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Combining Ability Analysis for Grain Quality Characters of Diverse CMS Lines in Hybrid Rice

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ABSTRACT: The general combining ability (GCA) of the parents and specific combining ability (SCA) of the crosses for twelve grain quality traits were determined using a line × tester mating design with three cytoplasmic male sterile (CMS) lines and eleven elite testers. Significant variations were reported in the lines as well as the testers for majority of characters. Allowing for the scope of heterosis breeding the combining ability analysis expressed the predominance of non-additive gene action for kernel length, kernel breadth, kernel length to breadth ratio, kernel length after cooking, kernel elongation ratio, hulling percentage, milling percentage, head rice recovery, gel consistency, alkali spreading value and amylose content; while additive gene action predominated in the character kernel breadth after cooking, which allows the scope for transgressive breeding. The GCA effect estimates revealed that among all the lines IR58025A and IR79156A were the best combiners for most of quality characters like kernel breadth, kernel length after cooking, kernel breadth after cooking, kernel elongation ratio, hulling percentage, head rice recovery, milling percentage, alkali spreading value and amylose content. Among the testers Anjali was the best general combiner for three quality characters viz., hulling %, milling %, and head rice recovery, whereas Govind was the best general combiner for kernel breadth, kernel breath after cooking, and gel consistency The cross IR79156A × Pant Dhan -12 had desirable SCA effects for two quality traits viz., kernel breadth and kernel breadth after cooking, hence was the best combiner.

Keywords: CMS lines, general combining ability, specific combining ability; line × tester.

INTRODUCTION

Rice (*Oryza sativa* L., 2n=2x=24) is the second most predominant cereal crop in the world, feeding more than 60% of the world's population (Abbas *et al*., 2021). Cultivated over an area of nearly 162 million hectares it yields 756 million tonnes (FAOSTAT 2021) per annum. This production should be increased to cope with continuing population growth and the threat of environmental pressures (Chang *et al*., 2016). Hybrid rice technology utilizes the phenomenon of hybrid vigour to boost the rice yield potential by 15-25% over current commercial cultivars (Yang and Hwa, 2008). But the increased yield of rice hybrids alone does not ensure profitability to the farmers if their grain quality is not acceptable and don't fetch high premium in the market. Thus, in rice research the grain quality; which was formerly overshadowed by the desire for better yield has now become an important and essential tool for variety adoption.

Rice grain quality is difficult to quantify precisely because quality preferences change within country, region and between different ethnic groups. Hence, breeding objectives are to be augmented giving equal weightage to high yield and preferred grain quality (physical and chemical) for better consumer acceptance (Tiwari *et al*., 2021).

The combining ability of the parents in terms of quality should be good so as to obtain crosses with desirable quality attributes. This necessitates the identification of parents with good general combing ability (GCA) effects and cross combinations with high specific combining ability effects (SCA) for economic exploitation of heterosis and isolation of pure lines among the progenies of the heterotic hybrids. The line × tester analysis is widely employed to investigate general (GCA) and specific combining ability (SCA) effects (Kamara *et al*., 2021) which enables screening of large number of parental lines (Kempthorne 1957).

Combining ability analysis facilitates selecting the best parents for crossing and identifying promising cross recombinants (Kempthorne 1969). The GCA and SCA variances are utilized to identify the contribution of additive and non-additive gene effects, whereas SCA indicates the deviation of hybrid performance from the used parents, and it is related to non-additive gene effects (Bradshaw 2017; Parimala *et al*., 2018). Moreover, the line × tester analysis determines gene action that is responsible for the expression of the studied traits **(**Mutimaamba *et al*., 2020). Hence, the present study was taken up to assess the combining ability of parents and hybrids for grain quality traits in hybrid rice.

MATERIALS AND METHODS

The material for the present investigation comprised of three lines viz., Pant CMS-3A, IR59025A and IR79156A which were crossed with eight testers Pant Dhan-12, Pant Dhan-18, Anjali, Govind, Prasad, Sarju-52, Pusa Basmati-1121, Pusa Basmati-1509, Pusa Basmati-1 in line × tester design at Norman. E. Borlaug crop research centre at G.B.P.U.AT, Pantnagar during the year 2018. The 24 F1s along with their parents were evaluated during Kharif of 2019. Observations were recorded on physical, cooking and chemical quality characters. 100 grams of representative sample was used for estimation of hulling and milling with Satake dehusker (Type-TM05) and Satake Grain Testing Mill (Type TM05) polished respectively. Full rice and $3/4^{th}$ kernels were taken as whole milled rice for computation of head rice recovery. The kernel characters were recorded from 10 randomly selected kernels respectively. Kernel dimensions were obtained using dial micrometre and kernel length to breadth ratio was compared **(**Murthy and Govindaswamy, 1967). A five-gram sample of rice was placed in a labelled test tube with 15 ml water and soaked for ten minutes. For 20 minutes, the tubes were immersed in a water bath that was kept at a boiling temperature (100°C). The length of the cooked kernel was measured in millimetres after it was cooked. The elongation ratio was estimated by dividing the length of cooked rice kernels by the raw rice kernels' original average length. Graph sheet was used to quantify cooking traits. Dehusked grains were used to facilitate the alkali digestion test. For the analysis of gel consistency and amylose content deshusked rice were grounded into rice flour.

RESULTS AND DISCUSSION

The analysis of variance in majority of traits revealed highly significant differences among the genotypes. It also expressed significant difference among the parents and crosses for all characters except for kernel breadth after cooking and alkali spreading value. The lines and testers were found to be non-significant for most of the characters. Variation amongst the parents *vs* crosses were significant for majority of quality characters except kernel breadth after cooking, and hulling percentage which points towards the presence of substantial heterosis in crosses (Table 1). The mean squares due to lines × tester's interaction component also inferred significant difference for of all the characters. This result indicates that both the additive and non-additive variance were important for the study of these characters.

The variation attributable to GCA was higher than SCA in the current investigation (Lal *et al*., 2021) as evidenced by the ratio being more than one for kernel breadth after cooking, indicating that additive gene action was predominantly controlling this qualitative attribute (Table 1).

Table 1: Analysis of variance of combining ability for grain quality characters in rice.

Source of variation	df	Kernel length	Kernel breadth	Kernel length to breadth ratio	Kernel length after cooking	Kernel breadth after cooking	Kernel elongation ratio
Replicates	2	0.0019	0.0025**	0.03**	0.0058	0.0031	0.0001
Treatments	46	2.9**	0.37**	1.87**	26.06**	0.76**	0.19**
Parents	13	5.21**	0.66**	3.23**	62.41**	0.78**	0.39**
Crosses	32	1.95**	0.22**	1.20**	12.11**	0.73**	0.12**
Parents vs crosses	1	3.44**	1.39**	5.36**	0.17	1.80**	0.087**
Lines	2	0.67	0.09	0.55	2.81	0.74	0.13
Testers	10	3.26	0.29	2.37**	22.35**	0.73	0.14
Lines × testers	20	1.41**	0.20**	0.68**	7.92**	0.73**	0.11**
Error	92	0.036	0.031	0.022	0.093	0.058	0.0039
σ^2 GCA		0.0091**	0.004	0.0089**	0.072**	0.0001	0.0001
σ^2 SCA		0.46**	0.66**	0.22**	2.61**	2.40**	0.036**
σ2 GCA/ σ^2 SCA		0.019	0.0060	0.040	0.027	4.17	0.0028
Source of variation	**df**	**Hulling %**	**Milling %**	**Head rice recovery**	**Gel consistency**	**Alkali spreading value**	**Amylose content**
Replicates	2	3.31	0.91	0.18	5.19	0.0038	1.82**
Treatments	46	5.49	10.34**	23.76**	171.86**	1.71**	4.84**
Parents	13	2.97	14.41**	45.22**	316.84**	1.75**	2.76**
Crosses	32	6.68**	7.84**	11.75**	116.25**	1.72**	5.83**
Parents vs crosses	1	0.038	37.41**	128.90**	66.78**	0.99**	0.084
Lines	2	9.79	4.69	0.46	54.30	0.17	1.62
Testers	10	4.07	6.91	9.67	267.66**	4.11**	6.64
Lines × testers	20	7.68**	8.61**	13.92**	46.73**	0.68**	5.85**
Error	92	3.73	2.16	1.89	3.41	0.017	0.35
σ2 GCA		0.017	0.013	0.037	1.19**	0.018**	0.03
σ^2 SCA		1.45**	2.21**	3.98**	14.52**	0.22**	1.82*
σ2 GCA/ σ^2 SCA		0.012	0.006	0.01	0.081	0.082	0.016

"Significant at p=0.5, **Significant at p = 0.01

Hence, transgressive breeding may be useful for this character. This was in line with the findings previously reported (Sharma *et al*., 2007, Kumar *et al*., 2007, Asfaliza *et al*., 2012). Variance due to SCA was higher than GCA in characters like kernel length, kernel breadth, L/B ratio, kernel length after cooking, kernel elongation ratio, hulling percentage, milling percentage, head rice recovery, gel consistency, alkali spreading value, and amylose content, as evidenced by the ratio being less than one, implied a significant role of non-additive gene action. This indicated that heterosis breeding is a better choice for these characters. The findings were consistent with previous research.

High SCA effect results mostly from dominance and interaction effects existing between the hybridizing parents. None of the hybrids had a favourable SCA effect for all the characters. In the present investigation, positive specific combining ability (SCA) is desired for all the characters. The cross combination which had desirable SCA effects for two quality characters was IR79156A × Pant Dhan -12 for kernel breadth and kernel breadth after cooking (Table 2). The best combiners for cooking quality traits were IR79156A × Pant Dhan-18 for kernel length, Pant CMS 3A × Pant Dhan-4 for L/B ratio, IR58025A × Prasad for kernel length after cooking, Pant CMS-3A × Pusa Basmati-1121 for kernel elongation ratio. For the other quality traits the top combiners were IR79156A × Pusa Basmati-1 for hulling, IR58025A × Pant Dhan-19 for milling and IR58025A × Sarju-52 for head rice recovery. While for gel consistency and amylose content the best combiners were Pant CMS-3A × Pusa Basmati-1509, and IR58025A × Prasad respectively.

Rice cooking time is determined by the coarseness of the grain. The intermediate alkali spreading value indicated medium disintegration and was categorized as intermediate gelatinization temperature, which is ideal for high-quality grain (Shivani *et al*., 2009). Parents with intermediate combining ability are selected to produce crosses with intermediate gelatinization and alkali spreading values, which would result in crosses with average SCA effects for these characteristics. Pant CMS-3A × Pusa Bamati-1 exhibited moderate SCA effects for alkali spreading value (Table 2).

Table 2: Estimates of GCA and SCA effects for quality physical characters in rice.

Parents	Kernel length	Kernal breadth	Kernel length to breadth ratio	Kernel length after cooking	Kernel breadth after cooking	Kernel elongation ratio
Lines						
Pant CMS-3A	0.507 ***	-0.067 ***	0.348 ***	0.107 ***	-0.018 *	-0.101 ***
IR58025A	0.383 ***	0.077 ***	0.060 ***	0.152 ***	-0.071 ***	-0.060 ***
IR79156A	0.269 ***	0.015 **	0.125 ***	0.708 ***	0.093 **	0.029 ***
SE	0.0033	0.0089	0.0274	0.0521	0.0131	0.0101
Testers						
Pant Dhan-4	-0.218 ***	0.090 ***	-0.270 ***	-1.306 ***	0.061 ***	-0.142 ***
Pant Dhan-12	-0.109 *	0.116 ***	-0.237 ***	-0.254 ***	0.023	-0.004
Pant Dhan-18	-0.195 ***	-0.058 ***	-0.022	-0.728 ***	-0.368 ***	-0.051 ***
Pant Dhan-19	0.06	-0.072 ***	0.125 ***	-0.407 ***	-0.025	-0.061 ***
Anjali	-0.451 ***	0.073 ***	-0.353 ***	-1.378 ***	0.122 ***	-0.104 ***
Govind	0.518 ***	0.210 ***	-0.100 **	0.128	0.302 ***	-0.087 ***
Prasad	-0.475 ***	0.069 ***	-0.360 ***	-0.404 ***	0.256 ***	0.073 ***
Sarju-52	-0.577 ***	0.067 ***	-0.360 ***	-0.500 ***	-0.048 **	0.063 ***
Pusa Basmati-1121	1.082 ***	-0.198 ***	0.946 ***	2.810 ***	-0.189 ***	0.136 ***
Pusa Basmati-1509	0.969 ***	-0.194 ***	0.877 ***	2.972 ***	-0.043 *	0.171 ***
Pusa Basmati-1	1.668 ***	-0.132 ***	1.089 ***	3.387 ***	-0.148 ***	0.090 ***
SE	0.0637	0.0170	0.0525	0.0998	0.0251	0.0193
Crosses						
Pant CMS-3A × Pant Dhan-4	0.883 ***	-0.186 ***	0.829 ***	2.171 ***	-0.096 *	0.129 ***
Pant CMS-3A × Pant Dhan-12	-0.452 ***	-0.176 ***	0.04	-0.561 **	-0.178 ***	0.015
Pant CMS-3A × Pant Dhan-18	-0.21	-0.059	0.041	0.19	0.453 ***	0.065
Pant CMS-3A × Pant Dhan-19	-0.075	0.195 ***	-0.382 ***	-0.438 *	0.169 ***	-0.038
Pant CMS-3A × Anjali	0.016	-0.120 ***	0.209 *	-0.027	-0.168 ***	0.005
Pant CMS-3A × Govind	0.358 **	0.164 ***	-0.177 *	0.031	-0.104 *	-0.046
Pant CMS-3A × Prasad	0.270 *	0.108 ***	-0.077	-0.860 ***	0.002	-0.199 ***
Pant CMS-3A × Sarju-52	-0.564 ***	-0.184 ***	-0.027	-1.948 ***	-0.597 ***	-0.166 ***
Pant CMS-3A × Pusa Basmati-1121	-0.534 ***	0.065 *	-0.359 ***	1.405 ***	0.353 ***	0.282 ***
Pant CMS-3A × Pusa Basmati-1509	0.016	0.097 **	-0.144	1.713 ***	0.017	0.203 ***
Pant CMS-3A × Pusa Basmati-1	0.537 ***	0.112 ***	0.084	-1.008 ***	-0.018	-0.183 ***
IR58025A × Pant Dhan-4	-0.183	-0.03	-0.079	0.543 **	0.116 **	0.117 **
IR58025A × Pant Dhan-12	0.769 ***	-0.217 ***	0.695 ***	2.200 ***	0.014	0.110 **
IR58025A × Pant Dhan-18	0.281 *	-0.053	0.212 *	0.238	-1.915 ***	-0.037
IR58025A × Pant Dhan-19	-0.461 ***	-0.189 ***	0.116	-1.064 ***	-0.182 ***	-0.063
IR58025A × Anjali	-0.820 ***	-0.034	-0.376 ***	0.018	-0.049	0.197 ***
IR58025A × Govind	0.571 ***	0.630 ***	-0.629 ***	-0.508 **	0.405 ***	-0.157 ***
IR58025A × Prasad	0.184	-0.089 **	0.195 *	2.388 ***	-0.029	0.256 ***
IR58025A × Sarju-52	0.126	-0.208 ***	0.331 ***	1.030 ***	0.408 ***	0.103 **
IR58025A × Pusa Basmati-1121	-0.123	-0.143 ***	0.255 **	-3.280 ***	0.266 ***	-0.373 ***

IR58025A × Pusa Basmati-1509	-0.354 **	-0.007	-0.220 **	-1.466 ***	-0.02	-0.108 **
IR58056A × Pusa Basmati-1	0.041	-0.079 *	0.175 *	-0.327	-0.025	-0.048
IR58056A × Pant Dhan-4	-0.686 ***	0.121 ***	-0.561 ***	-0.610 ***	-0.138 **	0.079 *
IR58056A × Pant Dhan-12	-0.021	0.731 ***	-0.974 ***	-2.192 ***	0.494 ***	-0.298 ***
IR58056A × Pant Dhan-18	1.078 ***	-0.121 ***	0.788 ***	0.705 ***	0.355 ***	-0.125 ***
IR58056A × Pant Dhan-19	1.010 ***	0.026	0.444 ***	0.690 ***	0.138 **	-0.111 **
IR58056A × Anjali	0.600 ***	-0.142 ***	0.489 ***	2.362 ***	-0.209 ***	0.202 ***
IR58056A × Govind	-0.538 ***	-0.369 ***	0.333 ***	-0.534 **	-0.329 ***	0.041
IR58056A × Prasad	0.098	-0.108 ***	0.173 *	-1.178 ***	0.167 ***	-0.206 ***
IR58056A × Sarju-52	0.400 ***	0.021	0.049	-0.526 **	-0.009	-0.159 ***
IR58056A × Pusa Basmati-1121	-0.149	-0.001	-0.1	1.684 ***	-0.028	0.219 ***
IR58056A × Pusa Basmati-1509	-0.303 **	-0.095 **	0.052	0.442 **	0.296 ***	0.120 ***
IR58056A × Pusa Basmati-1	-1.772 ***	-0.167 ***	-0.573 ***	-1.413 ***	-0.269 ***	0.211 ***
SE	0.1103	**0.0294**	**0.0910**	**0.1728**	**0.0435**	**0.0335**
Parents	**Hulling %**	**Milling %**	**Head rice recovery**	**Gel consistency**	**Alkali spreading value**	**Amylose content**
Lines						
Pant CMS-3A	-0.313	0.775 ***	0.171	2.567 ***	-0.013	-0.077
IR58025A	-0.023	0.801 ***	0.337 *	1.415 ***	0.027	0.242 ***
IR79156A	0.645 **	0.658 ***	0.447 **	0.193	-0.133 ***	-0.021
SE	0.3179	0.2449	0.2454	0.3101	0.0225	0.1091
Testers						
Pant Dhan-4	-0.193	1.380 ***	1.030 **	2.978 ***	0.924 ***	0.470 ***
Pant Dhan-12	0.152***	1.005 *	0.142	3.378 ***	0.316 ***	1.448 ***
Pant Dhan-18	0.193**	0.868 *	0.980 **	0.976 *	0.258 ***	0.600 ***
Pant Dhan-19	-0.04	0.7	0.261	2.747 ***	0.347 ***	0.023
Anjali	0.627**	2.136 ***	1.525 ***	2.126 ***	-0.313 ***	0.263 *
Govind	-0.273	0.909 *	1.190 ***	6.827 ***	-1.549 ***	-1.571 ***
Prasad	-0.255	1.228 **	-1.489 ***	1.129 **	0.955 ***	0.537 ***
Sarju-52	0.184**	-0.492	-0.495	3.487 ***	-0.390 ***	0.367 **
Pusa Basmati-1121	0.126**	-0.745	-2.280 ***	-8.194 ***	0.088 **	0.229
Pusa Basmati-1509	0.449**	-1.761 ***	-1.212 ***	-9.297 ***	-0.116 ***	-0.355 **
Pusa Basmati-1	-0.53	0.116	1.014 **	-9.637 ***	0.206 ***	0.093
SE	0.6087	0.4690	0.3381	0.5938	0.0432	0.2089
Crosses						
Pant CMS-3A × Pant Dhan-4	-1.914	-2.410 *	1.923 *	4.594 ***	0.746 ***	0.773 *
Pant CMS-3A × Pant Dhan-12	0.971	0.356	1.264	-2.183 *	-0.132	0.458
Pant CMS-3A × Pant Dhan-18	0.323	-0.888	2.073 *	-3.310 ***	0.106	-0.677 *
Pant CMS-3A × Pant Dhan-19	-2.121	-2.936 **	-1.348	-0.171	-0.776 ***	0.62
Pant CMS-3A × Anjali	0.466	0.424	-0.392	-3.310 ***	0.017	-0.07
Pant CMS-3A × Govind	0.625	-0.959	0.92	-2.232 *	0.313 ***	0.204
Pant CMS-3A × Prasad	-0.842	-0.177	-2.759 **	0.083	0.546 ***	-0.584
Pant CMS-3A × Sarju-52	0.219	-1.814	-4.372 ***	-4.331 ***	-0.476 ***	-1.673 ***
Pant CMS-3A × Pusa Basmati-1121	1.573	-1.095	2.683 **	5.973 ***	-0.054	-0.009
Pant CMS-3A × Pusa Basmati-1509	0.147	1.231	-0.096	0.959	-0.613 ***	1.058 **
Pant CMS-3A × Pusa Basmati-1	-0.307	-1.796	-0.011	0.322	0.378 ***	-0.343
IR58025A × Pant Dhan-4	-0.033	1.704	-2.806 ***	-11.031 ***	0.467 ***	0.183
IR58025A × Pant Dhan-12	0.552	-1.351	0.534	-4.058 ***	-0.162 *	0.349
IR58025A × Pant Dhan-18	1.541	-3.114 **	-0.884	3.791 ***	-0.650 ***	0.474
IR58025A × Pant Dhan-19	1.097	2.714 **	0.576	-0.91	-0.363 ***	-0.109
IR58025A × Anjali	-0.563	-1.132	-1.495	-4.439 ***	0.367 ***	-0.342
IR58025A × Govind	-1.644	-0.395	0.414	0.23	-0.454 ***	0.521
IR58025A × Prasad	-1.061	-0.444	2.099 *	1.498	0.169 *	2.566 ***
IR58025A × Sarju-52	-0.33	-0.374	3.569 ***	5.444 ***	0.174 *	-0.413
IR58025A × Pusa Basmati-1121	1.027	-1.351	-0.164	-0.489	0.053	0.465
IR58025A × Pusa Basmati-1509	0.255	1.371	1.608	2.144 *	-0.099	-4.282 ***
IR58056A × Pusa Basmati-1	-0.856	-0.079	-3.048 ***	-4.080 ***	-0.052	0.544
IR58056A × Pant Dhan-4	0.818	-1.743	-3.404 ***	0.258	-0.713 ***	0.726 *
IR58056A × Pant Dhan-12	-3.987 ***	-1.554	-0.396	3.571 ***	-0.792 ***	0.318
IR58056A × Pant Dhan-18	1.752	1.586	0.549	-2.637 **	-0.253 **	-0.910 **
IR58056A × Pant Dhan-19	0.538	-1.826	-0.345	0.549	-0.233 **	0.481
IR58056A × Anjali	-0.932	-1.369	0.258	-1.377	-0.199 *	0.294
IR58056A × Govind	1.508	2.034 *	-0.884	1.342	0.953 ***	1.457 ***
IR58056A × Prasad	-0.466	-1.294	1.108	-2.286 *	-0.014	-2.060 ***
IR58056A × Sarju-52	1.091	-0.254	2.041 *	-1.904 *	0.334 ***	-0.553
IR58056A × Pusa Basmati-1121	2.525 *	2.192 *	-0.414	-2.657 **	0.219 **	-0.082
IR58056A × Pusa Basmati-1509	-0.164	-0.062	-0.329	1.836	0.637 ***	1.108 ***
IR58056A × Pusa Basmati-1	2.762 *	-0.349	0.769	-1.024	-0.015	-2.516 ***
SE	1.0544	0.8123	0.8140	1.0285	0.0748	0.3619

“Significant at p = 0.05, **Significant at p=0.01

The findings of this study revealed that no cross was favourable for all characters, although one cross had positive SCA effects for two characters. The SCA value is a valuable metric for determining the usefulness of a cross combination for heterosis exploitation. The cross IR79156A × Pant Dhan -12 involved a high × high general combiner for quality traits, therefore allowing it to be exploited to produce superior recombinants in future generations.

From this research of quality characters, the relevance of high × high general combiners with high SCA effects was revealed which may be further used for improvement through single plant selection in segregating generations. However, in crosses with high SCA effects due to high × low general combiners, population improvement is required. Crosses involving low × low general combiners that have high SCA effects might be used in a heterosis breeding programme.

CONCLUSION

The study was aimed to determine the combining ability analysis of diverse CMS lines of hybrid rice. Forty-seven genotypes, comprising of three cytoplasmic male sterile (CMS) lines, eleven testers and thirty-three crosses were evaluated for grain quality characters. The evaluated parental genotypes and their hybrid combinations displayed significant variations indicating substantial genetic variability that could be exploited in hybrid rice breeding programme. Significant GCA and SCA effects were detected for the assessed traits among crosses and parents, which implies that both additive and non-additive effects influence these traits in the selected parents and crosses. For most quality characters, such as kernel breadth, kernel length after cooking, kernel breadth after cooking, kernel elongation ratio, hulling percentage, head rice recovery, milling percentage, alkali spreading value, and amylose content, the CMS lines IR58025A and IR79156A were identified as good combiners. Anjali was the top general combiner among all the testers for three quality characters: hulling, milling, and head rice recovery, while Govind was the best parental line for kernel breadth, kernel breath after cooking, and gel consistency. The hybrid IR79156A × Pant Dhan -12 exhibited best SCA for two traits viz., kernel breadth and kernel breadth after cooking. Therefore, the current research would form a baseline to improve quality characters in hybrid rice breeding programmes by use of these aforesaid genotypes.

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Conflict of Interest. The authors declare no conflict of interest pertaining to this manuscript.

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