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# Combining ability of new Basmati fertility restorers for grain yield and its components in rice (*Oryza sativa* L.)

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## Abstract

**A line × tester (L × T) analysis was carried out in rice to characterize the newly identified fertility restorers of basmati type and their hybrids for general (*gca*) and specific (*sca*) combining ability. Twenty-one fertility restorers including 11 basmati type were selected after screening 45 improved germplasm collections with 4 cytosterile lines. The restorers and their hybrids were evaluated for grain yield and its component traits in a randomized block design (RBD). Of the 11 basmati type 5 were identified to be effective restorers. Restorer Basmati 385 and HKR 241 were found to be good general combiners for grain yield/plant, biomass yield/plant, 1000 grain weight and number of primaries/panicle, P1031 for 1000 grain weight and effective tillers/plant while, Karnal Local for biomass yield/plant and 1000 grain weight. Among CMS lines IR 58025A and PMS 3A were characterized as good general combiners for grain yield and other traits. The specific cross combinations characterized with high significant *sca* effects were IR 58025A × Basmati 385, IR 62829A × Basmati 385, IR 62829A × HKR 241 and PMS 3A × P1031-8-5-1 for grain yield/plant, biomass yield/plant and effective tillers/plant. IR 62829A × Karnal Local for 1000 grain weight, PMS 10A × SAP Khalsa 7 for days to 50% flowering and PMS 3A × HKR 241 for primaries/panicle. The *gca* effects of the parents were not reflected in the *sca* effects of the crosses in all traits studied. No generalized order of nicking among the parents to produce desirable combination was observed. Any sort of combination among the parents gave hybrid vigour over the parents which might be due to favorable dominant genes, over dominance or epistatic action of the genes.**

**Key words:** Rice, basmati hybrids, combining ability, fertility restorers, *Oryza sativa*

## Introduction

The concept of general and specific combining ability is useful to characterize inbreds (fertility restorers and CMS lines) for their nicking ability in hybrid breeding programme and elucidate the nature and magnitude of gene action involved for trait of interest. With increasing interest in the exploitation of heterosis in rice, there is a need to subject various CMS lines and restorers to combining ability test, so as to identify the most potential parents to develop heterotic hybrids. Even though, there are many studies conducted on combining ability in rice following diallel and L × T analysis, the studies pertaining to crosses involving CMS lines and restorers are very limited [1, 2]. Further, due to non-availability of restorers and maintainers of basmati type, most of the studies reported earlier pertained to traditional rice varieties as parents.

Basmati is India's prized long grain rice with unique quality features. It is characterized with long slender superfine grain, exquisite aroma, high volume expansion resulting from linear kernel elongation with minimum breadth wise swelling, fluffiness, appealing taste and longer shelf life. It is an important foreign exchange commodity and fetches higher premium in the national and international market. During 2005-06, 1.06 million tonnes of Basmati rice was exported with a forex earning of Rs. 3030 crores [3]. However, yield of basmati rice are as low as 1/3rd of the non-basmati rice. To increase export and production, exploitation of heterosis is one the various breeding strategies used. But in basmati rice, lack of suitable fertility restorers and sterility maintainers is a constraint in hybrid development. To develop A and R lines with required basmati quality characteristics advanced progenies from conventional breeding program 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 [4, 5]. In this article authors report on the combining ability of newly identified fertility restorers of basmati background.

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**Materials and methods**

*Experiment I* : Four CMS lines *viz.*, IR 58025A, IR 62829A, PMS 10A and PMS 3A and 45 improved germplasm developed at IARI, New Delhi including 27 aromatic and 18 non-aromatic disease resistant collections from the Rice Research Station CCS, Haryana Agricultural University, Kaul were used. Crosses in all combinations between CMS 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 (Tamilnadu). Thirty day old seedlings were transplanted in the main field at a spacing of 20 × 15 cm with row length 1.5 m. Randomized complete block design (RBD) with two replications was followed. Standard agronomic practices were employed for raising normal crop. To estimate pollen fertility at the time of flowering, panicles from individual $F_1$ plants were collected and fixed in acetoalcohol (1:3) solution. Anthers of spikelets representing lower, middle and top portion of the panicle were smeared in 1% acetocarmine and pollen were examined under light microscope. Deeply stained, fully developed and round pollen grains were considered as fertile. Based on pollen fertility (initial screening) 19 restorers of which 11 were Basmati and 8 non-basmati type and 2 maintainers of basmati type were selected and crossed with 4 CMS lines to produce 1.5-2.0 g hand cross seed per cross for experiment II.

*Experiment II* : The eighty four hybrids were raised in 2m long plot at a spacing of 20 × 15cm with two replications in RBD at IARI, New Delhi. Nursery raising and transplanting were carried out as like in Experiment 1. Hybrids were grown together followed by parents in contiguous plots randomizing hybrids and parents separately in RCBD [6]. To estimate spikelet fertility (final screening), two panicles per plant selected at random and one from the main culm of five randomly selected plants per hybrid from each replication were harvested at maturity. Number of fertile and sterile spikelets were counted and percentage spikelet fertility averaged over replications was computed. Pollen parents were classified as effective restorers with spikelet fertility (SF) > 80 % and pollen fertility (PF) >60%, partial restorers with SF 21-79% and PF 30-59% and maintainers with SF and PF < 1 % [7]. Of the 21 pollen parents 5 of basmati type were found to be effective restorers. All hybrids including those of basmati type were evaluated in one experiment for grain yield and its components.

*Observations* : The observations were recorded on five randomly selected plants per genotype per replication for grain yield/plant, biomass/plant, 1000 grain weight, days to 50% flowering, plant height, number of effective tillers/plant and number of primary branches/panicle. Two pollen parents as maintainers and their hybrids were excluded from seed related characteristics. Combining ability analysis was carried out following Line × Tester design [8].

**Results and discussion**

The results of analysis of variance for combining ability for yield and its components revealed that the variance due to lines were significant ($p<0.01$) for biomass/plant, days to 50% flowering, plant height, effective tillers/plant and primaries/panicle indicating their contribution to combining ability. The variance due to testers was significant for 1000 grain weight, days to 50% flowering, plant height and primaries per panicle while L × T component of variance for all traits indicating that lines interacted considerably with testers. The estimates of variances due to *gca* and *sca* indicated the predominance of *sca* variance for all traits studied except for plant height and primaries/panicle.

*General combining ability effects of parents* : The estimates of *gca* effects (Table 1) ranged from –5.17 to 14.70 for grain yield/plant, –13.59 to 22.63 for biomass yield/plant, –0.32 to 1.19 for 1000 grain weight, –3.77 to 14.49 for days to 50% flowering, –2.92 to 2.59 for effective tillers/plant and from –1.03 to 1.31 for primaries /panicle. Among the testers (basmati type restorers) Basmati 385 and HKR 241 recorded significant *gca* effects for grain yield/plant, biomass yield/plant, 1000 grain weight and number of primaries/panicle therefore, were characterized as good general combiners for these traits. P1031 had significant *gca* effects for 1000 grain weight and effective tillers/plant and was found to be good general combiner for these traits. Restorer Karnal Local was good general combiner for biomass yield/plant and 1000 grain weight but with non-significant *gca* effects was average combiner for grain yield/plant. However, it had highest (19.04 gm) grain yield/plant and with late maturity and tall height. Among CMS lines IR 58025A and PMS 3A possessed significant *gca* effects for grain yield/plant, biomass yield/plant and primaries/panicle hence, were rated as good general combiners for these traits. PMS 10A was found to be good general combiner for number of primaries/panicle while IR 62829A for effective tillers/plant. The evaluation of parents based on both *per se* performance as well as *gca* effects indicated that Basmati 385 was the best parent among restorers while, CMS line IR 58025A having high mean grain yield/plant was the best for incorporating yield and IR 62829A with low mean values for days to 50% flowering and plant height was good for earliness and dwarfness.

*Specific combining ability effects of hybrids* : The perusal of *sca* effects of hybrids (Table 2) revealed

**Table 1.** Mean performance and general combining ability effects of lines and testers@ for grain yield and its component traits

| Testers/lines | Days to 50% flowering | Grain yield/plant (gm) | *gca* effects | | | | | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|
| | | | Grain yield/plant (gm) | Biomass/ plant (gm) | Test grain weight (gm) | Effective tillers/ plant | No. of primaries/ panicle | |
| P1031-8-5-1-1 | 94.00 | 11.00 | –5.17** | –13.59** | 1.10** | 2.58* | –0.38 | 103.35 |
| HKR-241 | 99.00 | 13.13 | 5.51** | 11.36** | 0.92* | –1.62 | 1.25** | 120.40 |
| Bas 385 | 97.00 | 15.99 | 14.70** | 22.63** | 1.19** | –0.44 | 1.31** | 120.30 |
| SAF Khalsa 7 | 115.00 | 11.59 | –3.85* | 2.52 | 0.39 | –0.41 | 0.48* | 103.40 |
| Karnal local | 104.00 | 19.04 | –3.26 | 8.32** | 1.15** | 0.09 | –0.59* | 130.00 |
| IR-58025B | 98.00 | 25.17 | 3.77** | 5.86** | 0.20 | 0.39 | 0.32** | 90.70 |
| IR-62829B | 86.00 | 18.32 | –3.66** | –8.07** | –0.32* | 2.59** | –1.03** | 74.40 |
| PMS-10B | 94.00 | 22.53 | –2.56** | –4.32** | 0.08 | –2.92** | 0.24** | 80.00 |
| PMS-3B | 103.00 | 20.51 | 2.46** | 6.53** | 0.04 | –0.05 | 0.47** | 80.70 |
| SE (gi) L | - | - | 0.75 | 1.51 | 0.16 | 10.36 | 10.09 | - |
| SE (gj) T | - | - | 1.83 | 3.70 | 0.38 | 0.93 | 10.51 | - |
| SE (gi-gj)L | - | - | 11.06 | 2.13 | 10.23 | 0.51 | 10.13 | - |
| SE (gi-gj)T | - | - | 2.59 | 5.23 | 0.54 | 11.32 | 11.32 | - |

*,** Significant at 0.05 and 0.01 levels of probability. @Data of only basmati effective restorers is given.

**Table 2.** Mean performance and specific combining ability effects of hybrids@ for grain yield and its component traits

| Hybrids | Days to 50% flowering | Grain yield/plant (gm) | *gca* effects | | | | | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|
| | | | Grain yield/plant (gm) | Biomass/ plant (gm) | Test grain weight (gm) | Effective tilllers/ plant | No. of primaries/ panicle | |
| IR 58025A/P1031-8-5-1-1 | 96.50 | 19.23 | –5.99 | –6.67 | 1.02 | –1.90 | –0.16 | 89.50 |
| IR 62829A/P1031-8-5-1-1 | 94.00 | 16.67 | –1.12 | –2.29 | 1.24 | –3.60* | 0.59 | 98.80 |
| PMS 10A/P1031-8-5-1-1 | 95.00 | 16.85 | –2.04 | –6.15 | –0.46 | –2.84 | –0.83* | 102.95 |
| PMS 3A/P1031-8-5-1-1 | 93.50 | 33.06 | 9.15** | 15.10* | –1.79** | 8.34** | 0.39 | 92.80 |
| IR58025A/HKR 241 | 95.00 | 22.39 | –13.58** | –26.15** | 0.18 | –2.70 | –1.88** | 116.20 |
| IR62829A/P1031-8-5-1-1 | 97.00 | 39.00 | 10.46** | 22.69** | 2.19** | 1.30 | –0.33 | 113.00 |
| PMS 10A/P1031-8-5-1-1 | 106.50 | 30.54 | 0.90 | 6.43 | –0.60 | 2.01 | 0.70 | 103.50 |
| PMS 3A/P1031-8-5-1-1 | 105.00 | 36.89 | 2.22 | –2.96 | –1.76** | –0.61 | 1.51** | 107.40 |
| IR58025A/Bas 385 | 96.50 | 56.26 | 11.17** | 26.68** | 0.23 | 4.01* | 0.96* | 120.30 |
| IR62829A/P1031-8-5-1-1 | 95.00 | 45.92 | 8.26* | 17.12** | 0.32 | –1.09 | –0.29 | 120.50 |
| PMS10A/P1031-8-5-1-1 | 94.50 | 28.33 | –10.43** | –22.74** | 0.54 | –0.28 | –0.46 | 123.50 |
| PMS3A/P1031-8-5-1-1 | 101.50 | 34.80 | –8.99** | –21.06 | –1.15 | –2.65 | –0.20 | 117.00 |
| IR58025A/SAP Khalsa 7 | 103.00 | 20.31 | –6.24 | –7.56 | –0.72 | –0.81 | –0.82* | 116.30 |
| IR62829A/P1031-8-5-1-1 | 97.00 | 23.17 | 4.05 | 8.30 | 1.26 | 3.29* | –0.87* | 122.80 |
| PMS10A/P1031-8-5-1-1 | 112.00 | 17.36 | –2.85 | –7.54 | –0.23 | –2.20 | 0.36 | 116.70 |
| PMS 3A/P1031-8-5-1-1 | 111.50 | 30.27 | 5.03 | 6.801 | –0.31 | –0.28 | 1.33** | 117.30 |
| IR58025A/Karnal local | 104.00 | 30.36 | 3.23 | 1.05 | –1.18 | 1.69 | –0.14 | 139.10 |
| IR62829A/P1031-8-5-1-1 | 106.00 | 30.39 | 10.69** | 11.08 | 1.69* | 0.79 | –0.39 | 134.50 |
| PMS 10A/P1031-8-5-1-1 | 114.00 | 19.56 | –1.23 | 1.61 | –0.65 | 1.30 | 0.14 | 131.40 |
| PMS3A/P1031-8-5-1-1 | 114.00 | 13.13 | 12.69** | –13.74* | 0.14 | –3.78* | 0.40 | 128.90 |
| SE ($S_{ij}$) | - | - | 3.17 | 6.40 | 0.66 | 1.62 | 0.40 | - |
| SE($S_{ij}$-$S_{kl}$) | - | - | 4.48 | 9.05 | 0.93 | 2.29 | 0.57 | - |

*,**Significant at 0.05 and 0.01 levels of probability; @Data of hybrids involving basmati effective restorers is given

that 6 crosses had desirable *sca* effects for grain yield/plant, 4 for biomass yield/plant, 2 for 1000 grain weight and 3 each for effective tillers/plant and number of primaries/panicle. Hybrid IR 58025A × Basmati 385 recorded the highest grain yield/plant with significantly higher *sca* effects for yield and its components *viz.*, grain yield/plant, biomass yield/plant, effective tillers/plant and primaries/panicle. The other outstanding hybrids for grain yield/plant were IR 62829A × Basmati 385 having significant *sca* effects for grain yield/plant and biomass yield/plant while IR 62829A × HKR 241 with significant *sca* effects for grain yield/plant, biomass yield/plant and 1000 grain weight. Hybrid PMS 3A × P1031 showed significant *sca* effects for grain yield/plant, biomass yield/plant and effective tillers/panicle while PMS 3A × Karnal Local had only for grain yield/plant. Hybrid IR 62829A × SAP Khalsa 7 was comparatively early than other hybrids had recorded significant *sca* effects for effective tillers/plant while PMS 3A × HKR 241, a semi-tall with high mean grain yield/plant and PMS 3A × SAP Khalsa 7 for primaries/panicle. Further, it was observed that parents with high × high (IR 58025A × Basmati 385), high × low (PMS 3A × P1031, IR 62829A × HKR 241, IR 62829A × Basmati 385) high × average (PMS 3A × Karnal Local) and low × average (IR 62829A × Karnal Local) *gca* effects had contributed for the expression of high *sca* effects of grain yield/plant. Parents with high × high (IR 58025A × Basmati 385) high × low (IR 62829A × HKR 241, IR 62829A × Basmati 385) and low × low (PMS 3A × P 1031) *gca* effects produced high *sca* effects for biomass yield/plant, low × high (IR 62829A × HKR 241 and IR 62829A × Karnal Local) for 1000 grain weight while high × low (PMS 3A × P1031, IR 62829A × SAP Khalsa 7) and low × low (IR 58025A × Basmati 385) for effective tillers/plant. This suggested the involvement of all three types of gene effects *viz.*, additive × additive, additive × non-additive and non-additive × non-additive for grain yield/plant and biomass yield/plant, additive × non-additive and non-additive × non-additive for effective tillers/plant and only non-additive × additive for 1000 grain weight. Parents only with high × high (IR 58025A × Basmati 385, PMS 3A × HKR 241 and PMS 3A × SAP Khalsa 7) resulted into high *sca* effects for primaries/panicle. However, for three hybrids *viz.*, IR 58025A × HKR 241, IR 58025A × SAP Khalsa 7 and IR 62829A × SAP Khalsa 7 reverse order of exhibiting significant negative *sca* effects involving parents with high × high *gca* effects was observed. This indicated that additive × additive gene effects not necessarily responsible for expression of this trait.

For most of the traits only a few cross combinations revealed additive × additive gene effects for high *sca* effects. Predominantly additive × non-additive type of gene interaction was responsible for many traits involving crosses with high *sca* effects. Importance of both additive and non-additive gene effects have been reported by several workers for yield and its components [9-11], for 1000 grain weight [12], days to 50% flowering [13] and for number of tillers/plant [14]. The estimate of variances were greater in magnitude than *gca* variances for grain yield/plant, biomass yield/plant, 1000 grain weight, days to 50% flowering and effective tillers/plant indicating the predominance of non-additive gene action. The presence of non-additive gene action offers scope for exploitation of hybrid vigour in rice. Similar findings were made by various workers for yield and its related components [15-17], days to flowering [16], dry matter production [18]. The *gca/sca* ratio > 1.00 for primaries/panicle revealed predominance of additive and additive × additive gene action. The pre-pondrance of additive gene action has also been observed by workers for yield [19] and days to 50% flowering [20]. The difference in results of various workers might be due to different combinations of parents involved.

An examination of the relationship of *sca* effects of hybrids and *gca* effects of parents established that absolute heterosis is not merely due to high *sca* effects and it would not be possible to isolate hybrids where all attributes are in the most desirable combination. Also, it appeared that desirable *sca* effects of the hybrids were not necessarily depended on the level of *gca* effects of the parents invloved. For instance, in the case of IR 62829A × Karnal Local where the hybrid registered very high *sca* effects for yield while their parents exhibited low × average *gca* effects. IR 58025A × HKR 241 recorded lowest *sca* effects while its parents have high × high *gca* effects. Similarly, highest yielding and heterotic hybrids IR 58025A × Basmati 385 and IR 62829A × Basmati 385 recorded high *sca* effects with high × high and low × high *gca* parents, respectively. This situation poses a problem whether the parental selection should be based on *per se* performance of the parents or *gca* effects of the parents or *sca* effects of the hybrids. In crops like rice, which are autogamous direct utilization of hybrids *per se* performance though, a good indication of the parental potentiality, does not predict the nature of segregants in later generations. Choice of the hybrids on the basis of *sca* effects need not necessarily exhibit high mean expression also. The mean expression is a realized value while *sca* effects is an inference drawn. For a given hybrid the *sca* effects may be high or low depending upon the magnitude of the parental expression. Therefore, it may be appropriate to correlate the *sca* effects and the mean expression of hybrids to decide on the selection potential of hybrids. A comparison of the combining ability effects of the parents and corresponding crosses indicated that in most of the cases *gca* effects of the parents are not reflected in the *sca* effects of the crosses in all traits studied. Thus, in certain cases crossing two good combiners did not necessarily result in a good specific combination and the same was true for poor combiners. A majority of the top *sca* combinations for yield involved atleast one parent possessing high *gca* effects, however, there was no generalized order of nicking among the parents to produce desirable combinations. In some cases, average combiners were also involved in producing good hybrid combinations. Any sort of combination among the parents could give hybrid vigour over the parents, which might be due to favourable dominant genes, over dominance or epistatic action of the genes [21]. This emphasized the actual making and testing of crosses in hybrid breeding programme. It would be better to select at least one parent possessing high general combining ability to get heterotic $F_1$ hybrids. In this study, basmati type restorers Basmati 385 and HKR 241 were found to be good general combiners and produced high yielding hybrids thus, would be suitable for developing basmati hybrids in combination with basmati CMS lines.

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