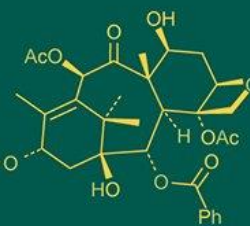
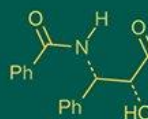


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## Heterosis studies in bread wheat (*Triticum aestivum* L.) for yield and its component traits over the environments

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### Abstract

A set of diallel crosses in bread wheat (*Triticum aestivum* L.) using 10 parents in full diallel design was attempted during rabi-2023-24 to estimate the extent of all three types of heterosis for yield and its component traits over two locations during rabi-2024-25. The magnitude of significant desirable heterosis, heterobeltiosis and useful heterosis (over check variety MACS-6478) were reported for grain yield and its component traits in promising direct and reciprocal crosses over the environments. Out of total 90 crosses (45 direct and 45 reciprocals) 23 crosses exhibited significant desirable heterosis, heterobeltiosis and useful heterosis for grain yield plant-1 over two locations and on pooled basis. The reciprocal cross MACS-6478 x HD-3086 exhibited highest significant heterosis (79.59%) on mid parent, heterobeltiosis (57.13%) on better parent and useful heterosis (51.78%) on check variety MACS-6478 over two locations on pooled basis. The other potential crosses that reported significant heterosis in all three categories were direct cross AKAW-2862-1 x SSN-2021-41 exhibited 77.94% heterosis, 42.32% heterobeltiosis and 39.13% useful heterosis followed by direct cross AKAW-1071 x MACS-6478 reported 50.12% heterosis, 44.74% heterobeltiosis and 39.82% useful heterosis. The crosses exhibited heterosis for grain yield plant-1 were not heterotic for all the traits. The character plant height was independently associated with grain yield plant-1. However, the traits viz, no. of grains spike-1, grain wt. spike-1 and 1000 grain wt. was closely associated with grain yield plant-1 on pooled environment basis. The study on heterosis reveals a good scope for isolation of superior genotypes from the subsequent segregating generations of these potential crosses for improvement of the grain yield and other yield component traits in wheat.

**Keywords:** Wheat, heterosis, heterobeltiosis, useful heterosis, grain yield, pooled environments

### Introduction

Bread wheat (*Triticum aestivum* L.) is the most important food grain crop among the cereals and stands next to rice in India. It is one of the ancient grain crops consumed as primary food by human beings since the dawn of civilization and is known as the protector of man from hunger. It is a self-pollinated crop belonging to the family Poaceae. It is a hexaploid species ( $2n=6x=42$ : AABBDD genomes) with 21 pairs of chromosomes. It significantly contributed towards the success of the “Green Revolution” and has greatly helped to transform our country from a situation of ship to mouth to become a self-sufficient. In India, it is the second most important crop after rice and occupies 318.33 lakh hectares with a total production of 1132.92 lakh tonnes and productivity of 3560 kg/ha during 2024-25 crop season (USDA Report, 2024-25). It is third ranking cereal crop in the world in terms of area and production followed by maize and rice. Major wheat growing states in India are Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar and Gujarat.

The term “heterosis”, which is now widely used in crop breeding, was coined by Shull (1908)<sup>[15]</sup>. It refers to the process in which the  $F_1$  hybrid obtained by crossing two individuals having dissimilar genetic constitution that shows either increased or decreased vigour over the better or mid parental value. The commercial utilization of the hybrid primarily is based on its performance that need to be compared with the best commercial variety of the region. Therefore, the term “useful heterosis or standard heterosis” suggested for comparing the yields of hybrids with that of the highest yielding and widely adopted commercial variety of

the region (Meredith and Bridge, 1972). Exploitation of heterosis is an important strategy for increasing the yield potential of wheat. However, wheat hybrids recorded 13.5% more yield than their parents due to hybrid stability, responsiveness to farm input and better tolerance to abiotic stress (Farooq *et al.*, 2014). The study of heterosis is useful in eliminating less productive crosses in F1 generation itself. The rejection of crosses, which shows no heterosis, would enable the breeder to concentrate the attention to few, but possibly more productive crosses [4, 11].

### Materials and methods

The present investigation was carried out at two locations viz, Wheat Research Unit, Dr PDKV, Akola (M.S.) and Agriculture Research Station, Niphad under MPKV, Rahuri (M.S.). The experimental material used was ten varieties of bread wheat (*Triticum aestivum* L.) viz, AKAW-3717, AKAW-2862-1, AKAW-2344, AKAW-1071, HD-3086, HI-1633, GW-2010-288, SSN-2021-41, AKW-381 and MACS-6478. These parental lines were crossed in all possible combinations including reciprocals during rabi-2023-24 at Wheat Research Unit, Dr PDKV, Akola. Total 90 crosses comprising 45 direct crosses and 45 reciprocal crosses were attempted in full diallel fashion.

These 90 crosses along with ten parents and a check variety MACS-6478 were evaluated in an experiment with full diallel fashion using Randomized Block Design with three replications at two locations viz, Wheat Research Unit, Dr PDKV, Akola (M.S.) and at Agriculture Research Station, Niphad, Dist-Nashik (M.S.) during rabi-2024-25. All recommended package of practices were followed at both the locations to raise the healthy crop. Ten observations were recorded viz, days to heading, days to maturity, plant height (cm), number of effective tillers plant-1, spike length (cm), number of spikelets spike-1, number of grains spike-1, grain weight spike-1 (g), 1000 grain weight (g) and grain yield plant-1 (g).

**Estimation of Heterosis, Heterobeltiosis and Economic Heterosis:** The per cent increase or decrease of F1 over the mid parent, better parent and best check variety has been referred as relative or average heterosis, heterobeltiosis and economic heterosis, respectively. Heterosis over mid parent and best standard check was calculated as per the usual procedure whereas; heterobeltiosis was calculated as per procedure suggested by Fonesca and Paterson (1968). They were calculated as follows.

#### i) Heterosis

$$\text{Heterosis (\%)} = \frac{F_1 - MP}{MP} \times 100$$

Its significance was tested by student 't' test as follows

$$t_{(f-1)(r-1)} = \frac{(F_1 - MP)}{SE_{(F_1 - MP)}}$$

$$SE_{(F_1 - MP)} = \sqrt{\frac{3MSe}{2r}}$$

#### ii) Heterobeltiosis

$$\text{Heterobeltiosis (\%)} = \frac{F_1 - BP}{BP} \times 100$$

Its significance was tested by student 't' test as follows

$$t_{(f-1)(r-1)} = \frac{(F_1 - BP)}{SE_{(F_1 - BP)}}$$

$$SE_{(F_1 - BP)} = \sqrt{\frac{2MSe}{r}}$$

#### iii) Economic Heterosis

$$\text{Economic Heterosis (\%)} = \frac{F_1 - SC}{SC} \times 100$$

Its significance was tested by student 't' test as follows

$$t_{(t-1)(r-1)} = \frac{(F_1 - SC)}{SE_{(F_1 - SC)}}$$

$$SE_{(F_1 - SC)} = \sqrt{\frac{2MSe}{2r}}$$

Where,

- F1 = Mean value of cross,
- MP = Mean of two parents of corresponding F1 i.e. (P1+P2)/ 2,
- P1 = Mean value of first parent,
- P2 = Mean of second parent,
- BP = Mean value of better parent,
- SC = Mean of check genotype,
- R = Number of replications,
- MSe = Error mean square,
- t = Table value of 't' at error d. f. corresponding to 5% or 1% level of significance.

Negative direction of heterosis has been considered desirable for the traits days to heading, days to maturity, plant height. Whereas, positive direction was considered desirable for rest of the characters.

### Results and Discussion

The range of heterosis, heterobeltiosis and useful heterosis over check variety MACS-6478 and the number of direct and reciprocal crosses that exhibited significant desirable heterosis for days to heading, days to maturity and plant height in negative direction and for other traits viz, number of effective tillers plant-1, spike length, number of spikelets spike-1, number of grains spike-1, grain weight spike-1, 1000 grain weight and grain yield plant-1 in positive direction is given in Table-1. It revealed that the number of crosses exhibited significant heterosis over mid parent are more followed by useful heterosis and heterobeltiosis. However, in plant breeding for commercialization of hybrids, its performance is tested over the check variety, so here useful heterosis is important criteria to select the promising crosses that performed better over the check variety for grain yield and other component traits.

The estimates of heterosis, heterobeltiosis and useful heterosis for grain yield plant-1 at different environments is shown in Table-2. At Akola the heterosis for grain yield plant-1 was ranged from -51.81 percent to 88.89 percent. The highest magnitude of heterosis was scored by direct crosses AKAW-2862-1 x SSN-2021-41 (88.89 percent), followed by AKAW-1071 x SSN-2021-41 (81.54 percent) and AKAW-2344 x SSN-2021-41 (81.85 percent). Out of 90

cross combinations including reciprocals 36 crosses showed significant heterosis in desirable direction. At Niphad the heterosis for grain yield plant-1 was ranged from -41.03 percent to 82.14 percent. The highest magnitude of heterosis was recorded by reciprocal crosses SSN-2021-41 x HI-1633 (82.14 percent) followed by MACS-6478 x HD-3086 (80.00 percent) and SSN-2021-41 x HD-3086 (74.55 percent). Out of 90 cross combinations including reciprocals 30 crosses showed significant heterosis in desirable direction. In pooled data the heterosis for grain yield plant-1 was ranged from -43.56 percent to 79.59 percent. The highest magnitude of heterosis was recorded by reciprocal crosses MACS-6478 x HD-3086 (79.59 percent) followed by SSN-2021-41 x HI-1633 (78.51 percent) and direct cross AKAW-2862-1 x SSN-2021-41 (77.94 percent). Out of 90 cross combinations including reciprocals 35 crosses showed significant heterosis in desirable direction.

The similar results showing the presence of significant heterosis for important yield and its component traits viz, days to maturity, plant height, number of effective tillers plant-1, spike length, number of spikelets spike-1, number of spikes plant-1, number of grains spike-1, grain weight spike-1, 1000 grain weight, grain yield plant-1 were reported by Ahmad and Jaiswal (2016), Sharma *et al.* (2018), Kumar *et al.* (2018), Nagar *et al.* (2019), Kumar *et al.* (2020), Marwa and Ali (2021), Bilgin *et al.* (2022), Choudhary *et al.* (2022), Gungor *et al.* (2024) and Yadav *et al.* (2025) [8, 9, 10, 12, 14, 19].

At Akola the heterobeltiosis for grain yield plant-1 was ranged from -55.56 percent to 56.71 percent. The highest magnitude of heterobeltiosis was recorded by direct crosses AKAW-2344 x SSN-2021-41 (56.71 percent) followed by AKAW-1071 x SSN-2021-41 (55.32 percent) and reciprocal cross MACS-6478 x HD-3086 (53.31 percent). Out of 90 cross combinations including reciprocals 30 crosses showed significant heterobeltiosis in desirable direction. At Niphad the heterobeltiosis for grain yield plant-1 was ranged from -45.33 percent to 61.54 percent. The highest magnitude of heterobeltiosis was recorded by reciprocal crosses MACS-6478 x HD-3086 (61.54 percent) followed by SSN-2021-41 x HI-1633 (59.38 percent) and direct cross AKAW-1071 x MACS-6478 (56.45 percent). Out of 90 cross combinations including reciprocals 26 crosses showed significant heterobeltiosis in desirable direction.

In pooled data the heterobeltiosis for grain yield plant-1 was ranged from -45.90 percent to 57.13 percent. The highest magnitude of heterobeltiosis was recorded by reciprocal crosses MACS-6478 x HD-3086 (57.13 percent) followed by SSN-2021-41 x HI-1633 (54.29 percent) and direct cross AKAW-2344 x SSN-2021-41 (52.93 percent). Out of 90 cross combinations including reciprocals 31 crosses showed significant heterobeltiosis in desirable direction.

The similar findings for showing the significant heterobeltiosis over better parents for important yield and yield contributing traits like days to heading, days to maturity, plant height, number of effective tillers plant-1, spike length, number of spikelets spike-1, number of grains spike-1, grain weight spike-1, 1000 grain weight, grain yield plant-1 were also reported by Ahmad and Jaiswal (2016), Sharma *et al.* (2018), Kumar *et al.* (2018), Saren *et al.* (2018), Nagar *et al.* (2019), Tomar *et al.* (2020), Upadhyay *et al.* (2020), Kumar *et al.* (2020), Bilgin *et al.* (2022), Choudhary *et al.* (2022), Khan *et al.* (2022), Gungor *et al.* (2024) and Yadav *et al.* (2025) [2, 3, 6, 7, 8, 9, 12, 13, 14, 16, 17, 19].

At Akola the useful heterosis for grain yield plant-1 was ranged from -53.51 percent to 60.40 percent. The highest magnitude of useful heterosis was recorded by the reciprocal cross MACS-6478 x HD-3086 (60.40 percent) followed by direct crosses AKAW-2862-1 x SSN-2021-41 (58.08 percent) and GW-2010-288 x MACS-6478 (55.75 percent). Out of 90 cross combinations including reciprocals 26 crosses showed significant useful heterosis in desirable direction. At Niphad the useful heterosis for grain yield plant-1 was ranged from -52.26 percent to 45.44 percent. The highest magnitude of useful heterosis was recorded by reciprocal crosses AKAW-1071 x AKAW-2344 (45.44 percent) followed by MACS-6478 x HD-3086 (43.21 percent) and direct cross AKAW-1071 x MACS-6478 (42.30 percent). Out of 90 cross combinations including reciprocals 10 crosses showed significant useful heterosis in desirable direction. In pooled data the useful heterosis for grain yield plant-1 was ranged from -48.26 percent to 51.78 percent. The highest magnitude of useful heterosis was recorded by reciprocal cross MACS-6478 x HD-3086 (51.78 percent) followed by direct crosses AKAW-1071 x MACS-6478 (39.82 percent) and cross GW-2010-288 x MACS-6478 (39.13 percent). Out of 90 cross combinations including reciprocals 24 crosses showed significant useful heterosis in desirable direction.

The similar findings for showing the significant useful heterosis over the check variety for important yield and yield contributing traits like days to heading, days to maturity, plant height, number of effective tillers plant-1, spike length, number of spikelets spike-1, number of grains spike-1, grain weight spike-1, 1000 grain weight, grain weight plant-1 were also reported by Ahmad and Jaiswal (2016), Kumar *et al.* (2018), Sharma *et al.* (2018), Saren *et al.* (2018), Nagar *et al.* (2019), Khan *et al.* (2022), Yadav *et al.* (2022) and recently by Yadav *et al.* (2025) [1, 7, 8, 12, 13, 14, 18, 19].

The crosses exhibited heterosis for grain yield plant-1 was not heterotic for all the traits (Table-3). The character plant height was independently associated with grain yield plant-1. However, the traits viz, no. of grains spike-1, grain wt. spike-1 and 1000 grain wt. was closely associated with grain yield plant-1 on pooled environment basis. The study on heterosis reveals a good scope for isolation of superior genotypes from the subsequent segregating generations of these potential crosses for improvement of the grain yield and other yield component traits in wheat.

## Conclusion

Overall results on analysis of three types of heterosis i.e average heterosis (H1) over mid parent value, heterobeltiosis (H2) over the better parent and Useful heterosis (H3) over the check variety MACS-6478 at two locations viz, Akola and Niphad and also on pooled data revealed that the following two direct crosses viz., AKAW-2862-1 x SSN-2021-41 and AKAW-1071 x MACS-6478 were exhibited higher significant heterosis for grain yield plot-1 (77.94% and 50.12%) on mid parent value over two environments in pooled data. These two direct crosses also exhibited significant heterobeltiosis for grain yield plot-1 (44.05% and 44.76%) and also recorded highest significant useful heterosis over check variety MACS-6478 for grain yield plot-1 (44.05% and 44.76%). Whereas, one reciprocal cross MACS-6478 x HD-3086 exhibited significant heterosis for higher grain yield (79.59%) over two

environments in pooled data. It has also recorded significant heterobeltiosis for higher grain yield plot-1 (57.14%) and recorded highest significant useful heterosis for grain yield plot-1 (57.14%) over the check variety MACS-6478.

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### Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

### Competing Interests

Authors have declared that no competing interests exist.

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**Table 1:** Range of heterosis, heterobeltiosis and useful heterosis and number of promising crosses for ten characters on two locations

| Sr No | Character                                    | Range of heterosis (%) |                 |                 |                 |                 |                 |                  |                 |                 | Number of promising crosses |             |             |                 |             |             |                  |             |             |
|-------|----------------------------------------------|------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|------------------|-----------------|-----------------|-----------------------------|-------------|-------------|-----------------|-------------|-------------|------------------|-------------|-------------|
|       |                                              | Heterosis              |                 |                 | Heterobeltiosis |                 |                 | Useful heterosis |                 |                 | Heterosis                   |             |             | Heterobeltiosis |             |             | Useful heterosis |             |             |
|       |                                              | A k o l a              | N i p h a d     | P o o l e d     | A k o l a       | N i p h a d     | P o o l e d     | A k o l a        | N i p h a d     | P o o l e d     | A k o l a                   | N i p h a d | P o o l e d | A k o l a       | N i p h a d | P o o l e d | A k o l a        | N i p h a d | P o o l e d |
| 1     | Days to heading                              | -15.31 to 11.78        | -9.54 to 8.74   | -10.22 to 8.86  | -13.96 to 28.30 | -8.47 to 13.89  | -14.57 to 18.22 | -13.88 to 9.04   | -13.54 to 4.69  | -12.63 to 3.95  | 25                          | 5           | 14          | 3               | 1           | 8           | 3                | 23          | 37          |
| 2     | Days to maturity                             | -8.22 to 9.04          | -5.16 to 4.45   | -5.83 to 5.59   | -6.42 to 16.78  | -3.95 to 6.74   | -3.84 to 10.63  | -5.59 to 8.83    | -7.28 to 1.96   | -5.74 to 1.72   | 20                          | 4           | 13          | 3               | 0           | 3           | 6                | 13          | 23          |
| 3     | Plant height                                 | -24.53 to 5.02         | -22.36 to 10.43 | -18.78 to 6.30  | -19.25 to 14.58 | -16.30 to 11.48 | -15.50 to 13.08 | -16.07 to 18.34  | -18.99 to 9.60  | -16.02 to 12.38 | 25                          | 29          | 40          | 7               | 12          | 21          | 4                | 33          | 21          |
| 4     | No. of effective tillers plant <sup>-1</sup> | -10.50 to 33.73        | -8.74 to 49.86  | -9.74 to 41.07  | -15.34 to 23.97 | -15.88 to 45.52 | -15.57 to 41.34 | -11.30 to 22.83  | -11.36 to 31.65 | -9.24 to 23.02  | 37                          | 39          | 45          | 23              | 23          | 37          | 17               | 12          | 26          |
| 5     | Spike length                                 | -23.26 to 21.36        | -26.60 to 14.10 | -22.15 to 15.06 | -35.79 to 14.00 | -40.90 to 13.15 | -36.84 to 11.81 | -17.35 to 39.64  | -20.09 to 20.62 | -18.22 to 30.16 | 5                           | 5           | 5           | 1               | 1           | 2           | 2                | 1           | 3           |
| 6     | No. of spikelets spike <sup>-1</sup>         | -12.85 to 11.66        | -12.68 to 9.95  | -12.77 to 9.72  | -19.87 to 8.74  | -18.58 to 9.32  | -19.24 to 8.34  | -9.47 to 16.84   | -12.40 to 16.23 | -11.20 to 16.50 | 11                          | 8           | 10          | 4               | 2           | 3           | 7                | 4           | 7           |
| 7     | No. of grains spike <sup>-1</sup>            | -21.55 to 25.84        | -31.33 to 22.10 | -21.21 to 16.95 | -26.38 to 18.04 | -32.35 to 20.01 | -25.51 to 15.32 | -8.84 to 32.52   | -35.99 to 11.33 | -20.17 to 21.13 | 16                          | 9           | 18          | 7               | 3           | 4           | 31               | 1           | 8           |
| 8     | Grains wt. spike <sup>-1</sup>               | -15.72 to 63.98        | -23.62 to 53.80 | -23.36 to 55.70 | -24.26 to 60.18 | -25.41 to 49.18 | -23.53 to 52.84 | -23.90 to 66.90  | -27.21 to 48.73 | -25.36 to 57.96 | 36                          | 36          | 44          | 22              | 18          | 29          | 17               | 9           | 17          |
| 9     | 1000 grain wt.                               | -12.81 to 41.73        | -13.81 to 35.24 | -12.14 to 36.55 | -14.05 to 40.67 | -18.99 to 34.89 | -15.11 to 31.30 | -25.94 to 25.57  | -15.15 to 38.21 | -19.90 to 28.93 | 26                          | 31          | 36          | 22              | 13          | 22          | 1                | 16          | 9           |
| 10    | Grain yield plant <sup>-1</sup>              | -51.81 to 88.89        | -41.03 to 82.14 | -43.56 to 79.59 | -55.56 to 56.71 | -45.33 to 61.54 | -45.90 to 57.13 | -53.51 to 60.40  | -52.26 to 45.44 | -48.26 to 51.78 | 36                          | 30          | 35          | 30              | 26          | 31          | 26               | 10          | 24          |

**Table 2:** Estimates of heterosis, heterobeltiosis and useful heterosis for grain yield plant-1 at different environments.

| Sr<br>No       | Genotypes               | Grain weight plant <sup>-1</sup> (g) |          |          |                 |          |          |                  |          |          |
|----------------|-------------------------|--------------------------------------|----------|----------|-----------------|----------|----------|------------------|----------|----------|
|                |                         | Heterosis                            |          |          | Heterobeltiosis |          |          | Useful heterosis |          |          |
|                |                         | Akola                                | Niphad   | Pooled   | Akola           | Niphad   | Pooled   | Akola            | Niphad   | Pooled   |
| Direct crosses |                         |                                      |          |          |                 |          |          |                  |          |          |
| 1              | AKAW-3717 x AKAW-2862-1 | -29.41**                             | -33.33** | -31.25** | -37.52**        | -33.34** | -35.31** | -30.26**         | -43.17** | -36.76** |
| 2              | AKAW-3717 x AKAW-2344   | -6.49                                | -14.71*  | -10.34*  | -17.10*         | -10.03   | -13.37** | -16.31**         | -34.08** | -25.26** |
| 3              | AKAW-3717 x AKAW-1071   | -5.13                                | -9.33    | -7.19    | -15.03*         | -7.53    | -8.97*   | -13.99**         | -22.71** | -18.36** |
| 4              | AKAW-3717 x HD-3086     | 2.78                                 | -12.12   | -4.35    | -17.10*         | -7.53    | -12.04*  | -13.99**         | -34.08** | -24.11** |
| 5              | AKAW-3717 x HI-1633     | 25.64**                              | 16.42*   | 21.38**  | 11.48           | 22.46**  | 17.28**  | 13.91*           | -11.35*  | 1.18     |
| 6              | AKAW-3717 x GW-2010-288 | 12.71**                              | 4.11     | 8.70*    | 0.04            | 8.28     | 4.38     | 9.26             | -13.62*  | -2.27    |
| 7              | AKAW-3717 x SSN-2021-41 | -1.49                                | 22.03**  | 9.52*    | 2.91            | -17.53** | -8.04    | -23.29**         | -18.17** | -20.66** |
| 8              | AKAW-3717 x AKW-381     | 43.21**                              | 22.62**  | 33.42**  | 17.14**         | 41.50**  | 29.72**  | 34.83**          | 2.29     | 18.43**  |
| 9              | AKAW-3717 x MACS-6478   | -20.00**                             | -13.51*  | -16.98** | -17.95**        | -24.45** | -21.43** | -20.96**         | -27.26** | -24.11** |
| 10             | AKAW-2862-1 x AKAW-2344 | -9.76*                               | -15.07*  | -12.26** | -22.53**        | -17.79** | -20.02** | -13.99**         | -29.53** | -21.81** |
| 11             | AKAW-2862-1 x AKAW-1071 | 44.58**                              | 20.00**  | 32.52**  | 19.96**         | 33.32**  | 27.03**  | 39.48**          | 9.11     | 24.18**  |
| 12             | AKAW-2862-1 x HD-3086   | 53.25**                              | 38.03**  | 45.95**  | 22.46**         | 31.09**  | 27.03**  | 37.16**          | 11.38*   | 24.18**  |
| 13             | AKAW-2862-1 x HI-1633   | 37.35**                              | 38.89**  | 38.06**  | 24.96**         | 26.65**  | 25.85**  | 32.51**          | 13.66*   | 23.03**  |

|    |                           |          |          |          |          |          |          |          |          |          |
|----|---------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 14 | AKAW-2862-1 x GW-2010-288 | 40.27**  | 30.77**  | 35.82**  | 27.46**  | 37.76**  | 32.91**  | 44.13**  | 15.93**  | 29.93**  |
| 15 | AKAW-2862-1 x SSN-2021-41 | 88.89**  | 65.63**  | 77.94**  | 32.45**  | 51.09**  | 42.32**  | 58.08**  | 20.48**  | 39.13**  |
| 16 | AKAW-2862-1 x AKW-381     | -27.91** | -33.67** | -30.66** | -35.02** | -31.12** | -32.96** | -27.94** | -40.90** | -34.46** |
| 17 | AKAW-2862-1 x MACS-6478   | 31.11**  | 34.18**  | 32.54**  | 32.45**  | 31.09**  | 31.73**  | 37.16**  | 20.48**  | 28.78**  |
| 18 | AKAW-2344 x AKAW-1071     | -9.33    | -17.81** | -13.51** | -25.03** | -10.49   | -17.95** | -20.96** | -31.81** | -26.41** |
| 19 | AKAW-2344 x HD-3086       | 10.14    | -9.38    | 0.75     | -12.11   | 2.67     | -4.24    | -11.66*  | -34.08** | -22.96** |
| 20 | AKAW-2344 x HI-1633       | 20.00**  | 10.77    | 15.71**  | 9.11     | 18.46**  | 15.77**  | 4.61     | -18.17** | -6.86    |
| 21 | AKAW-2344 x GW-2010-288   | -27.86** | -18.31** | -23.38** | -23.66** | -33.19** | -28.77** | -32.58** | -34.08** | -33.31** |
| 22 | AKAW-2344 x SSN-2021-41   | 81.25**  | 71.93**  | 76.86**  | 48.51**  | 56.71**  | 52.93**  | 34.83**  | 11.38*   | 23.03**  |
| 23 | AKAW-2344 x AKW-381       | 2.56     | -10.36   | -3.61    | -16.70*  | -2.41    | -9.32*   | -7.01    | -27.26** | -17.21** |
| 24 | AKAW-2344 x MACS-6478     | -39.02** | -30.56** | -35.06** | -35.90** | -44.45** | -40.46** | -41.88** | -43.17** | -42.51** |
| 25 | AKAW-1071 x HD-3086       | -25.71** | -21.13** | -23.40** | -30.02** | -31.55** | -30.77** | -39.56** | -36.35** | -37.91** |
| 26 | AKAW-1071 x HI-1633       | -34.21** | -36.11** | -35.14** | -42.52** | -34.19** | -38.46** | -41.88** | -47.72** | -44.81** |
| 27 | AKAW-1071 x GW-2010-288   | 22.85**  | 7.69     | 15.43**  | 4.96     | 15.19**  | 12.98**  | 16.23**  | -4.53    | 5.78     |
| 28 | AKAW-1071 x SSN-2021-41   | 81.54**  | 50.00**  | 65.89**  | 19.96**  | 55.32**  | 37.18**  | 37.16**  | 9.11     | 23.03**  |
| 29 | AKAW-1071 x AKW-381       | -16.46** | -26.02** | -21.22** | -27.53** | -19.49** | -21.92** | -23.29** | -34.08** | -28.71** |
| 30 | AKAW-1071 x MACS-6478     | 42.17**  | 58.48**  | 50.12**  | 56.45**  | 31.09**  | 44.75**  | 37.16**  | 42.30**  | 39.82**  |
| 31 | HD-3086 x HI-1633         | 65.71**  | 46.03**  | 56.39**  | 43.66**  | 52.69**  | 48.64**  | 34.83**  | 4.56     | 19.58**  |
| 32 | HD-3086 x GW-2010-288     | 29.97**  | 15.94*   | 23.27**  | 5.30     | 12.89*   | 9.29*    | 13.91*   | -9.07    | 2.33     |
| 33 | HD-3086 x SSN-2021-41     | 45.76**  | 34.55**  | 40.35**  | 19.34*   | 34.30**  | 26.94**  | -0.04    | -15.89** | -8.01*   |
| 34 | HD-3086 x AKW-381         | -20.55** | -27.95** | -24.16** | -34.92** | -29.25** | -31.99** | -32.58** | -43.17** | -37.91** |
| 35 | HD-3086 x MACS-6478       | 9.09     | 2.86     | 6.12     | -7.69    | -6.68    | -7.15    | -2.36    | -18.17** | -10.31*  |
| 36 | HI-1633 x GW-2010-288     | -31.20** | -28.57** | -29.99** | -34.19** | -35.49** | -34.92** | -34.91** | -43.17** | -39.06** |
| 37 | HI-1633 x SSN-2021-41     | 75.38**  | 67.86**  | 71.90**  | 46.79**  | 50.06**  | 48.64**  | 32.51**  | 6.84     | 19.58**  |
| 38 | HI-1633 x AKW-381         | -29.11** | -40.34** | -34.40** | -45.33** | -31.69** | -38.29** | -34.91** | -52.26** | -43.66** |
| 39 | HI-1633 x MACS-6478       | -34.94** | -32.39** | -33.77** | -38.46** | -40.01** | -39.29** | -37.23** | -45.44** | -41.36** |
| 40 | GW-2010-288 x SSN-2021-41 | 2.27     | 0.00     | 1.21     | -18.39** | -17.06** | -17.72** | -16.31** | -29.53** | -22.96** |
| 41 | GW-2010-288 x AKW-381     | -40.76** | -39.79** | -40.30** | -40.13** | -42.41** | -41.06** | -41.88** | -47.72** | -44.81** |
| 42 | GW-2010-288 x MACS-6478   | 51.58**  | 40.26**  | 46.31**  | 38.46**  | 48.87**  | 44.04**  | 55.75**  | 22.75**  | 39.13**  |
| 43 | SSN-2021-41 x AKW-381     | -14.71*  | 8.97     | -3.37    | -11.49   | -29.25** | -20.66** | -32.58** | -22.71** | -27.56** |
| 44 | SSN-2021-41 x MACS-6478   | -16.67** | -23.81** | -20.00** | -38.46** | -33.34** | -35.72** | -30.26** | -45.44** | -37.91** |
| 45 | AKW-381 x MACS-6478       | 0.00     | -6.98    | -3.30    | -7.69    | -4.46    | -5.96    | -0.04    | -18.17** | -9.16    |

Table 2 cont....

| Sr No | Genotypes                 | Grain weight plant <sup>-1</sup> (g) |          |          |                 |          |          |                  |          |          |
|-------|---------------------------|--------------------------------------|----------|----------|-----------------|----------|----------|------------------|----------|----------|
|       |                           | Heterosis                            |          |          | Heterobeltiosis |          |          | Useful heterosis |          |          |
|       |                           | Akola                                | Niphad   | Pooled   | Akola           | Niphad   | Pooled   | Akola            | Niphad   | Pooled   |
|       | <b>Reciprocal crosses</b> |                                      |          |          |                 |          |          |                  |          |          |
| 46    | AKAW-2862-1 x AKAW-3717   | -29.41**                             | -36.00** | -32.50** | -40.02**        | -33.34** | -36.49** | -30.26**         | -45.44** | -37.91** |
| 47    | AKAW-2344 x AKAW-3717     | -37.66**                             | -38.24** | -37.93** | -39.97**        | -40.02** | -40.03** | -44.21**         | -52.26** | -48.26** |
| 48    | AKAW-2344 x AKAW-2862-1   | 34.15**                              | 28.77**  | 31.61**  | 17.46**         | 22.21**  | 19.97**  | 27.86**          | 6.84     | 17.28**  |
| 49    | AKAW-1071 x AKAW-3717     | -20.51**                             | -30.67** | -25.49** | -35.02**        | -22.53** | -26.92** | -27.94**         | -40.90** | -34.46** |
| 50    | AKAW-1071 x AKAW-2862-1   | -51.81**                             | -35.00** | -43.56** | -35.02**        | -55.56** | -45.90** | -53.51**         | -40.90** | -47.11** |
| 51    | AKAW-1071 x AKAW-2344     | -25.33**                             | -34.25** | -29.73** | -40.02**        | -26.29** | -33.33** | -34.91**         | 45.44**  | -40.21** |
| 52    | HD-3086 x AKAW-3717       | -25.00**                             | -27.27** | -26.09** | -31.40**        | -32.52** | -32.03** | -37.23**         | -45.44** | -41.36** |

|    |                           |          |          |          |          |          |          |          |          |          |
|----|---------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 53 | HD-3086 x AKAW-2862-1     | 42.86**  | 32.39**  | 37.84**  | 17.46**  | 22.21**  | 19.97**  | 27.86**  | 6.84     | 17.28**  |
| 54 | HD-3086 x AKAW-2344       | -1.45    | -18.75** | -9.77*   | -21.20** | -8.14    | -14.24** | -20.96** | -40.90** | -31.01** |
| 55 | HD-3086 x AKAW-1071       | 20.00**  | 9.86     | 14.89**  | -2.53    | 10.57    | 3.85     | -2.36    | -11.35*  | -6.86    |
| 56 | HI-1633 x AKAW-3717       | -30.77** | -28.36** | -29.66** | -31.40** | -32.52** | -32.03** | -37.23** | -45.44** | -41.36** |
| 57 | HI-1633 x AKAW-2862-1     | -37.35** | -25.00** | -31.61** | -32.52** | -42.23** | -37.66** | -39.56** | -38.63** | -39.06** |
| 58 | HI-1633 x AKAW-2344       | -1.33    | -4.62    | -2.86    | -6.04    | -2.60    | -2.81    | -13.99** | -29.53** | -21.81** |
| 59 | HI-1633 x AKAW-1071       | 44.74**  | 22.22**  | 33.78**  | 9.96     | 44.79**  | 26.92**  | 27.86**  | 0.02     | 13.83**  |
| 60 | HI-1633 x HD-3086         | 65.71**  | 39.68**  | 53.38**  | 37.42**  | 52.69**  | 45.79**  | 34.83**  | 0.02     | 17.28**  |
| 61 | GW-2010-288 x AKAW-3717   | -40.05** | -36.99** | -38.62** | -39.45** | -42.41** | -41.06** | -41.88** | -47.72** | -44.81** |
| 62 | GW-2010-288 x AKAW-2862-1 | 49.32**  | 35.90**  | 43.03**  | 32.45**  | 46.65**  | 39.97**  | 53.43**  | 20.48**  | 36.83**  |
| 63 | GW-2010-288 x AKAW-2344   | -25.37** | -23.94** | -24.70** | -28.92** | -30.89** | -30.00** | -30.26** | -38.63** | -34.46** |
| 64 | GW-2010-288 x AKAW-1071   | -31.20** | -41.03** | -36.01** | -42.52** | -35.49** | -37.37** | -34.91** | -47.72** | -41.36** |
| 65 | GW-2010-288 x HD-3086     | -23.08** | -33.33** | -27.98** | -39.45** | -33.19** | -36.14** | -32.58** | -47.72** | -40.21** |
| 66 | GW-2010-288 x HI-1633     | 49.88**  | 40.00**  | 45.31**  | 28.99**  | 40.53**  | 35.08**  | 41.80**  | 11.38*   | 26.48**  |
| 67 | SSN-2021-41 x AKAW-3717   | 40.30**  | 35.59**  | 38.10**  | 14.34**  | 17.46**  | 16.00**  | 9.26     | -9.07    | 0.03     |
| 68 | SSN-2021-41 x AKAW-2862-1 | 36.13**  | 68.75**  | 51.48**  | 35.00**  | 8.89     | 21.18**  | 13.92*   | 22.75**  | 18.44**  |
| 69 | SSN-2021-41 x AKAW-2344   | -31.25** | -19.30*  | -25.62** | -30.30** | -40.56** | -35.71** | -48.86** | -47.72** | -48.26** |
| 70 | SSN-2021-41 x AKAW-1071   | 53.85**  | 34.38**  | 44.19**  | 7.50     | 31.63**  | 19.23**  | 16.23**  | -2.25    | 6.93     |
| 71 | SSN-2021-41 x HD-3086     | 38.98**  | 74.55**  | 56.14**  | 54.84**  | 28.05**  | 41.27**  | -4.69    | 9.11     | 2.33     |
| 72 | SSN-2021-41 x HI-1633     | 75.38**  | 82.14**  | 78.51**  | 59.38**  | 50.06**  | 54.29**  | 32.51**  | 15.93**  | 24.18**  |
| 73 | SSN-2021-41 x GW-2010-288 | 10.80    | 45.16**  | 26.89**  | 18.42**  | -10.15   | 3.19     | -9.34    | 2.29     | -3.41    |
| 74 | AKW-381 x AKAW-3717       | 6.17     | -7.36    | -0.26    | -11.49** | 4.91     | -3.03    | -0.04    | -22.71** | -11.46** |
| 75 | AKW-381 x AKAW-2862-1     | 6.98     | -3.06    | 2.19     | -5.03    | 2.21     | -1.20    | 6.93     | -13.62*  | -3.41    |
| 76 | AKW-381 x AKAW-2344       | 48.72**  | 31.65**  | 40.56**  | 22.35**  | 41.50**  | 32.24**  | 34.83**  | 6.84     | 20.73**  |
| 77 | AKW-381 x AKAW-1071       | 16.46**  | -3.06    | 6.73     | -5.03    | 12.23*   | 5.79     | 6.93     | -13.62*  | -3.41    |
| 78 | AKW-381 x HD-3086         | 58.90**  | 35.45**  | 47.47**  | 22.35**  | 41.50**  | 32.24**  | 34.83**  | 6.84     | 20.73**  |
| 79 | AKW-381 x HI-1633         | -29.11** | -31.82** | -30.39** | -37.52** | -31.69** | -34.51** | -34.91** | -45.44** | -40.21** |
| 80 | AKW-381 x GW-2010-288     | -5.21    | -8.38    | -6.72    | -8.89    | -7.85    | -7.90    | -7.01    | -20.44** | -13.76** |
| 81 | AKW-381 x SSN-2021-41     | 29.41**  | 12.18    | 21.17**  | -8.89    | 7.35     | -0.51    | 2.29     | -20.44** | -9.16*   |
| 82 | MACS-6478 x AKAW-3717     | -41.18** | -16.22*  | -29.56** | -20.51** | -44.45** | -33.34** | -41.88** | -29.53** | -35.61** |
| 83 | MACS-6478 x AKAW-2862-1   | 11.11*   | 6.33     | 8.88*    | 4.96     | 11.10*   | 8.21*    | 16.23**  | -4.53    | 5.78     |
| 84 | MACS-6478 x AKAW-2344     | -31.71** | -36.94** | -34.16** | -41.79** | -37.79** | -39.65** | -34.91** | -48.40** | -41.70** |
| 85 | MACS-6478 x AKAW-1071     | -34.94** | -34.18** | -34.57** | -35.02** | -40.01** | -36.91** | -37.23** | -40.90** | -39.06** |
| 86 | MACS-6478 x HD-3086       | 79.22**  | 80.00**  | 79.59**  | 61.54**  | 53.31**  | 57.13**  | 60.40**  | 43.21**  | 51.78**  |
| 87 | MACS-6478 x HI-1633       | -44.58** | -29.58** | -37.66** | -35.90** | -48.90** | -42.86** | -46.53** | -43.17** | -44.81** |
| 88 | MACS-6478 x GW-2010-288   | -43.44** | -37.66** | -40.75** | -38.46** | -44.45** | -41.67** | -41.88** | -45.44** | -43.66** |
| 89 | MACS-6478 x SSN-2021-41   | -2.78    | -7.94    | -5.19    | -25.64** | -22.23** | -23.81** | -18.64** | -34.08** | -26.41** |
| 90 | MACS-6478 x AKW-381       | -13.95** | -19.90** | -16.77** | -20.51** | -17.79** | -19.05** | -13.99** | -29.53** | -21.81** |
|    | SE (M)±                   | 0.515    | 0.552    | 0.387    | 0.638    | 0.594    | 0.447    | 0.594    | 0.638    | 0.447    |
|    | CD (5%)                   | 1.436    | 1.540    | 1.080    | 1.778    | 1.658    | 1.247    | 1.658    | 1.778    | 1.247    |
|    | CD (1%)                   | 1.893    | 2.031    | 1.424    | 2.345    | 2.186    | 1.645    | 2.186    | 2.345    | 1.645    |

\* Significance at 5% level \*\* significance at 1% level

**Table 3.** Relationship of significant desirable heterosis (H1), heterobeltiosis (H2) and useful heterosis (H3) for grain yield per plant with other yield contributing characters over the environments (pooled).

| Sr No | Crosses                          | Type of heterosis | Grain yield plant <sup>-1</sup> | Days to heading | Days to maturity | Plant height | No. of effective tillers plant <sup>-1</sup> | Spike length | No. of spikelets spike <sup>-1</sup> | No. of grains spike <sup>-1</sup> | Grains wt. spike <sup>-1</sup> | 1000 grain wt. |
|-------|----------------------------------|-------------------|---------------------------------|-----------------|------------------|--------------|----------------------------------------------|--------------|--------------------------------------|-----------------------------------|--------------------------------|----------------|
| 1     | P <sub>1</sub> x P <sub>9</sub>  | H <sub>1</sub>    | 33.42**                         | -               | -                | -            | 10.85**                                      | -            | -                                    | 6.51*                             | 24.05**                        | 16.64**        |
|       | 8                                | H <sub>2</sub>    | 29.72**                         | -               | -                | -            | -                                            | -            | -                                    | -                                 | 22.53**                        | 15.74**        |
|       |                                  | H <sub>3</sub>    | 18.43**                         | -               | -                | -            | 15.44**                                      | -            | -                                    | -                                 | -                              | -              |
| 2     | P <sub>2</sub> x P <sub>4</sub>  | H <sub>1</sub>    | 32.52**                         | -               | -2.34*           | -            | 23.02**                                      | -            | -                                    | -                                 | -                              | -              |
|       | 11                               | H <sub>2</sub>    | 27.03**                         | -               | -                | -            | 18.37**                                      | -            | -                                    | -                                 | -                              | -              |
|       |                                  | H <sub>3</sub>    | 24.18**                         | -6.31**         | -4.16**          | -            | 15.30**                                      | -            | -                                    | -                                 | -                              | -              |
| 3     | P <sub>2</sub> x P <sub>5</sub>  | H <sub>1</sub>    | 45.95**                         | -               | -                | -            | 31.88**                                      | -            | -                                    | 9.28**                            | 28.66**                        | 18.13**        |
|       | 12                               | H <sub>2</sub>    | 27.03**                         | -               | -                | -            | 29.68**                                      | -            | -                                    | -                                 | 18.10**                        | 15.65**        |
|       |                                  | H <sub>3</sub>    | 24.18**                         | -6.57**         | -3.30*           | -            | 16.76**                                      | -            | -                                    | -                                 | 14.70**                        | 13.76**        |
| 4     | P <sub>2</sub> x P <sub>6</sub>  | H <sub>1</sub>    | 38.06**                         | -               | -                | -            | 26.94**                                      | -            | -                                    | -                                 | 26.16**                        | 19.77**        |
|       | 13                               | H <sub>2</sub>    | 25.85**                         | -               | -                | -            | 23.70**                                      | -            | -                                    | -                                 | 25.26**                        | 19.31**        |
|       |                                  | H <sub>3</sub>    | 23.03**                         | -6.84**         | -3.88**          | -            | 17.36**                                      | -            | -                                    | -                                 | 23.24**                        | 17.37**        |
| 5     | P <sub>2</sub> x P <sub>7</sub>  | H <sub>1</sub>    | 35.82**                         | -               | -                | -            | 26.22**                                      | -            | -                                    | -                                 | 18.10**                        | 23.15**        |
|       | 14                               | H <sub>2</sub>    | 32.91**                         | -               | -                | -            | 20.08**                                      | -            | -                                    | -                                 | 14.42**                        | 23.04**        |
|       |                                  | H <sub>3</sub>    | 29.93**                         | -6.84**         | -3.88**          | -            | 19.77**                                      | -            | -                                    | -                                 | 18.34**                        | 21.04**        |
| 6     | P <sub>2</sub> x P <sub>8</sub>  | H <sub>1</sub>    | 77.94**                         | -               | -                | -            | 24.36**                                      | -            | -                                    | -                                 | 24.08**                        | 17.70**        |
|       | 15                               | H <sub>2</sub>    | 42.32**                         | -               | -                | -            | 16.67**                                      | -            | -                                    | -                                 | 11.82**                        | 8.23*          |
|       |                                  | H <sub>3</sub>    | 39.13**                         | -4.73*          | -                | -            | -                                            | -            | -                                    | -                                 | 8.61**                         | -              |
| 7     | P <sub>2</sub> x P <sub>10</sub> | H <sub>1</sub>    | 32.54**                         | -               | -2.40*           | -            | 25.91**                                      | -            | -                                    | -                                 | 11.45**                        | 7.04*          |
|       | 17                               | H <sub>2</sub>    | 31.73**                         | -               | -                | -            | 18.75**                                      | -            | -                                    | -                                 | 10.05**                        | -              |
|       |                                  | H <sub>3</sub>    | 28.78**                         | -7.89**         | -3.88**          | -            | 20.63**                                      | -            | -                                    | -                                 | 9.47**                         | -              |
| 8     | P <sub>3</sub> x P <sub>8</sub>  | H <sub>1</sub>    | 76.86**                         | -3.24**         | -                | -            | 40.10**                                      | 15.06**      | 9.72**                               | 11.38**                           | 31.44**                        | 18.11**        |
|       | 22                               | H <sub>2</sub>    | 52.93**                         | -               | -                | -            | 31.22**                                      | -            | 16.50**                              | -                                 | 19.68**                        | 16.18**        |
|       |                                  | H <sub>3</sub>    | 23.03**                         | -               | -                | -            | 18.57**                                      | 30.16**      | -                                    | 13.83**                           | 13.96**                        | -              |

**Table 3. cont....**

| Sr No | Crosses                          | Type of heterosis | Grain yield plant <sup>-1</sup> | Days to heading | Days to maturity | Plant height | No. of effective tillers plant <sup>-1</sup> | Spike length | No. of spikelets spike <sup>-1</sup> | No. of grains spike <sup>-1</sup> | Grains wt. spike <sup>-1</sup> | 1000 grain wt. |
|-------|----------------------------------|-------------------|---------------------------------|-----------------|------------------|--------------|----------------------------------------------|--------------|--------------------------------------|-----------------------------------|--------------------------------|----------------|
| 9     | P <sub>4</sub> x P <sub>8</sub>  | H <sub>1</sub>    | 65.89**                         | -               | -                | -            | 29.40**                                      | -            | 9.28**                               | 14.18**                           | 29.76**                        | 13.43**        |
|       | 28                               | H <sub>2</sub>    | 37.18**                         | -               | -                | -            | 17.11**                                      | -            | 6.90**                               | 10.73**                           | 16.91**                        | -              |
|       |                                  | H <sub>3</sub>    | 23.03**                         | -               | -                | -            | 14.07**                                      | -            | 6.35**                               | 10.82**                           | 14.11**                        | -              |
| 10    | P <sub>4</sub> x P <sub>10</sub> | H <sub>1</sub>    | 50.12**                         | -               | -                | -            | 19.29**                                      | -            | 4.15*                                | 12.11**                           | -                              | -              |
|       | 30                               | H <sub>2</sub>    | 44.75**                         | -               | -                | -            | 16.83**                                      | -            | 4.13*                                | 9.46**                            | -                              | -              |
|       |                                  | H <sub>3</sub>    | 39.82**                         | -               | -                | -            | 18.69**                                      | -            | -                                    | 14.97**                           | -                              | -              |
| 11    | P <sub>5</sub> x P <sub>6</sub>  | H <sub>1</sub>    | 56.39**                         | -               | -                | -            | 19.51**                                      | -            | -                                    | 11.46**                           | 15.37**                        | -              |
|       | 31                               | H <sub>2</sub>    | 48.64**                         | -               | -                | -            | 14.58**                                      | -            | -                                    | -                                 | 5.37*                          | -              |
|       |                                  | H <sub>3</sub>    | 19.58**                         | -7.89**         | -4.31**          | -            | 8.71*                                        | -            | -                                    | -                                 | -                              | -              |
| 12    | P <sub>6</sub> x P <sub>8</sub>  | H <sub>1</sub>    | 71.90**                         | -3.48*          | -                | -            | 27.07**                                      | 6.13*        | -                                    | 8.22**                            | 28.95**                        | 20.52**        |
|       | 37                               | H <sub>2</sub>    | 48.64**                         | -               | -                | -            | 16.38**                                      | -            | -                                    | -                                 | 15.44**                        | 11.21**        |

|    |                                  |                |         |         |         |   |         |         |       |         |         |         |
|----|----------------------------------|----------------|---------|---------|---------|---|---------|---------|-------|---------|---------|---------|
|    |                                  | H <sub>3</sub> | 19.58** | -4.99*  | -       | - | 10.41** | -       | -     | -       | 13.78** | 8.56*   |
| 13 | P <sub>7</sub> x P <sub>10</sub> | H <sub>1</sub> | 46.31** | -3.74*  | -2.49*  | - | 11.38** | 14.95** | 3.67* | 15.81** | 55.70** | 34.42** |
|    | 42                               | H <sub>2</sub> | 44.04** | -       | -       | - | 10.37** | 11.81** | -     | 15.32** | 52.84** | 31.30** |
|    |                                  | H <sub>3</sub> | 39.13** | -8.68** | 4.59**  | - | 12.12** | 10.70** | 4.46* | 21.13** | 57.96** | 28.93** |
| 14 | P <sub>3</sub> x P <sub>2</sub>  | H <sub>1</sub> | 31.61** | -4.24*  | -2.78*  | - | 23.67** | -       | -     | -       | 9.07**  | 17.66** |
|    | 48                               | H <sub>2</sub> | 19.97** | -       | -       | - | 23.88** | -       | -     | -       | 7.96**  | 9.86*   |
|    |                                  | H <sub>3</sub> | 17.28** | 4.99*   | -       | - | 11.54** | -       | 4.28* | -       | 4.86*   | 8.07*   |
| 15 | P <sub>5</sub> x P <sub>2</sub>  | H <sub>1</sub> | 37.84** | -       | -       | - | 24.90** | -       | -     | 14.44** | 15.19** | -       |
|    | 53                               | H <sub>2</sub> | 19.97** | -       | -       | - | 22.81** | -       | -     | 7.22*   | 5.89*   | -       |
|    |                                  | H <sub>3</sub> | 17.28** | -7.89** | -4.16** | - | 10.58** | -       | -     | -       | -       | -       |
| 16 | P <sub>6</sub> x P <sub>5</sub>  | H <sub>1</sub> | 53.38** | -       | -       | - | 18.18** | 6.50*   | -     | 16.02** | 24.26** | 7.50*   |
|    | 60                               | H <sub>2</sub> | 45.79** | -       | -       | - | 13.97** | -       | -     | 7.70*   | 13.28** | -       |
|    |                                  | H <sub>3</sub> | 17.28** | -6.31** | -3.73** | - | 8.13*   | -       | -     | 7.17*   | 11.66** | -       |

Table 3. cont....

| Sr No | Crosses                          | Type of heterosis | Grain yield plant <sup>-1</sup> | Days to heading | Days to maturity | Plant height | No. of effective tillers plant <sup>-1</sup> | Spike length | No. of spikelets spike <sup>-1</sup> | No. of grains spike <sup>-1</sup> | Grains wt. spike <sup>-1</sup> | 1000 grain wt. |
|-------|----------------------------------|-------------------|---------------------------------|-----------------|------------------|--------------|----------------------------------------------|--------------|--------------------------------------|-----------------------------------|--------------------------------|----------------|
| 17    | P <sub>7</sub> x P <sub>2</sub>  | H <sub>1</sub>    | 37.28**                         | -               | -                | -            | 20.95**                                      | 14.79**      | 6.70**                               | 16.95**                           | 25.75**                        | 7.51*          |
|       | 62                               | H <sub>2</sub>    | 19.97**                         | -               | -                | -            | 15.07**                                      | 6.10*        | 5.74*                                | 13.25**                           | 29.93**                        | -              |
|       |                                  | H <sub>3</sub>    | 17.28**                         | -8.68**         | -4.59**          | -            | 14.77**                                      | -            | 6.87**                               | 17.95**                           | 26.01**                        | -              |
| 18    | P <sub>7</sub> x P <sub>6</sub>  | H <sub>1</sub>    | 45.31**                         | -               | -                | -            | 14.31**                                      | 12.11**      | 3.67*                                | -                                 | 12.57**                        | 14.42**        |
|       | 66                               | H <sub>2</sub>    | 35.08**                         | -               | -                | -            | 11.52**                                      | 10.57**      | -                                    | -                                 | 15.45**                        | 14.09**        |
|       |                                  | H <sub>3</sub>    | 26.48**                         | -8.94**         | -4.88**          | -            | 11.23**                                      | 9.47**       | -                                    | -                                 | 13.59**                        | 12.03**        |
| 19    | P <sub>8</sub> x P <sub>2</sub>  | H <sub>1</sub>    | 51.48**                         | -               | -                | -            | 41.07**                                      | 6.12*        | -                                    | -                                 | 21.31**                        | 16.49**        |
|       | 68                               | H <sub>2</sub>    | 21.18**                         | -               | -                | -            | 32.35**                                      | -            | -                                    | -                                 | 9.49**                         | -              |
|       |                                  | H <sub>3</sub>    | 18.44**                         | -               | -                | -            | 19.17**                                      | -            | -                                    | -                                 | 6.19*                          | -              |
| 20    | P <sub>8</sub> x P <sub>6</sub>  | H <sub>1</sub>    | 78.51**                         | -               | -                | -            | 30.64**                                      | -            | 8.51**                               | 8.67*                             | 16.67**                        | -              |
|       | 72                               | H <sub>2</sub>    | 54.29**                         | -               | -                | -            | 19.65**                                      | -            | 8.34**                               | -                                 | -                              | -              |
|       |                                  | H <sub>3</sub>    | 24.18**                         | -               | -                | -            | 13.52**                                      | -            | -                                    | -                                 | -                              | -              |
| 21    | P <sub>9</sub> x P <sub>3</sub>  | H <sub>1</sub>    | 40.56**                         | -6.36**         | -3.19**          | -            | 19.15**                                      | -            | -                                    | -                                 | 11.30**                        | 19.74**        |
|       | 76                               | H <sub>2</sub>    | 32.24**                         | -14.57**        | -                | -            | 24.83**                                      | -            | -                                    | -                                 | -                              | 19.05**        |
|       |                                  | H <sub>3</sub>    | 20.73**                         | -8.94**         | -4.16**          | -            | 12.79**                                      | -            | -                                    | -                                 | -                              | -              |
| 22    | P <sub>9</sub> x P <sub>5</sub>  | H <sub>1</sub>    | 47.47**                         | -               | -                | -            | 16.76**                                      | -            | -                                    | -                                 | 13.24**                        | -              |
|       | 78                               | H <sub>2</sub>    | 32.24**                         | -7.86**         | -                | -            | 24.76**                                      | -            | -                                    | -                                 | 12.27**                        | -              |
|       |                                  | H <sub>3</sub>    | 20.73**                         | 10.52**         | -5.17**          | -            | 8.59*                                        | -            | -                                    | -                                 | -                              | -              |
| 23    | P <sub>10</sub> x P <sub>5</sub> | H <sub>1</sub>    | 79.59**                         | -               | -                | -            | 30.43**                                      | 5.88*        | 4.39*                                | 7.69*                             | 19.00**                        | 10.68**        |
|       | 86                               | H <sub>2</sub>    | 57.13**                         | -               | -                | -            | 41.34**                                      | -            | -                                    | -                                 | 8.09**                         | 10.32*         |
|       |                                  | H <sub>3</sub>    | 51.78**                         | -               | -                | -            | 23.02**                                      | -            | -                                    | -                                 | 7.58**                         | -              |