Combining ability analysis and gene action of grain quality traits in rice (*Oryza sativa* L.) using line × tester analysis

S. Santha*, R.Vaithilingam, A. Karthikeyan and T. Jayaraj

Tamil Nadu Rice Research Institute, Tamil Nadu Agricultural University, Thanjavur- 613501 (Tamil Nadu), INDIA
*Corresponding author. E-mail: santhatnau@gmail.com

Abstract: In rice, twelve lines were crossed with five testers in a line × tester mating design and the resultant 60 hybrids along with their parents were evaluated for their combining ability effects for 15 grain quality traits. The results revealed that the ratio of GCA : SCA variances computed for all the fifteen grain quality traits showed the predominance of non-additive gene action. Among the lines, ADT (R) 47 showed significant desirable *gca* effects at 1% probability level (p = 0.01) for 11 grain quality traits *viz.*, hulling percentage, milling percentage, head rice recovery percentage, kernel breadth, kernel breadth after cooking, breadth wise expansion ratio, gelatinization temperature, amylose content, gel consistency, water uptake and volume expansion ratio. Among the testers, Pusa 1460 showed significant desirable *gca* effects at 1% probability level (p = 0.01) for 10 grain quality traits *viz.*, kernel length, kernel breadth, kernel length/breadth ratio, kernel length after cooking, kernel breadth after cooking, linear elongation ratio, gelatinization temperature, amylose content, water uptake and volume expansion ratio and hence they were adjudged as the best combiners for the improvement of the respective traits. Among the hybrids, the hybrids CO 47/ Imp., Samba Mahsuri, ADT (R) 47/IRBB 21 and ADT (R) 46/IRBB 21 were identified as best hybrids for exploitation of grain quality traits since they revealed significant *sca* effects at 1% probability level (p = 0.01) for eight, eight and five grain quality traits, respectively.

Keywords: GCA, Line x Tester, Quality, Rice, SCA

INTRODUCTION

Known in Ancient India as the "Sustainer of the Human Race" , rice is perhaps the best showcase for the wonders of farmer innovation. It was domesticated in South Asia about 12000 years ago. The rice (*Oryza sativa* L.) being the staple food of Asian countries, is consumed by more than half of the world's population. Rice is high in carbohydrates, low in fat, moderate in proteins, vitamins, minerals and contributes to two third of calorific needs of the consumers. It had been used as a major food for over ten thousand years and has been cultivated in 114countries. Major advances had occurred in rice production during the past four decades due to adoption of hitechpackages. After the achievement of self sufficiency in rice production through high yielding varieties/hybrids, the demand for fine rice is increasing. Rice quality is of great importance for all people involved in producing, processing and consuming rice, because it affects the nutritional and commercial value of grains (Lodh, 2002 and Babu*et al.,*2013). The primary components of rice grain quality influencing the commercial value include appearance, milling, cooking and eating quality which are determined by their physical and chemical properties. Generally, the appearance of rice

grain is determined by of grain length, grain breadth, grain thickness and grain shape as length:breadth ratio (L/B ratio). The milling quality is assessed by using three principal characters *viz*., hulling, milling yield and head rice recovery. The eating and cooking quality of rice is usually evaluated by three physical and chemical characteristics of the starch as indirect indices: amylose content, gel consistency and gelatinization temperature. Of these, the amylose content of rice grains is recognized as one of the most important determinants of eating and cooking quality (Jue*et al*., 2009).

Success in any breeding programme for improvement of traits of economic importance such as grain quality traits depends upon the appropriate selection of parents and crosses. Combining ability analysis is one of the valuable tools available to ascertain the combining ability effects and helps in selecting the desirable parents and crosses for the further exploitation. It provides information on the nature and magnitude of gene effects governing various traits. General combining ability (GCA) is attributed to additive gene effects and additive x additive epistasis, and is theoretically fixable. On the other hand, specific combining ability attributable to non-additive gene action may be due to dominance or epistasis or both and is non-fixable. In

this context, Line × Tester analysis (Kempthorne (1957) is one of the important biometrical tools which provides information on the nature of gene action as additive and non additive, besides it aids to assess the general combining ability of the parents and specific combining ability of the hybrids. Recently, Line × Tester analysis was done by Venkatesan*et al*. (2008), Tyagi*et al*. (2010), Immanuel Selvaraj*et al.* (2011), Rajendra Reddy *et al*. (2012),Priyanka*et al*. (2014),and Showkat *et al*.(2015) for estimation of gene action in rice. Therefore, the present investigation was undertaken to select potential parents and hybrids for rice grain quality traits, besides to elucidate the nature of gene action governing the inheritance of various grain quality traits.

MATERIALS AND METHODS

The present investigation was carried out during two seasons during September 2013and May 2014 at Plant Breeding and Genetics Unit of Tamil Nadu Rice Research Institute, Aduthurai. A total of twelve high yielding genotypes susceptible to bacterial leaf blight disease as 'lines' and five donors for the said disease as 'testers' are the materials chosen for the present study. The 12 lines wereADT 39, ADT 42, ADT 43, ADT (R) 45, ADT (R) 46, ADT (R) 47, TNAU Rice ADT 49, CO 47, ASD 16, TKM 11, TKM 12 and TRY 2 and the five testers were Pusa 1460, Imp. Samba Mahsuri, Ajaya, IRBB 60 and IRBB 21.All the parents were raised in a crossing block at the South Farm, Tamil Nadu Rice Research Institute, Aduthurai during September 2013. Sowing and transplanting of parents were done thrice at weekly intervals in order to ensure synchronization in flowering of lines and testers which have duration range of 105 to 135 days. Twenty five days old seedlings of 17 entries were transplanted under irrigated condition in each three rows of three meter row length in the mainfield adopting a spacing of 30 x 20 cm. A wider spacing of 60cm was maintained between three rows of each entry for ease of hybridization All the recommended agronomical package of practices were well adopted to keep the plants uniformly good throughout the crop growth period.Five testers and 12 lines were grown, and at flowering stage, they were crossed with each other in a line × tester manner as described by Kempthorne (1957) to produce 60 hybrids. The resultant 60 F_1s together with 17 parental lines were grown during May 2014 in a Randomized Complete Block Design with three replications. Twenty five days old seedlings were transplanted in 3m row with 20 x 10cm spacing. The resultant 60 hybrids along with their parents were studied to analyse the *per se* performance and combining ability of 15 grain quality traits *viz.,* hulling percentage (HP), milling percentage (MP), head rice recovery percentage (HRR), kernel length (KL), kernel breadth (KB), kernel length/breadth ratio (KLBR), kernel

length after cooking (KLAC), kernel breadth after cooking (KBAC), linear elongation ratio (LER), breadth wise expansion ratio (BER), gelatinization temperature (GT), amylose content (AC), gel consistency (GC), water uptake(WU) and volume expansion ratio (VER).

To estimate Hulling Percentage(HP), **a** known quantity of rough rice (paddy) was cleaned, dried to 12-14% moisture content and dehulled with a McGill Laboratory Sheller and hulling percentage was estimated as follows,

$$\text{Hulling percentage} = \frac{\text{Weight of hulled rice(g)}}{\text{Weight of rough rice(g)}} \times 100$$

…..... 1

To estimate Milling Percentage (MP), **a**fter hulling, the brown rice was milled and polished in a Kett polisher for a standard time to find out the milling percentage. Milling percentage was estimated as follows,

$$\text{Milling percentage} = \frac{\text{Weight of milled rice(g)}}{\text{Weight of rough rice(g)}} \times 100$$

---2

To estimate Head Rice Recovery Percentage (HRR),the milled samples were sieved to separate whole grains from the broken ones. Small portion of broken kernels which passed along whole kernels were separated by hand. Head rice recovery, which is the estimate of full size plus three fourth size kernels was expressed in percentage.

$$\text{Head rice recovery} = \frac{\text{Weight of head rice(g)}}{\text{Weight of rough rice (g)}} \times 100$$

---3

Kernel length and breadth of ten dehusked rice kernels before milling (brown rice) in three sets was measured using graph sheet and the mean was expressed in millimeters (mm).Kernel length and breadth after cooking was measured by following the method described by Azenz and Shafi(1966).The ratio of mean length of cooked rice to mean length of milled rice was computed as linear elongation ratio (Juliano and Perez., 1984).Gelatinization Temperature was estimated based on Alkali Spreading Value (ASV) of milled rice based on Standard Evaluation System (IRRI, 1997).The standard procedure of Juliano (1979) was used for estimating the amylose content. Gel consistency was analyzed based on the method described by Cagampang*et al*. (1973).The ratio of milled rice was expressed as volume expansion (Varghese, 1960).

RESULTS AND DISCUSSION

The analysis of variance for 15 rice grain quality characters *viz*.,hulling percentage, milling percentage, head rice recovery percentage, kernel length, kernel breadth, kernel length/breadth ratio, kernel length after cooking, kernel breadth after cooking, linear elongation ratio, breadth wise expansion ratio, gelatinization temperature, amylose content, gel

consistency, water uptake and volume expansion ratio showed significant differences among 77 genotypes for all the traits studied.Analyses of variance for combining ability for 15 grain quality traits are presented in Table 1. The variance due to the lines, testers and line x tester, parents and crosses vs parents were found to be significant for most of the characters studied, except for hulling, milling percentages and breadth wise expansion in lines and testers; for head rice recovery percentage in lines and amylose content, gel consistency and water uptake in testers. The variance due to specific combining ability (SCA)was found to be higher than the variance due to general combining ability(GCA) for all the characters. The GCA/SCA was less than unity for all the characters.These results are in confirmity with the findings of Manickavelu *et al.* (2006)and Shivani*et al.* (2008) for hulling percentage, head rice recovery percentage, kernel length, kernel length/breadth ratio and kernel length after cooking, Veerabadhiran*et al.* (2009) for milling percentage, kernel length, kernel length after cooking and breadth wise expansion ratio Dhanavendran (2010), Tyagi *et al.*(2010) and Umadevi *et al.* (2010) for hulling, milling and head rice recovery percentages, kernel length and kernel breadth Hassan*et al.* (2011) for amylose content, Hasan *et al.*(2013) for milling percentage and Showkat *et al.*(2015) hulling percentage, milling percentage, head rice recovery, kernel length after cooking and kernel breadth after cooking in rice .

The presence of greater non-additive genetic variance for all the characters offers the scope for exploitation of hybrid vigour through heterosis breeding. The observations suggest that a breeding method that can incorporate both additive and non additive genetic components would be a useful strategy. Recurrent selection method, which provides better opportunity for selection, recombination and accumulation of desired genes, should help to increase fixable as well as non fixable types of gene effects.

The high *gca* effect for a particular trait of a parent indicates the additive gene effect for the trait governed by the genes in the parent concerned. Dhillon (1975) in his review on application of partial diallel crosses in plant breeding pointed out that combining ability of parents gives useful information on the choice of parents in terms of expected performance of their progenies. According to the book entitled Principles of crop improvement by Simmonds (1979), the *gca* effect is considered as the inherent genetic value of the parent for at rait which is due to additive gene effect and it is fixable.

The estimates of gca effects of the parents (Table 3) revealed that among the lines ADT (R) 47 showed desirable *gca* effects for hulling percentage, milling percentage, head rice recovery percentage, kernel breadth, kernel breadth after cooking, breadth wise expansion ratio, gelatinization temperature, amylose content, gel consistency, water uptake and volume expansion ratio (11 characters) while CO 47 recorded high *gca* effects for hulling percentage, milling percentage, kernel breadth, kernel breadth after cooking, linear elongation ratio, breadth wise expansion ratio and volume expansion ratio (7 characters). The parent ADT 39recorded significant *gca* effects for kernel length after cooking, linear elongation ratio, gelatinization temperature, gel consistency, water uptake and volume expansion ratio (6 characters). The parent ADT 43 was good combiner for head rice recovery percentage, kernel length after cooking, linear elongation ratio, gel consistency, water uptake and volume expansion ratio (6 characters) while ADT (R) 46 for kernel length, kernel length/ breadth ratio, gelatinization temperature, amylose content, gel consistency and volume expansion ratio (6 characters), TNAU Rice ADT 49 for kernel breadth, kernel length/breadth ratio, kernel breadth after cooking, linear elongation ratio and water uptake (5 characters), TRY 2 for kernel length, kernel length/ breadth ratio, kernel length after cooking, gelatinization temperature and water uptake (5 characters), ADT 42 for hulling percentage, gel consistency, water uptake and volume expansion ratio (4 characters), ADT (R) 45, for kernel breadth, kernel breadth after cooking, linear elongation ratio and breadth wise expansion ratio (4 characters),TKM 12 for kernel length after cooking, linear elongation ratio, amylose content and volume expansion ratio (4 characters), ASD 16 for hulling percentage, milling percentage, head rice recovery percentage and breadth wise expansion ratio (4 characters) and TKM 11 for kernel length, kernel length/breadth ratioand breadth wise expansion ratio (3 characters) had desirable *gca* effects for their respective traits.

Among testers, Pusa 1460 was good general combiner for kernel length, kernel breadth, kernel length/breadth ratio, kernel length after cooking, kernel breadth after cooking, linear elongation ratio, gelatinization temperature, amylose content, water uptake, volume expansion ratio (10 characters), Imp. Samba Mahsuri for hulling percentage, milling percentage, head rice recovery percentage,kernel breadth, kernel breadth after cooking, breadth wise expansion ratio, amylose content and gel consistency (8 characters) and IRBB 60 for head rice recovery percentage, kernel length, kernel length/breadth ratio, kernel length after cooking and amylose content (5 characters) and Ajaya for breadth wise expansion ratio and gel consistency (2 characters) recorded desirable mean values

From the above results, it is inferred that ADT (R) 47, Pusa 1460, Imp. Samba Mahsuri, CO 47, ADT 39, ADT 43 and ADT (R) 46 were adjudged as the best since they had significantly desirable *gca* effects at1% probability level (p = 0.01) for more than five

characters. These were followed by IRBB 60, TNAU Rice ADT 49 and TRY 2 which possessed favourable *gca* effects for five traits at 1% probability level (p = 0.01) .

Selvaraj*et al*. (2011) stated that it would be valuable to compare combining ability values of the parents with their *per se* performance for different characters and also reported that there was close association between the *gca* effects and *per se* performance of the parents in rice.

Regarding grain quality traits, among lines ADT (R) 47(Table 2 and 3) for six traits *viz.,*head rice recovery percentage, kernel breadth, kernel breadth after cooking, breadth wise expansion ratio, amylose content and volume expansion ratio, ADT (R) 46 for four traits *viz.,* kernel length, kernel length/breadth ratio, gelatinization temperature and amylose content, ADT 42 for hulling percentage, gel consistency and water uptake, TRY 2 for kernel length, kernel length after cooking and gelatinization temperature, TNAU Rice ADT 49 for kernel breadth and kernel breadth after cooking, CO 47 for linear elongation ratio and breadth wise expansion ratio, ADT 39 for volume expansion ratio and TKM 12 for kernel length after cooking recorded high mean values combined with significant *gca* effects.

Regarding testers, Pusa 1460 exhibited high *per se* performance coupled with significant *gca* effects for eight traits *viz.,*kernellength,kernel breadth, kernel length/breadth ratio, kernel length after cooking, linear elongation ratio, gelatinization temperature, amylose content and water uptake followed by Imp. Samba Mahsuri for six traits *viz.,*hulling percentage, milling percentage, head rice recovery percentage, kernel breadth, kernel breadth after cooking and gel consistency. The other testers *viz.,*IRBB 60 and Ajaya were found desirable for two traits each.

Hence, the parents, Pusa 1460, Imp. Samba Mahsuri,ADT (R) 47,ADT (R) 46,ADT 42 and TRY 2 were identified as superior for three to eight traits.

Specific combining ability is the deviation from the performance predicted under general combining ability (Allard, 1960). The *sca* value of any cross is helpful in predicting the performance of the hybrids which are better than the *gca*of parents(Jain ying ping and Virmani,1990), Latha *et al.*(2013), Priyanka *et al.* (2014) and Showkat *et al.* (2015) in rice.

Data on specific combining ability effects for all the crosses (Table 4)suggested that, CO 47/Imp. Samba Mahsuri for hulling percentage, milling percentage, head rice recovery percentage, kernel length, kernel length/breadth ratio, gel consistency, water uptake and volume expansion ratio (8 traits), ADT (R) 47/IRBB 21 for hulling percentage, milling percentage, kernel length/breadth ratio, kernel length after cooking, kernel breadth after cooking, breadth wise expansion ratio, gel consistency and water uptake (8 traits), ADT (R) 46/IRBB 21 for kernel length after cooking, kernel

breadth after cooking, linear elongation ratio, gelatinization temperature and amylose content (5 traits) while ADT 39/Pusa 1460 for kernel length, kernel length after cooking, kernel breadth after cooking and breadth wise expansion ratio (4 traits), ADT 43/Pusa 1460 for kernel length/breadth ratio, kernel breadth after cooking, breadth wise expansion ratio and volume expansion ratio (4 traits), ASD 16/ IRBB 21 for hulling percentage, milling percentage and breadth wise expansion ratio (3 traits) exhibited highest significant *sca* effects.

The hybrids, ADT 42/Pusa 1460 for hulling and milling percentage, ADT (R) 45/Imp. Samba Mahsuri for head rice recovery percentage and linear elongation ratio, TNAU Rice ADT 49/Imp. Samba Mahsuri for amylose content and volume expansion ratio, ASD 16/ Ajaya for head rice recovery percentage and gel consistency, TKM 11/Pusa 1460 for kernel length/ breadth ratio and gelatinization temperature, TKM 11/ Ajaya for kernel length after cooking and gel consistency (each for two traits) showed the highest significant *sca* effects). The other crosses exhibited significance for one trait only.

Therefore, it is concluded that the hybrids CO 47/Imp. Samba Mahsuri, ADT (R) 47/IRBB 21 and ADT (R) 46/IRBB 21 were identified as best hybrids for exploitation of grain quality traits since they revealed significant *sca* effects for eight, eight and five traits respectively.

Dwivedi and Pandey (2012) in rice reported that the crosses involving at least one parent with high *gca* effects would be best and ideal for selection and these crosses were expected to produce segregants of fixable nature in segregating generation following simple pedigree method.In the present investigation, for grain quality traits, the hybrid CO 47/Imp.SambaMahsuri for hulling percentage and milling percentage, TKM 11/Pusa1460 for kernel length/breadth ratio, ADT 39/ Pusa1460 for kernel length after cooking, ADT (R) 46/ IRBB 21 for kernel breadth after cooking, CO 47/ Pusa1460 for linear elongation ratio, ADT (R) 47/ Imp.SambaMahsuri, ADT (R) 46/IRBB 60 for amylose content, ADT(R) 47/Pusa1460 for water uptake, ADT 39/IRBB 21 and ADT 43/Pusa1460 for volume expansion ratio involved the parents with high x high *gca* effects. These crosses are expected to throw some useful transgressive segregants in the breeding program through pedigree method of selection.

In rice Amirthadevarathnam (1983) and Verma *et al.* (2009) stated that there are instances where poor x poor combiners produced good cross combinations. Similar results were obtained in the present investigation. The hybrids TNAU Rice ADT 49/Pusa1460 for hulling percentage, CO 47/Imp. Samba Mahsuri for kernel length, ADT (R) 47/IRBB 21 and TKM 11/ Ajaya for kernel length after cooking, ADT (R) 47/ IRBB 60 for linear elongation ratio, TKM 12/Ajaya for

Table 1. Analysis of variance (Mean sum of squares) for combining ability of different rice grain quality traits.

Sl. No	Sources	DF	Mean sum of squares						
			Hulling percentage	Milling percentage	Head rice recovery percentage	Kernel length	Kernel breadth	Kernel length/ breadth ratio	Kernel length after cooking
1	Genotypes	76	71.7662**	58.0941**	102.4519**	0.7767**	0.0781**	0.2976**	3.9281**
2	Cross	59	75.7859**	63.3439**	105.3265**	0.7063**	0.0682**	0.2679**	3.9856**
3	Line	11	85.8072	94.0144	122.4278	1.7656**	0.1300**	0.4379**	4.2605**
4	Tester	4	108.2899	107.1632	443.5339**	2.9716**	0.1547*	1.2382**	21.8506**
5	Line × Tester	44	70.3256**	51.6927**	70.3050**	0.2356**	0.0449**	0.1372**	2.2928**
6	Parent	16	61.2807**	41.6477**	46.4163**	0.9901**	0.1195**	0.4155**	3.9183**
7	Crosses vs Parents	1	2.3750	11.5000*	829.4219**	1.5160**	0.0005**	0.1683**	0.6938**
8	Error	152	2.6039	2.7336	1.7765	0.0212	0.0064	0.0146	0.0156
9	σ^2 GCA		0.0695	0.1483	0.4458	0.0060	0.0003	0.0017	0.0215
10	σ^2 SCA		22.7756	16.5835	22.8847	0.0718	0.0131	0.0413	0.7619
11	σ^2 GCA/σ^2 SCA		0.0030	0.0087	0.0194	0.0835	0.0223	0.0411	0.0282

* Significant at 5 % level ; ** Significant at 1% level

Contd…………

Table 1. Contd.

Sl. No	Sources	DF	Mean sum of squares							
			Kernel breadth after cooking	Linear elongation ratio	Breadth wise expansion ratio	Gelatinization temperature	Amylose content	Gel consistency	Water uptake	Volume expansion ratio
1	Genotypes	76	0.1448**	0.0922**	0.0381**	5.5941**	84.6335**	1087.0148**	0.8678**	0.8316**
2	Cross	59	0.1417**	0.1054**	0.0366**	5.0844**	94.8687**	1249.0523**	0.8869**	0.7622**
3	Line	11	0.2148**	0.2263**	0.0566	11.0889**	295.5258**	3734.5045**	1.8518**	2.8153**
4	Tester	4	0.1776**	0.2203**	0.0145	12.1611**	26.1111	1074.9653	0.5941	0.1453**
5	Line × Tester	44	0.1201**	0.0648**	0.0337**	2.9399**	50.9552**	643.5153**	0.6723**	0.3050**
6	Parent	16	0.1526**	0.0452**	0.0444**	7.6299**	40.5725**	510.4577**	0.6071**	0.9667**
7	Crosses vs Parents	1	0.2033**	0.0595**	0.0253*	3.0952**	185.7305**	751.7187**	3.9099**	2.7654**
8	Error	152	0.0059	0.0026	0.0037	0.2147	0.1193	0.9718	0.0197	0.0125
9	σ^2GCA		0.0003	0.0005	0.0000	0.0273	0.5590	7.7080	0.0027	0.0058
10	σ^2SCA		0.0381	0.0207	0.0101	0.9075	16.9387	214.1285	0.2157	0.0987
11	σ^2GCA/σ^2SCA		0.0070	0.0242	-	0.0300	0.0330	0.0035	0.0125	0.0581

* Significant at 5 % level; ** Significant at 1% level

Table 2. Mean performance of parents for different rice grain quality traits.

Sl. No	Parents	HP (%)	MP (%)	HRR (%)	KL (mm)	KB (mm)	KLBR	KLAC (mm)
	Lines							
1	ADT 39	78.36**	65.44	59.81	5.83	2.03	2.87	9.00
2	ADT 42	79.47**	75.73**	66.87**	6.70**	2.27	2.95	9.27
3	ADT43	76.33**	63.45	57.13	5.90	1.93**	3.06*	8.77
4	ADT(R)45	73.40	66.71	57.26	5.87	2.13	2.76	8.73
5	ADT(R)46	73.71	66.45	60.68**	6.83**	2.17	3.16**	11.53**
6	ADT(R)47	71.51	63.62	54.73	5.70	2.00*	2.85	8.43
7	TNAU Rice ADT 49	73.96	68.37	65.00**	5.60	1.93**	2.89	9.20
8	CO 47	65.85	62.15	54.99	5.70	2.03	2.80	9.37
9	ASD 16	69.39	64.96	57.63	5.47	2.67	2.05	7.70
10	TKM 11	69.52	64.77	57.77	5.63	2.20	2.56	8.83
11	TKM 12	68.82	62.29	54.82	5.67	2.13	2.62	9.80*
12	TRY 2	72.48	68.81	56.91	6.33*	2.27	2.80	10.37**
	Testers							
13	Pusa1460	63.18	59.39	51.56	7.53**	1.90**	3.96	12.47**
14	Imp. Samba Mahsuri	79.68**	70.70**	60.76**	5.43	1.93**	2.81	9.57
15	Ajaya	73.81	65.81	58.92	6.43**	2.43	2.64	10.17**
16	IRBB 60	73.76	63.88	56.09	6.40**	2.23	2.87	10.10**
17	IRBB 21	75.30	65.94	53.14	6.40**	2.17	2.94	9.33
	Grand Mean	72.85	65.79	57.89	6.08	2.14	2.86	9.57
	SE	0.93	0.95	0.77	0.08	0.05	0.67	0.07
	CD at 5%	2.58	2.65	2.13	0.23	0.12	0.19	0.20
	CD at 1 %	3.40	3.48	2.80	0.30	0.17	0.25	0.26

*Significant at 5 % level; **Significant at 1% level

Contd........

Table 2. Contd.

Sl. No	Parents	KBAC (mm)	LER	BER	GT	AC (%)	GC (mm)	WU	VER
	Lines								
1	ADT 39	3.00	1.74	1.55	**2.00**	**20.47**	84.00	3.40	**5.86****
2	ADT 42	**3.23**	1.58	1.49	**2.00**	21.70	**107.33***	**4.02****	3.59
3	ADT43	2.93	1.67	1.52	**2.00**	20.57	87.00	3.03	4.19
4	ADT (R)45	2.97	**1.51**	1.48	2.67	24.80	82.67	3.23	**4.40****
5	ADT (R)46	3.03	1.80	**1.57**	**5.00****	**29.80****	92.33	**2.65**	4.20
6	ADT (R)47	**2.43****	1.62	**1.30****	**2.00**	**23.80****	81.67	2.99	**4.39****
7	TNAU Rice ADT 49	**2.60****	1.72	**1.30****	2.67	20.83	80.33	2.95	4.01
8	CO 47	2.83	**1.83****	**1.16****	2.67	21.97	**100.33****	3.69	4.01
9	ASD 16	3.00	**1.85****	**1.57**	**4.67****	20.73	**103.67****	3.24	**3.39**
10	TKM 11	2.93	1.58	1.54	**2.00**	22.77	92.00	3.54	3.99
11	TKM 12	2.90	1.80	1.45	2.67	**23.80****	92.67	3.68	**4.59****
12	TRY 2	3.17	1.78	1.53	**7.00****	**30.43****	60.00	3.42	**4.39****
	Testers								
13	Pusa1460	2.93	**1.85****	**1.62**	**5.33****	**26.53****	90.33	**4.15****	**4.00**
14	Imp. Samba Mahsuri	**2.50****	**1.90****	1.40	2.67	21.23	**94.67****	**3.35**	**3.39**
15	Ajaya	**3.13**	1.73	**1.38***	**5.33****	20.13	**97.00****	**3.77***	3.99
16	IRBB 60	**3.13**	1.69	1.57	**5.33****	**17.20**	90.00	**4.34****	3.72
17	IRBB 21	3.03	**1.51**	1.52	3.67	17.47	**120.33****	3.64	3.79
	Grand Mean	**2.93**	**1.72**	**1.47**	**3.51**	**22.60**	**91.55**	**3.48**	**4.11**
	SE	**0.04**	**0.03**	**0.03**	**0.26**	**0.19**	**0.57**	**0.08**	**0.06**
	CD at 5%	**0.12**	**0.08**	**0.08**	**0.74**	**0.55**	**1.58**	**0.22**	**0.17**
	CD at 1 %	**0.16**	**0.11**	**0.13**	**0.97**	**0.73**	**2.08**	**0.29**	**0.23**

*Significant at 5 % level; **Significant at 1% level

Table 3. General combining ability effects of lines and testers for different rice grain quality traits.

Sl. No	Parents	HP	MP	HRR	KL	KB	KLBR	KLAC
	Lines							
1	ADT 39	-1.64 **	0.66 ns	-1.00 **	-0.10 **	0.03 ns	-0.08 **	0.87 **
2	ADT 42	2.35 **	0.48 ns	-2.23 **	-0.05 ns	0.07 **	-0.11 **	-0.23 **
3	ADT43	0.20 ns	-0.21 ns	0.98 **	-0.02 ns	0.01 ns	0.00 ns	0.13 **
4	ADT (R)45	-0.93 *	-1.13 **	-0.86 **	-0.20 **	-0.07 **	-0.00 ns	-0.01 ns
5	ADT (R)46	-0.18 ns	-0.43 ns	-2.01 **	0.34 **	-0.04 ns	0.22 **	0.01 ns
6	ADT (R)47	2.34 **	1.59 **	3.76 **	-0.28 **	-0.09 **	-0.01 ns	-1.03 **
7	TNAU Rice ADT 49	-1.00 **	-3.40 **	-3.61 **	-0.13 **	-0.12 **	0.12 **	-0.30 **
8	CO 47	3.55 **	3.71 **	-0.15 ns	-0.29 **	-0.07 **	-0.04 ns	-0.07 **
9	ASD 16	3.37 **	4.55 **	6.94 **	-0.37 **	0.23 **	-0.40 **	-0.41 **
10	TKM 11	-2.56 **	-3.25 **	-1.63 **	0.49 **	0.01 ns	0.06 *	-0.16 **
11	TKM 12	-3.62 **	-2.76 **	-0.06 ns	-0.13 **	0.00 ns	-0.04 ns	0.25 **
12	TRY 2	-1.89 **	0.18 ns	-0.13 ns	0.75 **	0.06 **	0.27 **	0.94 **
	Testers							
1	Pusa1460	-0.96 **	-2.11 **	-4.37 **	0.37 **	-0.05 **	0.26 **	1.26 **
2	Imp. SambaMahsuri	2.93 **	2.68 **	5.31 **	-0.27 **	-0.06 **	-0.03 ns	-0.22 **
3	Ajaya	0.25 ns	0.12 ns	-0.37 ns	-0.22 **	0.04 **	-0.14 **	-0.49 **
4	IRBB 60	-1.04 **	-0.22 ns	0.64 **	0.24 **	-0.01 ns	0.11 **	0.17 **
5	IRBB 21	-1.18 **	-0.47 *	-1.20 **	-0.11 **	0.09 **	-0.19 **	-0.72 **
	SE(Lines)	0.37	0.36	0.33	0.04	0.02	0.03	0.02
	SE (Testers)	0.24	0.23	0.21	0.03	0.01	0.02	0.01

* Significant at 5 % level; **Significant at 1% level

Contd………

Table 3. Contd….

Sl. No	Parents	KBAC	LER	BER	GT	AC	GC	WU	VER
	Lines								
1	ADT39	0.06 **	0.24 **	0.02 ns	0.28 *	1.25 **	13.07 **	0.15 **	0.50 **
2	ADT 42	0.14 **	-0.07 **	0.00 ns	-0.12 ns	-2.11 **	21.47 **	0.27 **	0.31 **
3	ADT43	0.04 ns	0.09 **	0.04 *	-0.46 **	-1.00 **	15.53 **	0.15 **	0.39 **
4	ADT (R)45	-0.20 **	0.04 **	-0.08 **	-0.92 **	-3.50 **	-4.67 **	-0.97 **	-0.39 **
5	ADT (R)46	0.06 **	-0.10 **	0.02 ns	1.54 **	4.42 **	25.20 **	-0.11 **	0.84 **
6	ADT (R)47	-0.15 **	-0.15 **	-0.06 **	0.74 **	11.26 **	6.47 **	0.34 **	0.18 **
7	TNAU Rice ADT 49	-0.13 **	0.06 **	0.04 **	-0.79 **	-1.66 **	-12.07 **	0.14 **	-0.28 **
8	CO 47	-0.11 **	0.07 **	-0.04 **	-1.12 **	-5.58 **	-18.60 **	0.08 *	-0.15 **
9	ASD 16	0.07 **	-0.05 **	-0.08 **	0.01 ns	-1.60 **	-18.47 **	-0.17 **	-0.21 **
10	TKM 11	-0.02 ns	-0.18 **	-0.03 *	-0.26 *	-1.22 **	-10.60 **	-0.24 **	-0.18 **
11	TKM 12	0.13 **	0.11 **	0.12 **	-0.32 **	2.42 **	-14.67 **	0.12 **	-0.45 **
12	TRY 2	0.11 **	-0.06 **	0.05 **	1.41 **	-2.68 **	-2.67 **	0.23 **	-0.54 **
	Testers								
1	Pusa1460	-0.06 **	0.12 **	-0.00 ns	0.91 **	0.56 **	-4.34 **	0.20 **	0.08 **
2	Imp. SambaMahsuri	-0.08 **	0.01 ns	-0.02 *	-0.65 **	0.27 **	5.61 **	-0.02 ns	-0.09 **
3	Ajaya	0.03 *	-0.03 **	-0.02 *	-0.29 **	-0.24 **	6.27 **	0.05 ns	0.00 ns
4	IRBB 60	0.03 *	-0.02 *	0.03 **	-0.09 ns	0.77 **	-2.92 **	-0.11 **	-0.03 ns
5	IRBB 21	0.09 **	-0.09 **	0.01 ns	0.13 ns	-1.36 **	-4.62 **	-0.11 **	0.03 *
	SE(Lines)	0.02	0.01	0.01	0.12	0.09	0.27	0.04	0.02
	SE(Testers)	0.01	0.01	0.01	0.07	0.06	0.18	0.03	0.02

*Significant at 5 % level ; ** Significant at 1% level

Table 4. Specific combining ability effects of hybrid combinations for different rice grain quality traits.

Sl. No	Hybrids	HP	MP	HRR	KL	KB	KLBR	KLAC
1	ADT39/Pusa1460	-4.96 **	-2.27 *	0.02 ns	0.39 **	0.08 ns	0.05 ns	1.04 **
2	ADT39/Imp.SambaMahsuri	1.76 ns	1.68 ns	-0.12 ns	-0.11 ns	0.02 ns	-0.09 ns	0.09 ns
3	ADT39/Ajaya	-1.29 ns	-0.71 ns	-3.45 **	0.17 *	-0.01 ns	0.09 ns	0.62 **
4	ADT39/IRBB 60	5.47 **	2.49 **	-0.91 ns	-0.65 **	-0.03 ns	-0.25 **	-2.21 **
5	ADT39/IRBB 21	-0.99 ns	-1.20 ns	4.46 **	0.20 *	-0.07 ns	0.20 **	0.46 **
6	ADT42/Pusa1460	7.09 **	8.02 **	-5.95 **	-0.29 **	0.07 ns	-0.25 **	-0.60 **
7	ADT42/Imp.SambaMahsuri	-3.12 **	-5.11 **	2.40 **	-0.19 *	-0.02 ns	-0.08 ns	-0.15 *
8	ADT42/Ajaya	-1.85 *	-3.04 **	-0.15 ns	0.19 *	-0.09 ns	0.19 **	0.48 **
9	ADT42/IRBB 60	-2.83 **	-0.11 ns	-1.05 ns	0.27 **	0.20 **	-0.11 ns	1.12 **
10	ADT42/IRBB 21	0.71 ns	0.25 ns	4.74 **	0.02 ns	-0.17 **	0.26 **	-0.85 **
11	ADT43/Pusa1460	0.40 ns	1.28 ns	1.21 ns	0.14 ns	-0.10 *	0.20 **	-0.43 **
12	ADT43/Imp.SambaMahsuri	0.47 ns	-4.85 **	-1.56 *	-0.25 **	0.01 ns	-0.17 *	-0.21 **
13	ADT43/Ajaya	0.90 ns	3.70 **	2.54 **	0.03 ns	0.21 **	-0.26 **	-0.61 **
14	ADT43/IRBB 60	-1.72 ns	-0.68 ns	4.03 **	0.33 **	-0.07 ns	0.27 **	0.83 **
15	ADT43/IRBB 21	-0.06 ns	0.55 ns	-6.22 **	-0.25 **	-0.05 ns	-0.05 ns	0.42 **
16	ADT (R) 45/Pusa1460	2.62 **	2.73 **	3.55 **	0.09 ns	0.01 ns	0.04 ns	0.01 ns
17	ADT (R) 45/Imp.SambaMahsuri	3.82 **	3.26 **	10.13 **	-0.01 ns	-0.02 ns	0.01 ns	0.63 **
18	ADT (R) 45/Ajaya	-0.89 ns	-2.19 *	-4.42 **	0.07 ns	-0.05 ns	0.09 ns	-1.74 **
19	ADT (R) 45/IRBB 60	-1.72 ns	-1.22 ns	-1.45 ns	0.11 ns	0.13 **	-0.11 ns	0.23 **
20	ADT (R) 45/IRBB 21	-3.82 **	-2.58 **	-7.81 **	-0.27 **	-0.07 ns	-0.02 ns	0.86 **
21	ADT (R)46/Pusa1460	2.72 **	4.29 **	1.32 ns	-0.18 *	0.08 ns	-0.21 **	-0.03 ns
22	ADT(R) 46/Imp.SambaMahsuri	-2.95 **	0.26 ns	-4.64 **	-0.18 *	-0.05 ns	-0.03 ns	0.08 ns
23	ADT(R)46/Ajaya	2.65 **	-2.41 *	2.18 **	-0.03 ns	0.02 ns	-0.05 ns	-1.19 **
24	ADT(R)46/IRBB 60	2.32 *	2.59 **	5.57 **	0.03 ns	-0.08 ns	0.16 *	-0.88 **
25	ADT(R)46/IRBB 21	-4.75 **	-4.73 **	-4.42 **	0.36 **	0.03 ns	0.13 ns	2.02 **
26	ADT (R)47/Pusa1460	-4.87 **	-2.33 *	-1.47 ns	-0.27 **	0.10 *	-0.27 **	0.14 ns
27	ADT (R)47/Imp. SambaMahsuri	-0.81 ns	-2.28 *	-0.66 ns	0.01 ns	0.08 ns	-0.10 ns	-0.81 **
28	ADT(R)47/Ajaya	-3.60 **	1.04 ns	-0.73 ns	0.12 ns	0.04 ns	-0.01 ns	-0.11 ns
29	ADT(R)47/IRBB 60	-1.39 ns	-0.70 ns	-1.73 *	-0.07 ns	-0.07 ns	0.11 ns	1.59 **
30	ADT (R)47/IRBB 21	10.68 **	4.27 **	4.60 **	0.21 *	-0.15**	0.28 **	-0.81 **

*Significant at 5 % level ; ** Significant at 1% level

Contd……….

Table 4. Contd.

Sl. No	Hybrids	HP	MP	HRR	KL	KB	KLBR	KLAC
31	TNAU Rice ADT49/Pusa1460	8.97 **	4.12 **	0.88 ns	-0.05 ns	0.00 ns	-0.01 ns	-0.19 **
32	TNAU Rice ADT49/Imp. Samba Mahsuri	1.40 ns	-1.59 ns	0.44 ns	-0.04 ns	-0.08 ns	0.09 ns	-0.75 **
33	TNAU Rice ADT49/Ajaya	-2.11 *	0.15 ns	-1.59 *	0.01 ns	-0.06 ns	0.07 ns	0.55 **
34	TNAU Rice ADT 49/IRBB 60	-3.71 **	-1.09 ns	-2.31 **	-0.15 ns	0.06 ns	-0.14 ns	-0.34 **
35	TNAU Rice ADT 49/IRBB 21	-4.55 **	-1.59 ns	2.59 **	0.23 **	0.08 ns	-0.00 ns	0.72 **
36	CO47/Pusa1460	-2.73 **	-1.22 ns	0.29 ns	-0.49 **	-0.02 ns	-0.21 **	0.15 *
37	CO47/Imp. Samba Mahsuri	10.12 **	12.17 **	6.90 **	0.85 **	0.06 ns	0.32 **	-0.37 **
38	CO47/Ajaya	1.12 ns	-1.01 ns	-4.76 **	-0.04 ns	-0.01 ns	-0.02 ns	0.03 ns
39	CO47/IRBB 60	-9.53 **	-8.74 **	-8.42 **	0.10 ns	0.14 **	-0.13 ns	0.57 **
40	CO47/IRBB 21	1.01 ns	-1.20 ns	5.98 **	-0.41 **	-0.17 **	0.04 ns	-0.37 **
41	ASD 16/Pusa1460	-6.91 **	-3.73 **	-6.94 **	0.26 **	-0.19 **	0.28 **	0.48 **
42	ASD 16/Imp. Samba Mahsuri	-8.48 **	-6.34 **	-8.35 **	0.13 **	0.02 ns	-0.03 ns	0.99 **
43	ASD 16/Ajaya	6.21 **	3.55 **	8.04 **	-0.25 **	0.05 ns	-0.18 *	0.19 **
44	ASD 16/IRBB 60	1.92 *	1.51 ns	2.12 **	0.09 ns	-0.19 **	0.24 **	-0.63 **
45	ASD 16/IRBB 21	7.26 **	5.01 **	5.13 **	-0.23 **	0.30**	-0.32 **	-1.04 **
46	TKM 11/Pusa1460	-3.66 **	-5.54 **	4.04 **	0.07 ns	-0.10 *	0.36 **	-0.36 **
47	TKM 11/ Imp. Samba Mahsuri	2.25 *	2.41 *	-3.26 **	0.01 ns	0.04 ns	0.09 ns	0.69 **
48	TKM 11/Ajaya	0.61 ns	1.78 ns	-0.61 ns	0.09 ns	0.01 ns	0.17 *	1.05 **
49	TKM 11/IRBB 60	1.98 *	1.25 ns	-0.43 ns	-0.24 **	0.09 *	-0.44 **	-0.67 **
50	TKM 11/IRBB 21	-1.18 ns	0.10 ns	0.25 ns	0.08 ns	-0.05 ns	-0.19 **	-0.71 **
51	TKM 12/Pusa1460	0.99 ns	-7.71 **	2.81 **	0.18 *	0.17 **	-0.19 **	-0.15 *
52	TKM 12/ Imp. Samba Mahsuri	-2.81 **	0.55 ns	0.33 ns	0.09 ns	-0.02 ns	0.03 ns	-0.30 **
53	TKM 12/Ajaya	1.39 ns	2.73 **	4.52 **	-0.17 *	-0.15 **	0.10 ns	0.47 **
54	TKM 12/IRBB 60	2.12 *	2.57 **	-2.31 **	0.11 ns	-0.20 **	0.37 **	-0.03 ns
55	TKM 12/IRBB 21	-1.68 ns	1.85 ns	-5.36 **	-0.21 *	0.19 **	-0.30 **	0.00 ns
56	TRY 2/Pusa1460	0.33 ns	2.34 *	0.25 ns	0.17 *	-0.09 ns	0.21 **	-0.07 ns
57	TRY 2/ Imp. Samba Mahsuri	-1.64 ns	-0.16 ns	-1.61 *	-0.32 **	-0.08 ns	-0.05 ns	0.11 ns
58	TRY 2/Ajaya	-3.13 **	-3.59 **	-1.58 **	-0.21 *	0.05 ns	-0.18 **	0.25 **
59	TRY 2/IRBB 60	7.08 **	2.13 *	6.89 **	0.10 ns	0.01 ns	0.04 ns	0.42 **
60	TRY 2/IRBB 21	-2.63 **	-0.73 ns	-3.96 **	0.25 **	0.10 *	-0.02 ns	-0.72 **
	SE	**0.82**	**0.81**	**0.74**	**0.08**	**0.04**	**0.07**	**0.05**

Contd............

*Significant at 5 % level ; ** Significant at 1% level

Table 4. Contd.

Sl. No	Hybrids	KBAC	LER	BER	GT	AC	GC	WU	VER
1	ADT39/Pusa1460	-0.36 **	0.09 **	-0.21 **	1.03 **	-0.51 *	5.07 **	0.19 *	0.01 ns
2	ADT39/Imp.SambaMahsuri	0.05 ns	0.01 ns	0.05 ns	0.25 ns	-2.02 **	-5.54 **	-0.24 **	0.11 ns
3	ADT39/Ajaya	-0.02 ns	0.04 ns	-0.03 ns	-0.11 ns	-1.57 **	-17.21 **	-0.45 **	-0.28 **
4	ADT39/IRBB 60	0.18 **	-0.22 **	0.10 **	0.03 ns	0.75 **	4.66 **	-0.10 ns	-0.29 **
5	ADT39/IRBB 21	0.15 **	0.08 **	0.10 **	-1.19 **	3.35 **	13.02 **	0.60 **	0.45 **
6	ADT42/Pusa1460	0.29 **	-0.09 **	0.08 *	-0.91 **	-0.21 ns	-2.66 **	-0.20 *	-0.17 **
7	ADT42/Imp.SambaMahsuri	-0.06 ns	0.01 ns	0.03 ns	-0.35 ns	-0.93 **	6.39 **	0.15 ns	-0.07 ns
8	ADT42/Ajaya	0.07 ns	0.09 **	0.06 ns	0.29 ns	5.59 **	-8.94 **	0.23 **	0.04 ns
9	ADT42/IRBB 60	-0.07 ns	0.12 **	-0.12 **	0.09 ns	-3.66 **	0.59 ns	-0.27 **	0.03 ns
10	ADT42/IRBB 21	-0.23 **	-0.13 **	-0.05 ns	0.87 **	-0.79 **	4.62 **	0.09 ns	0.17 **
11	ADT43/Pusa1460	-0.50 **	-0.19 **	-0.23 **	-1.24 **	-2.65 **	5.94 **	-0.22 **	0.39 **
12	ADT43/Imp.SambaMahsuri	0.15 **	0.10 **	0.07 ns	-0.02 ns	0.76 **	0.99 ns	-0.10 ns	-0.54 **
13	ADT43/Ajaya	0.07 ns	-0.10 **	0.01 ns	-0.38 ns	-2.92 **	-2.34 **	-0.26 **	0.26 **
14	ADT43/IRBB 60	0.18 **	0.13 **	0.06 ns	0.43 ns	1.77 **	3.86 **	0.61 **	0.16 *
15	ADT43/IRBB 21	0.11 *	0.05 ns	0.10 **	1.21 **	3.04 **	-8.45 **	-0.01 ns	-0.27 **
16	ADT (R) 45/Pusa1460	0.03 ns	-0.06 *	0.02 ns	0.23 ns	-0.99 **	6.14 **	0.05 ns	0.50 **
17	ADT (R) 45/Imp.SambaMahsuri	-0.09 ns	0.19 **	-0.05 ns	0.45 ns	-0.58 **	1.53 **	-0.20 *	-0.13 *
18	ADT (R) 45/Ajaya	-0.26 **	-0.31 **	-0.08 *	0.09 ns	-0.83 **	-16.14 **	0.00 ns	-0.22 **
19	ADT (R) 45/IRBB 60	-0.03 ns	-0.04 ns	-0.06 ns	0.23 ns	0.53 **	-8.28 **	0.32 **	0.34 **
20	ADT (R) 45/IRBB 21	0.34 **	0.23 **	0.18 **	-0.99 **	1.86 **	16.75 **	-0.17 *	-0.49 **
21	ADT (R)46/Pusa1460	-0.10 *	0.02 ns	0.01 ns	0.43 ns	-4.11 **	-0.39 ns	-0.37 **	0.40 **
22	ADT (R)46/ Imp.SambaMahsuri	-0.08 ns	-0.02 ns	-0.02 ns	1.98 **	-6.23 **	0.99 ns	0.39 **	-0.36 **
23	ADT (R)46/Ajaya	0.05 ns	-0.14 **	-0.03 ns	-2.38 **	-0.75 **	-0.01 ns	-0.01 ns	-0.12 ns
24	ADT(R)46/IRBB 60	-0.05 ns	-0.11 **	-0.05 ns	-1.57 **	4.71 **	-10.81 **	0.09 ns	0.01 ns
25	ADT(R)46/IRBB 21	0.18 **	0.25 **	0.09 *	1.54 **	6.38 **	10.22 **	-0.10 ns	0.08 ns
26	ADT (R)47/Pusa1460	0.45 **	0.06 *	0.17 **	0.56 *	3.41 **	-1.66 **	1.24 **	-0.11 ns
27	ADT (R) 47/Imp. SambaMahsuri	-0.30 **	-0.13 **	-0.16 **	-1.22 **	5.63 **	-2.61 **	-0.99 **	0.06 ns
28	ADT (R)47/Ajaya	0.13 **	-0.05 ns	0.11 **	0.42 ns	4.52 **	2.73 **	-0.01 ns	0.00 ns
29	ADT(R)47/IRBB 60	0.13 **	0.24 **	0.07 ns	1.23 **	1.04 **	-4.08 **	-0.07 ns	0.03 ns
30	ADT(R)47/IRBB 21	-0.40 **	-0.13 **	-0.19 **	-0.99 **	-14.60 **	5.62 **	-0.17 *	0.01 ns

*Significant at 5 % level ; ** Significant at 1 % level

Contd………

Table 4. Contd.

Sl. No	Hybrids	KBAC	LER	BER	GT	AC	GC	WU	VER
31	TNAU Rice ADT49/Pusa1460	0.06 ns	-0.03 ns	0.03 ns	1.09 **	6.53 **	-30.46 **	-0.17 *	-0.88 **
32	TNAU Rice ADT 49/Imp. Samba Mahsuri	-0.15 **	-0.07 *	-0.08 *	-0.35 ns	7.82 **	6.26 **	0.20 *	0.59 **
33	TNAU Rice ADT 49/Ajaya	-0.09 *	0.09 **	-0.09 **	-0.04 ns	-5.30 **	21.59 **	-0.29 **	0.26 **
34	TNAU Rice ADT 49 IRBB 60	0.11 *	-0.05 ns	0.17 **	-0.24 ns	-6.21 **	8.46 **	-0.37 **	0.03 ns
35	TNAU Rice ADT49 / IRBB 21	0.08 ns	0.04 ns	-0.03 ns	-0.46 ns	-2.84 **	-5.85 **	0.64 **	0.00 ns
36	CO47/Pusa1460	0.01 ns	0.20 **	0.00 ns	-0.57 *	-0.41 *	15.74 **	-0.75 **	-0.07 ns
37	CO 47/Imp. Samba Mahsuri	0.19 **	-0.37 **	0.07 *	-0.02 ns	-0.66 **	29.79 **	0.74 **	0.50 **
38	CO47/Ajaya	-0.11 *	0.02 ns	-0.03 ns	-0.38 ns	-2.87 **	-22.54 **	0.13 ns	0.04 ns
39	CO47/IRBB 60	-0.01 ns	0.14 **	-0.03 ns	-0.57 *	0.42 *	-11.68 **	0.30 **	-0.57 **
40	CO47/IRBB 21	-0.08 ns	-0.00 ns	-0.01 ns	1.54 **	3.52 **	-11.32 **	-0.42 **	0.11 ns
41	ASD 16/Pusa1460	-0.07 ns	0.01 ns	0.05 ns	-0.04 ns	0.75 **	0.61 ns	0.89 **	-0.19 **
42	ASD 16/Imp. Samba Mahsuri	0.25 **	0.17 **	0.12 **	0.52 ns	-1.83 **	-40.67 **	0.20 *	0.18 **
43	ASD 16/Ajaya	0.01 ns	0.08 *	-0.09 *	0.49 ns	4.48 **	26.99 **	-0.27 **	0.09 ns
44	ASD 16/IRBB 60	-0.09 *	-0.10 **	0.04 ns	-0.71 **	-2.20 **	5.86 **	-0.39 **	0.05 ns
45	ASD 16/IRBB 21	-0.09 *	-0.15 **	-0.13 **	-0.26 ns	-1.20 **	7.22 **	-0.43 **	-0.14 *
46	TKM 11/Pusa1460	0.25 **	-0.05 ns	0.12 **	1.23 **	-2.67 **	3.74 **	-0.67 **	0.25 **
47	TKM 11/Imp. Samba Mahsuri	-0.03 ns	0.14 **	-0.01 ns	-0.22 ns	-0.32 ns	-11.87 **	-0.21 **	-0.41 **
48	TKM 11/Ajaya	-0.01 ns	0.12 **	0.03 ns	-0.24 ns	-0.74 **	18.46 **	0.18 *	-0.04 ns
49	TKM 11/IRBB 60	-0.11 *	-0.10 **	-0.04 ns	0.23 ns	1.85 **	-5.68 **	0.27 **	0.23 **
50	TKM 11/IRBB 21	-0.10 *	-0.11 **	-0.10 **	-0.99 **	1.88 **	-4.65 **	0.44 **	-0.03 ns
51	TKM 12/Pusa1460	0.06 ns	0.09 **	-0.05 ns	-1.37 **	-0.15 ns	-4.19 **	-0.20 *	-0.27 **
52	TKM 12/ Imp. Samba Mahsuri	-0.02 ns	-0.10 **	-0.05 ns	-0.15 ns	0.24 ns	12.19 **	0.35 **	0.30 **
53	TKM 12/Ajaya	0.11 *	0.09 **	0.12 **	1.49 **	0.55 **	4.53 **	-0.09 ns	-0.10 ns
54	TKM 12/IRBB 60	-0.09 *	-0.03 ns	-0.00 ns	0.63 *	0.08 ns	14.72 **	0.10 ns	0.03 ns
55	TKM 12/IRBB 21	-0.06 ns	-0.05 ns	-0.02 ns	-0.59 *	-0.72 **	-27.25 **	-0.15 ns	0.04 ns
56	TRY 2/Pusa1460	-0.12 **	-0.05 ns	0.00 ns	-0.44 ns	1.03 **	2.14 **	0.21 **	0.15 *
57	TRY 2/Imp. Samba Mahsuri	0.10 *	0.05 ns	0.04 ns	-0.88 **	-1.89 **	2.53 **	-0.28 **	-0.22 **
58	TRY 2/Ajaya	0.06 ns	0.05 ns	0.02 ns	0.76 **	-0.17 ns	-7.14 **	0.85 **	0.06 ns
59	TRY 2/IRBB 60	-0.14 **	0.01 ns	-0.12 **	0.23 ns	0.92 **	2.39 **	-0.48 **	-0.05 ns
60	TRY 2/IRBB 21	0.10 *	-0.07 *	0.06 ns	0.34 ns	0.12 ns	0.08 ns	-0.30 **	0.06 ns
SE		0.04	0.03	0.03	0.26	0.21	0.61	0.09	0.05

*Significant at 5 % level ; ** Significant at 1% level

Table 5. Hybrids for recombination breedingforrice grain quality traits.

Characters	Parents	*gcaeffect*	Hybrids	*sca* effect	Hybrids selected for recombination breeding
Hulling percentage	ADT 42	2.35**	ADT 42/Imp. Samba Mahsuri	-3.12*	ADT (R) 47/Imp. Samba Mahsuri
	ADT (R) 47	2.34**	ADT (R) 47/Imp. Samba Mahsuri	-0.81ns	
	CO 47	3.55**	CO 47/Imp. Samba Mahsuri	10.12**	
	ASD 16	3.37**	ASD 16/Imp. Samba Mahsuri	-8.48**	
	Imp. Samba Mahsuri	2.93**			
Milling percentage	ADT (R) 47	1.59**	ADT (R) 47/Imp. Samba Mahsuri	-2.28*	-
	CO 47	3.71**	CO 47/Imp. Samba Mahsuri	12.17**	
	ASD 16	4.55**	ASD 16/Imp. Samba Mahsuri	-6.34**	
	Imp. Samba Mahsuri	2.68**			
Head rice recovery percentage	ADT 43	0.98**	ADT 43/ Imp. Samba Mahsuri	-1.56*	ADT (R) 47/Imp. Samba Mahsuri
	ADT (R) 47	3.76**	ADT (R) 47 / Imp. Samba Mahsuri	-0.66ns	
	ASD 16	6.94**	ASD16/ Imp. Samba Mahsuri	-8.35**	
	Imp. Samba Mahsuri	5.31**	ADT 43/ IRBB 60	4.03**	
	IRBB 60	0.64**	ADT (R) 47/ IRBB 60	-1.73*	
			ASD 16/ IRBB 60	2.12**	
Kernel length	ADT (R) 46	0.34**	ADT (R) 46/Pusa 1460	-0.18*	TKM 11/Pusa 1460
	TKM 11	0.49**	TKM 11/Pusa 1460	0.07ns	ADT (R) 46/IRBB 60
	TRY 2	0.75**	TRY 2/Pusa 1460	0.17*	TRY 2/IRBB 60
	Pusa 1460	-0.37**	ADT (R) 46/IRBB 60	0.03ns	
	IRBB 60	0.24**	TKM 11/IRBB 60	-0.24**	
			TRY 2/IRBB 60	0.10ns	

Contd.........

Table 5. Contd..

Characters	Parents	gca effect	Hybrids	sca effect	Hybrids selected for recombination breeding
Kernel breadth	ADT (R) 45	-0.07**	ADT (R) 45/Pusa 1460	0.01ns	ADT (R) 45/Pusa 1460
	ADT (R) 47	-0.09**	ADT (R) 47/Pusa 1460	0.10*	TNAU Rice ADT 49/Pusa 1460
	TNAU Rice ADT 49	-0.12**	TNAU Rice ADT 49/Pusa 1460	-0.00ns	CO 47/Pusa 1460
	CO 47	-0.07**	CO 47/ Pusa 1460	-0.02ns	ADT (R) 45/Imp. Samba Mahsuri
	Pusa 1460	-0.05**	ADT (R) 45/Imp. Samba Mahsuri	-0.02ns	ADT (R) 47/Imp. Samba Mahsuri
	Imp. Samba Mahsuri	-0.06**	ADT (R) 47/Imp. Samba Mahsuri	0.08ns	TNAU Rice ADT 49/Imp. Samba Mahsuri
			TNAU Rice ADT 49/Imp. Samba Mahsuri	-0.08ns	CO 47/Imp. Samba Mahsuri
			CO 47/Imp. Samba Mahsuri	0.06ns	
Kernel length/ breadth ratio	ADT (R) 46	0.22**	ADT (R) 46/Pusa 1460	-0.21**	TNAU Rice ADT 49/Pusa 1460
	TNAU Rice ADT 49	0.12**	TNAU Rice ADT 49 /Pusa 1460	-0.01ns	TNAU Rice ADT 49/IRBB 60
	TKM 11	0.06*	TKM 11/Pusa 1460	0.36**	TRY 2/IRBB 60
	TRY 2	0.27**	TRY 2/Pusa 1460	0.21**	
	Pusa 1460	0.26**	ADT (R) 46/ IRBB 60	0.16*	
	IRBB 60	0.11**	TNAU Rice ADT 49 / IRBB 60	-0.14ns	
			TKM 11/ IRBB 60	-0.44**	
			TRY 2/ IRBB 60	0.04ns	
Kernel length after cooking	ADT 39	0.87**	ADT 39/Pusa 1460	1.04**	TRY 2/Pusa 1460
	ADT 43	0.13**	ADT 43/Pusa 1460	-0.43**	TKM 12/ IRBB 60
	TKM 12	0.25**	TKM 12/Pusa 1460	-0.15*	
	TRY 2	0.94**	TRY 2/Pusa 1460	-0.07ns	
	Pusa 1460	1.26**	ADT 39 / IRBB 60	-2.21**	
	IRBB 60	0.17**	ADT 43 / IRBB 60	0.83**	
			TKM 12/ IRBB 60	-0.03ns	
			TRY 2/ IRBB 60	0.42**	
Kernel breadth after cooking	ADT (R) 45	-0.20**	ADT (R) 45/Pusa 1460	0.03ns	ADT (R) 45/Pusa 1460
	ADT (R) 47	-0.15**	ADT (R) 47/Pusa 1460	0.45**	TNAU Rice ADT 49/Pusa 1460
	TNAU Rice ADT 49	-0.13**	TNAU Rice ADT 49/Pusa 1460	0.06ns	CO 47/Pusa 1460
	CO 47	-0.11**	CO 47/Pusa 1460	0.01ns	ADT (R) 45/Imp. Samba Mahsuri
	Pusa 1460	-0.06**	ADT (R) 45/Imp. Samba Mahsuri	-0.09ns	
	Imp. Samba Mahsuri	-0.08**	ADT (R) 47/Imp. Samba Mahsuri	-0.30**	
			TNAU Rice ADT 49/Imp. Samba Mahsuri	-0.15**	
			CO 47/Imp. Samba Mahsuri	0.19**	

Table 5. Contd..

Characters	Parents	*gca* effect	Hybrids	*sca* effect	Hybrids selected for recombination breeding
Linear elongation ratio	ADT 39	0.24**	ADT 39/Pusa 1460	0.09**	TNAU Rice ADT 49/Pusa 1460
	ADT 43	0.09**	ADT 43/Pusa 1460	-0.19**	
	ADT (R) 45	0.04**	ADT (R) 45/Pusa 1460	-0.06*	
	TNAU Rice ADT 49	0.06**	TNAU Rice ADT 49/Pusa 1460	-0.03ns	
	CO 47	0.07**	CO 47/Pusa 1460	0.20**	
	TKM 12	0.11**	TKM 12/Pusa 1460	0.09**	
	Pusa 1460	0.12**			
Breadth wise expansion ratio	ADT (R) 45	-0.08**	ADT (R) 45/Imp. Samba Mahsuri	-0.05ns	ADT (R) 45/Imp. Samba Mahsuri
	ADT (R) 47	-0.06**	ADT (R) 47/Imp. Samba Mahsuri	-0.16**	CO 47/Ajaya
	CO 47	-0.04**	CO 47/Imp. Samba Mahsuri	0.07*	
	ASD 16	-0.08**	ASD 16/Imp. Samba Mahsuri	0.12*	
	Imp. Samba Mahsuri	-0.02*	ADT (R) 45/Ajaya	-0.08*	
	Ajaya	-0.02*	ADT (R) 47/Ajaya	0.11**	
			CO 47/ Ajaya	-0.03ns	
			ASD 16/ Ajaya	-0.09*	
Gelatinization temperature	ADT 39	0.28*	ADT 39/Pusa 1460	1.03**	ADT (R) 46/Pusa 1460
	ADT (R) 46	1.54**	ADT (R) 46/Pusa 1460	0.43ns	TRY 2/Pusa 1460
	ADT (R) 47	0.74**	ADT (R) 47/Pusa 1460	0.56*	
	TRY 2	1.41**	TRY 2/Pusa 1460	-0.44ns	
	Pusa 1460	0.91**			
Amylose content	ADT 39	1.25**	ADT 39/Pusa 1460	-0.51*	TKM 12 /Pusa 1460
	ADT (R) 46	4.42**	ADT (R) 46/Pusa 1460	-4.11**	
	ADT (R) 47	11.26**	ADT (R) 47/Pusa 1460	3.41**	
	TKM 12	2.42**	TKM 12/Pusa 1460	-0.15ns	
	Pusa 1460	0.56**			

Table 5. Contd..

Characters	Parents	gca effect	Hybrids	sca effect	Hybrids selected for recombination breeding
Gel consistency	ADT 39	13.07**	ADT 39/Imp. Samba Mahsuri	-5.54**	ADT 43/Imp. Samba Mahsuri
	ADT 42	21.47**	ADT 42/Imp. Samba Mahsuri	6.39**	ADT (R) 46/Imp. Samba Mahsuri
	ADT 43	15.53**	ADT 43/Imp. Samba Mahsuri	0.99ns	ADT (R) 46/ Ajaya
	ADT (R) 46	25.20**	ADT (R) 46/Imp. Samba Mahsuri	0.99ns	
	ADT (R) 47	6.47**	ADT (R) 47/Imp. Samba Mahsuri	-2.61**	
	Imp. Samba Mahsuri	5.61**	ADT 39/Ajaya	-17.21**	
	Ajaya	6.27**	ADT 42/Ajaya	-8.94**	
			ADT 43/Ajaya	-2.34**	
			ADT (R) 46/Ajaya	-0.01ns	
			ADT (R) 47/Ajaya	2.73**	
Water uptake	ADT 39	0.15***	ADT 39/Pusa 1460	0.19*	-
	ADT 42	0.27***	ADT 42/Pusa 1460	-0.20*	
	ADT 43	0.15***	ADT 43/Pusa 1460	-0.22**	
	ADT (R) 47	0.34***	ADT (R) 47/Pusa 1460	-1.24**	
	TNAU Rice ADT 49	0.14***	TNAU Rice ADT 49/Pusa 1460	-0.17*	
	CO 47	0.08*	CO 47/Pusa 1460	-0.75**	
	TKM 12	0.12***	TKM 12/Pusa 1460	-0.20*	
	TRY 2	0.23***	TRY 2/Pusa 1460	0.21**	
	Pusa 1460	0.20**			
Volume expansion ratio	ADT 39	0.50**	ADT 39/Pusa 1460	0.01ns	ADT 39/Pusa 1460
	ADT 42	0.31***	ADT 42/Pusa 1460	-0.17**	ADT (R) 47/Pusa 1460
	ADT 43	0.39**	ADT 43/Pusa 1460	0.39**	ADT (R) 46/IRBB 21
	ADT (R) 46	0.84**	ADT (R) 46/Pusa 1460	0.40**	ADT (R) 47/IRBB 21
	ADT (R) 47	0.18***	ADT (R) 47/Pusa 1460	-0.11ns	
	Pusa 1460	0.08**	ADT 39/IRBB 21	0.45**	
	IRBB 21	0.03*	ADT 42/ IRBB 21	0.17**	
			ADT 43/IRBB 21	-0.27**	
			ADT (R) 46/IRBB 21	0.08ns	
			ADT (R) 47/IRBB 21	0.01ns	

gelatinization temperature showed high *sca* effects for their respective traits and involved the parents of low x low *gca* effects. These hybrids also could be advanced further.

Selection of hybrids for recombination breeding would pave the way for isolating useful segregants in the desirable direction in the subsequent generations. Capitalization of additive gene action, the fixable variance, is important to proceed with recombination breeding. The *gca* effect is a value derived from the general mean of all the hybrids involving all the parents. Generally, parents with high *gca* are preferred for recombination breeding irrespective of their mean performance. Since high x high general combiners would involve interaction between the positive x positive alleles and can be fixable in subsequent generations if no repulsion phase linkage involved. On the other hand, parents with high *gca* effect will not necessarily generate good combinations always due to interaction effects. Nadarajan and SreeRangasamy (1990) through genetic analysis in cotton opined that hybrids having parents with high *gca* effect and non significant *sca* effects would be useful for recombination breeding. Based on these criteria, in rice hybrids were identified for improvement of characters through recombination breeding and are presented here under.

The hybrids were evaluated for all the fifteen grain quality traits and are listed as suitable for recombination breeding (Table 5).In grain quality traits, for hulling percentage, the parents ADT 42, ADT(R)47, CO 47, ASD 16 and Imp. Samba Mahsuri showed significant positive *gca* effects. Out of four hybrids combining these parents, only the hybrid ADT (R) 47/Imp.SambaMahsuri showed non significant *sca* effect. Therefore, this hybrid could be utilized for recombination breeding for the improvement of this trait. In the case of head rice recovery percentage, five parents *viz*., ADT 43, ADT (R) 47, ASD 16, Imp.SambaMahsuri and IRBB 60 expressed significant *gca* effects and one hybrid *viz*.,ADT (R) 47/Imp.SambaMahsuri only had non significant *sca* effect and could be exploited for recombination breeding. For kernel length, five parents *viz*., ADT(R) 46,TKM 11, TRY 2, Pusa 1460, and IRBB 60 expressed significant positive *gca* effects and their respective hybrids, TKM 11/Pusa1460, ADT (R) 46/IRBB 60 and TRY 2/IRBB 60 showed non significant *sca* effects which could be utilized for recombination breeding programme.

With regard to kernel breadth, significant negative *gca* effects combining non significant *sca* effect is desirable. Keeping this view, ADT (R)45/Pusa1460, TNAU Rice ADT 49/Pusa1460,CO 47/Pusa1460, ADT (R)45/Imp.SambaMahsuri, ADT (R)47/Imp.SambaMahsuri, TNAU Rice ADT 49/Imp. Samba Mahsuri and CO 47/Imp. Samba Mahsuri could be exploited for this trait. For kernel length/breadth ratio, TNAU Rice ADT 49/Pusa1460, TNAU Rice ADT 49/IRBB 60, TRY 2/

IRBB 60 could be utilized for improvement of this trait. For kernel length after cooking, TRY 2/Pusa1460 and TKM 12/IRBB 60 could be exploited. For kernel breadth after cookingADT (R)45/Pusa1460, TNAU Rice ADT 49/Pusa1460,CO 47/Pusa1460 and ADT (R)45/Imp.SambaMahsuri could be utilized.

The hybrids *viz*., TNAU Rice ADT 49/Pusa1460,ADT (R)45/Imp.SambaMahsuri, and CO 47/Ajaya, for linear elongation ratio, ADT (R)45/Imp.SambaMahsuri and CO 47/Ajaya, for breadth wise expansion ratio, ADT (R)46/Pusa1460 and TRY 2/Pusa1460 for gelatinization temperature,TKM 12/Pusa1460 for amylose content, ADT 43/Imp. Samba Mahsuri, ADT(R) 46/Imp. Samba Mahsuri, ADT (R) 46/Ajaya for gel consistency, ADT 39/Pusa1460, ADT (R) 47/Pusa1460, ADT (R) 46/IRBB 21, ADT (R) 47/IRBB 21 for volume expansion ratio could be exploited for the improvement of their respective traits.

To summarise that TNAU Rice ADT 49/ Pusa1460 is praise worthy, since it could be used to identify superior segregants for four characters *viz.,* kernel breadth, kernel length/breadth ratio, kernel breadth after cooking and linear elongation ratio followed by ADT (R) 45/Imp.SambaMahsuri which exhibited non significant *sca* effect for three characters *viz*., kernel breadth, kernel breadth after cooking and breadth wise expansion ratio. The hybrid ADT 47/Imp.SambaMahsuri could be also exploited for three characters *viz.,* hulling percentage, head rice recovery percentage and kernel breadth. Gnanamalar (2004) reported similar reports that the hybrids with non significant *sca* effect combining the parents of significantly high *gca* effects could be exploited for recombination breeding for improving grain quality traits in rice.

Conclusion

The study revealed that the ratio of GCA : SCA variances computed for all the fifteen grain quality traits showed the predominance of non-additive gene action. Based on *gca* effects, among the parents ADT (R) 47, Pusa 1460, Imp. Samba Mahsuri, CO 47, ADT 39, ADT 43 and ADT (R) 46 were adjudged as the best since they had significant desirable *gca* effects at 1% probability level (p=0.01) for more than five grain quality characters. These were followed by IRBB 60, TNAU Rice ADT 49 and TRY 2 which showed significant favourable *gca* effects at 1% probability level (p=0.001) for five quality traits. Among the hybrids, the hybrids CO 47/Imp. Samba Mahsuri, ADT (R) 47/ IRBB 21 and ADT (R) 46/IRBB 21 were identified as best hybrids for exploitation of grain quality traits since they revealed significant *sca* effects at 1% probability level (p=0.01) for eight, eight and five grain quality traits respectively, The hybrids TNAU Rice ADT 49/ Pusa1460 is praise worthy, since it could be used to identify superior segregants for four characters *viz.,* kernel breadth (0.00), kernel length/breadth ratio(-

0.01),kernel breadth after cooking(0.06) and linear elongation ratio(-0,03) which exhibited non significant *sca* effect combining the parents of significantly high *gca* effects could be exploited for recombination breeding.

REFERENCES

Allard, R. W. (1960). *Principles of Pl. Breed*.**,** John Wiley and Sons, Inc. New York.

Amirthadevarathinam, A. (1983). Combining ability and heterosis in dry and semi - dry paddy. *Madras Agric. J.,*70**:** 233-237

Azenz, M. A. and Shafi, M.(1966). Quality of rice. *Dept. of Agric. West Pakistan Tech. Bull.,*13**:** 50p

Babu, M.S., Satyanarayana, P.S., Madhuri,J.and Kumar, R.V. (2000). Combining ability analysis for identification of elite parents for heterotic rice hybrids. *Oryza*, 37 (1): 19 -22

Cagampang, G.B., Perez,C.M. and Juliano, B.O.(1973). A gel consistency test for eating quality of rice. *J. Sci. Food Chem.,*31: 281- 283

Dhanavendran, K.S. (2010). Genetic analysis of yield, physical and physico chemical quality traits in rice (*Oryza sativa* L.). M.Sc (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore. India.

Dhillon, B.S. 1975. The application of partial diallel crosses in plant breeding - A review. *Crop Improv.,* 2: 1-7

Dwivedi. D.K, and Pandey, M.P.(2012). Gene action and heterosis for yield and associated traits in indica and tropical japonica crosses of rice (*Oryza sativa* L.) involving wide compatibility gene(s). *International Journal of Plant Breeding and Genetics*, 6(3): 140-150

Gnanamalar, R.P. (2004). Genetic analysis of grain quality traits in rice (*Oryza sativa* L.). Ph.D.Thesis, Tamil Nadu Agricultural University, Coimbatore. India.

Hasan,M.J., Kulsum,U.K., Lipi,L.F. and Shamdudin,A.K.M. (2013).Combining ability studies for developing new rice hybrids in bangaladesh. *Bangaladesh Journal of botany*,42(2): 215-222

Hassan, H.M,. EL-Abd,A.B. and El-Baghdady, N.M.(2011). Combining ability for some root, physiological and grain quality traits in rice (*Oryza sativa* L.*)* under water deficit conditions. *J. Agric. Res. Kafer El-Sheikh Uni.,*37(2): 239-256

Immanuel Selvaraj, C., Nagarajan,P.,Thiyagarajan,K., Bharathi,M., and Rabindran,R.(2011). Studies on heterosis and combining ability of well known blast resistant rice genotypes with high yielding varieties of rice. *Int. J. Plant Breed. Genet.,*5(2): 111-129

IRRI, 1997. Standard Evaluation System. *IRRI*, Manila, Philippines.

Jain Ying Peng and Virmani,S. S. 1990. Combining ability for yield and four related traits in selection to breeding in rice. *Oryza***, 27:** 1-10

Jue Lou., Liang Chen., Gaohong Yue., Qiaojun Lou., Han-

wei Mei., Liang Xiang., Lijun Luo.,(2009). QTL mapping of grain quality traits in rice. *J. Cereal Sci.,*50: 145 -151

Juliano, B.O., and Perez, C. M. (1984). Results of collaborative test on the measurement of grain elongation of milled rice during cooking. *J. Cereal Sci.,*2**:** 281 – 292

Kempthorne, O. (1957). An introduction to genetic studies. John Wiley and Sons Inc., New York.

Latha,S.,Sharma,D.andSanghera,G.S,(2013).Combining ability and heterosis for grain yield and its components in rice(*Oryza sativa L.*).*Notulae Scientia Biologicae*,5 (1):90-97

Lodh, S.B. (2002). Quality evaluation of rice for domestic and international consumers. *In: Genetic evaluation and utilization (GEU) in rice improvement, CRRI*, Cuttack: 135-140

Manickavelu, A., Nadarajan, N.,Ganesh,S.K. and Gnanamalar, R.P.(2006). Genetic analysis of biparental progenies in rice (*Oryza sativa* L.). *Asian J. Plant Sci.,*5 (1):33-36

Nadarajan, N. and SreeRangaswamy, S.R. 1990. Study of heterosis and combining ability in *Gossypiumhirsutum* L. *J. Indian Soc. Cotton Improv.,*15**:** 88 - 94

Priyanka, K.,Jaiswal,H.K. and Waza,S.A.(2014).Combining ability and heterosis for yield and its component traits and some grain quality parameters in rice (*Oryza sativa* L.).*Journal of Applied and Natural Science*,6(2):495-506

Shivani. D., Viraktamath,B.C., and SudheerKumar,S.(2008). Combining ability studies for grain quality traits in tropical japonica/indica hybrids of rice. *J. Res. ANGRAU.,* 36(1)**:** 21 – 23

Showkat, A.,Waza,H.K.,Jaiswal,T., Sravan.,Kumari Priyanka, Dilrupa,A., Bano.AndVedP.Rai(2015). Combining ability analysis for various yield and quality traits in rice(*Oryza sativa L.)*

Simmonds, N.E. (1979). *Principles of crop improvement.* Longman Inc., New York. 408p

Tyagi. J.P, Tejbir Singh and Singh,V.P.(2010). Genetic analysis of combining ability for quality characters in basmati rice. *Oryza,*47(2): 96-99

Umadevi, M., Veerabadhiran,P., Manonmani, S.and Shanmugasundaram, P.(2010). Physico-chemical and cooking characteristics of rice genotypes. *Electronic Journal of Plant Breeding,*1(2):114-123

Vargese, D. D. (1960). A standard process for cooking rice for experimental purpose. *Madras Agric. J.,* **36:** 217

Veerabadhiran. P., Umadevi,M.,andPushpam,R.(2009). Genetic variability, heritability and genetic advance of grain quality in hybrid rice. *Madras Agric. J.,*96 (1-6)**:** 95-99

Venkatesan, M., Anbuselvam, Y., Murugan,S. and Palani Raja,K.(2008). Heterosis for yield and its components and grain traits in rice. *Oryza,* 45: 76-78

Verma, O.P., Santoshi, U.S. and Srivastava,H. K.(2009). Governance of gene action and combining ability for certain grain quality traits in three diverse rice (*Oryza sativa* L.) growing ecosystems. *J. Sustainable Agric.,*22 (4)**:** 63-78