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# Heterotic potential of basmati fertility restorers for grain yield and its components in rice (*Oryza sativa* L.)

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## Abstract

**Basmati rice (*Oryza sativa* L.) which is characterized with long slender superfine grain, exquisite aroma and high volume expansion resulting from linear cooked kernel elongation with minimum breadthwise swelling is an internationally traded commodity. It's yields are as low as one third of non-basmati rice. A study was undertaken to evaluate the heterotic potential of basmati fertility restorers for grain yield and its components, phenological and morphological traits. Forty-five improved germplasm lines of aromatic and non-aromatic rices were test crossed with four cytoplasmic male sterile (CMS) lines *viz.*, IR 5 8025 A, IR 62829A, PMS 10A and PMS 3 A of wild abortive cytosterile source to identify fertility restorers with basmati background. Eighty-four hybrids derived from 4 CMS lines and 21 restorers were evaluated in a randomised block design (RBD) for heterosis. Observations were recorded for grain yield and its components, phenological and morphological traits. Analysis of variance revealed significant differences (p < 0.01) among hybrids for all traits. Five of the basmati restorers having fertility restoration > 80% produced hybrids with heterobeltiosis ranging from 20.64 to 150.66% and superiority over check ranging from 15.17 to 284.55%. Hybrids were superior to their parents for grain yield per plant, biological yield per plant, days to 50% flowering, number of effective tillers per plant and number of primaries per panicle indicated substantial heterosis. However, superiority of parents over hybrids for harvest index, 1000 grain weight and days to maturity revealed negative heterosis. Hybrid IR 58025A × Basmati 385 recorded the highest (56.26 g) grain yield per plant. The restorers Basmati 385 and HKR 241 were found heterotic with all four CMS lines. Based on yield performance and heterosis promising hybrids of basmati restorers identified were PMS 3A × P1031-8-5-1 (early), IR 58025A × Basmati 385, IR 62829A × Basmati 385, IR 62829A × HKR 241 (medium) and PMS 3A × HKR 241 (late). Heterosis in grain yield was due to concomitant heterosis in one or more major yield components. Hybrids exhibiting higher grain yield also combined heterosis for semi-dwarf plant type and reduced total growth duration. As the restorers were tall and late in maturity, to develop semi-dwarf, high yielding basmati hybrids fitting into multiple cropping system it is suggested to use stiff stem dwarf and early maturing basmati CMS lines as and when available.**


**Key words:** Rice, basmati hybrids, heterosis, fertility restorers

## Introduction

Rice (*Oryza sativa* L.) grown in the states of Punjab, Haryana, Western Uttar Pradesh and Uttaranchal will have to find place in the international market as the major rice growing states have become self sufficient in rice production. To remain competitive in the international market, the choice lies with the basmati rice. This region is also gifted with agronomic conditions most conducive for the production of best quality basmati rice. Basmati rice is known and preferred for its unique cooking and eating quality. It is characterized with long slender superfine grain, exquisite aroma, high volume expansion resulting from linear cooked kernel elongation with minimum breadthwise swelling, fluffiness, appealing taste and longer shelf life. This kind of rice fetches a premium in the national and international market earning annually a substantial foreign exchange worth $ 800 million [1]. However, yield of traditional basmati varieties is as low as l/3rd of the semi-dwarf high yielding non-basmati varieties. Commercial exploitation of heterosis to increase rice yields has been successfully demonstrated in China. Rice hybrids yield about 20% higher than varieties. In order to increase production and export, the Indian Council of Agricultural Research (ICAR) has intensified research on hybrid development including in basmati rice. Development of basmati rice is one of the main mandate of Indian Agricultural Research Institute (IARI), New Delhi where the present research work was carried out.

The principal steps in hybrid breeding programme are the development of parental lines namely cytoplasmic male sterile (CMS) A line, its maintainer B line and fertility restorer R line and their evaluation for relative combining ability and heterosis. Several CMS lines of non-basmati and a few of basmati origin suited to local conditions have been developed and a few of them have been reported to be relatively more stable. But none of the available CMS lines possess as typical basmati quality attributes. Similar is the case with available restorers pertaining to quality. To develop A and R lines with required basmati quality characteristics advanced progenies from conventional breeding program

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were evaluated to identify right kind of restorers and maintainers possessing typical basmati quality attributes. The authors have been successful in identifying fertility restorers and sterility maintainers possessing basmati characteristics [2, 3]. So with the identification and availability of basmati fertility restorers and sterility maintainers, stage has been set for the development of basmati hybrids as and when basmati CMS lines are developed. The performance of rice hybrids and their heterotic potential for grain yield and its components, phenological and morphological attributes have been reported in this article to evaluate these basmati fertility restorers.

**Materials and methods**

*Experiment I*: Four CMS lines *viz.*, IR 58025A, IR 62829A, PMS 10A and PMS 3A and 45 improved basmati germplasm developed at IARI, New Delhi including 18 non-aromatic disease resistant collections from the Rice Research Station CCS, Haryana Agricultural University, Kaul were used in the study. Crosses in all combinations between CMS A lines and pollen parents were effected. The $F_1$ seeds of successful crosses were germinated in petriplates. The seedlings were transplanted to raised nursery beds after four days of germination as off season nursery at Rice Breeding and Genetics Research Centre, Aduthurai (South India). Thirty day old seedlings were transplanted in the main field at a spacing of 20cm × 15cm with row length 1.5 m. Randomised complete block design (RBD) with two replications was followed. Standard agronomic practices were employed for raising normal crop. Pollen and spikelet fertility was estimated as described by Sarial and Singh [3]. Based on pollen and spikelet fertility 19 restorers (11 basmati and 8 non-basmati type) categorized as effective and partial restorers and two maintainers (basmati type) were selected and crosses attempted in Line × Tester design to produce 1.5-2.0 g hand crossed seeds for each of the 84 hybrids for experiment II.

*Experiment II*: The hybrids were raised in 2m length plot at a spacing of 20cm × 15cm with two replications in RBD at IARI, New Delhi. Nursery raising and transplanting were carried out like Experiment 1. Hybrids were grown together followed by parents in contiguous plots in RBD randomizing hybrids and parents separately. Three checks namely, Pusa 169, Pusa 44-33 and PR-110, representing medium-early, medium and late growth duration for grain yield and its components, phonological and morphological traits were included.

*Observations*: The observations were recorded on five randomly selected plants per genotype per replication for grain yield per plant, biological yield per plant, harvest index, 1000 grain weight, days to 50% flowering, days to maturity, plant height, number of effective tillers per plant and number of primary branches per panicle. Two pollen parents as maintainers and their hybrids were excluded from seed related characteristics.

*Estimation of heterosis*: The magnitude of heterosis was expressed as heterosis over mid parent (Ha), better parent (Hb) and superiority over check variety (Sc).

**Results and discussion**

ANOVA revealed that there were significant differences among parents and hybrids for yield and its components, phenological and morphological traits. Among yield and its components, however, hybrids differed significantly for grain yield per plant and biological yield per plant but there were no significant differences among the parents. Partitioning of parents mean squares indicated that female parents showed significant difference for phenological and morphological traits. There were no significant differences among female parents for yield and its components. Variances due to male parents differed significantly for all traits except grain yield per plant and biological yield per plant. The comparison of female vs male parents revealed that they differed significantly for harvest index and 1000 test grain weight, days to 50% flowering, plant height and effective tillers per plant. Average heterosis as indicated by 1 degree of freedom comparison, parents vs hybrids mean squares was significant for grain yield per plant, biological yield per plant and phenological and morphological traits.

*Mean performance of hybrids and parents*: Out of total 84 hybrids, mean performance of 20 hybrids, those involving 5 effective basmati restorers and 4 non-basmati CMS lines are given in Table 1. Mean grain yield per plant of parents and hybrids ranged from 11.00 to 25.17 g and 13.13 to 56.26 g; biological yield per plant 25.92 to 50.72 g and 32.36 to 111.58 g; harvest index 0.31 to 0.57 and 0.22 to 0.55; 1000 grain weight 16.65 to 25.17 g and 20.25 to 23.84; days to 50% flowering 86.00 to 104.00 and 93.50 to 114.00; days to maturity 122.00 to 144.00 and 116.00 to 149.00; plant height 74.40 to 120.40 cm and 92.80 to 139.10 cm; effective tillers per plant 6.60 to 17.80 and 10.40 to 26.80 and primaries per panicle from 7.20 to 11.20 and 9.20 to 14.45, respectively. Hybrids were higher in range than parents for grain yield per plant, biological yield per plant, days to 50% flowering, effective tillers per plant and primaries per panicle and lower for harvest index, 1000 grain weight and days to maturity. Hybrid IR 58025A × Basmati 385 recorded the highest grain and biological yield per plant followed by IR 62829A × Basmati 385 and IR 62829A × HKR

**Table 1.** Mean performance of hybrids (involving basmati restorers) and parents for different traits

| Sl. No. | Hybrids/parents | GYP(g) | BYP(g) | HI | TGW (g) | DTF | DTM | PHT (cm) | ETP | PPP |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | IR 58025A/P1031-8-5-1 | 19.23 | 42.02 | 0.48 | 23.37 | 96.50 | 114.00 | 89.50 | 17.00 | 11.00 |
| 2. | IR 62829A/P1031-8-5-1 | 16.67 | 32.47 | 0.50 | 23.08 | 94.00 | 114.00 | 98.80 | 17.50 | 10.40 |
| 3. | PMS 10A/P1031-8-5-1 | 16.85 | 32.36 | 0.52 | 21.77 | 95.00 | 132.00 | 102.95 | 12.75 | 10.25 |
| 4. | PMS 3A/P1031-8-5-1 | 33.06 | 64.46 | 0.51 | 20.40 | 93.50 | 116.00 | 92.80 | 26.80 | 11.70 |
| 5. | IR 58025A/HKR 241 | 22.39 | 47.49 | 0.48 | 22.35 | 95.00 | 132.00 | 116.20 | 12.00 | 10.90 |
| 6. | IR 62829A/HKR 241 | 39.00 | 82.40 | 0.47 | 23.84 | 97.00 | 132.00 | 113.00 | 18.20 | 11.10 |
| 7. | PMS 10A/HKR 241 | 30.54 | 69.88 | 0.44 | 21.45 | 106.50 | 133.00 | 103.50 | 13.40 | 13.40 |
| 8. | PMS 3A/HKR 241 | 36.89 | 71.35 | 0.51 | 20.25 | 105.00 | 149.00 | 107.40 | 13.65 | 14.45 |
| 9. | IR 58025A/Basmati 385 | 56.26 | 111.58 | 0.52 | 22.67 | 96.50 | 127.50 | 120.30 | 19.90 | 12.80 |
| 10. | IR 62829A/Basmati 385 | 45.92 | 88.10 | 0.51 | 22.25 | 95.00 | 127.50 | 120.50 | 17.00 | 10.20 |
| 11. | PMS 10A/Basmati 385 | 28.33 | 51.99 | 0.55 | 22.92 | 94.50 | 132.00 | 123.50 | 12.30 | 11.30 |
| 12. | PMS 3A/Basmati 385 | 34.80 | 64.52 | 0.54 | 21.13 | 101.50 | 132.00 | 117.00 | 12.80 | 11.80 |
| 13. | IR 58025A/SAF Khalsa 7 | 20.31 | 52.19 | 0.45 | 20.92 | 103.00 | 144.00 | 116.30 | 15.10 | 11.20 |
| 14. | IR 62829A/SAF Khalsa 7 | 23.17 | 54.12 | 0.41 | 22.39 | 97.00 | 131.00 | 122.80 | 21.40 | 9.80 |
| 15. | PMS 10A/SAF Khalsa 7 | 17.36 | 42.03 | 0.43 | 21.30 | 112.00 | 149.00 | 116.70 | 10.40 | 12.30 |
| 16. | PMS 3A/SAF Khalsa 7 | 30.27 | 67.24 | 0.39 | 21.17 | 111.50 | 149.00 | 117.30 | 15.20 | 13.50 |
| 17. | IR 58025A/Karnal Local | 30.36 | 71.65 | 0.43 | 21.22 | 104.00 | 143.50 | 139.10 | 18.10 | 10.80 |
| 18. | IR 62829A/Karnal Local | 30.39 | 67.74 | 0.43 | 23.58 | 106.00 | 143.50 | 134.50 | 19.40 | 9.20 |
| 19. | PMS 10A/Karnal Local | 19.56 | 62.03 | 0.31 | 21.63 | 114.00 | 149.00 | 131.40 | 14.40 | 11.00 |
| 20. | PMS 3A/Karnal Local | 13.13 | 57.53 | 0.22 | 22.38 | 114.00 | 149.00 | 128.90 | 12.20 | 11.50 |
| 21. | P 1031-8-5-1-1 | 11.00 | 25.92 | 0.43 | 25.17 | 94.00 | 129.50 | 103.35 | 12.50 | 9.00 |
| 22. | HKR 241 | 13.13 | 39.86 | 0.33 | 21.92 | 99.00 | 143.00 | 120.40 | 6.60 | 10.10 |
| 23. | Bas 385 | 15.99 | 35.05 | 0.45 | 20.45 | 97.00 | 130.50 | 120.30 | 10.60 | 10.10 |
| 24. | SAF Khalsa 7 | 11.59 | 32.71 | 0.31 | 22.58 | 115.00 | 144.00 | 103.40 | 11.00 | 10.40 |
| 25. | Karnal Local | 19.04 | 49.81 | 0.38 | 22.87 | 104.00 | 135.00 | 130.00 | 15.00 | 7.80 |
| 26. | IR 58025B | 25.17 | 50.72 | 0.50 | 17.76 | 98.00 | 131.50 | 90.70 | 17.80 | 10.50 |
| 27. | IR 62829B | 18.32 | 32.44 | 0.56 | 18.33 | 86.00 | 123.00 | 74.40 | 17.20 | 7.20 |
| 28. | PMS 10B | 22.53 | 44.60 | 0.50 | 16.65 | 94.00 | 132.00 | 80.00 | 12.20 | 11.20 |
| 29. | PMS 3B | 20.51 | 35.94 | 0.57 | 16.77 | 103.00 | 133.50 | 80.70 | 10.20 | 10.40 |
| 30. | PUSA 169 | 14.00 | 41.59 | 0.34 | 21.78 | 95.00 | 122.00 | 97.00 | 12.50 | 8.50 |
| 31. | PR 110 | 14.63 | 36.02 | 0.41 | 23.51 | 98.00 | 131.00 | 96.50 | 11.50 | 11.10 |
| 32. | PUSA 44-33 | 15.00 | 32.06 | 0.47 | 23.02 | 105.00 | 140.00 | 80.00 | 10.00 | 11.00 |

GYP = Grain yield per plant, BYP = Biological yield per plant, HI = Harvest index, TGW = 1000 grain weight, DTF = Days to 50% flowering, DTM = Days to maturity, PHT = Plant height, ETP = Effective tillers per plant, PPP = Primaries per panicle

241. In general, hybrids of restorer Basmati 385 recorded highest grain yield and harvest index followed by HKR 241 while those of P1031-8-5-1 exhibited higher 1000 grain weight, shortest plant height and medium maturity whereas hybrids of Karnal Local and SAF Khalsa 7 were late in maturity.

*Heterosis*: Heterosis, heterobeltiosis and superiority over check in per cent of 20 hybrids involving basmati restorers for different traits are given in Table 2. Among hybrids involving basmati restorers nine showed significant positive heterosis, seven heterobeltiosis and 11 superiority over check ranging from 62.69 to 173.41%, 59.61 to 150.66% and 93.64 to 284.55%, respectively for grain yield per plant. The highest yielding hybrid IR 58025A × Basmati 385 showed highest significant positive heterosis and superiority over check. In order of merit, other high yielding and heterobeltiotic hybrids which exhibited significant superiority over checks were IR 62829A × Basmati 385, IR 62829A × HKR241, PMS 3A × HKR 241, PMS 3A × Basmati 385 and PMS 3A × P1031-8-5-1. In general, hybrids involving Basmati 385 and HKR 241 were significantly heterobeltiotic and superior over respective checks. In case of biological yield per plant 11 hybrids had significant positive heterosis, eight heterobeltiosis and 12 superiority over check which varied from 42.53 to 161.06%, 56.71 to 151.36% and 54.99 to 209.77%, respectively. For harvest index only two hybrids *viz*., PMS 10A × Basmati 385 (13.54 %) and IR 58025A × HKR 241 (16.36 %) showed significant positive heterosis while 9 hybrids exhibited significant superiority over check ranging from 17.07 to 50.00 %. For test grain weight nine hybrids showed significant positive heterosis varying from 11.21 to 23.50 % while one hybrid (PMS 10A × Bas 385) showed significant heterobeltiosis (12.03 %).

In case of days to 50% flowering 11 hybrids recorded significant positive heterosis, 14 heterobeltiosis and seven had significant superiority over check ranging from 2.29 to 15.15 %, 4.64 to 23.26 % and 3.57 to 8. 57%, respectively. The range for significant positive heterosis, heterobeltiosis and superiority over check showing earliness varied from −12.64 to −2.67%, −11.97 to −7.32 and −6.56 to −2.67% exhibited by six, three and five hybrids, respectively for days to maturity. The fifteen hybrids which exhibited significant heterosis for plant height were also significantly heterobeltiotic and superior over check. However, only one hybrid IR 58025A × P 1031-8-5-1 recorded significant negative heterosis showing dwarfness. The range of significant positive heterosis for effective tillers per plant varied from 40.14 to 136.12 % for five hybrids, superiority over check from 50.00 to 114.40% for seven while two hybrids were found significant over better parent. Primaries per panicle had significant positive heterosis varying from 20.62 to 40.98 % showed by six heterobeltiosis from 19.64 to 38.94% recorded by four and superiority over check from 15.31 to 37.65 % exhibited by eight hybrids.

Heterotic advantage of hybrids over parental lines must be sufficiently large to justify increased cost of hybrid seed production particularly in self pollinated crops like rice. Though the magnitude of heterosis varied among the hybrids, the superiority of hybrids to their parents indicated substantial heterosis for grain yield per plant, biological yield per plant, days to 50% flowering, effective tillers per plant and primaries per panicle. However, superiority of parents to hybrids derived from them revealed nagative heterosis for harvest index, and days to maturity. Moderate to high estimates of heterosis for yield and its components were observed. Based on yield performance, extent of heterosis, heterobeltiosis and superiority over checks, promising hybrids of basmati restorers identified were PMS 3A × P1031-8-5-1 (early), IR 58025A × Basmati 385, IR 62829A × Basmati 385, IR 62829A × HKR 241 (medium) and PMS 3A × HKR241 (late). Heterotic expression for major components had trends similar to grain yield. Heterosis in grain yield was due to concomitant heterosis in one or more major yield components like biological yield, effective tillers, primaries per panicle (Table 2), number of spikelets per panicle and panicle length [4]. The magnitude of positive heterosis for biological yield per plant was higher indicating that increased grain yield was invariably due to increased dry matter production. In general, all heterotic hybrids showed significant positive heterosis for biological yield. Similar results were also reported by earlier workers [5-7].

As regards relationship between biological yield and harvest index observation made by [8, 9] support present findings that mostly the $F_1$ hybrids tended to have lower harvest index as compared to parents. Hybrids had similar 1000 seed weight but those involving Basmati 385 and HKR 241 revealed highly significant heterosis based on mid parental values. This trait as well as tiller number per plant should be considered when selecting high yielding cultivars. The significant *gca* of seed weight [4] and heterosis expressed by crosses suggest that these restorers would be suitable parents for breeding programme aimed at improving seed size. The hybrids have also shown significant heterosis for tillers number and primaries per panicle but heterobeltiosis and superiority over check for these traits were significant in some cases only.

The restorers included in our study were semi-tall to tall (103-130 cm) and CMS lines dwarf to semi-dwarf (74.40-90.70 cm). Majority of the hybrids exhibited significant positive heterosis for plant height over short and mid parental values but were not tall than taller parent thereby showing tendency towards dwarfness except hybrids of Karnal Local. This is an encouraging trend to breed semi-dwarf hybrids so as to prevent lodging due to tall plant type and weak stem of traditional basmati cultivars. It is quite remarkable to note that almost all hybrids exhibiting higher grain yield also combined significant heterosis for plant height. The higher magnitude of positive heterosis for plant height was also reported by [10, 11 and 7]. In general, hybrids with restorers PI 031-8-5-1, HKR 241 and Basmati 385 flowered earlier than their parents and standard check while those of SAF Khalsa 7 and Karnal Local exhibited lateness. The magnitude of *gca* were also highest for these parents. P1031-8-5-1 was the only restorer with significant negative *gca* effect, hence good for developing hybrids with shorter duration [4] The negative heterosis for days to flowering is advantageous because this leads to earlier maturity consequently enabling the hybrids to increase per day productivity. Negative heterosis for days to 50% flowering and days to maturity combined with heterobeltiosis and superiority over check for grain yield of those restorers is highly encouraging as the hybrids would not only be superior in their yield potential but also exhibit higher productivity and shorter duration.

These findings are in confirmatory with the earlier reports of [7, 11 and 12]. Selection of parents for days to 50% flowering and plant height depends upon the objectives and target environment the breeder has in mind. For optimally managed and multiple cropping systems earliness and short height are in general preferred whereas in ill drained and deep water situations generally late and taller varieties fit better. In case of medium duration representing typical basmati varieties semi-dwarf plant type with sturdy culms should form a

**Table 2.** Heterosis (upper), heterobeltiosis (middle) and superiority over check (lower) in % of hybrids involving basmati restorers for different traits in rice

| | | GYP(g) | BYP (g) | HI | TGW (g) | DTF | DTM | PHT (cm) | ETP | PPP |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | IR 58025A/P1031-8-5-1-1 | 6.30 | 9.66 | 3.26 | 8.86 | 0.52 | −12.64** | −7.76* | 12.21 | 12.82 |
| | | −23.60 | −17.15 | −4.04 | −7.15 | 2.66 | −11.97** | −1.32 | −4.49 | 4.76 |
| | | 37.36 | 1.03 | 41.18** | 7.30 | 1.58 | −6.56** | −7.73* | 36.00 | 29.41** |
| 2. | IR 62829A/P1031-8-5-1-1 | 13.69 | 11.27 | 2.02 | 6.09 | 4.44** | −9.70** | 11.17** | 17.85 | 28.40 |
| | | −9.01 | 0.08 | −10.62 | −8.32 | 9.30** | −7.32** | 32.80** | 1.74 | 15.56 |
| | | 19.07 | 21.93 | 47.06** | 5.97 | −1.05 | −6.56** | 1.86 | 40.00 | 22.35* |
| 3. | PMS 10A/P1031-8-5-1-1 | 0.49 | −8.21 | 12.90 | 4.10 | 1.06 | 0.96 | 12.30** | 3.24 | 1.49 |
| | | −25.21 | −27.40 | 3.84 | −13.51** | 1.06 | 1.93 | 28.69** | 2.00 | −8.48 |
| | | 15.17 | 10.16 | 26.83** | −7.40 | −3.06* | 0.76 | 6.68* | 10.87 | −7.66 |
| 4. | PMS 3A/P1031-8-5-1-1 | 109.80** | 108.44** | 2.00 | −2.73 | −5.08** | −11.79** | 0.84 | 136.12** | 20.62* |
| | | 61.19* | 79.37** | −11.30 | −18.95** | −0.53 | −10.42** | 14.99** | 114.40** | 12.50 |
| | | 136.40** | 54.99* | 50.00** | −6.34 | −1.58 | −4.92* | −4.33 | 114.40** | 37.65* |
| 5. | IR 58025A/HKR 241 | 16.93 | 4.85 | 16.36* | 12.61* | −3.55** | −3.06* | 0.38 | 28.11** | −32.58* |
| | | −11.03 | −6.38 | −3.03 | 1.94 | −3.06* | 0.38 | 28.11** | −32.58* | 3.81 |
| | | 53.04 | 31.84 | 17.07* | −4.93 | −3.06 | 0.76 | 20.41** | 4.35 | −1.80 |
| 6. | IR 62829A/HKR 241 | 148.04** | 127.91** | 6.15 | 18.46** | 4.86** | −0.75 | 16.02** | 52.94* | 28.32 |
| | | 112.91** | 106.71** | −15.93* | 8.76 | 12.79** | 7.32** | 51.88** | 5.81 | 9.90 |
| | | 166.57** | 144.67** | 14.63 | 1.40 | −1.02 | 0.76 | 17.10** | 58.26** | 0.00 |
| 7. | PMS 10A/HKR 241 | 71.28** | 65.50** | 5.39 | 11.21* | 10.36** | −3.27** | 3.29 | 42.55 | 25.82** |
| | | 35.55 | 56.71* | −12.87 | −2.14 | 13.30** | 0.76 | 29.38** | 9.84 | 19.64** |
| | | 108.75** | 94.00** | 7.32 | −8.76 | 8.67** | 1.53 | 7.25* | 16.52 | 20.72* |
| 8. | PMS 3A/HKR 241 | 119.29** | 88.26** | 13.81 | 4.64 | 3.96** | 7.78** | 6.81 | 62.50* | 40.98** |
| | | 79.84** | 79.00** | −10.43 | −7.64 | 6.06** | 11.61** | 33.09** | 33.82 | 38.94** |
| | | 145.93** | 122.55** | 8.51 | −12.03* | 7.14** | 6.43** | 34.25** | 36.50 | 31.36** |
| 9. | IR 58025A/Basmati 385 | 173.41** | 160.18** | 10.53 | 18.63** | −1.03 | −2.67* | 14.03** | 40.14* | 24.27** |
| | | 123.56** | 119.99** | 6.06 | 10.83 | −0.52 | −2.30 | 32.64** | 11.80 | 21.90** |
| | | 284.55** | 209.77** | 26.83** | −3.57 | −1.53 | −2.67* | 24.66** | 73.04** | 15.31* |
| 10. | IR 62829A/Basmati 385 | 167.68** | 161.06** | 0.98 | 14.74** | 3.83** | 0.59 | 23.78** | 22.30 | 17.92 |
| | | 150.66** | 151.36** | −8.85 | 8.78 | 10.47** | 3.66* | 61.96** | −1.16 | 0.99 |
| | | 213.87** | 144.58** | 24.39* | −5.36 | −3.06* | −2.67* | 24.87** | 47.83 | −8.11 |
| 11. | PMS 10A/Basmati 385 | 47.12 | 30.54 | 13.54* | 23.50** | −1.05 | 0.57 | 23.32** | 7.89 | 6.10 |
| | | 25.77 | 16.57 | 7.92 | 12.03* | 0.53 | 1.15 | 54.38** | 0.82 | 0.89 |
| | | 93.64* | 44.34 | 34.15** | −2.51 | −3.57** | 0.76 | 27.98** | 6.96 | 16.36* |
| 12. | PMS 3A/Basmati 385 | 90.68** | 81.77** | 4.85 | 13.54* | 1.50 | 0.00 | 16.42** | 2.31 | 15.12 |
| | | 69.67** | 79.52** | −6.09 | 3.32 | 4.64** | 1.15 | 44.98** | 20.75 | 13.46 |
| | | 137.87* | 79.12** | 31.71** | −10.12* | 3.57** | 0.76 | 21.24** | 11.30 | 6.31 |
| 13. | IR 58025A/SAF Khalsa 7 | 10.47 | 25.13 | −2.47 | 3.69 | −3.29** | 4.54** | 19.84** | 4.86 | 7.18 |
| | | −19.31 | 2.91 | −20.20* | −7.37 | 5.10** | 9.51** | 28.22** | −15.17 | 6.67 |
| | | 35.40 | 62.79 | −4.25 | −9.12 | −1.90 | 2.86* | 45.38** | 51.00 | 1.82 |
| 14. | IR 62829A/SAF Khalsa 7 | 54.87 | 66.16* | −2.27 | 9.42 | −3.48** | −1.87 | 38.13** | 51.77** | 11.36 |
| | | 26.45 | 65.49 | −23.89** | −0.89 | 12.79** | 6.50** | 65.05** | 24.42 | −5.77 |
| | | 58.37 | 50.25 | 0.00 | −4.76 | −1.02 | 0.00 | 27.25** | 86.08** | −11.71 |
| 15. | PMS 10A/SAF Khalsa 7 | 1.74 | 8.75 | 0.00 | 8.53 | 7.18** | 7.97** | 27.26** | −10.34 | 13.89 |
| | | −22.95 | −5.75 | −18.81* | −5.71 | 19.15** | 12.88** | 45.87** | 14.75 | 9.82 |
| | | 15.73 | 31.09 | −8.51 | −7.47 | 6.67** | 6.43** | 45.88** | 4.00 | 0.00 |
| 16. | PMS 3A/SAF Khalsa 7 | 88.57** | 95.89** | 1.12 | 7.60 | 2.29* | 7.39** | 27.43** | 43.00 | 29.81** |
| | | 47.59 | 87.08** | −21.74** | −6.24 | 8.25** | 11.61** | 45.35** | 38.18 | 29.81** |
| | | 101.80** | 109.73** | −17.02* | −8.04 | 6.19** | 6.43** | 46.63** | 52.00* | 22.73* |
| 17. | IR 58025A/Karnal local | 37.36 | 42.53* | −3.41 | 4.44 | 2.97* | 7.69** | 26.05** | 10.37 | 18.03 |
| | | 20.64 | 41.26 | −14.14 | −7.21 | 6.12** | 9.13** | 53.36** | 1.69 | 2.86 |
| | | 102.40** | 123.49** | −8.51 | −7.82 | −0.90 | 2.50 | 73.88** | 81.00** | −1.82 |
| 18. | IR 62829AA/Karnal local | 62.69* | 64.72** | −9.47 | 14.44** | 11.58** | 11.24** | 31.60** | 20.50 | 22.67 |
| | | 59.61* | 36.01 | −23.89** | 3.08 | 23.26** | 16.67** | 80.78** | 12.79 | 17.95 |
| | | 102.60** | 111.29** | −8.51 | 2.43 | 0.95 | 2.50 | 68.13** | 68.70** | −16.36 |
| 19. | PMS 10A/Karnal local | −5.87 | 31.40 | −29.21** | 9.45 | 15.15** | 11.61** | 25.14** | 5.88 | 15.79 |
| | | −13.16 | 24.52 | −37.62** | −5.42 | 21.28** | 12.88** | 64.25** | −4.00 | −1.79 |
| | | 30.40 | 93.48** | −34.04** | −6.04 | 8.57** | 6.43** | 64.25** | 44.00 | 8.18 |
| 20. | PMS 3A/Karnal local | −33.60 | 34.18 | −53.12** | 12.90* | 10.14** | 10.99** | 22.35** | −3.17 | 26.37* |
| | | −35.98 | 15.50 | −60.87** | −2.14 | 10.68** | 11.61** | 59.73** | −18.67 | 10.58 |
| | | −12.47 | 79.44** | −53.19** | −2.78 | 8.57** | 6.43** | 61.13** | 22.00 | 4.55 |
| | S.E. (Ha) | 5.40 | 10.84 | 0.039 | 1.18 | 1.39 | 1.90 | 2.87 | 2.84 | 0.79 |
| | S.E. (Hb/Sc) | 4.68 | 9.84 | 0.034 | 1.02 | 1.20 | 1.64 | 3.63 | 2.46 | 0.95 |

*,**Significant at 5% and 1% level, respectively; GYP = Grain yield per plant, BYP = Biological yield per plant, HI = Harvest index, TGW = 1000 grain weight, DTF = Days to 50% flowering, DTM = Days to maturity, PHT = Plant height, ETP = Effective tillers per plant, PPP = Primaries per panicle

better choice. As the restorer parents are tall and late in maturity, therefore, to develop high yielding, semi-dwarf basmati hybrids fitting into multiple cropping system it is suggested to use dwarf and early maturing basmati CMS lines as and when available. Hybrid advantage in this study is likely to be maximized since hybrid seed was produced by hand-pollination thus insuring 100 per cent purity. Commercial seed production systems may not result in 100 per cent hybrid seed. Similarly, full fertility restoration may be a problem with basmati CMS lines under some situations. Hybrid yield advantage is already being realized in rice hybrids. Potential for increased productivity of basmati quality hybrids would offer opportunities for higher production and income in the basmati growing region.

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