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Genetic Architecture of Grain Quality Traits in the Biparental Progenies (BIPs) of Rice (*Oryza sativa*. L)

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Investigation was carried out with an objective of studying the genetic architecture of biparental progenies (BIPs) of JGL 384 x Rasi cross combination of rice in terms of grain quality parameters. Intermated progenies (BIPs) showed superior mean performance than their parents, F_1, F_2 and F_3 generations for hulling (76.24%), milling (72.24%), head rice recovery (67.48%), kernel length after cooking (9.78), kernel L / B ratio after cooking (3.08), linear elongation ratio (1.66), volume expansion ratio (4.94) and amylose content (22.64%). Enhanced trait mean value might be due to pooling of favorable alleles through recombination, considerable heterozygosity, accumulation of favorable alleles of low frequency and breaking up of undesirable linkages which was possible because of intermating. Combining ability analysis of NCD II revealed that cooking traits like kernel length after cooking and volume expansion ratio were governed by additive genes. Hence, for the improvement of these traits pure line selection, mass selection and or progeny selection will be suggested and selection might be effective at this level. Other grain quality traits *viz.,* hulling percentage, milling percentage, head rice recovery, kernel length, kernel breadth, kernel L/B ratio, kernel breadth after cooking, kernel L/B ratio after cooking, linear elongation ratio, breadth wise expansion ratio, gel consistency, gelatinization temperature and amylose content were governed by dominant genes. Hence, these traits could be improved by recombination breeding by taking up selection at later generations, alternatively one or two more cycles of intermating may break the undesirable linkages among the traits of interest.

Key words: Biparental mating, NCD II, Rice grain quality

Rice (*Oryza sativa* L.) is the major staple cereal food crop fulfilling about 60 % dietary requirement, 20 % calorie and 14 % protein requirements of world's population. Of the annual world production of 596.49 million tonnes from 155.13 million hectares, Asia produces 540.62 million tonnes from 138.56 million hectares. Per capita consumption of rice in Asia ranges from 132 to 45grams per day (Swaminathan and Appa Rao, 2009). In the present decade, the rate of increase in rice production is lower (1.5% per year) than the increase in population (1.8% per year). The present world population of 6.3 billion is likely to reach 8.50 billion by 2030. Out of this, 5 billion people will be rice consumers and there is a need of 38 per cent more rice by 2030. If this target is not achieved, severe food shortage will occur in the next century (Khush, 2005). To meet this challenge there is a need to develop rice varieties with higher yield potential and greater yield stability (Khush, 2006).

High yielding ability, acceptable grain quality with resistance to pest and diseases is an important criterion in most of the rice breeding programmes. Rice grain quality is mainly determined by the combination of many physical as well as chemical characters. Physical quality characters include kernel size, shape, hulling, milling percentage and head rice recovery. Chemical quality is mainly determined by amylose content, gelatinization temperature, gel consistency. High volume expansion and greater length wise expansion of kernel during cooking decide the consumer preference. Rice with soft to medium gel consistency, intermediate amylose content and gelatinization temperature is a preferred level for the consumer which determines the eating and cooking quality of rice grains (Bao *et al.,* 2002). Amylose content has been reported to be governed by the *waxy* (*Wx*) locus which is located on chromosome 6 (Septiningsih *et al.,* 2003) and independent studies on amylose content indicated that *wx* locus is linked to the gene for alkali spreading score, which is an indicator of temperature at which rice grain becomes gelatinous during cooking (Sano. 1984).

Biparental mating is one of the simplest random mating design available to effect forced recombination and breaking down of undesirable linkages as pointed out by Comstock and Robinson

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(1952). To develop high yielding genotypes coupled with acceptable grain quality and tolerance to biotic and abiotic stresses, a population with high variability serves always as prime source for effective selection, particularly the role by F_2 segregants in throwing much variability is highly recognized. The F_2 are the critical generation in rice breeding and they determine the eventual success or failure of hybridization programme (Jennings *et al*., 1979). The intercrossing or intermating in the F_2 segregants provides chances of finding superior recombinants in F_3 or later generations and a greater amount of concealed genetic variations particularly of the additive type would be released there by improving response to selection (Moll and Robinson, 1967). Frederickson and Kronstad (1985) stressed that in autogamous crops, intermating among early segregants could open vistas to new levels of genetic variability by breaking up of the genetic recombination within the linkage group. Hence the present study was undertaken to know the genetics behind the cooking and eating quality traits of rice grains following North Carolina Design II (NCD II) of biparental mating.

Materials and Methods

F_2 generation seeds of JGL 384 × Rasi cross combination and their parents were obtained and experiments were conducted at Paddy Breeding Station, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Tamil Nadu, Coimbatore, India. F_2 generation which comprised the biparental mating block was raised during Kharif 2007-2008 in non – replicated rows of 800 single plants. North Carolina Design II (NCD II) or Factorial Mating Design of biparental mating as suggested by Comstock and Robinson (1952) was followed to synthesis biparental progenies, in which within F_2 population, eight plants were selected at random, among them four were treated as male parents and the remaining four were treated as female parents. Each male parent was crossed with each female parent and sixteen biparental progenies (BIPs) were made which would constitute one set, like wise two sets were made and finally a total of 32 BIPs were synthesized. Simultaneously the respective male and female parents were also selfed to generate F_3 families. For crossing wet cloth method as suggested by Chaisang *et al*. (1967) was followed. The parents, F_1, F_2 generation, F_3 families and biparental progenies (BIPs) were raised during Rabi 2007-2008 in a Randomized Block design with two replications adopting a spacing of 20 cm between rows and 10 cm between plants. Grain quality parameters were recorded on all the plants within the intermated progenies and five plants in each F_3 families.

Measurement of physical and cooking quality traits

The following twelve physical and cooking quality characters *viz.,* hulling percentage (H %), milling percentage (M %), head rice recovery (HRR), kernel length (KL), kernel breadth (KB), kernel L / B ratio (K L/B), kernel length after cooking (KLAC), kernel breadth after cooking (KBAC), kernel L / B ratio after cooing (K L/B AC), linear elongation ratio (LER), breadth wise expansion ratio (BER) and volume expansion ratio (VER) were measured as per the “Standard Evaluation System for rice” (SES, 1996) descriptors suggested by IRRI.

Assessment of chemical quality characters

Alkali spreading value / Gelatinization temperature (ASV)

Gelatinization temperature (GT) was estimated based on alkali spreading value (ASV) of milled rice. The method developed by Little *et al.* (1958) was used to score alkali spreading value. Two sets of seven whole milled kernels of each entry were placed in Petri plates containing 10 ml of 1.7 % potassium hydroxide (KOH) solution. The kernels were arranged in such a way to provide space between kernels for spreading. The plates were covered and incubated at room temperature for 23 hours. The appearance and disintegration of kernels were rated visually as follows (Score 1: Grains unaffected, Score 2: Kernel swollen, Score 3: Kernel swollen with collar incomplete and narrow, Score 4: Kernel swollen with collar complete and wide, Score 5: Kernel split or segmented with collar complete and wide, Score 6: Kernel dispersed, merging with collar and kernels that were dispersed and disappeared completely were given a score of 7. A low ASV corresponds to a high GT, conversely, a high ASV indicates a low GT.

Gel consistency (GC)

The GC was measured in duplicates according to the method of Cagampang *et al.* (1973). Briefly, 100 mg rice flour was weighed in a 110 mm culture tube, to which 0.2 ml of 95% ethanol containing 0.025% thymol blue was added to prevent clumping of the powder during gelatinization. 1ml of 0.2 N KOH was added and vortexed thoroughly. The tubes were covered with glass marbles and boiled vigorously in a water bath for 8 min. After standing at room temperature for 5 min, the tubes were put on ice for 20 min, and then laid down horizontally on a table surface. The gel length was measured 1 hr later as the distance from the bottom of the tube to the front of the gel migration. The gel length thus obtained provides a measurement of the gel consistency; longer the distance softer the gel.

Amylose content (AC)

The simplified procedure of Juliano (1979) was used for estimating amylose content. Two sets of milled rice flour (50 mg) were taken in 50 ml volumetric flask. To this, 0.5 ml of 95 % ethanol was added to wash the sample adhering to the flask followed by 5 ml of 1 N NaOH. The material was left undisturbed overnight to gelatinize the starch or keep in water bath at 65oC for 30 min. The solution was made up to 50 ml. Sample extract of 2.5 ml was pippetted out into another 50 ml volumetric flask. To this, 20 ml of distilled water was added followed by three drops of phenolphthalein to develop pink colour. Then 0.1 N HCl was added drop by drop until the colour disappeared. The volume was made up to 50 ml after the addition of 1 ml of iodine reagent and the blue colour developed was read at 590 nm. Amylose concentration (0-600) was obtained by plotting the absorbance in the standard curve. Amylose content of each genotype was expressed as percentage of total quantity of sample taken for analysis. Based on amylose content the rice was categorized as below (< 2.00%: Waxy, 2.01 to 8.00%: Very low, 8.01 to 20.00%: Low, 20.00 to 25.00%: Intermediate, > 25 %: High)

Statistical analysis

The mean data collected from Parents, F_1, F_2 generation, 16 F_3 families and 32 BIPs were subjected for statistical analysis. After ascertaining the significant difference among the BIPs using RBD, the mean data were subjected to analysis of variance appropriate to NCD II (Comstock and Robinson, 1952).

Results and Discussion

Mean performance is a basic and an important criterion in selecting superior segregants. According to Finkner *et al.* (1973), progenies with highest mean were relatively effective in selecting the superior segregants. Joshi (1979) experienced that intermating of F_2 population found to increase the population mean in BIPs. This is of immense value to the breeder, because usually populations mean go on decreasing progressively from F_2 generation onwards as homozygosity increases from F_3 generation. In the present investigation, biparental progenies showed superior mean performance for the grain quality parameters like, hulling percentage (76.24%), milling percentage (72.24%), kernel length after cooking (9.78), kernel L/B after cooking (3.08), linear elongation ratio (1.66), volume expansion ratio (4.94) and amylose content (22.64%) than their parents, F_1, F_2 and F_3 generations. The head rice recovery (67.48%) in BIPs was slightly lower than parent JGL 384 (67.61%), and it was higher than parent Rasi, F_1, F_2 and F_3 generations (Table 1) . The present results were in accordance with the findings of Yuvaraja (2000) who stated that the amylose content in BIPs were numerically higher than their parents, F_2 and

Table 1. Mean performance of parents, F_1, F_2, F_3 generations and BIPs for different grain quality characters

Characters	Parents		Generations						
	JGL 384	Rasi	F_1	F_2		F_3		BIPs	
	Mean	Mean	Mean	Mean	Range	Mean	Range	Mean	Range
Hulling (%)	73.21	70.45	72.21	71.76	64.18 – 80.18	74.06	69.76 – 81.19	76.24	65.18 – 82.71
Milling (%)	71..41	65.93	67.07	67.81	60.84 – 75.59	70.26	64.50 – 75.07	72.42	61.28 – 79.15
HRR (%)	67.61	53.55	60.72	63.28	54.48 – 71.15	64.65	56.49 – 71.29	67.48	55.28 – 74.88
KL (mm)	5.93	5.6	5.83	5.77	5.3 – 6.20	5.85	5.45 – 6.12	5.89	5.35 – 6.15
KB (mm)	2	2.4	2.33	2.31	2.0 – 2.5	2.07	2.15 – 2.40	2.27	2.10 – 2.50
K L/B	2.97	2.34	2.5	2.52	2.12 – 2.95	2.82	2.44 – 2.74	2.6	2.33 – 2.93
KLAC (mm)	9.4	8.9	9.1	9.47	8.50 – 10.42	9.45	8.85 – 9.90	9.78	9.15 – 10.65
KBAC (mm)	3.1	3.45	3.1	3.21	3.00 – 3.40	3.18	2.95 – 3.35	3.18	2.95 – 3.45
L/B AC	3.03	2.58	2.94	2.95	2.43 – 3.50	2.98	2.65 – 3.23	3.08	2.87 – 3.29
LER	1.59	1.59	1.56	1.64	1.57 – 1.71	1.62	1.34 – 1.76	1.66	1.56 – 1.80
BER	1.55	1.44	1.33	1.39	1.32 – 1.52	1.54	1.35-1.56	1.4	1.28 – 1.52
GC (mm)	94	88	91	92	60.00 – 123.00	91	68.5 – 116.00	90	27.00 – 133.50
GT	1.62*	2.58*	2.38*	1.94*	1.00 – 2.65	2.26*	2.00 – 2.45	2.00*	1.41 – 2.65
VER	4.8	3.87	4.57	4.78	3.8 – 5.6	4.39	3.90 – 4.70	4.94	4.00 – 5.40
AC (%)	21.5	20.43	20.83	21.71	15.60 – 27.50	20.42	15.60 – 23.00	22.64	16.80 – 28.40

HRR – Head rice recovery
KL – Kernel length
KB – Kernel breadth
K L/B kernel Length / Breadth ratio
* - Square Root Transformed Values
KLAC – Kernel length after cooking
KBAC – Kernel breadth after cooking
L/BAC – kernel length / breadth after cooking
LER – Linear elongation ratio
BER – Breadth wise expansion ratio
GC – Gel consistency
GT – Gelatinization temperature
VER – Volume expansion ratio
AC – Amylose content

F_3 progenies. Mean values for amylose content (22.64%) and gelatinization temperature (4) were intermediate in BIPs. The amylose content of BIPs ranged from low (16.80%) to higher (28.40%) and this range of values was reduced in F_2 (15.60 to 27.50%) and F_3 (15.60 – 23.00%) generations. Amylose content of rice determines the hardness and stickiness of cooked rice (Juliano, 1993). It indicates that intermating provides an opportunity for isolating superior segregants with intermediate amylose content. Enhancement in the trait mean value might be due to pooling of favorable alleles through recombination which was possible because of intermating. Biparental mating thus proves as an efficient breeding strategy for the improvement of grain quality traits.

Increase in mean values for many of the characters in biparental progenies as compared to F_3 progenies could be the result of considerable heterozygosity (heterotic effect) in BIPs as it is derived by crossing selected parents in F_2 and reduction in F_3 generation due to inbreeding depression as it is obtained by selecting the F_2 (Gardner *et al.* 1953).

The higher mean and wider range in biparental progenies for most of the characters might be due to creation of additional variability than in the F_3 progenies by nullifying the effect of selfing (Nemathullah and Jha, 1993) in wheat. The superior mean performance of biparental progenies could be attributed to the accumulation of favorable genes of low frequency present over the population, dominance deviations and epistatic interaction in biparental progenies (Srivastava *et al.* 1989). The release of concealed genetic variability by breaking undesirable linkage might be another reason for increased mean and wide range of biparental progenies (Sethi *et al.* 1995).

The combining ability analysis of BIPs for different grain quality traits exhibited highly significant mean square values for the traits *viz.,* hulling percentage, milling percentage, head rice recovery, linear elongation ratio, volume expansion ratio, gel consistency and amylose content. This significance was observed in between male half sib family groups (M), between female half sib family groups (F) and male × female full sib family families (Table 2). It was evident from the result that adequate genetic variability was present among the intermated progenies.

The success of any plant breeding programme depends to greater extent on the knowledge of genetic architecture of the population handled by the breeder (Tai, 1979). An overall understanding of the gene action for different characters is possible by making comparison of variance due to additive and or dominance. The breeding method might be decided based on the relative importance of additive and dominance variances (Barker, 1978). Higher magnitude of additive variance indicated the predominance of additive gene action and that of dominance variance indicated the non – additive type of gene action. The choice of the breeding method primarily depends upon the nature and magnitude of gene action. If additive variance is greater and additive gene action forms the principal component of genetic variance, use of pedigree method would be desirable as the gene effects are fixable, then the choice of fixing superior genotypes in early segregating generation will be high and rewarding. If dominance variance is predominant the selection has to be postponed to later generations and appropriate breeding techniques should be adopted to obtain useful and superior genotypes. The non – additive effects is non – fixable, yet it can be exploited through heterosis breeding.

Table 2. Analyses of Variance of NCD II for different quality parameters of cross JGL 384 X Rasi

Source of variation	df	Mean squares														
		Hulling	Milling	HRR	KL	KB	K L/B	KLAC	KBAC	K L/B AC	LER	BER	GC	GT	VER	AC
Between male half sib family groups (M)	6	88.55**	70.07**	124.90**	0.07**	0.01	0.03*	0.26*	0.04**	0.03*	0.01**	0.01	1321.62**	0.14	0.51**	18.65**
Between female half sib family groups (F)	6	54.41**	51.61**	50.65**	0.06*	0.02	0.06**	0.57**	0.03*	0.03*	0.01**	0.005	1376.54**	0.24*	0.50**	6.48**
Male x Female	18	33.18**	38.91**	24.64**	0.04	0.2**	0.02	0.15	0.02	0.02	0.01**	0.01	998.62**	0.12	0.10**	5.53**
Within Full sib families	30	0.13	0.99	0.06	0.02	0.01	0.01	0.09	0.01	0.01	0.001	0.005	25.95	0.07	.006	0.07

** - Significant at 1 % level * - Significant at 5 % level
HRR – Head rice recovery
KL – Kernel length
KB – Kernel breadth
K L/B kernel L/B ratio
KLAC – Kernel length after cooking
KBAC – Kernel breadth after cooking
K L / B AC – kernel length / breadth after cooking LER – Linear elongation ratio BER – Breadth wise expansion ratio
GC – Gel consistency
GT – Gelatinization temperature
VER – Volume expansion ratio
AC – Amylose content

A combining ability variance estimates revealed that additive genetic variance was higher than dominance genetic variance and also additive / dominance ratio was more than one for kernel length after cooking (1.21) and volume expansion ratio (2.48) (Table 3). This indicates the predominance of additive gene in the governance of these traits. Additive genetic variance is associated with homozygosity and also fixable in nature. Therefore, selection for kernel length after cooking and volume expansion ratio governed by additive genetic variance will be very effective. Existence of additive genetic variance is pre requisite for improvement through selection because this is the only variance that responds to selection. Additive genetic variance is a measure of additive gene action and this gene action is the chief cause of resemblance between relatives and progress by selection is directly proportional to the degree of resemblance between parents and progeny. Thus additive gene action is a measure of breeding value of a genotype. Hence for the traits kernel length after cooking and volume expansion ratio reliance should be placed on pure line selection, mass selection and or progeny selection. This is in agreement with the findings of Shanthi *et al.* (2004), Manickavelu *et al.* (2006) and Thirugnana kumar *et al.* (2007) . Further this trait could be improved by pedigree breeding method while going for hybridization and selection.

Among the fifteen grain quality traits studied *viz.,* hulling percentage, milling percentage, head rice recovery, kernel length, kernel breadth, kernel L/B ratio, kernel breadth after cooking, kernel L/B ratio after cooking, linear elongation ratio, breadth wise expansion ratio, gel consistency, gelatinization temperature and amylose content exhibited high degree of dominance variance than additive genetic variance (Table 3). Hence, it was concluded that these characters were governed by non – additive type of gene action. It is in accordance with the results of Raju *et al.* (2006), Sharma *et al.* (2006) and Thirugnana kumar *et al.* (2007). Normally dominance genetic variance is associated with heterozygosity and it is not fixable, therefore, selection for these traits is not effective. Dominance variance is the chief cause of heterosis or hybrid vigor. The preponderance of non – additive gene action for these traits under study indicated that improvement

Table 3. Estimation of variance components of BIPs for different grain quality traits in JGL 384 ´ Rasi

Genetic components	Hulling	Milling	HRR	KL	KB	L/B ratio	KLAC	KBAC	L/B AC	LER	BER	GC	GT	VER	AC
Variance due to males	6.92	3.89	12.53	0.003	0.001	0.001	0.014	0.003	0.001	0.0001	0.007	40.38	0.003	0.052	1.641
Variance due to females	2.65	1.59	3.25	0.003	0.001	0.005	0.053	0.002	0.002	0.0001	0.004	47.24	0.014	0.051	0.119
Variance due to male x females	16.53	19.41	12.29	0.013	0.005	0.007	0.028	0.003	0.003	0.005	0.0015	486.34	0.025	0.021	20.727
Additive genetic variance	19.15	10.96	31.57	0.01	0.0001	0.013	0.133	0.009	0.006	0.0001	0.001	175.23	0.034	0.206	3.52
Dominance variance	66.11	77.64	49.15	0.05	0.02	0.03	0.110	0.01	0.01	0.02	0.01	1945.3	0.10	0.08	10.91
Additive / Dominance ratio	0.290	0.141	0.642	0.225	0.0001	0.431	1.205	0.729	0.625	0.007	0.104	0.090	0.336	2.480	0.323

HRR – Head rice recovery
KL – Kernel length
KB – Kernel breadth K
L/B kernel L/B ratio
KLAC – Kernel length after cooking
KBAC – Kernel breadth after cooking
L / B AC – kernel length / breadth after cooking
LER – Linear elongation ratio
BER – Breadth wise expansion ratio
GC – Gel consistency
GT – Gelatinization temperature
VER – Volume expansion ratio
AC – Amylose content

of these characters could be possible through heterosis breeding. But, rice being a self pollinated crop, heterosis breeding is not widely adopted, unlike recombination breeding. Therefore, to get better genotypes with the acceptable grain quality by the way of recombination breeding hybridization followed by selection at later generations is suggested for exploiting dominance gene action. Alternatively, two or more cycles of intermating among the selected segregants might not only break the undesirable linkages if any, but also allow accumulation of favorable alleles for the improvement of traits of interest. It was concluded that biparental or intermating is an effective breeding strategy to accumulate most of the favourable alleles for different traits into a single genotype by breaking undesirable linkages among the favourable and unfavourable genes.

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