Biological Forum – An International Journal **15(7): 01-09(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Estimation of Combining Ability using Line × Tester Analysis for Yield and its Contributing Traits in Aromatic rice (*Oryza sativa* L.)

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(Received: 02 April 2023; Revised: 22 April 2023; Accepted: 18 May 2023; Published: 05 July 2023)
(Published by Research Trend)

ABSTRACT: The current investigation was conducted to study the estimates of combining ability and heterosis in order to comprehend the nature and kind of gene action, select superior genotypes, and generate the best cross combinations. Combining ability study for eleven yield characteristics was carried out on 25 crosses generated by utilising Line × Tester mating design. with 5 traditional non-aromatic lines including PKV HMT, RFS-2019-3, Zincorice MS, HMT Sona and Improved Samba Mahsuri and 5 aromatic testers including Pusa1121, Badshahbhog Sel-1, Trombay Chhattisgarh Dubraj Mutant (TCDM-1), Chhattisgarh Devbhog and R2281-308-1-185-1. ANOVA for Line × Tester design revealed that there was significant variance in treatments for all eleven characters studied. For all characters except panicle length, the variation due to line × tester effects were noted as significant. For all traits studied, the magnitude of Specific combining ability (SCA) variance was found to be higher than the General combining ability (GCA) variance, with the exception of days to 50% flowering, plant height (cm), panicle length (cm), and biological yield per plant (g), indicating a significant role of non-additive gene action (dominance & epistasis) in controlling these traits. The genotype PKV HMT among the lines and Pusa 1121 among the testers were found to be the best general combiners for grain yield per plant (g). Among the crosses the best specific combiner for grain yield per plant (g) observed for PKV HMT/Pusa 1121, Improved Samba Mahsuri/R2281-308-1-185-1, and Improved Samba Mahsuri/Chhattisgarh Devbhog, so, these hybrids can be utilized either for heterosis breeding or multiple cross-breeding programmes to acquire transgressive segregants and a large genetic base population for the improvement of quality rice production.

Keywords: Gene action, Non- additive, Specific combining ability, General combining ability, Heterosis.

INTRODUCTION

The popularity of aromatic rice varieties has increased globally. It is an essential source for many Asian countries' diets and food security (Kumar *et al*., 2020). When rice is consumed as whole grain, the most crucial physical characteristics are size, shape, uniformity, and general appearance. Customers want this along with great cooking qualities. The physicochemical qualities of starch, which constitute nearly 90% of milled rice, have a significant role in these traits. It is imperative to make grain quality enhancements that do not impair productivity in order to benefit all rice producers and consumers (Sadhana *et al*., 2022). Basmati rice is native to the Indian subcontinent (Singh *et al*., 2000). Basmati rice, also known as aromatic rice, is typically grown in northwest Indian states like Punjab, Uttar Pradesh, Himachal Pradesh, Jammu & Kashmir, and Haryana. The Indo-Gangetic plains is blessed with premium quality basmati rice that has remarkable grain and cooking qualities characterized by long kernel, high elongation ratio after cooking, pleasant fragrance and excellent flavor (Singh *et al*., 2018). In India, nearly every state has its own distinctive fragrant rice type. Furthermore, the green revolution, which put a greater emphasis on production than quality, has already caused significant losses (Sing and Sing 1998). The cultivation of rice is essential for the country's food and nutritional security and millions of Indians rely on it for their cultural, social and economic well-being. The largest acreage and second-highest level of rice production among the nations that cultivate rice are both in India.

Aromatic or fragrant rice refers to a collection of rice cultivars that cook up with an outstanding flavour and are highly prized in Indian culture. In addition to the domestic markets, the Basmati class of rice, which is known around the world for its pleasant scent, extremely long superfine grain, exceptional grain elongation, and soft texture of cooked rice, also fetches a premium price worldwide. With consistent exports of 1.5 to 2.5 million tonnes of non-Basmati rice and 0.5 to 0.6 million tonnes of Basmati rice, India has grown to be a significant exporter of aromatic rice, contributing in between Rs. 3000 and Rs. 4000 crores for the Indian economy. Improvement of basmati varieties became necessary due to the rising demand for high-quality fragrant rice on global markets, and it has been one of the research areas that has received the most attention till date. Basmati types were partly ignored since they had little export potential. Traditional basmati cultivars restricted cultivation regions are a result of their lack of scent retention. Therefore, appropriate approaches for the selection of high yielding varieties include the identification and characterization of important factors with regard to their relationship with yield and other quality traits.

The relevance of quality concerns has increased in recent years, particularly in countries having self-sufficient production. The average consumers prefer quality rice production which continues to rise in per capita income. The capacity to combine has been useful in identifying good parents and crosses, and the potentiality of rice hybrids has been well established. In contrast to General Combining Ability, which measures additive and additive × additive gene action, Specific Combining Ability measures non-additive gene action and is used to select desired parents and crosses in the plant breeding programme (Sprague and Tatum 1942). The success of any breeding programme depends on selecting the ideal parents for the hybridization process. Combining ability analysis identifies the method of gene action as well as parents with high general combining effects and cross combinations with high specific combining effects. The selection of the parents for a population breeding or hybridization plan is then aided by this. In the current study, the line × tester analysis was performed, which proposed as one of the biometrical approaches used to evaluate combining ability (Kempthorne, 1957). It is necessary that greater degrees of heterosis for quality traits, in addition to yield and yield attributes, be taken into account throughout the commercial development of rice hybrids (Waza *et al*., 2016).

MATERIAL AND METHODS

Crosses generated at the Research cum Instructional Farm, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, Department of Genetics and Plant Breeding. To create a total of 25 F_1 hybrid combinations using line × tester mating design, five non-aromatic rice varieties including PKV HMT, RFS-2019-3, Zinco Rice MS, HMT Sona and Improved Samba Mahsuri were used as the female parents (Lines) and five indigenous aromatic rice varieties including Pusa 1121, Badshahbhog Sel-1, Trombay Chhattisgarh Dubraj Mutant (TCDM-1) and Chhattisgarh Devbhog were used as male parents (Testers) during *kharif* 2020.Data has been recorded for eleven yields and their attributing traits, including days to 50% flowering, plant height (cm), panicle length (cm), number of effective tillers per plant, total number of spikelets per panicle, number of fertile spikelets per panicle, spikelet fertility (%), 1000 seed weight (g), grain yield per plant (g), biological yield per plant (g) and harvest index (%) to estimate heterosis, combining ability and gene action associated with it.

Twenty-five crosses produced in *kharif*,2020 constituted the experimental materials. The Randomised Block Design (RBD) was utilised to examine all of the F_1s in field conditions together with their parents for several yield-related traits. In *summer*, 2020-21 nurseries were raised with their parents for 25 crosses. The field was then planted with seedlings that were 21 days old, with a row to row and plant to plant spacing of 15 cm × 20 cm., the net plot area was 9.2 m × 2 m. This Combining ability technique has been utilised in mostly all of the major agricultural crops in order to estimate GCA & SCA variance and effects and to understand the nature of gene action involved in the expression of several quantitative traits. (Singh and Narayanan 2013). For combining ability analysis, Kempthorne's approach was applied (Kempthorne, 1957). It determined the mean sum of squares resulting from different variance sources. The statistical analysis of GCA and SCA effects was also done in the software WINDOSTAT. Using the overall mean of each F_1 hybrid over replication for each character, heterosis for each attribute was calculated. For the purpose of finding the best genotypes for the traits being studied, heterosis can be assessed.

Table 1: Genotypes used as parents in line × tester analysis.

Sr. No.	Genotypes	Source	Salient feature
	Female/ Line (non-aromatic)		
1.	PKV HMT	PDKV, Akola	Non-aromatic, Fine Slender
2.	RFS-2019-3	IGKV, Raipur	Non-aromatic, Fine Slender
3.	Zinco Rice MS	IGKV, Raipur	Non-aromatic Fine Slender, High Zn content
4.	HMT Sona		Non-aromatic, Fine Slender
5.	Improved Samba Mahsuri	IIRR, Hyderabad	Non-aromatic, Medium Slender, BLB resistant
	Male/Testers (aromatic)		
6.	Pusa 1121	IARI, New Delhi	Basmati type, Long Slender
7.	Badshahbhog Sel-1	IGKV, Raipur	Aromatic, Short Bold, Tall
8.	Trombay Chhattisgarh Dubraj Mutant (TCDM-1)	IGKV, Raipur	Aromatic, Short Slender, Semi- Dwarf
9.	Chhattisgarh Devbhog	IGKV, Raipur	Aromatic, High Yielding, Medium Slender, Semi-Dwarf
10.	R2281-308-1-185-1	IGKV, Raipur	Aromatic, Medium Slender, Semi- Dwarf

RESULTS AND DISCUSSION

ANOVA findings revealed that there was considerable variance in treatments for all eleven traits studied. The vast amount of variation among the characters is revealed by the fact that variation resulting from parents was significant for each of them. The variance resulting from lines was found to be significant, with the exception of panicle length. The variation resulting from testers found to be significant for all characters. Plant height, effective tillers per plant, biological yield, and 1000 seed weight showed significant variations due to parent vs. cross, but not for other traits (Table 2). The findings of Ambikabathy *et al*. (2019); Singh *et al*. (2019); Awad-Allah (2020); Kumar *et al*. (2020); Alok &Sujeet (2020) are in agreement with the results of the current study.

For all of the traits under study, significant variation in variance due to crosses was observed, suggesting the varying performance of cross-combinations in various traits. Three components make up the variation due to cross: line effects, tester effects, and line × tester effects. With the exception of plant height, panicle length, spikelet fertility %, grain yield per plant, and harvest index, all characteristics showed significant variation as a result of lines effect.

The variation caused by the testers effect was significant, with the exception of days to 50 % flowering, total spikelets per panicle, spikelets filled per panicle, spikelet fertility percentage, grain yield per plant, and 1000 seed weight. For all the characters used in the study, with the exception of panicle length, there was a significant variation driven by line × tester effects. This indicated that the material utilised for research had adequate variability. For parents and their crosses, the results of the current study agreed with those of Nessreen and Heba (2021). Similar results for parents, crosses, and parents vs. crosses were reported by Sharma and Jaiswal (2020); Pandey (2020). The treatments, parents, crosses, and line × tester interactions revealed results that were similar to those of Ramesh *et al*. (2018).

For grain yield per plant (g), Pusa 1121 and Chhattisgarh Devbhog showed positive significant GCA impacts, whereas Zinco Rice MS, PKV HMT, and HMT Sona exhibited positive significant effects among the lines (Table 3). These lines were generally good general combiners for other yield-related traits. Zinco Rice MS combined well for days to 50% flowering, biological yield per plant (g), plant height (cm) and effective tillers per plant while PKV HMT combined well for 1000 seed weight (g) and harvest Index (%). HMT Sona combined well for plant height (cm), effective tillers per plant and spikelets fertility %. In addition, some lines combined well for traits related to yield, they did not combine well for grain yield per plant (g). For instance, RFS-2019-3 combined well in terms of total spikelets per panicle, filled spikelets per panicle and effective tillers per plant.

The specific combining ability effects among 25 crosses (5 Lines × 5 Testers) for eleven yield and its attributing traits (Table 4). For days to 50% flowering, the crosses PKV HMT/Trombay Chhattisgarh Dubraj Mutant (TCDM-1), PKV HMT/Badshahbhog Sel-1, and Zinco Rice MS/Pusa 1121 showed the most acceptable specific combining ability effects. A maximum negative significant specific combining ability effect for plant height (cm) was shown by the crosses HMT Sona/Pusa 1121, Zinco Rice MS/ Badshahbhog Sel-1, and RFS-2019-3/ Badshahbhog Sel-1, which had the greatest negative value of all the crosses investigated. Among the 25 crosses, the PKV HMT/Pusa 1121 cross had the highest positive significant effect on specific combining ability, showing that it was an excellent specific combiner for panicle length (cm). Crosses PKV HMT/Pusa 1121, Improved Samba Mahsuri/Badshahbhog Sel-1, and Improved Samba Mahsuri/Chhattisgarh Devbhog exhibited the highest positive significant specific combining ability effects for effective tiller per plant. For the total number of spikelets per panicle, the crosses RFS-2019-3/Badshahbhog Sel-1, Zinco Rice MS/R2281-308-1-185-1, and Zinco Rice MS/Trombay Chhattisgarh Dubraj Mutant (TCDM-1) had the greatest specific combining ability effects. RFS-2019-3/Badshahbhog Sel-1 crosse had the greatest amount of positive, statistically significant specific combining ability effects for the number of filled spikelets per panicle, followed by Zinco Rice MS/R2281-308-1-185-1 and Zinco Rice MS/Trombay Chhattisgarh Dubraj Mutant (TCDM-1). The cross Improved Samba Mahsuri/Badshahbhog Sel-1 showed the highest positive significant SCA effect on spikelet fertility%, followed by PKV HMT/Badshahbhog Sel-1 and PKV HMT/Pusa 1121. The cross PKV HMT/Pusa 1121 had the highest positive significant SCA effect on grain yield per plant (g), followed by Improved Samba Mahsuri/R2281-308-1-185-1 and Improved Samba Mahsuri/Chhattisgarh Devbhog. This suggests that these combinations are effective for creating high-yielding cultivars. For biological yield per plant, the cross PKV HMT/Trombay Chhattisgarh Dubraj Mutant (TCDM-1), Zinco Rice MS/Badshahbhog Sel-1 and HMT Sona /R2281-308-1-185-1 shown the highest positive significant SCA effects. The crosses PKV HMT/Trombay Chhattisgarh Dubraj Mutant (TCDM-1), Zinco Rice MS/Badshahbhog Sel-1, and HMT Sona/R2281-308-1-185-1revealed the highest positive significant SCA effects for 1000 seed weight (g). The harvest index among the crosses revealed positive, significant SCA effects. The greatest value has been given by the cross of PKV HMT/Pusa 1121, RFS-2019-3/Badshahbhog Sel-1, and Improved Samba Mahsuri/R2281-308-1-185-1. Consequently, it was chosen for the best specific combiner for the harvest index.

In the current study it was noted that the value of GCA variance was found to be higher than SCA variance for days to 50% flowering, plant height (cm), panicle length and biological yield per plant, indicated that there was supremacy of additive type gene action for this trait Therefore, progeny selection will be beneficial for genetic enhancement of these traits; in fact, similar results were found for plant height by Sameer *et al*.

(2020). However, for effective tillers per plant, total spikelets per panicle, filled spikelets per panicle, spikelet fertility percent, grain yield per plant (g), 1000 seed weight, and harvest index (%), the value of SCA variances was shown to be higher than GCA variances. This suggests that non-additive gene activity (dominance & epistasis) predominates, suggesting that heterosis breeding may be rewarding. For effects on trait effective tillers per plant Ghara *et al*. (2014); Ramesh *et al.* (2018); Ambikabathy *et al*. (2021); Nanditha *et al*. (2021); Rohit *et al.* (2022) all came to similar conclusions. For the total number of spikelets per panicle, these findings concur with those of Yadav *et al*. (2021); Keerthiraj *et al.* (2021). Similar findings for the number of filled spikelets per panicle were made by Sao and Motiramani (2006); Mirarab *et al.* (2011); Tiwari *et al.* (2011); Ramesh *et al.* (2018); Ambikabathy *et al*. (2021). These results for spikelet fertility percent are consistent with those of Yadav *et al.* (2021); Hussein *et al*. (2021); Nanditha *et al*. (2021). Similar findings were also supported by Singh *et al*. (2007); Satheesh *et al*. (2010); Mirarab *et al*. (2011); El-Rewainy *et al*. (2011) Srivastava *et al*. (2012); Ghara *et al*. (2012); Pratap *et al*. (2013); Utharasu and Kumar (2013); Ghosh *et al*.(2013); Hasan *et al*. (2013); Gahtyari *et al*. (2017); Kishor *et al*.(2017); Keerthiraj *et al*.(2021); Hussein *et al*. (2021); Yadav *et al*.(2021); Gaballah *et al*. (2021) for grain yield per plant. Similar findings were also supported by Zhu *et al*. (2009); Satheesh *et al*. (2010); El-Rewainy *et al*. (2011), Ghosh *et al*. (2013); Ali *et al*. (2017); Ramesh *et al*. (2018); Nanditha *et al*. (2021) for biological yield per plant (g). For the harvest index (%), similar conclusions were also validated by Panwar (2005); Kumar *et al*. (2007); Malik and Singh (2013); Srijan *et al*. (2016).

Table 2: ANOVA table for the combining ability analysis in rice.

Sr.No.	Source of variations	D. f.	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Effective tillers per plant	Total number of spikelets per panicle	Number of filled spikelets per panicle
1.	Replicates	1	2.8	4.2	6.6	2.5	501.7	459.7
2.	Treatments	34	45.1**	948.8**	10.1**	12.4**	4674.8**	3340.4**
3.	Parents	9	73.0**	1221.1**	13.6**	12.5**	2578.2**	2365.8**
4.	Parents (Line)	4	97.9**	92.8**	3.1	15.7**	2558.9**	1966.1**
5.	Parents (Testers)	4	63.6**	2228.7**	21.1**	11.3**	3241.9**	3276.1**
6.	Parents (L vs T)	1	11.2**	1703.8**	25.9**	4.2*	0.5	323.2
7.	Parents vs Crosses	1	0.04	442.8**	1.9	4.6*	0.2	35.2
8.	Crosses	24	36.5**	867.8**	9.1*	12.7**	5655.9**	3843.6**
9.	Line Effect	4	120.2**	106.0	3.9	23.3*	13099.0*	9814.9*
10.	Tester Effect	4	21.4	4586.7**	36.3**	30.8**	8037.5	4989.6
11.	Line × Tester effect	16	19.4**	128.5**	3.6	5.6**	3199.7**	2064.2**
12.	Error	34	1.4	21.3	2.9	0.7	159.7	118.5
	Total	69	23.0	478.1	6.5	6.5	2389.5	1711.1
* Significant at p=0.05% level, ** Significant at p=0.01% level								

Table 2. Contd….

Sr. No.	Source of variations	D. f.	Spikelets fertility %	Grain yield per plant (g)	Biological Yield per plant (g)	1000 seed weight (g)	Harvest Index (%)
1.	Replicates	1	0.03	0.5	6.0	0.7	3.9
2.	Treatments	34	55.8**	27.2**	406.0**	50.2**	33.4**
3.	Parents	9	54.8**	22.0**	392.9**	53.9**	59.0**
4.	Parents (Line)	4	20.6*	20.3**	129.3*	14.4**	17.3**
5.	Parents (Testers)	4	72.3**	16.1**	526.9**	73.9**	114.6**
6.	Parents (L vs T)	1	121.5**	52.4**	911.2**	132.1**	2.8
7.	Parents vs Crosses	1	1.9	2.9	263.4*	25.1**	22.3
8.	Crosses	24	58.5**	30.2**	416.8**	49.9**	24.3**
9.	Line Effect	4	31.7	50.4	764.3**	120.5*	17.6
10.	Tester Effect	4	79.9	28.1	1096.5**	64.0	58.6*
11.	Line × Tester effect	16	59.8**	25.6**	160.1**	28.7**	17.4**
12.	Error	34	6.6	1.2	38.2	1.7	2.1
13.	Total	69	30.8	14.0	219.0	25.6	17.6
*Significant at p=0.05% level, **Significant at p=0.01% level							

Table 3: General combining ability effects of parents for grain yield and its contributing traits in rice.

Sr. No.	Parents	Days to 50% flowering	Plant height (cm)	nicle ngth cm)	Effective tillers per plant	Total number of spikelets per panicle	Number of filled spikelets per panicle
1.	PKV HMT	1.7**	-1.6	0.06	-1.5**	-7.3**	-5.8*
2.	RFS-2019-3	3.1**	2.2*	.00**	0.9**	58.6**	49.3**
3.	Zinco Rice MS	-5.6**	-2.3*	.34	1.0 **	-31.0**	-30.2**
4.	HMT Sona	-1.0**	-2.8**	.06	1.3**	6.8*	8.3**
5.	Improved Samba Mahsuri	1.8**	4.5**	.67	-1.7**	-27.0**	-21.6**
6.	Pusa 1121	-2.5**	7.7**	.05	0.8**	-37.1**	-29.9**
7.	Badshahbhog Sel-1	0.3	34.3**	.7**	-2.4**	39.1**	29.9**
8.	Trombay Chhattisgarh Dubraj Mutant (TCDM-1)	0.1	-13.8**	.1**	0.6*	1.6	-5.4
9.	Chhattisgarh Devbhog	1.0*	-13.1**	0.60	2.0**	10.3*	11.6**
10.	R2281-308-1-185-1	1.1**	-15.0**	1.06	-0.9**	-13.9**	-6.1

Table 3 Contd…

Sr. No.		Spikelets fertility %	Grain yield per plant (g)	Biological yield per plant (g)	1000 seed weight (g)	Harvest Index (%)
1.	PKV HMT	0.8	1.8**	0.7	5.5**	1.9**
2.	RFS-2019-3	0.3	-0.6**	1.5	-3.4**	-1.5**
3.	Zinco Rice MS	-3.0**	1.8**	8.0**	0.5*	0.1
4.	HMT Sona	1.5**	0.4*	4.4**	-2.1**	-0.8**
5.	Improved Samba Mahsuri	0.2	-3.5**	-14.7**	-0.5	0.2
6.	Pusa 1121	1.0	1.8**	16.6**	3.6**	-3.3**
7.	Badshahbhog Sel-1	-1.7*	-0.2	1.7	0.5	-1.2*
8.	Trombay Chhattisgarh Dubraj Mutant (TCDM-1)	-3.9**	-0.04	-6.6**	0.1	2.6**
9.	Chhattisgarh Devbhog	1.3	1.0**	-1.0	-3.2**	1.9**
10.	R2281-308-1-185-1	3.2**	-2.5**	-10.6**	-1.1*	-0.07
*Significant at p=0.05% level, ** Significant at p=0.01% level						

Table 4: Specific Combining Ability Effects of crosses for grain yield and its contributing traits in rice.

Characters	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Effective tillers per plant	Total number of spikelets per panicle	Number of filled spikelets per panicle
PKV HMT/Pusa 1121	4.4**	9.2**	1.8*	2.1**	-8.9	-0.7
PKV HMT/Badshahbhog Sel-1	-3.4**	-0.1	-2.2	-0.07	-33.4**	-14.6
PKV HMT/Trombay Chhattisgarh Dubraj Mutant (TCDM-1)	-4.2**	-3.0	-0.9	-0.1	19.9*	2.1
PKV HMT/Chhattisgarh Devbhog	5.4**	-2.2	0.4	-3.1**	11.8	6.6
PKV HMT/ R2281-308-1-185-1	-2.2*	-3.8	0.9	1.2	10.5	6.5
RFS-2019-3/Pusa 1121	1	-9.7**	0.07	-0.03	-13.7	-7.9
RFS-2019-3/Badshahbhog Sel-1	0.7	3.3	1.5	0.8	110.0**	81.0**
RFS-2019-3/Trombay Chhattisgarh Dubraj Mutant (TCDM-1)	-0.1	1.6	-1.5	0.3	-31.4**	-23.0**
RFS-2019-3/Chhattisgarh Devbhog		3.6	-0.06	0.2	-26.4**	-23.4**
RFS-2019-3/R2281-308-1-185-1	-1.6	1.1	-0.002	-1.4*	-38.4**	-26.6**
Zinco Rice MS/Pusa 1121	-2.8**	-1.9	-0.7	0.1	21.0*	16.5*
Zinco Rice MS/Badshahbhog Sel-1	2.4*	-10.6**	-0.8	-0.5	-77.4**	-74.8**
Zinco Rice MS/Trombay Chhattisgarh Dubraj Mutant (TCDM-1)	0.1	3.2	0.5	0.4	22.7*	22.1**
Zinco Rice MS/Chhattisgarh Devbhog	-2.3*	4.5	0.1	0.4	10.4	13.8
Zinco Rice MS/R2281-308-1-185-1	2.6**	4.7	0.7	-0.4	23.2*	22.3**
*Significant at p=0.05% level, **Significant at p=0.01% level						

Table 4. Contd….

Characters	Spikelets fertility %	Grain yield per plant (g)	Biological yield per plant (g)	1000 seed weight (g)	Harvest Index (%)
PKV HMT/Pusa 1121	5.2 **	8.9 **	13.2 **	0.8	6.3**
PKV HMT/Badshahbhog Sel-1	6.8 **	-4.4 **	-6.7	-0.3	-3.6 **
PKV HMT/Trombay Chhattisgarh Dubraj Mutant (TCDM-1)	-7.7 **	-4.0 **	-7.0	7.7 **	-3.0 **
PKV HMT/Chhattisgarh Devbhog	-2.2	0.3	-3.0	-5.2**	2.5*
PKV HMT/ R2281-308-1-185-1	-2.0	-0.8	3.5	-3.0**	-2.1
RFS-2019-3/Pusa 1121	0.8	-0.6	-0.5	-0.8	0.2
RFS-2019-3/Badshahbhog Sel-1	-3.2	1.0	-4.5	1.0	3.3 **
RFS-2019-3/Trombay Chhattisgarh Dubraj Mutant (TCDM-1)	1.6	1.5	9.8 *	-2.1 *	-1.7
RFS-2019-3/Chhattisgarh Devbhog	-1.4	-0.4	-1.2	1.0	-0.3
RFS-2019-3/R2281-308-1-185-1	2.1	-1.5	-3.4	0.8	-1.5
Zinco Rice MS/Pusa 1121	-0.04	-1.3	8.3	-0.9	-2.9 **
Zinco Rice MS/Badshahbhog Sel-1	-8.8 **	1.7 *	0.8	4.5 **	1.6
Zinco Rice MS/Trombay Chhattisgarh Dubraj Mutant (TCDM-1)	2.3	0.9	-0.9	-3.5 **	1.0
Zinco Rice MS/Chhattisgarh Devbhog	3.9 *	-0.7	-2.2	3.5**	-0.9
Zinco Rice MS/R2281-308-1-185-1	2.5	-0.5	-6.0	-3.6**	1.0
*Significant at p=0.05% level, ** Significant at p=0.01% level					

Table 4. Contd….

Characters	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Effective tillers per plant	Total number of spikelets per panicle	Number of filled spikelets per panicle
HMT Sona/Pusa 1121	0.1	-12.3 **	-1.3	1.0	-2.3	-1.6
HMT Sona/Badshahbhog Sel-1	-0.2	12.9**	2.2	-1.9 **	8.3	-3.1
HMT Sona/Trombay Chhattisgarh Dubraj Mutant (TCDM-1)	-0.5	-2.0	0.6	0.5	4.5	14.0
HMT Sona/Chhattisgarh Devbhog	-1.900 *	-0.04	-0.4	0.8	-7.8	-2.5
HMT Sona /R2281-308-1-185-1	2.500 **	1.4	-1.1	-0.4	-2.6	-6.6
Improved Samba Mahsuri /Pusa 1121	-2.700 **	14.7**	0.1	-3.3**	3.9	-6.2
Improved Samba Mahsuri /Badshahbhog Sel-1	0.5	-5.5	-0.7	1.8**	-7.4	11.6
Improved Samba Mahsuri /Trombay Chhattisgarh Dubraj Mutant (TCDM-1)	4.700 **	0.2	1.2	-1.1	-15.8	-15.2
Improved Samba Mahsuri /Chhattisgarh Devbhog	-1.2	-5.9	-0.1	1.4*	12.0	5.5
Improved Samba Mahsuri /R2281-308-1-185-1	-1.3	-3.5	-0.5	1.1	7.2	4.3
CD95% SCA	1.7	6.7	2.5	1.5	18.4	15.8
*Significant at p=0.05% level, **Significant at p = 0.01%level						

Table 4. Contd...

Characters	Spikelets fertility %	Grain yield per plant (g)	Biological yield per plant (g	1000 seed weight (g)	Harvest Index (%)
HMT Sona/Pusa 1121	0.4	-0.8	-0.2	-2.2*	-0.2
HMT Sona/Badshahbhog Sel-1	-4.7 *	0.9	3.3	-1.6	0.4
HMT Sona/Trombay Chhattisgarh Dubraj Mutant (TCDM-1)	5.2 **	2.7**	3.7	-2.4*	2.1
HMT Sona/Chhattisgarh Devbhog	1.8	-2.0 *	-3.1	1.8	-2.1 *
HMT Sona /R2281-308-1-185-1	-2.7	-0.8	-3.5	4.5 **	-0.1
Improved Samba Mahsuri /Pusa 1121	-6.5**	-6.0**	-20.7**	3.2 **	-3.3**
Improved Samba Mahsuri /Badshahbhog Sel-1	9.9**	0.6	7.1	-3.6 **	-1.7
Improved Samba Mahsuri /Trombay Chhattisgarh Dubraj Mutant (TCDM-1)	-1.3	-1.2	-5.6	0.3	1.5
Improved Samba Mahsuri /Chhattisgarh Devbhog	-2.03	2.8**	9.6 *	-1.2	0.8
Improved Samba Mahsuri /R2281-308-1-185-1	0.07	3.7**	9.5 *	1.2	2.6*
CD95% SCA	3.7	1.6	9.0	1.9	2.1
*Significant at p=0.05% level, **Significant at p=0.01% level					

Table 5: Best general and specific combiners for grain yield and its attributing traits in rice.

Sr. No.	Traits	Best general combiner		Best specific combiner
		Lines	testers	
1.	Days to 50% flowering	Zinco Rice MS	Pusa 1121	PKV HMT /Trombay Chhattisgarh Dubraj Mutant (TCDM-1) PKV HMT/ Badshahbhog Sel-1 Zinco Rice MS /Pusa 1121
2.	Plant height(cm)	HMT Sona	R2281-308-1-185-1	HMT Sona/Pusa 1121 Zinco Rice MS/ Badshahbhog Sel-1 RFS-2019-3/ Badshahbhog Sel-1
3.	Panicle length (cm)	Improved Samba Mahsuri	Badshahbhog Sel-1	HMT Sona/ Badshahbhog Sel-1 PKV HMT/Pusa 1121 Improved Samba Mahsuri/Trombay Chhattisgarh Dubraj Mutant (TCDM-1)
4.	Effective tillers per plant	HMT Sona	Chhattisgarh Devbhog	PKV HMT/Pusa 1121 Improved Samba Mahsuri/Badshahbhog Sel-1 Improved Samba Mahsuri/Chhattisgarh Devbhog
5.	Total number of spikelets per panicle	RFS-2019-3	Badshahbhog Sel-1	RFS-2019-3/Badshahbhog Sel-1 Zinco Rice MS/R2281-308-1-185-1 Zinco Rice MS/Trombay Chhattisgarh Dubraj Mutant (TCDM-1)
6.	Number of filled spikelets per panicle	RFS-2019-3	Badshahbhog Sel-1	RFS-2019-3/Badshahbhog Sel-1 Zinco Rice MS/R2281-308-1-185-1 Zinco Rice MS/Trombay Chhattisgarh Dubraj Mutant (TCDM-1)
7.	Spikelets fertility %	HMT Sona	R2281-308-1-185-1	Improved Samba Mahsuri/Badshahbhog Sel-1 PKV HMT/Badshahbhog Sel-1 PKV HMT/Pusa 1121
8.	Grain yield per plant (g)	PKV HMT	Pusa 1121	PKV HMT/Pusa 1121 Improved Samba Mahsuri/R2281-308-1-185-1 Improved Samba Mahsuri/Chhattisgarh Devbhog
9.	Biological yield per plant (g)	Zinco Rice MS	Pusa 1121	PKV HMT/Pusa 1121 RFS-2019-3/Trombay Chhattisgarh Dubraj Mutant (TCDM-1) Improved Samba Mahsuri/Chhattisgarh Devbhog
10.	1000 seed weight (g)	PKV HMT	Pusa 1121	PKV HMT/Trombay Chhattisgarh Dubraj Mutant (TCDM-1) Zinco Rice MS/Badshahbhog Sel-1 HMT Sona /R2281-308-1-185-1
11.	Harvest Index (%)	PKV HMT	Trombay Chhattisgarh Dubraj Mutant (TCDM-1)	PKV HMT/Pusa 1121 RFS-2019-3/Badshahbhog Sel-1 Improved Samba Mahsuri/R2281-308-1-185-1

CONCLUSIONS

From the current study it is observed that the highest positive significant SCA effects for grain yield per plant (g) were recorded for cross PKV HMT/Pusa 1121, Improved Samba Mahsuri/R2281-308-1-185-1 and Improved Samba Mahsuri/Chhattisgarh Devbhog. This indicate there is involvement of non-additive gene action and they are effective combinations for creating high-yielding cultivars. The crosses PKV HMT/Trombay Chhattisgarh Dubraj Mutant (TCDM-1), PKV HMT/ Badshahbhog Sel-1, and Zinco Rice MS/Pusa 1121 showed the highest negative significant specific combining ability effects for days to 50% flowering, this indicates that there is a preponderance of additive gene action, so progeny selection will be effective for genetic improvement of this trait, negative values direct that these are good combiners and indicated the efficacy of these crosses in breeding for earliness. The maximum negative significant SCA effects have shown by cross HMT Sona/Pusa 112 followed by RFS-2019-3/ Badshahbhog Sel-1 and Zinco Rice MS/ Badshahbhog Sel-1 for plant height (cm) represented in Table 5. These crosses were used to develop dwarf and semi dwarf varieties.

FUTURE SCOPE

It came to be known that the best specific combiners to create early maturing genotypes were PKV HMT/Trombay Chhattisgarh Dubraj Mutant (TCDM-1), PKV HMT/Badshahbhog Sel-1, and Zinco Rice MS/Pusa 1121. The most effective specific combiners for enhancing grains yield per plant (g) has been found to be PKV HMT/ Pusa 1121. To obtain the finest general combiners for desired traits, the crossing programme will utilise more lines and testers**.**

Acknowledgement. The authors are obliged to Indira Gandhi Krishi Vishwavidyalaya, Raipur for providing technical assistance and financial support during the Ph.D. research work of the first author.

Conflict of Interest. None.

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How to cite this article: Khemlata Thakur, Abhinav Sao, Deepak Gauraha, Sunil Nair and Krishna Tandekar (2023). Estimation of Combining Ability using Line × Tester Analysis for Yield and its Contributing Traits in Aromatic rice (*Oryza sativa* L.). *Biological Forum – An International Journal*, *15*(7): 01-09.