -40.81 ** | 2.48 | -2.04 | 9.04 | 1.32 | 13.47 ** | 8.49 ** | 1.34 | 7.65 | 5.25 |
| TP10106 x ADT 39 | 3.39 | -42.31 ** | -45.08 ** | 2.33 | -4.44 | -8.26 | 1.35 | 17.85 ** | 14.04 ** | 1.30 | 5.41 | 3.72 |
| TP10106 x TPS 3 | 6.47 | 25.40 ** | 15.07 ** | 2.10 | -14.38 ** | -16.31 ** | 1.21 | 0.97 | 0.83 | 1.29 | 6.30 | 3.19 |

**Table 3e:** Heterosis for gelatinization temperature, gel consistency and amylose content

| Cross combination | Gelatinization temperature | | | Gel consistency | | | Amylose content | | |
|---|---|---|---|---|---|---|---|---|---|
| | μ | $H_1$ | $H_2$ | μ | $H_1$ | $H_2$ | μ | $H_1$ | $H_2$ |
| ADT 38 x Thuyamalli | 3.57 | -5.14 | -16.86 * | 94.03 | -2.27 | -2.29 | 30.93 | -2.28 | -4.50 |
| ADT 38 xChandaikar | 3.50 | 2.29 | -3.14 | 94.53 | -1.22 | -1.77 | 29.44 | -2.17 | -4.79 |
| ADT 38 x Norungan | 2.90 | -8.57 | -10.22 | 86.33 | -7.44 * | -10.29 ** | 30.00 | -6.60 | -9.96 * |
| ADT 38 x Sivappumalli | 2.83 | -11.46 | -12.28 | 89.39 | 30.09 ** | -7.11 | 29.96 | 20.81 ** | -3.12 |
| ADT 38 x ADT 39 | 2.97 | -15.44 | -21.65 * | 89.54 | -5.66 | -6.96 | 24.47 | -14.86 ** | -20.85 ** |
| ADT 38 x TPS 3 | 3.64 | 44.79 ** | 12.59 | 97.13 | 29.81 ** | 0.93 | 32.91 | 33.96 ** | 6.43 |
| IR 20 x Thuyamalli | 2.59 | -26.52 ** | -39.63 ** | 77.67 | -3.93 | -19.26 ** | 19.30 | -30.44 ** | -40.41 ** |
| IR 20 xChandaikar | 4.60 | 44.35 ** | 27.31 ** | 85.30 | 6.19 | -10.37 ** | 26.00 | -0.70 | -11.15* |
| IR 20 xNorungan | 2.06 | -29.74 ** | -33.73 ** | 81.93 | 5.18 | -9.28 * | 19.28 | -31.67 ** | -42.15 ** |
| IR 20 xSivappumalli | 2.22 | -25.13 * | -29.97 ** | 90.97 | 70.54 ** | 38.92 ** | 22.43 | 7.40 | -2.90 |
| IR 20 x ADT 39 | 2.50 | -23.52 ** | -33.89 ** | 85.80 | 7.88 * | -8.32 * | 21.50 | -13.43 ** | -19.08 ** |
| IR 20 x TPS 3 | 1.64 | -27.96 * | -40.58 ** | 85.70 | 44.15 ** | 30.87 ** | 22.45 | 8.67 | -2.84 |
| ACK 14072xThuyamalli | 3.30 | 0.92 | -23.08 ** | 75.60 | -19.63 ** | -21.41 ** | 27.82 | -2.24 | -14.10 ** |
| ACK 14072 x Chandaikar | 2.70 | -7.79 | -25.18 ** | 66.33 | -29.10 ** | -30.30 ** | 21.60 | -19.70 ** | -26.19 ** |
| ACK 14072 x Norungan | 2.57 | -4.29 | -17.56 | 77.67 | -14.77 ** | -15.53 ** | 24.13 | -16.57 ** | -27.57 ** |
| ACK 14072 xSivappumalli | 1.59 | -41.33 ** | -49.84 ** | 77.97 | 17.12 ** | -15.20 ** | 21.55 | -0.26 | -12.17 * |
| ACK 14072 x ADT 39 | 1.93 | -35.95 ** | -48.94 ** | 61.93 | -33.24 ** | -33.82 ** | 20.57 | -19.51 ** | -22.59 ** |
| ACK 14072 xTPS 3 | 2.09 | 3.22 | -7.26 | 51.77 | -28.78 ** | -43.70 ** | 18.50 | -13.44 * | -24.59 ** |
| CO 50 x Thuyamalli | 3.50 | -14.82 * | -18.49 * | 49.97 | -38.72 ** | -48.06 ** | 28.17 | -18.80 ** | -23.84 ** |
| CO 50 x Chandaikar | 3.21 | -14.69 | -18.03 * | 33.33 | -58.86 ** | -64.97 ** | 33.13 | 0.03 | -10.41 ** |
| CO 50 xNorungan | 2.83 | -19.43 * | -27.72 ** | 67.33 | -14.32 ** | -25.44 ** | 32.33 | -8.02 * | -12.57 ** |
| CO 50 x Sivappumalli | 3.57 | 0.80 | -8.84 | 56.03 | 3.70 | -16.20 ** | 27.87 | 0.14 | -24.65 ** |
| CO 50 x ADT 39 | 2.63 | -31.66 ** | -32.82 ** | 75.63 | -5.72 | -19.18 ** | 28.90 | -9.05 * | -21.86 ** |
| CO 50 x TPS 3 | 2.47 | -13.65 | -37.07 ** | 32.60 | -45.80 ** | -51.25 ** | 26.63 | -3.49 | -27.99 ** |
| CR 1009 SUB 1 xThuyamalli | 4.90 | 28.55 ** | 14.22 | 84.31 | -10.29 ** | -12.36 ** | 22.86 | -16.45 ** | -29.41 ** |
| CR 1009 SUB 1 x Chandaikar | 4.89 | 40.88 ** | 35.42 ** | 82.84 | -11.36 ** | -12.95 ** | 20.90 | -19.01 ** | -28.59 ** |
| CR1009 SUB 1 x Norungan | 4.81 | 49.12 ** | 44.20 ** | 83.80 | -7.95 * | -8.67 * | 20.31 | -27.01 ** | -39.04 ** |
| CR 1009 SUB 1x Sivappumalli | 2.68 | -17.68 | -19.70 | 70.20 | 5.60 | -23.50 ** | 21.54 | 5.04 | -3.58 |
| CR 1009 sub 1x ADT 39 | 4.67 | 31.09 ** | 23.24 * | 83.92 | -9.44 ** | -10.32 ** | 20.77 | -15.05 ** | -21.82 ** |
| CR 1009 SUB 1 x TPS 3 | 3.07 | 19.64 | -8.00 | 82.09 | 13.08 ** | -10.54 ** | 19.23 | -5.17 | -13.94 * |
| White Ponni xThuyamalli | 3.82 | -13.02 | -14.99 * | 94.30 | 5.56 | -1.98 | 27.75 | 2.94 | -14.33 ** |
| White Ponni x Chandaikar | 3.62 | -10.61 | -19.36 * | 94.80 | 6.74 | -0.39 | 27.61 | 8.72 | -5.65 |
| White Ponni x Norungan | 3.48 | -8.59 | -22.63 ** | 91.01 | 5.36 | 0.78 | 25.46 | -7.16 | -23.59 ** |
| White Ponni x Sivappumalli | 3.53 | -7.79 | -21.36 ** | 94.03 | 52.09 ** | 14.04 ** | 24.23 | 20.56 ** | 12.57 |
| White Ponni xADT 39 | 2.88 | -30.35 ** | -35.83 ** | 92.07 | 4.60 | -1.62 | 24.95 | 3.74 | -6.11 |
| White Ponni x TPS 3 | 2.97 | -5.62 | -33.98 ** | 76.67 | 12.85 ** | -7.02 | 19.77 | -0.51 | -8.18 |
| TP10106 xThuyamalli | 2.15 | -29.12 ** | -49.88 ** | 93.74 | -0.61 | -2.55 | 22.19 | -18.67 ** | -31.49 ** |
| TP10106 xChandaikar | 2.73 | 1.42 | -24.35 * | 93.94 | 0.14 | -1.29 | 24.88 | -3.27 | -14.98 ** |
| TP10106 xNorungan | 2.90 | 18.47 | -6.96 | 90.79 | -0.64 | -1.79 | 22.84 | -17.70 ** | -31.46 ** |
| TP10106 xSivappumalli | 1.64 | -33.83 ** | -48.37 ** | 81.18 | 21.48 ** | -12.19 ** | 21.90 | 7.24 | -1.23 |
| TP10106 x ADT 39 | 1.65 | -40.56 ** | -56.34 ** | 85.16 | -8.44 * | -9.00 * | 20.76 | -14.82 ** | -21.87 ** |
| TP10106 x TPS 3 | 1.93 | 7.94 | 7.43 | 81.54 | 11.80 ** | -11.80 ** | 20.02 | -0.86 | -9.72 |

Thousand grain weight constitute an important trait for bold grain rice varieties as evidenced from the studies of (Zewdu 2020) Significant and positive heterosis over better parent ranged from 36.20(CR 1009 Sub 1 x ADT 39) to 6.88 (TP10106 x Chandaikar) was reported among nine cross combinations. Considering the impact of quality traits in generated cross combinations interpreted that positively significant milling per cent was shown by seven crosses with a range of significant values of 29 (White ponni x Thuyamalli) to 6.97 per cent (IR 20 x ADT 39) besides the head rice recovery exhibited positively significant heterobeltiosison 8 crosses with a range between7.13 (ACK 14072 x Norungan) and 31.83 (White ponni x Thuyamalli). Grain length and breadth also shown at significantly superiority level in 4 crosses with a range of 20.13 (ADT 38 x TPS 3) and the lowest heterosis value of 13.83 (ADT 38 xThuyamalli) in blemishing higher premium price of slender grain as investigated by (Bano and Singh 2018) [1]. Heterosis in negative direction is preferred for grain breadth to produce slender grains and21 hybrids exhibited significantly negative heterobeltiosis ranged from -11.59(CO 50 x Shivapumalli) to -35.26 (IR 20 x Thuyamalli).

The heterosis over better parent for trait length breadth ratio ranged from 38.78(ADT 38 xThuyamalli) to 17.82 (ADT 38 x ADT 39). While the length after cooking shown positively significant heterobeltiosis by 6 superior hybrids ranged from 23.72 (ADT 38 x ADT 39) to 6.17 (ADT 38 x Chandaikar), breadth after cooking exhibited negative heterobeltiosis in 16 hybrids with values from -11.50 (CO 50 x Shivapumalli) to -31.70 (IR 20 x Thuyamalli). Linear elongation ratio of cooked rice shown positive heterobeltiosis in 3 hybrids with values ranged from 14.04 (TP10106 x TPS 3) to 8.62 (IR 20 x Norungan) and 8.49 (TP10106 X ADT 39) besides in cooked rice, the breadth elongation ratio negative heterosis in 2 hybrids with values of -10.61 (White ponni x Chandaikar) and -22.14 (TP10106 x Norungan). The cooking quality of rice is highly influenced by gelatinization temperature such that low gelatinization variety requires less amount of water and cooks faster than one with high gelatinization (Tuaño *et al.*, (2018) [5] and hence negative heterosis is favored for gelatinization temperature. Twenty seven cross combinations had shown negative heterosis over better parent ranged from -14.99 (White ponni x Thuyamalli) to -56.34 (TP10106 x ADT 39)

and further plant breeders are also instigated to develop rice genotypes with soft gel consistency that registered negatively significant heterobeltiosis in 14 with values ranged from -8.67(CR 1009 sub 1 x Norungan) to -51.25 (CO 50 X TPS 3). Moreover, the rice grains with higher amylase content will show greater volume expansion and higher degree of flakiness that succumbs grain dry after cooking besides hard upon cooling since with low amylose content as pronounced by (Pokhrel *et al.*, 2020) [2].

From this study it was concluded that higher heterosis existed only for the yield components such as number of productive tiller panicle length, number of grains per panicle and single plant yield whereas lower heterobeltioticvigour was exhibited by the quality traits *viz.*, length breadth ratio, LER, BER and amylose content. The cross combinations *viz.*, White Ponnix Thuyamalli, White Ponnix Chandaikar, ADT 38 x ADT 39,IR 20 xThuyamalli, IR 20 x ADT 39,ACK14072 x Sivapumalli, CR 1009 sub 1 x ADT 39 and ADT 38 xThuyamalli could be exploited further to retrieve progenies exhibiting superior yield contributing traits.

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