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# GENETIC VARIABILITY, HERITABILITY AND CORRELATION COEFFICIENTS OF GRAIN QUALITY CHARACTERS IN RICE (*Oryza sativa* L.)

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## SUMMARY

Ninety-two rice (*Oryza sativa L.*) genotypes were evaluated during kharif 2013 to estimate the genetic variability, heritability and correlation coefficients for 14 physicochemical and cooking quality traits. The experiment was conducted in a complete randomized block design with 3 replications. Highly significant ($P < 0.01$) differences were observed for all 14 quality characters studied. Among the traits, head rice recovery (%), water uptake, gel consistency and alkali spreading value exhibited high estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV). Highest broad sense heritability and genetic advance was obtained for head rice recovery (89% and 29%), milling (84% and 21%), water uptake (90% and 24%), amylose content (93% and 29%) and gel consistency (90% and 31%) which suggested that these traits would respond to selection owing to their high genetic variability and transmissibility. High estimates of heritability in association with medium genetic advance observed for KLAC (89% and 13%), elongation ratio (86% and 11%) and alkali spreading value (80% and 19%) suggested the role of both additive and non-additive gene action in their inheritance. The significant positive correlation of KLAC with ER ($r = 0.638$) and L/B ratio ($r = 0.556$), ASV with water uptake ($r = 0.426$), hulling % with milling % ($r = 0.60$) and with HRR % ($r = 0.150$) indicated that these are the primary traits for improvement of rice grain quality.

**Key words:** Genetic variability, quality, heritability, genetic advance, correlation, rice (*Oryza sativa* L.)

**Key findings:** The study revealed that the genotypes IR 64, MTU1010, Indravati, BR2655, NLR 33359, Swarna, Chittimutyalu, Kalanamak, Basmati 386, Pusa Basmati 1, Ranbir Basmati, Vasumati and Yamini possessed good quality traits and these varieties may be used in breeding programs.

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## INTRODUCTION

Rice is one of the major food grain crops in the world particularly in Asian countries. Traditionally, rice plant breeders concentrated on breeding for high yield. In recent decades as living conditions are being steadily improved, human demand for high quality rice is continuously on increase, which entailed in incorporation of preferred grain quality features as the most important objective next to enhancement in yield. Also quality characteristics increase the total economic value of rice. Hence, improving rice grain quality has been a major concern in rice breeding programs to meet the consumer preference and market demand. The rice grain quality traits generally include milling quality, appearance quality, and nutritional quality in terms of cooking and eating quality which are most important for the consumers. Hence selection for improved milling, cooking, eating and processing qualities is crucial to meet consumers' preference and industry standards.

Rice is the only cereal crop cooked and consumed mainly as whole grains, and quality considerations are more important (Hossain *et al*., 2009). Physical quality properties such as size, shape, uniformity and general appearance (Cruz and Khush, 2000; Sellappan *et al*., 2009); Kernel shape and L/B ratio are important features while assessing grain quality (Rita and Sarawgi, 2008). The gelatinization temperature (GT), gel consistency (GC) and amylose content (AC) are another set of traits, which are directly related to cooking and eating quality (Little *et al.,* 1958). Starch (amylose and amylopectin) and protein composition are equally important in determining the cooking quality of rice (Lisle *et al.,* 2000; Ahmed *et al.,* 2007). The quality desired would vary from one geographical region to the other and depends on consumer preference (Juliano *et al*., 1964; Azeez and Shafi, 1966). For example in *japonica* rice eating countries, low amylose and short grain is preferred while in *indica* rice consuming countries, long grain with intermediate amylose and alkali spreading value, soft gel consistency and high volume expansion of cooked rice is preferred (Hossain *et al*., 2009).

A wide range of genetic variability has been reported for quality traits in the past, but still there exists untapped genetic variability in germplasm which is of paramount importance in selecting the potential parents so as to get maximum heterosis and superior recombinants with respect to quality components. Genetic parameters such as genotypic coefficient of variation and phenotypic coefficient of variation are useful in detecting the amount of variability present in the germplasm. Heritability coupled with high genetic advance helps in determining the influence environment on the expression the genotypic and reliability of characters. Genotypic correlation among grain quality and its components provide the information about their performance and association with one another. With the above background information, the present investigation was undertaken to estimate genetic variability for quality characteristics and unravel the correlation of different grain quality traits among a set of 92 rice genotypes.

## MATERIALS AND METHODS

The present investigation was carried out in ICAR-Indian Institute of Rice Research (IIRR) (formerly Directorate of Rice Research) farm at ICRISAT campus, Patancheru during Kharif 2013. Experimental materials consisted of 92 rice genotypes (Table 1) which includes varieties, hybrids, aromatic rice, red rice and land races grown in randomized complete block design with 3 replications. Seed material was collected from different institutes of Indian Council of Agricultural Research and State Agricultural Universities. The genotypes possessed different maturity durations and are adapted to different ecosystems of rice. Each genotype was grown in 5 $m^2$ plot. Recommended management practices were followed.

After harvesting, threshing and cleaning, the seeds from individual genotypes were dried under shade until moisture content reaches to 14%. The seed was dehusked in a Satake laboratory huller (Type THU 35 A) and polished in a Satake Rice Polisher (Type TM 05). The polished seed (8%) obtained was then utilized for the analysis of 14 seed quality traits namely hulling (%), milling (%), head rice recovery (%), kernel length and breadth (mm), length/breadth ratio (L/B), 1000-grain weight (g) (physical quality traits); kernel length after cooking (KLAC) (mm), kernel elongation ratio (ER), volume expansion ratio (VER) and water uptake (cooking quality traits); amylose content (%), gel consistency (mm), alkali spreading value (chemical quality traits) at Quality Laboratory, Indian Institute of Rice Research Hyderabad. Milling percentage was calculated by dividing the weight of milled rice by weight of paddy. The HRR percentage and broken rice were calculated using the standard formula of (weight of milled rice/weight of grain) x 100] (Cruz and Khush, 2000)**.**

**Table 1.** List of genotypes used in this study.

| Genotype | Genotype | Genotype | Genotype |
|---|---|---|---|
| Aishwarya | IR 64 | MSS - 5 | Ranjeet |
| Amulya | Jaya | MTU -1001 (Vijetha) | Sabita |
| As 100 | Jalpriya | MTU-1010 (C. Sannalu) | SGT 1 |
| Basmati 386 | Jagabandu | MTU-3626 (Prabhat) | Sashi |
| Bhuban | Jalmagna | Nagari Dubraj | Shakthi |
| Bhudeb | Jalnidhi | Nalini | Sahyadri |
| Barah Avarodhi | Jyothi (PTB 39) | NLR 145 (Swarnamukhi) | Sahyadri 2 |
| Birupa | Kanchana | NLR 33654 (Apurva) | Sunandana |
| BPT 11711 | Kalanamak (ASG 4022) | NLR 33359 (Shravani) | Suraksha |
| BR 2655 | Khitish | Pant Dhan -16 | Swarna |
| Chittimutyalu | KHP - 2 | Prachi | Type 3 |
| CN 1039-9 | Konark | Pooja | Taroari Basmati |
| CN 1233-33-9-117 | KMP-101 | Pratap | Varsha |
| Dandi | Kranti | Pusa Basmati | Vasumathi |
| Dharitri | Karjat-2 | PR 111 | Vikas |
| DL 184 | Kavya | PR113 | VRM 3 |
| Gajapathi | Lalat | PR 114 | VRM 31 |
| Giri | Madhukar | PR 115 | VRS 3 |
| Gouri | Mahamaya | PR 116 | VRS 19 |
| GR 103 | Mandya Vijaya | PR 118 | VRS 25 |
| Harsha | Manohar Sali | PSD 1 | WGL 14 (W. Samba) |
| High iron rice | Matta Triveni | RAU 3043 (ASG 4013 ) | White Ponni |
| Indravati | MSE-9 | Ranbir Basmati | Yamini |

Twenty grains at random from each sample from each replication were dehusked by hand and the length and breadth in millimeters was recorded using Dial micrometer. The L/B ratio was calculated by dividing the average length by the average breadth of rice kernel. Based on the L/B ratio, grains were classified into long slender (LS), short slender (SS), medium slender (MS), long bold (LB) and short bold (SB) (Ramaiah, 1985). Kernel elongation ratio (ER) was calculated by dividing the average length of cooked kernel by the average length of the raw rice (Murthy, 1965). KLAC was measured by the method of Juliano *et al.* (1966). ASV was estimated by the method advocated by Little *et al.* (1958). The simplified procedure suggested by Jennings *et al.* (1979) was used for estimating the AC and gel consistency.

The data was analyzed by the Analysis of Variance (ANOVA) and interrelationships among traits values were estimated using SAS software version 9.1 (SAS Institute, 1998). Differences were declared statistically significant at $P < 0.05$. Where significant differences were detected, the means were separated by the least significant difference (LSD) at 5% probability level. In this study phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) was calculated by the formula given by Burton and Devane (1953). Heritability in broad sense ($h^2_b$) and genetic advance as percent of mean were estimated by the formula as suggested by Hanson *et al*. (1956) and Johnson *et al.* (1955).

## RESULTS AND DISCUSSION

The analysis of variance revealed highly significant differences among the genotypes for all the 14 quality characters indicating the existence of significant amount of variability among the characters studied. (Table 2).The genotype Varsha recorded maximum mean value for hulling (81.1%), whereas Indravati for milling percent (72%) and head rice recovery (68%). The promising cultures with high 1000-grain weight are Kranti, Mahamaya, and Madhukar which registered mean weight of 30.74 g, 30.53 g and 29.4 g respectively.

**Table 2.** Analysis of variance of 14 quality characters.

| Characters | Source of variation (mean sum of squares) | | |
|---|---|---|---|
| | Replication | Treatments | Error |
| Hulling (%) | 0.235 | 12.53** | 0.007 |
| Milling (%) | 0.137 | 40.93** | 0.006 |
| Head Rice recovery (%) | 15.249 | 641.8** | 10.038 |
| Kernel Length (mm) | 0.0002 | 1.30** | 0.0006 |
| Kernel Breadth (mm) | 0.0006 | 0.13** | 0.0003 |
| L/B ratio | 0.001 | 0.68** | 0.0005 |
| Kernel Length After Cooking | 0.059 | 7.24** | 0.007 |
| Water Uptake (ml) | 129.632 | 11856.7** | 36.73 |
| Volume Expansion Ratio | 0.006 | 0.54** | 0.005 |
| Elongation Ratio | 0.001 | 0.14** | 0.0002 |
| Alkali Spreading Value | 1.981 | 3.45** | 0.172 |
| Gel Consistency (mm) | 2.851 | 723.1** | 0.785 |
| Amylose Content (%) | 0.008 | 17.30** | 0.016 |
| 1000-grain weight (g) | 0.204 | 50.60** | 0.098 |

[*] Significant at 5% level, [**] Significant at 1% level

The genotype SGT 1 and Pusa Basmati 1 showed maximum mean value for kernel length (7.1 mm) and BPT 11711, Pusa Basmati 1, Yamini and Basmati 386 showed minimum value for kernel breadth (1.7 mm). Similarly high L/B values were recorded in all basmati varieties (> 3 mm).

The genotypes Chittimutyalu, BR-2655, MTU1001, NLR-33359, Nagari Dubraj, Type-3, Vasumati, Taroari Basmati, Ranbir Basmati, Basmati 386 and Yamini recorded desirable grain quality parameters such as intermediate value for alkali spreading value, gel consistency, amylose content and superior performance for elongation ratio and kernel length after cooking.

The intermediate ASV found in the current experiment indicated medium disintegration of rice which is highly desirable for quality grain (Bansal *et al*., 2006). The volume expansion ratio (VER) ranged from 4.1 (Suraksha and Karjat) to 5.77 (Kalanamak). A total of 57 genotypes recorded ideal VER of 4.0 to 5.0 (Table 3). Similar trend of VER had been observed in 21 varieties out of 41 elite rice varieties of Eastern India (Subudhi *et al*., 2012).

The relative values of genotypic and phenotypic coefficient of variation provide important information on the magnitude of variation. In general the phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) in all studied characters, but the most portion of phenotypic coefficient of variation was contributed by the genotypic component, less by environmental component. Also good correspondence was observed between PCV and GCV for all the characters (Table 3)

A wide range of PCV was observed for traits ranging from 2.61% for hulling % to 37.75% for water uptake. Similarly GCV showed wider range from 2.6% for hulling % to 37.58% for water uptake. High PCV and GCV were recorded for head rice recovery (29.49% and 30.18%), water uptake (37.58% and 37.75%), gel consistency (35.23% and 35.29%) and alkali spreading value (20.09% and 21.66%). Similar findings of high GCV and PCV were also reported by Chaudhari *et al.* (2007) for water uptake and gel consistency; Nayak *et al.* (2003), Chakraborty *et al.* (2009), Vanaja and Babu (2006), Sanjukta *et al.* (2007) and Veerabadhiran *et al.* (2009) for alkali spreading value whereas Gangashetty *et al*, (2013), Nagabhushan (2002) and Girish *et al.* (2006) for 1000-grain weight.

**Table 3.** Estimation of population mean, range and genetic parameters for 14 quality traits in rice genotypes.

| Character | Range | Mean ± S.E | ECV | GCV | PCV | Heritability (%) broad sense | Genetic advance (as % mean) |
|---|---|---|---|---|---|---|---|
| Hulling (%) | 69.50 - 82.13 | 78.50 ± 0.05 | 0.11 | 2.60 | 2.61 | 77 | 4 |
| Milling (%) | 58.30 - 75.60 | 67.93 ± 0.05 | 0.12 | 5.44 | 5.44 | 84 | 21 |
| Head rice recovery (%) | 19.10 - 72.73 | 65.85 ± 1.83 | 6.44 | 29.49 | 30.18 | 89 | 29 |
| Kernel length (mm) | 3.85 - 7.11 | 5.88 ± 0.02 | 0.45 | 11.19 | 11.20 | 95 | 4 |
| Kernel breadth (mm) | 1.50 - 2.58 | 2.09 ± 0.01 | 0.86 | 10.05 | 10.09 | 88 | 4 |
| Length/Breadth ratio | 1.51 - 4.16 | 2.84 ± 0.01 | 0.84 | 16.81 | 16.83 | 96 | 9 |
| 1000-grain weight (g) | 14.85 - 33.54 | 23.81 ± 0.18 | 1.32 | 17.23 | 17.28 | 90 | 31 |
| Volume expansion ratio | 4.10 - 5.77 | 4.94 ± 0.04 | 1.53 | 8.61 | 8.75 | 87 | 8 |
| Water uptake (ml) | 67.70 - 381 | 167.03 ± 3.50 | 3.63 | 37.58 | 37.75 | 90 | 24 |
| Kernel length after cooking(mm) | 6.80 - 15.60 | 10.38 ± 0.05 | 0.84 | 14.97 | 14.99 | 89 | 13 |
| Elongation ratio | 1.22 - 2.32 | 1.77 ± 0.01 | 0.96 | 12.46 | 12.49 | 86 | 11 |
| Alkali Spreading Value | 3.00 - 7.00 | 5.13 ± 0.24 | 8.10 | 20.09 | 21.66 | 80 | 19 |
| Amylose content (%) | 14.06 - 27.82 | 23.80 ± 0.07 | 0.54 | 9.86 | 9.88 | 93 | 29 |
| Gel consistency | 21.67 - 77.00 | 44.04 ± 0.51 | 2.01 | 35.23 | 35.29 | 90 | 31 |

ECV= Environmental coefficient of variation, GCV= Genotypic coefficient of variation, PCV= Phenotypic coefficient

The high magnitude of GCV and PCV for the above traits suggested the presence of high degree of variability and so better scope for the improvement through simple selection.

Low GCVs and PCVs (<10%) were found for the characters *viz* hulling % (2.6% &2.61%), milling % (5.44% & 5.44%), amylose content (9.86% & 9.88%) and volume expansion ratio (8.61% & 8.75%). Low GCV and PCV estimates were also noticed for hulling per cent (Vanaja and Babu, 2006; Uma devi *et al*., 2010) Similar kind of low GCV and PCV results for amylose content has been reported by Subbaiah *et al.* (2011) . Lower GCV and PCV estimates indicates narrow genetic base for these traits. Improvement in these characters can be brought about by hybridization or induced mutagenesis to widen genetic base followed by pedigree selection in advanced generations. While moderate GCV's and PCV's (10-20%) were observed for the traits – Kernel length (11.19% and 11.2%), kernel breadth (10.05% and 10.09%), length/breadth ratio 16.81% and 16.83%), kernel length after cooking (14.97% and 14.99%) and elongation ratio (12.46% and 12.49%). These results were consistent with the findings of Chauhan *et a*l. (1987), Kundu *et al.* (2008), Gangashetty *et al.* (2013) for kernel length and breadth; Subbaiah *et al.* (2011) for L/B ratio and kernel length after cooking and Nayak *et al.* (2003) for elongation ratio. This indicates the existence of comparatively moderate variability for these traits, which could be exploited for improvement through selection in advanced generations. On the whole, the close correspondence between the estimates of GCV and PCV for most of the traits indicated lesser environmental influence on the expression of traits, which is also reflected by their high heritability values.

Heritability in broad sense includes both fixable (additive) and non-fixable (dominant and epistatic) variances and also provides a good indication about the repeatability of the traits. The estimates of heritability for different characters were high and ranged from 77% to 96%. Although, the presence of high heritability values indicate the effectiveness of selection on the basis of phenotypic performance, it does not show any indication to the amount of genetic progress for selecting the best individuals which is possible by using the estimate of genetic advance.

Heritability estimates (above 60%) along with genetic advance (above 20%) would be helpful in predicting gain under selection than heritability estimates alone. In this study, head rice recovery (89 and 29), milling % (84 and 21), water uptake (90 and 24), amylose content (93 and 29) and gel consistency (90 and 31) recorded high heritability as well as high genetic advance. These observations corroborate well with those of Hussain *et al.* (1989), and Nayak *et al.* (2003) for head rice recovery; Hussain *et al.* (1989), Nayak *et al.* (2003), Sanjukta *et al.* (2007) and Chakraborty *et al.* (2010) for water uptake; Sanjukta *et al.* (2007) and Veerabadhiran *et al.* (2009) for amylose content.

The high estimates of heritability and lower estimates of genetic advance as percent of mean was recorded for the traits of hulling (77% and 4%), kernel length (95% and 4%), kernel breadth (88% and 4% ), L/B ratio (96% and 9%), volume expansion ratio (87% and 8%). This is an indication of more environmental influence on these characters. Sanjukta *et al.* (2007) also observed similar results for hulling %, kernel length and kernel breadth; Sharma and Sharma (2007) for L/B ratio. These characters showing high heritability with low genetic advance indicated the presence of non-additive gene action. Hence selection could be postponed for these characters. In other words these characters could be improved by intermating of superior genotypes of segregating population from recombination breeding.

The high estimates of heritability coupled with medium estimates of genetic advance was observed for KLAC (89% and 13%), elongation ratio (86% and 11%) and alkali spreading value (80% and 19%). These were in accordance with the findings of Chakraborty *et al.* (2009 and 2010) and Nayak and Reddy (2005). Thus it is interpreted that the characters i.e. KLAC, elongation ratio and alkali spreading value showed high heritability estimates and moderate genetic advance rendering them unsuitable for improvement through selection.

Correlation coefficient analysis among grain quality characters; between quality traits and 1000-grain weight was computed (Table 4). Correlation estimates showed the possibility of improvement of a character through selection for other character. The character hulling percent showed significant and positive correlation with milling percent ($r$ = 0.602) and head rice recovery ($r$ = 0.150). In the present study the positive significant correlation of hulling % with milling % and head rice recovery indicated that the genotypes with higher hulling percent also showed higher estimates for milled rice and head rice. Similar results were reported by several researchers Tejpal (1987), Sarkar *et al.* (1994), Chauhan *et al.* (1995) and Nayak *et al.* (2003). Hulling %, milling % and HRR are important quality attributes for rice that enhances commercial success of a variety. Simultaneous improvement of these 3 quality traits namely hulling percent, milling percent and head rice recovery can be made with the selection of a single trait is either hulling percent or milling percent or head rice recovery.

Head rice recovery showed negative but non-significant correlations with kernel dimensions like kernel length ($r$ = -0.005) and L/B ratio ($r$ = -0.157). HRR showed negative but non-significant correlation with grain L/B ratio. These findings were in agreement with the findings reported earlier by Gopalakrishna *et al.* (1982), Tejpal (1987) and Shivani *et al.* (2007). Genotypes with long slender grains are more prone to breakage than those possessing short bold grain. Head rice recovery exhibited positive non-significant association with alkali spreading value ($r$ = 0.065) and amylose content ($r$ = 0.052). Negative significant association of kernel breadth was observed with L/B ratio, (r = -0.747), water uptake ($r$ = -0.049) and alkali spreading value ($r$ = -0.171).

Kernel length after cooking is one of the important cooking quality attributes. Lengthwise expansion after cooking is considered a high desirable trait in high quality rice such as basmati rice of India. It fetches maximum premium because of its linear elongation. Grain shape and visual appearance of rice before and after cooking are important to determine acceptance of a rice variety. Prime rice eating nations have the inclination towards varieties that elongate considerably after cooking.

**Table 4.** Correlation coefficients for 14 quality characters among rice genotypes.

| No. | Character | Hulling (%) | Milling (%) | HRR (%) | KL (mm) | KB (mm) | L/B | VER | WU (ml) | KLAC (mm) | ER | ASV | AC (%) | GC (mm) | 1000-grain wt. (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Hulling (%) | 1 | 0.602 | 0.150 | -0.196 | 0.170 | -0.047 | 0.103 | 0.062 | 0.024 | -0.109 | -0.118 | 0.203 | 0.166 | 0.019 |
| | | | <0.0001 | <0.0001 | 0.061 | 0.103 | 0.655 | 0.327 | 0.553 | 0.817 | 0.298 | 0.260 | 0.051 | 0.113 | 0.854 |
| 2 | Milling (%) | | 1 | 0.154 | -0.064 | 0.035 | -0.032 | 0.005 | -0.102 | -0.087 | -0.132 | -0.208 | -0.165 | -0.020 | -0.089 |
| | | | | 0.143 | 0.539 | 0.737 | 0.757 | 0.958 | 0.330 | 0.408 | 0.209 | 0.045 | 0.114 | 0.845 | 0.398 |
| 3 | Head rice recovery (%) | | | 1 | -0.005 | -0.001 | -0.157 | -0.081 | 0.034 | -0.216 | -0.025 | 0.065 | 0.052 | -0.003 | -0.189 |
| | | | | | 0.958 | 0.988 | 0.132 | 0.438 | 0.744 | 0.038 | 0.812 | 0.537 | 0.617 | 0.976 | 0.070 |
| 4 | Kernel Length (mm) | | | | 1 | -0.279 | 0.202 | -0.038 | 0.108 | 0.112 | 0.109 | 0.166 | -0.087 | -0.166 | -0.060 |
| | | | | | | <0.0001 | 0.053 | 0.716 | <0.0001 | 0.286 | 0.299 | <0.0001 | 0.409 | 0.112 | 0.566 |
| 5 | Kernel Breadth (mm) | | | | | 1 | -0.747 | 0.141 | -0.049 | -0.243 | -0.092 | -0.171 | 0.323 | 0.092 | 0.388 |
| | | | | | | | <0.0001 | 0.177 | <0.0001 | 0.019 | 0.3810 | <0.0001 | 0.001 | 0.382 | <0.0001 |
| 6 | Length/Breadth ratio | | | | | | 1 | -0.204 | 0.182 | 0.556 | -0.088 | 0.056 | -0.125 | -0.068 | -0.092 |
| | | | | | | | | 0.051 | 0.081 | <0.0001 | 0.402 | 0.591 | 0.232 | 0.515 | 0.382 |
| 7 | Volume expansion ratio | | | | | | | 1 | -0.121 | -0.105 | 0.072 | -0.048 | -0.002 | -0.027 | 0.118 |
| | | | | | | | | | 0.250 | 0.317 | 0.494 | 0.649 | 0.978 | 0.795 | 0.258 |
| 8 | Water Uptake (ml) | | | | | | | | 1 | 0.149 | -0.029 | 0.426 | 0.068 | 0.004 | 0.159 |
| | | | | | | | | | | 0.155 | 0.779 | <0.0001 | 0.516 | 0.965 | 0.129 |
| 9 | Kernel Length After Cooking (mm) | | | | | | | | | 1 | 0.638 | 0.012 | -0.118 | -0.119 | 0.199 |
| | | | | | | | | | | | <0.0001 | 0.907 | 0.259 | 0.257 | 0.057 |
| 10 | Elongation Ratio | | | | | | | | | | 1 | 0.088 | -0.268 | -0.157 | 0.059 |
| | | | | | | | | | | | | 0.400 | 0.009 | 0.134 | 0.572 |
| 11 | Alkali Spreading Value | | | | | | | | | | | 1 | 0.016 | -0.067 | -0.080 |
| | | | | | | | | | | | | | 0.877 | 0.522 | 0.446 |
| 12 | Amylose Content (%) | | | | | | | | | | | | 1 | 0.157 | 0.133 |
| | | | | | | | | | | | | | | 0.134 | 0.205 |
| 13 | Gel Consistency (mm) | | | | | | | | | | | | | 1 | 0.108 |
| | | | | | | | | | | | | | | | 0.301 |
| 14 | 1000-grain wt. (g) | | | | | | | | | | | | | | 1 |

In this study, kernel length after cooking and kernel elongation ratio are interdependent as evidenced by the positive significant association between them (*r* = 0.638). Selection of either of the trait will ultimately enhance the mean performance of the interdependent trait. The kernel breadth showed highly significant but negative correlation with L/B ratio. Similar association was reported by Khatun *et al.* (2003), Sood and Siddiq (1980), Deosarkar and Nerkar (1994), and Christopher e*t al.* (1999).

Alkali spreading value showed positive significant correlation with water uptake (*r* = 0.426) and kernel length (*r* = 0.166) and negative non-significant correlation with gel consistency (*r* = -0.067) while volume expansion ratio did not show significant correlation with any one of the quality parameters. Positive significant association of alkali spreading value with water uptake indicates that genotypes with high water uptake had low gelatinization temperature (GT) which is consistent with the results reported earlier by Shivani *et al.* (2007), Tomar and Nanda (1982; 1987), Chauhan *et al.* (1995) and Choi *et al.* (1999). Gel consistency showed positive but non-significant correlation with amylose (*r* = 0.157). The observed non-significant positive correlation between gel consistency and amylose indicated higher amylose content may lead to the recovery of genotypes with soft gel consistency as reported by Shivani *et al.* (2007) and Khatun *et al.* (2003).

Physical quality trait namely L/B ratio was positively and significantly associated (*r* = 0.556) with cooking quality trait namely kernel length after cooking. L/B ratio is a good indicator of kernel length after cooking. Thus higher the L/B ratio, more the kernel length after cooking. Selection for these significantly and positively correlated traits will improve the overall quality trait.

The amylose content is a chemical quality trait that determines the texture of cooked rice. Varieties with intermediate amylose content and soft gel consistency are preferred by most rice consumers. The non-significant positive association (*r* = 0. 157) between these 2 chemical quality traits namely gel consistency and amylose content was found. Thus it showed that chances of selecting desirable intermediate values of gel consistency lead to automatic selection of intermediate and desirable level of amylose content.

## CONCLUSIONS

From this study, we conclude that the genotypes possessed adequate variability for the quality traits under study. Considering all the grain quality traits, the superior genotypes identified were Varsha,Vikas, Karjat-2, Sahyadri, Indravati and Vasumati for hulling %; Indravati, PR116, Amulya and Chittimuyalu for milling %; Indravati, Chittimutyalu and Pooja for HRR %, Pusa basmati1, Taroari Basmati, and Yamini for L/B ratio; RAU 3043, Chittimutyalu, Yamini, Jalanidhi, Basmati 386 and Kanchana for elongation ratio; Amulya, BR2655, CN1039-9, Kalanamak, Manoharsali , MSE-9, MTU1001, Nagari Dubraj, NLR33359, Prachi and Vasumati for acceptable cooking quality traits. Out of 92, genotypes IR 64, MTU1010, Indravati, BR2655, NLR 33359, Swarna of non- scented and Chittimutyalu, Kalanamak, Basmati 386, Pusa Basmati 1, Ranbir Basmati, Vasumati and Yamini of scented possessed all the good quality traits. So these varieties may be used in varietal development program and popularized among the farmers. Characters like head rice recovery %, water uptake, amylose content and gel consistency showed high heritability coupled with high genetic advance. Therefore, these characters needs top priority during selection. Based on correlation results the characters hulling %, milling %, head rice recovery %, kernel elongation ratio, kernel length after cooking, amylose content, gel consistency, alkali spreading value and kernel length can be used as selection indices for improving grain quality.

## REFERENCES

Ahmed J, Ramaswamy HS, Raghavan VGS (2007). Dielectric properties of Indian Basmati rice flour slurry. *J. Food Engineering* 80: 1125-1133.

Azeez MA, Shafi M (1966). Quality in rice. Department of Agriculture, West Pakistan Technology Bulletin. No. 13. pp. 50.

Bansal UK, Kaur H, Saini R (2006). Donors for quality characteristics in aromatic rice. Oryza. 43(3):197-202.

Burton GW, Devane EM (1953). Estimating heritability in fall fescue (*Festuca circunclinaceae*) from replicated clonal-material. *Agron. J.* 45: 478-481.

Chakraborty R, Chakraborty S, Dutta BK, Paul SB (2009). Genetic variability and genetic correlation among nutritional and cooking quality traits in bold grained rice. *Oryza*. 46(1): 21-25.

Chakraborty R, Chakraborty S, Dutta BK, Paul SB (2010). Genetic variability of nutritional and cooking quality traits in bold grained rice. *Oryza*. 47(3): 188-192.

Chaudhari M, Motirmani NK, Pravin J (2007). Variability and genetic divergence of aromatic rice (*Oryza sativa* L.). *Ann. Agric. Res. New Ser.* 28 (3 and 4): 268-272.

Chauhan JS, Nanda JS, Chauhan US, Ram HH (1987). Inheritance and inter relationship of some grain quality components in rice. *Oryza*. 24: 123-126.

Chauhan JS, Chauhan VS, Lodh SB (1995). Comparative analysis of variability and correlation between quality components in traditional rainfed upland and low land rice. *Indian J. Genet.* 55: 6-12.

Choi H, Cho J, Chi SY (1999). Varietal difference in water absorption characteristics of milled rice and its relation to the other grain quality components. *Korean J. Crop Sci.* 44: 288-295.

Christopher A, Jebaraj S, Backiyarani S (1999). Interrelationship and path analysis of certain cooking quality characters in heterogenousnous populations of rice (*Oryza Sativa* L). *Madras Agri. J*. 86: 187-191.

Cruz N D, Khush GS (2000). Rice grain quality evaluation procedures. In: R.K. Singh, U.S. Singh and G.S. Khush, eds., Aromatic rice. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, Calcutta, pp. 15-28.

Deosarkar DH, Nerkar YS (1994). Correlation and path analysis for grain quality characters in Indica rice. *J. Maharastra Agric. Univ*. 19: 175-177.

Gangashetty P, Salimath P, Hanamaratti N (2013). Genetic variability studies in genetically diverse non-basmati local aromatic genotypes in rice (*Oryza sativa*.L). *Rice genomics and genetics* 4 (2): 4-8.

Gholipoor M, Zeinali H, Rostami MA (1998). Study of correlation between yield and some important agronomic traits using path analysis in rice. *Iranian J. Agric. Sci*. 29 (3): 627-638.

Girish T, Gireesha T, Vaishali M, Hanamareddy B, Hittalmani S (2006). Response of a new IR50/Moroberekan recombinant inbred population of rice (*Oryza sativa* L.) from an indica × japonica cross for growth and yield traits under aerobic conditions. *Euphytica* 152: 149-16.

Gopalakrishna G, Agarwal RL, Mani SC (1982). Effects of dates of harvesting on milling of rice. *Oryza*. 19: 217-218.

Hanson GW, Robinson HF, Comstock RE (1956). Biometrical studies of yield in segregating population of Koreon lespedeza. *Agron. J.* 48: 268-272.

Hossain M S, Singh AK, Fasih-uz-Zaman (2009). Cooking and eating characteristics of some newly identified inter sub-specific (indica/japonica) rice hybrids. *Science Asia* 35: 320-325.

Hussain AA, Maurya DM, Vaish CP (1989). Studies on quality status of indigenous upland rice. *Indian J. Genet. Pl. Breed.* 47: 145-152.

Johnson HW, Robinson HF, Comstock RE (1955). Genotypic and phenotypic correlations in soybeans and their implication in selection. *Agronomy Journal*. 47: 477-483.

Jennings PR, Coffman WR, Kauffman MHE (1979). Grain quality: Rice improvement. International Rice Research Institute, Philippines Chapter, 6: 101-120.

Juliano BO, Onate LU, Imundo AM (1966). Relation of starch composition, protein content and gelatinization to cooking and eating quality of milled rice. *Food Technology* 19: 1006-1011.

Khatun MM, Hazrat Ali M, Quirio D, Cruz ND (2003). Correlation studies on grain physicochemical characteristics of aromatic rice. *Pakistan Journal of Biological Science* 6(5): 511-513.

Kundu A, Senapati BK, Bakshi A, Mandal GS (2008). Genetic variability of panicle characters in tall indica Aman rice. *Oryza*. 45(4): 320-323.

Little RR, Hilder GB, Dawson EH (1958). Differential effect of dilute alkali on 25 varieties of milled white rice. *Cereal Chemistry* 35: 111-126.

Lisle AJ, Martin M, Fitzgerald M (2000). A Chalky and translucent rice grain differs in starch composition and structure and cooking properties. *Cereal Chemistry* 77: 627-632.

Murthy PSN. (1965). Genetic studies in rice (*Oryza sativa* L.) with special reference to contain quality features. MSc (Botany) Thesis. Orissa University of Agriculture and Technology, Bhubaneswar, pp. 68.

Nagabhushan K. (2002). Detection of main effect QTL controlling plant traits and identification and mapping of RAPD markers associated with plant height in rice (*Oryza sativa* L.). MSc (Agri.) Thesis. University of Agricultural Sciences, Bangalore.

Nayak AR, Chaudhary D, Reddy JN (2003). Genetic variability and correlation study among quality characters in scented rice. *Agri. Sci. Digest* 23(3): 175-178.

Nayak AR, Reddy JN (2005). Seasonal influence on quality characters in scented rice (*Oryza sativa* L). *Indian J. Genet*. 65(2):127-128.

Ramaiah K (1985). Grain Classification Page No. 629 - Rice Research in India, ICAR Publication.

Rita B, Sarawgi AK (2008). Agro-morphological and quality characterization of Badshah bhog group from aromatic rice germplasm of Chhattisgarh. *Bangladesh Journal of Agriculture Research* 33: 479-492.

Sarkar KK, Bhutia KS (2007). Genetic variability and character association of quality traits in rice (*Oryza sativa* L.). *Oryza*. 44(1): 54-67.

Sarkar RK, Nanda BB, Dash AB, Lodh SB (1994). Grain characteristics and cooking quality of aromatic and non-aromatic long and slender varieties of rice (*Oryza Sativa* L). *Indian J. Agri Sci*. 64: 305-309.

Sanjukta D, Subudhi HN, Reddy JN (2007). Genetic variability in grain quality characteristics and yield in low land rice genotypes. *Oryza*. 44(4): 343-346

SAS Institute, (1998). SAS/STAT users guide: Version 9.1, 6.4th Ed., Vol. 2. SAS Institute, Cary, North Carolina, USA.

Sellappan K, Datta K, Parkhi, Datta SK (2009). Rice caryopsis structure in relation to distribution of micronutrients (iron, zinc, β-carotene) of rice cultivars including transgenic indica rice. *Plant Science* 177: 557-562.

Sharma AK, Sharma RN (2007). Genetic variability and character association in early maturing rice. *Oryza*. 44(4): 300-303.

Shivani D, Viraktamath BC, Shobha Rani N (2007). Correlation among various grain quality characteristics in rice. *Oryza*. 44(3): 212-215.

Sood BC, Siddiq EA (1980). Studies on component quality attributes of basmati rice. (*Oryza sativa* L.). *Z. Pflanzenzuchtg*. 84: 294-301.

Subbaiah PV, Reddi Sekhar M, Reddy KHP, Eswara Reddy NP (2011). Variability and genetic parameters for grain yield and its components and kernel quality attributes in CMS based rice hybrids (*Oryza sativa* L.). *International Journal of Applied Biology and Pharmaceutical Technology* 2(3): 603-609.

Subudhi HN, Swain D, Sanjukta D, Sharma SG, Singh N (2012). Studies on grain yield, physico-chemical and cooking characters of elite rice varieties (*Oryza sativa* L.) in Eastern India. *Journal of Agricultural Science* 4(12): 269-275.

Tejpal (1987). Genotype variability for grain quality characteristics. MSc Thesis, IARI, New Delhi, India.

Tomar JB, Nanda JS (1982). Correlations between quality traits in rice. Oryza. 19: 13-16.

Tomar JB, Nanda JS (1987). Genetics and correlation studies of gel consistency in rice. *Cereal Research Communications* 15(1):13-20.

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

Vanaja T, Babu LC (2006). Variability in grain quality attributes of high yielding rice varieties (*Oryza sativa* L.) of diverse origin. *Journal of Tropical Agriculture* 44(1-2): 61-63.

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