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Impact of intermating and linkage relationship among the grain quality traits in early segregating generations of rice

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ABSTRACT

Present investigation was taken up with the objective of studying the impact of biparental mating on linkage relationship among the grain quality parameters of rice. Association analysis revealed that, none of the grain quality parameters had significant positive association with grain yield except hulling parcentage in BIPs. A total of eighteen positive and significant associations in F_2s and 20 positive and significant associations in F_3 progenies were observed. But it was increased to 32 positive significant associations in BIPs. Like wise, negative association was also reduced in biparental progenies and it was only 10 negative associations in BIPs. But 23 negative associations in F_2s and 12 negative associations in F_3progenies were observed. It indicates that, inter correlations among the grain quality parameters were strengthened in BIPs and several new recombinants were synthesized in BIPs due to intermating in F_2 population. Several such new associations were observed among the grain quality parameters in BIPs than other two segregating generations (F_2 and F_3 generation). It was evident that reshuffling of genes were responsible for correlations among some characters resulting newer recombinations which presumably, were due to changes from a coupling to repulsion phase linkages.

Key words: *rice, biparental progenies, grain quality, correlation*

High yielding ability, acceptable grain quality with resistance to pest and diseases are some of the important criteria 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 length wise expansion of kernel during cooking decides the consumer preference. Rice with soft to medium gel consistency, intermediate amylose content and intermediate gelatinization temperature is preferred by the consumers. Amylose content is recognized as one of the most important determinants of eating and cooking quality (Bao *et al.,* 2002), it has been reported to be governed by the *waxy* (*Wx*) locus and mapped to chromosome 6 (Septiningsih *et al.,* 2003). Independent studies have indicated *wx* locus is linked to a gene for alkali spreading score, an indicator of the temperature at which rice grain becomes gelatinous during cooking (Sano. 1984).

Selection for specific characters may results in correlated response for some other characters (Falconer, 1977) due to genetic associations, thereby limiting the advance under selection for one or more traits. Therefore, the study which reveals the magnitude and direction of association between characters related to grain yield and quality should be given due consideration in any breeding programmes, so that selection may be delayed till sufficient recombination and consequently greater genetic variability is created for effective selection. Of the methods of improving the frequency of desirable recombinants, intermating in early segregating generations is the system recommended under the assumption that it can convert repulsion phase linkages into coupling phase due to forced recombinations and thereby release a greater amount of concealed genetic variation particularly of additive types. Such mating system would also break the pleatu of limited response to selection even in self pollinated crops under linkage disequilibrium (Moll and Robinson, 1967). However, intermated progenies could also be of great use to isolate desirable recombinants quite in early generations by recombining desired characters (Miller and Rawlings, 1967). To formulate the selection criteria association analysis is very useful as it reveals the extent and nature of inter relationship among the polygenic characters. Path coefficient analysis furnishes a means to measure the direct and indirect effects of a variable through other variables on the end product, which is yield. Furthermore, correlation in conjunction with path analysis will give a clear idea of nature of association and relative contribution which aids in simultaneous selection of character pairs. In the present investigation, the effectiveness of biparental mating in breaking the linkages and resulting changes in the magnitude and direction of association among the grain quality attributes is estimated by comparing intermated progenies (BIPs) with that of two early segregating generations (F_2 and F_3 generation) of rice.

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, Tamil Nadu Agricultural University, Coimbatore. F_2 generation which comprised the biparental mating block was raised during wet season 2008-2009 in non-replicated rows of 800 single plants. North carolina Design II suggested by Comstock and Robinson (1952) was followed 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. Simultaneously the respective male and female parents were also selfed to generate F_3 families. For crossing wet cloth method suggested by Chaisang *et al*. (1967) was followed. The F_3 families and biparental progenies were raised during Rabi 2008-2009 in a Randomized Block design with two replications adopting a spacing of 20 cm between rows and 10 cm between plants. After harvesting, the seed samples were sun dried to 12 to 14 % moisture content and all the samples were analyzed for fifteen grain quality measures.

The following physical and cooking quality characters *viz.,* hulling percentage, milling percentage, 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.

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 per cent potassium hydroxide 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 grains 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.

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. One milliliter 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 hour 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: the longer the distance, the softer the gel.

The simplified procedure of Juliano (1979) was used for estimating the amylose content. Two samples of milled rice flour (50 mg) were taken in 50 ml volumetric flask. To this, 0.5 ml of 95 per cent 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. 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 t'he 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)

Associations between single plant yield and grain quality parameters were estimated as per the method suggested by Goulden (1952). The path coefficient analysis was worked out as suggested by Dewey and Lu (1959). In the present study, single plant yield was treated as dependent variable and all other grain quality measures were treated as independent variables. The simultaneous equation which expresses the basic relationship between the path coefficients were solved to obtain the path coefficients. The direct and indirect effects were classified based on the scales given by Lenka and Mishra (1973).

RESULTS AND DISCUSSIONS

In the present investigation, most of the grain quality parameters had negative association with grain yield in F_2, F_3 and BIPs. In BIPs hulling percentage had significant positive association with single plant yield. Seven grain quality parameters in F_2 and nine quality traits in F_3 generations showed negative association with grain yield, but in biparental progenies, only five grain quality traits had negative association with single plant yield.

A total of 18 positive and significant associations in F_2s and 20 positive and significant associations in F_3 progenies were observed among the grain quality parameters. But it was increased to 32 positive significant associations in BIPs. Like wise, negative association was also changed towards positive direction in biparental progenies and only 10 negative associations was observed in BIPs. But it was 23 negative associations in F_2s and 12 in F_3 progenies (Table 1, 2 and 3). It indicated that, inter correlations among the grain quality parameters were strengthened in BIPs. Several such new recombinants were synthesized in BIPs due to intermating in F_2 generation. Among these associations, linear elongation ratio exhibited non significant negative relationship with hulling percentage in F_2 (-0.017) and F_3 (-0.333) generations which got shifted to highly significant positive association in BIPs (0.298). Kernel length after cooking showed significant positive relationship with milling percentage and head rice recovery in biparental progenies, but it was originally non significant negative in F_2 and F_3 progenies. Volume expansion ratio exhibited non significant positive association with head rice recovery in F_2 (0.057) and F_3 (0.017) generation which was shifted to positive direction in BIPs (0.331). In F_3 generation, kernel breadth had negative association with kernel breadth after cooking and this association was shifted to significant positive direction in F_2 and biparental progenies.

In F_3 generation, kernel L/B ratio showed significant negative association (-0.481) with kernel L/B ratio after cooking and it was shifted to positive and significant direction in BIPs (0.373), but it was positive and non significant in F_2 generation (0.045). Kernel length after cooking had negative relationship with kernel breadth after cooking in F_2 (-0.478) and F_3 (-0.045) generation which was shifted to highly significant and positive direction in BIPs (0.660). Asha Christopher *et al.* (1999) reported kernel length after cooking had positive association with kernel breadth after cooking in F_2 generation.

In F_2 (-0.491) and F_3 (-0.220) progenies, kernel breadth after cooking showed a negative relationship with linear elongation ratio which was shifted to highly significant and positive association in biparental progenies (0.524). Kernel L/B ratio showed highly significant positive association with BER in BIPs and it

Table1. Genotypic correlation between grain yield and grain quality parameters in F_2 generation

Characters	Hulling	Milling	HRR	KL	KB	L/B ratio	KLAC	KBAC	L/B AC	LER	BER	GC	GT	VER	AC	SPY
Hulling	1.000	0.899**	0.846**	-0.287*	0.386**	-0.321*	0.240	0.295*	-0.123	-0.017	0.095	0.238	-0.007	-0.003	-0.345*	-0.006
Milling		1.000	0.945**	-0.339*	0.383**	-0.334*	-0.222	0.251	-0.119	0.152	0.145	0.089	0.196	0.037	-0.276*	-0.052
HRR			1.000	-0.299*	0.383**	-0.301*	-0.189	0.225	-0.033	0.151	0.067	-0.050	0.241	0.057	-0.298*	-0.108
KL				1.000	-0.794**	0.969**	0.954**	-0.716**	0.019	0.416**	0.144	-0.266*	-0.268*	0.015	0.064	0.155
KB					1.000	-0.877**	-0.799**	0.668**	-0.071	-0.466**	-0.068	0.204	0.2898	-0.114	-0.126	-0.151
K L/ B						1.000	0.950**	-0.724**	0.045	0.484**	0.192	-0.246	-0.2778	0.058	0.106	0.105
KLAC							1.000	-0.748**	0.077	0.667**	0.229	-0.292*	-0.330*	0.182	0.052	0.198
KBAC								1.000	0.021	-0.491**	0.015	0.173	0.267*	-0.100	-0.108	0.102
L/B AC									1.000	0.208	0.111	-0.142	0.174	0.127	0.129	-0.076
LER										1.000	0.333*	-0.218	-0.339*	0.522**	0.016	0.233
BER											1.000	0.209	0.028	0.127	-0.198	0.239
GC												1.000	-0.118	-0.072	-0.006	0.019
GT													1.000	-0.063	-0.119	-0.004
VER														1.000	0.098	0.192
AMY															1.000	-0.024

*- significant at 5 % level   ** - significant at 1 % level

Table 2. Genotypic correlation between grain quality parameters and single plant yield in F_3 families

Characters	Hulling	Milling	HRR	KL	KB	L/B ratio	KLAC	KBAC	L/B AC	LER	BER	GC	GT	VER	AC	SPY
Hulling	1.000	0.750**	0.620**	0.266	0.222	0.297	-0.213	-0.166	-0.079	-0.335	-0.264	-0.215	0.432*	-0.228	-0.453*	-0.300
Milling		1.000	0.790**	0.182	-0.001	0.381	-0.288	-0.266	-0.110	-0.376	-0.201	0.182	0.445*	0.262	-0.319	-0.299
HRR			1.000	0.161	0.264	-0.015	-0.269	-0.325	-0.066	-0.363	-0.419	0.118	0.635**	0.071	-0.388	0.174
KL				1.000	0.878**	0.876**	0.072	0.082	-0.031	-0.635**	-0.383	0.023	0.071	-0.025	-0.462*	-0.408
KB					1.000	0.532*	0.308	-0.227	0.250	-0.334	-0.540*	-0.331	0.446*	-0.029	-0.607**	0.384
K L/ B						1.000	-0.349	0.519*	-0.481*	-0.918**	-0.061	0.458*	-0.394	0.200	-0.132	-0.860**
KLAC							1.000	-0.045	0.829**	0.720**	-0.266	-0.222	-0.739**	0.150	-0.418	0.114
KBAC								1.000	-0.595**	-0.220	0.994**	0.365	0.717**	0.538*	-0.156	-0.673**
L/B AC									1.000	0.728**	-0.684**	-0.372	-0.856**	-0.209	-0.202	0.425
LER										1.000	-0.053	-0.258	0.659**	0.074	-0.009	0.363
BER											1.000	0.459*	0.304	0.547*	0.221	-0.748**
GC												1.000	0.239	0.362	0.118	-0.162
GT													1.000	0.066	-0.284	0.121
VER														1.000	0.150	-0.398
AMY															1.000	-0.215
SPY																1.000

*- significant at 5 % level, ** - significant at 1 % level

Table 3. Genotypic correlation between grain yield and grain quality parameters in BIPs

Characters	Hulling	Milling	HRR	KL	KB	L/B ratio	KLAC	KBAC	L/B AC	LER	BER	GC	GT	VER	AC	SPY
Hulling	1.000	0.980**	0.951**	0.086	0.186	-0.073	0.385*	0.616**	-0.037	0.298*	0.274	0.066	0.019	0.274	-0.159	0.302*
Milling		1.000	0.940**	0.109	0.191	-0.078	0.297*	0.530**	-0.057	0.211	0.209	0.063	0.050	0.233	-0.180	0.286
HRR			1.000	0.114	0.284	-0.141	0.324*	0.639**	-0.147	0.227	0.285	0.077	-0.206	0.331*	-0.198	0.233
KL				1.000	-0.023	0.602**	-0.002	0.129	-0.145	-0.616**	0.357*	0.144	-0.264	-0.032	-0.336*	0.152
KB					1.000	-0.819**	0.037	0.566**	-0.462**	0.065	-0.793**	0.144	-0.130	0.310*	-0.139	-0.062
K L/ B						1.000	0.013	-0.338*	0.373*	-0.429**	0.701**	-0.019	-0.173	-0.220	-0.139	0.158
KLAC							1.000	0.660**	0.618**	0.798**	0.335*	0053	0.060	0.588**	-0.083	0.032
KBAC								1.000	-0.224	0.524**	0.328*	-0.034	0.742**	0.387*	-0.200	0.153
L/B AC									1.000	0.536**	0.143	0.113	-0.426**	0.461**	-0.213	0.040
LER										1.000	0.041	-0.080	0.208	0.442**	-0.060	-0.092
BER											1.000	-0.329*	0.352*	0.264	0.023	-0.027
GC												1.000	0.413**	0.006	-0.109	0.115
GT													1.000	-0.563**	0.082	-0.213
VER														1.000	0.176	0.001
AMY															1.000	-0.096
SPY																1.000

*- significant at 5 % level, ** - significant at 1 % level

was originally in negative direction in F_3 generation. Breadth wise expansion ratio exhibited a significant association with gelatinization temperature in BIPs but it was positive and non significant in F_2 and F_3 generation. Gelatinization temperature exhibited negative association with gel consistency in F_2 generation (-0.118) and positive and non significant in F_3 generation (0.239), but this association was shifted to highly significant and positive association in intermated progenies (0.413). The present findings were in accordance with the results of Krishna Veni and Shobha Rani (2006), who reported kernel length and kernel L/B ratio had negative relationship with grain yield. Krishna Naik *et al.* (2005) found negative relationship between single plant yield and amylose content. Positive association between hulling percentage and milling percentage was observed by Chauhan and Nanda (1983), between hulling percentage and head rice recovery by Chauhan (1998). Krishna Naik *et al.* (2005) found positive association between milling percentage and head rice recovery. The altered correlations from F_3 to BIPs were due to breakage of undesirable linkages and release of desirable variability through biparental mating (Kishore *et al.*, 1989).

Path coefficient analysis further provided an insight into the inter relationships of various grain quality characters with single plant yield. Path analysis indicated that in both F_3s and BIPs gelatinization temperature and amylose content showed positive direct effect with single plant yield (Table 4 and 5). The impact of biparental mating was apparent by the way of changing direct effect of traits on single plant yield in favourable direction from negative in F_3 generation to positive direction in BIPs. Such altered associations were noticed for hulling percentage, kernel breadth, kernel L/B ratio, kernel length after cooking and volume expansion ratio. Among these characters kernel length after cooking, hulling percentage and kernel L/B ratio had maximum direct effect on single plant yield. In contrary to this, a change from positive direct effect in F_3 to negative direct effect in BIPs were noticed for milling percentage, head rice recovery, kernel length, kernel L/B ratio after cooking, linear elongation ratio, breadth wise expansion ratio and gel consistency.

Gill *et al.* (1973) in wheat also reported such changes in the nature and magnitude of characters

Table 4. Indirect effect of different grain quality parameters on single plant yield in F_3 families

	Hulling	Milling	HRR	KL	KB	L/B ratio	KLAC	KBAC	L/B AC	LER	BER	GC	GT	VER	AC
Hulling	-1.126	0.349	0.541	1.230	-0.016	-0.500	0.788	0.120	-0.187	-1.021	-0.764	-0.011	0.128	0.184	-0.015
Milling	-0.845	0.465	0.689	0.839	0.001	-0.641	1.068	0.194	-0.261	-1.144	-0.582	0.009	0.132	-0.212	-0.010
HRR	-0.699	0.368	0.872	0.745	-0.019	0.024	0.996	0.237	-0.158	-1.104	-1.214	0.005	0.188	-0.057	-0.012
KL	-0.299	0.084	0.140	4.622	-0.064	-1.474	-0.267	-0.060	-0.073	-1.932	-1.110	0.001	0.021	0.020	-0.015
KB	-0.250	-0.001	0.230	4.059	-0.073	-0.893	-1.142	0.165	0.593	-1.016	-1.563	-0.016	0.132	0.185	-0.020
K L/ B	-0.335	0.177	-0.012	4.050	-0.039	-1.683	1.293	-0.378	-1.142	-2.793	-0.175	0.022	-0.117	-0.162	-0.004
KLAC	0.239	-0.134	-0.234	0.333	-0.022	0.587	-3.708	0.032	1.969	2.190	-0.770	-0.011	-0.219	-0.121	-0.014
KBAC	0.186	-0.124	-0.283	0.381	0.016	-0.873	0.165	-0.728	-1.413	-0.669	2.879	0.018	0.213	-0.435	-0.005
L/B AC	0.089	-0.051	-0.058	-0.143	-0.018	0.808	-3.073	0.433	2.376	2.216	-1.991	-0.018	-0.307	0.169	-0.006
LER	0.378	-0.175	-0.316	-2.935	0.024	1.545	-2.669	0.160	1.730	3.043	-0.152	-0.012	-0.196	-0.060	-0.001
BER	0.297	-0.093	-0.365	-1.771	0.039	0.101	0.986	-0.724	-1.633	-0.160	2.879	0.022	0.090	-0.443	0.007
GC	0.242	0.084	0.103	0.106	0.024	-0.771	0.824	-0.265	-0.883	-0.786	1.329	0.050	0.071	-0.293	0.003
GT	-0.487	0.207	0.553	0.328	-0.032	0.663	2.739	-0.522	-2.452	-2.004	0.881	0.011	0.297	-0.053	-0.009
VER	0.257	0.121	0.062	-0.118	0.016	-0.337	-0.556	-0.391	-0.495	0.226	1.585	0.018	0.019	-0.810	0.005
AMY	0.510	-0.148	-0.338	-2.137	0.044	0.222	1.549	0.113	-0.479	-0.027	0.639	0.005	-0.084	-0.121	0.003

*- significant at 5 % level, ** - significant at 1 % level

Table 5. Indirect effect of different grain quality measures on single plant yield in Biparental progenies

	Hulling	Milling	HRR	KL	KB	L/B ratio	KLAC	KBAC	L/B AC	LER	BER	GC	GT	VER	AC
Hulling	1.863	-0.689	-0.461	-0.108	0.061	-0.033	1.265	-1.027	0.057	-0.576	-0.045	-0.005	-0.009	0.010	-0.001
Milling	1.825	-0.703	-0.456	-0.137	0.063	-0.035	0.974	-0.884	0.087	-0.409	-0.034	-0.005	-0.008	0.008	-0.001
HRR	1.772	-0.661	-0.485	-0.142	0.093	-0.064	1.062	-1.066	0.225	-0.438	-0.046	-0.006	-0.022	0.012	-0.001
KL	0.160	-0.077	-0.055	-1.249	-0.008	0.273	-0.007	-0.215	0.223	1.192	-0.058	-0.012	-0.011	-0.001	-0.004
KB	0.347	-0.135	-0.138	0.029	0.327	-0.371	0.120	-0.943	0.708	-0.126	0.129	-0.012	-0.007	0.011	-0.002
K L/ B	-0.316	0.055	0.068	-0.751	-0.268	0.453	0.043	0.564	-0.572	0.831	-0.144	0.002	-0.008	-0.008	-0.001
KLAC	0.718	-0.209	-0.157	0.003	0.012	0.006	3.283	-1.100	-0.948	-1.544	-0.055	-0.004	0.005	0.021	0.000
KBAC	1.148	-0.373	-0.310	-0.161	0.185	-0.153	2.166	-1.667	0.344	-1.014	-0.053	0.003	0.026	0.014	-0.000
L/B AC	-0.070	0.040	0.071	0.181	-0.151	0.169	2.029	0.374	-1.533	-1.036	-0.023	-0.009	-0.019	0.017	0.000
LER	0.554	-0.149	-0.110	0.769	0.021	-0.195	2.619	-0.874	-0.821	-1.935	-0.007	0.006	0.010	0.016	0.002
BER	0.511	-0.147	-0.138	-0.446	-0.259	0.318	1.101	-0.547	-0.220	-0.079	-0.163	0.026	0.025	-0.010	0.000
GC	0.122	-0.044	-0.037	-0.180	0.047	-0.009	0.173	0.057	-0.173	0.155	0.054	-0.080	0.031	0.000	0.000
GT	-0.250	0.090	0.160	0.205	-0.035	-0.058	0.255	-0.667	0.434	-0.299	-0.062	-0.038	0.065	-0.016	0.004
VER	0.511	-0.164	-0.161	0.040	0.101	-0.100	1.929	-0.644	-0.708	-0.856	0.043	-0.001	-0.028	0.036	0.002
AMY	-0.167	0.067	0.048	0.732	-0.097	-0.060	0.023	0.041	-0.004	-0.730	-0.002	-0.002	0.042	0.009	0.006

*- significant at 5 % level, ** - significant at 1 % level

association in biparental progenies when compared to F_3 families. They have explained their results on the basis of linkage phenomenon *i.e.,* a higher correlation coefficient could be obtained if the linkage was more in repulsion phase and vice versa for coupling phase of linkage. Therefore, the changes in character association particularly in desirable direction are of greater significance in crop improvement. Both increase and decrease in correlation between various characters have been reported in wheat by Verma *et al.* (1979). Shifts in correlation matrix also were reported by Miller and Rawlings (1967) after several cycles of inter crossing in cotton. They suggested that breakage of coupling phase of linkages tend to decrease the correlation, whereas repulsion phase of linkage increased their magnitude. Under this assumption, the present investigation appear to have involved both coupling and repulsion phase of linkage as both increase and decrease in correlations, irrespective of the direction were observed in BIPs. Hence the effectiveness of the biparental mating approach would depend on the existing phase of linkage *i.e.,* coupling or repulsion.

It was evident that reshuffling of genes were responsible for correlations among some characters resulted in newer recombinations which presumably, were due to changes from a coupling to repulsion phase linkages. Biparental or intermating was found to be effective in changing not only the magnitude of correlation coefficient but also direct and indirect dependence of grain yield on cooking quality parameters. Intermating in early segregating generation together with selection would be effective in accumulating the desirable genes and also maintain greater genetic variability for selection. From the above discussion, it has become evident that biparental mating is likely to be useful under specific situation especially when repulsion phase of linkages are predominant, change in correlation coefficients, particularly from unfavorable to favorable ones, would provide greater scope for increasing the frequency of rare recombinants. Biparental mating was more effective in breakage of linkages, generating tremendous desirable genetic variability and dissipating negative correlation between yield and grain quality parameters thereby increasing the efficiency of selection for improving productivity.

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