Indian J. Plant Genet. Resour. 29(1): 22-31 (2016)
DOI 10.5958/0976-1926.2016.00005.X

Variability in Grain Quality Characters of Local Winter (*Sali*) Rice of Assam, India

Khanin Pathak[1], Sunayana Rathi[1], Harendra Verma[2], Ramendra Nath Sarma[2] and Samindra Baishya[1]
[1]*Department of Biochemistry & Agricultural Chemistry, Assam Agricultural University, Jorhat-785013, Assam, India*
[2]*Department of Plant Breeding & Genetics, Assam Agricultural University, Jorhat-785013, Assam, India*

(Received: 23 May 2015; Revised: 07 November 2015; Accepted: 18 November 2015)

The study on rice germplasm showed considerable genetic variation in different quality characters analyzed. The grain length varied from 5.10 to 8.03 mm, grain width from 2.00 to 3.17 mm, cooked grain length from 7.40 to 12.37 mm, cooked grain width from 3.30 to 7.17 mm, grain elongation ratio from 1.29 to 2.02 and grain widening ratio from 1.37 to 3.32. On dry weight basis, moisture contents of genotypes ranged from 8.33 to 10.74 per cent, amylose from 0.05 to 29.6 per cent, starch from 70.37 to 82.83 per cent, GC from 53 to 100.03 mm, GT from 2 to 7, crude fat content from 2.64 to 3.76 per cent, crude protein content 8.10 to 10.32 and lysine content from 2.71 to 3.39 (g/100 g of protein). UPGMA based cluster analysis revealed the existence of two major clusters (A and B) with additional sub clusters within each major cluster in *indica* rice genotypes under study for grain quality data. The difference between GCV and PCV was less for all characters except GT, which indicate greater correspondence between phenotype and genotype and less environmental influence and greater role of genetic factors on expression of grain quality traits. Based on above results amylose content trait would be highly effective to be used in breeding programmes for improving cooking and eating quality.

Key Words: Amylose content, Gel consistency, Gelatinization temperature, Genetic variability, Grain quality, Local winter/*Sali* rice

Introduction

After grain yield, grain quality is the major determinant for fetching higher price in the market. With the increase in demand for better grain quality in the economically developed and developing countries, quality has become important breeding objective in rice breeding programme in all countries. Quality improvement is also gaining prominence as unattractive grain character and unsatisfactory cooking quality hampers the acceptance and spread of high yielding variety. Rice quality is determined by some subjective and objective criteria based on the physical appearance of the milled rice, the cooking properties and the presence and absence of aroma of the rice. Generally, consumer preference is based on appearance, milling and cooking processes, grain shape and size.

Assam including North-East India, is traditionally a rice growing area and in which rice plays a significant role in economic and the socio-cultural life of the people of the region. *Sali* or winter rice (June/July-Nov/December) is dominant crop of the State covering 17 lakh hectares (71 percent of rice area) and contributing 73 percent of the total rice production (Anonymous, 2014). Based on grain quality parameters farmers traditionally classify *Sali* rice as normal *Sali* (*Sali* with coarse grain, *Lahi* with medium grain), *Joha* (scented), *Chakua* (semi glutinous) and *Bora* (glutinous). Farmers have been growing a large numbers of *Sali* traditional rice germplasms since long back for their livelihood without much information about the quality of the germplasm. The breeding efforts in Assam are mainly directed towards yield without focusing on grain quality parameters of the traditionally grown rice varieties of *Sali* season. A clear understanding of genetic base, through the characterization of local landraces for grain quality is essential to use them in a breeding programme. The information regarding those aspects in case of *sali* landraces are scanty and sporadic. Therefore, the present experiment was conducted to evaluate nature and intensity of variability in terms of grain quality of winter/*sali* landraces from Assam.

Materials and Methods

The experiment was conducted with 100 local winter/Sali rice genotypes including Ranjit (as check) a popular high yielding variety, collected from Regional Agricultural

**Author for Correspondence: Email- khanin_bio@yahoo.in*

Research Station, Assam Agricultural University, Jorhat, Assam, India. After harvest, samples were cleaned thoroughly using winnower to remove the chaff and other foreign matter and dried to 12-14% moisture content. Brown rice samples were used for analysis and three samples were drawn from same seed lot and treated as replication. Moisture content was determined by following the methods of AOAC (1970). The genotypes were characterized for grain length (mm), grain width (mm), cooked grain length (mm), grain elongation ratio after cooking, cooked grain width (mm), grain widening ratio after cooking following standard procedures (Shouichi *et al.,* 1976; Juliano and Perez, 1984). Similarly, alkali spreading value (Little *et al.,* 1958), gel consistency (Cagampang *et al.,* 1973), starch content (Chopra and Konwar, 1976), amylose content (Juliano, 1971), crude fat content (AOAC, 1970), crude protein content (Scales and Harrison, 1920) and lysine content (Mertz *et al.,* 1965) were also determined. The data generated from three replications were analyzed using analysis of variance (ANOVA) and the genetic parameters such as phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV), heritability in broad-sense (h^2), and genetic advance as percent of mean (genetic gain) were worked out as suggested by Johanson *et al.* (1955). Correlation coefficients were calculated according to Al-Jibouri *et al.* (1958). For clustering, data were analyzed using the software package, NTSYS-pc Version 2.1 (Rohlf, 2000).

Table 1. Analysis of variance for grain quality characters in Sali/ winter rice from Assam, India

Characteristics	Sources of variation		
	Replication	Genotype	Error
df	2	99	198
Moisture	0.00224	1.017**	0.0086
Grain length	0.2916	1.067**	0.0391
Grain width	0.03183	0.408**	0.0169
Cooked grain length	0.41314	3.517**	0.0496
Cooked grain width	0.1747	1.803**	0.0182
Grain elongation ratio	0.00971	0.072**	0.0042
Grain widening ratio	0.00048	0.353**	0.0181
Amylose content	0.00218	226.4**	0.0055
Amylopectin content	0.02936	228**	0.0194
Starch content	0.03387	18.51**	0.0003
GC	0.04843	375.9**	0.0056
GT	38.6533	6.719**	1.7106
Fat	0.02707	0.212**	0.0005
Protein	0.03368	0.876**	0.0037
Lysine (g/100 g protein)	0.00781	0.066**	0.0031

Df: Degrees of freedom; ** Significant at 1% level. Data for grain quality characteristics are mean sum of square.

Results and Discussion

The analysis of variance revealed significant variation among genotypes for all the characters studied (Table 1), indicating plentiful genetic variation in the genotypes under investigation. Selection of parents is an important criterion for the successful breeding programme. Sometimes the *per se* performance of genotypes are used for choosing parents. The *per* se performance of genotypes for different quality traits under investigation are shown in Table 2. Genetic improvement and success

Table 2. Estimates of genetic parameters for grain quality characteristics in Sali /winter rice from Assam, India

	Maximum	Minimum	Mean±SE	PCV (%)	GCV(%)	Heritabilty in broad sense	Genetic advance (5%)
Moisture (%)	10.74	7.29	9.3248±0.05	6.30	6.22	0.9752	12.65
Grain length (mm)	8.03	5.10	6.356±0.11	9.72	9.21	0.8977	17.98
Grain width (mm)	3.17	2.00	2.490±0.08	15.40	14.50	0.8854	28.11
Cooked grain length (mm)	12.37	7.40	10.3283+0.13	10.60	10.41	0.9589	20.99
Cooked grain width (mm)	7.17	3.30	5.223±0.08	15.00	14.77	0.9704	29.97
Grain elongation ratio	2.02	1.29	1.6315±0.04	10.00	9.21	0.8428	17.42
Grain widening ratio	3.32	1.37	2.1268±0.08	16.90	15.70	0.8605	30.00
Amylose content (%)	29.63	0.05	5.3997±0.04	161.00	160.86	0.9999	331.37
Amylopectin (%)	99.96	70.37	94.5986±0.08	9.22	9.22	0.9997	18.98
Starch (%)	82.83	70.37	76.7985±0.01	3.23	3.23	1.0000	6.66
GC (mm)	100.00	53.00	93.3948±0.04	12.00	11.99	1.0000	24.69
Alkali spreading value	8.00	1.33	5.8733±0.76	31.30	21.99	0.4939	1.87
Fat (%)	3.76	2.64	3.1306±0.01	8.51	8.47	0.9927	17.39
Protein (%)	10.43	8.07	9.3091±0.03	5.83	5.79	0.9876	11.86
Lysine (g/100gProtein)	3.39	2.65	2.9601±0.03	5.24	4.90	0.8731	9.42

PCV: Phenotypic coefficient of variation; GCV: Genotypic coefficient of variation.

of breeding programmes mainly depend on magnitude of genetic variation and extent of heritability for desirable characters in the germplasm, therefore conservation of variability has immense potential in breeding programmes for future generations. Rice grain shape preference varies among consumer group and regions and even in same region preference varies based on its end use. For instance, long and slender grain varieties are preferred by consumers in the United States and Western Europe and in most Asian countries or areas, including China, India, Pakistan, and Thailand; in contrast, consumers in Japan, South Korea, and Sri Lanka prefer short bold grain cultivars (Unnevehar *et al.,* 1992; Juliano and Villareal, 1993; Wan *et al.,* 2006) and in southern part of india medium/short slender type of grains are preferred (Viratmath *et al*, 2010) and in north eastern part of India short bold and medium slender grain cultivars with intermediate amylose content, soft GC and intermediate GT are preferred. In the present study, kernel length varied from 5.10 mm (Misiri Bora) to 8.03 mm (Pakhori Bora) and grain width ranged from 2.00 mm (Kmj Bora-16) to 3.17 mm (Silatika Bora, Sontuki). Kernel length with L/B ratio determines the grain shape. Very short grain and short grain rice class with L/B ratio were classified as short bold and medium slender. 18 genotypes were short bold, seven ecotypes classified as medium slender genotypes. Two genotypes were long slender (Ronga Bora-2 and Rupohi Bora-2) and 55 genotypes were long bold, 16 genotypes were long slender in grain shape with waxy type amylose content (1-2%), soft GC and high GT. Two genotypes Kmj Bora-56 and Pakhori Bora were extra long with very high (28.40%) and low (0.3%) amylose content respectively with soft GC and intermediate GT. In the present study, three short bold cultivars (Kmj Bora-8, Tangun Bora-2 and Til Kochu Bora) with preferred intermediate amylose content, soft gel consistency and intermediate gelatinization temperature were identified; and one medium slender genotypes Kmj Bora-90 was waxy type with soft GC and intermediate GT, these genotypes can be used in breeding programmes to develop short bold and medium slender with desirable or preferred eating and cooking quality rice. The length wise elongation upon cooking increase in girth is considered most desirable in high quality rice. During cooking rice grains absorb water and increase in length, breadth and volume (Sood, 1978). In the present study, cooked grain length varied from 7.40 (Kmj Bora-8) to 12.37 mm (Pakhori Bora). Cooked grain width ranged from 3.30 mm (Kola Bora-4) to 7.17 (Kmj Bora-61). Elongation ratio is an important parameter for cooked rice. Rathi *et al.* (2010) reported that cooked grain length varied from 6.5 mm to 10 mm and cooked grain width varied from 3 mm to 5 mm in *Ahu* rice of Assam, which is slightly less than present study due to difference in cultivars studied. If rice elongates length wise, it gives finer appearance and if it expands girth wise, it gives coarse look. Rice with high cooked grain length with finer appearance are preferred. In the present study, the linear elongation ratio varied from 1.29 mm (Kola Ampakhi) to 2.02 mm (Kmj Bora-61) while breadth wise elongation ratio ranged from 1.37 (Til Bora-1) to 3.32 (Kmj Bora-61). Srivastava and Jaiswal (2013) reported that elongation ratio in short grain aromatic cultivars varied from 1.36 to 1.70 with breadth wise expansion ratio of 1.12 to 1.54 and in basmati genotypes length wise elongation ratio varied from 1.70 to 1.91 while the breadth wise expansion ratio of 1.25 to 1.61 and non-aromatic types showed linear elongation ratio from 1.27 to 1.52 and breadth wise elongation ratio of 1.30 to 1.54. The grain elongation ratio varied from 1.0 to 1.6 while grain widening ratio was varied from 1 to 2.5 in upland rice of Assam (Rathi *et al.,* 2010), which is less than present study.

Amylose content is the major determinant of rice eating and cooking quality (Kumar and Khush, 1986; Juiano, 1993). The amylose content determines the stickyness, fluffyness, cohesiveness and tenderness or hardiness of the cooked rice. The varieties with intermediate amylose content (20-25%) are most preferred because they become fluffy, soft, moist and tender after cooking. The result of the present investigation revealed that altogether 78 of the genotypes could be grouped in to waxy (glutinous) category due to very low amylose rice (0-12% amylose) as per Juliano *et al.* (1981). Eleven genotypes could be considered as low amylose rice (12-20% amylose), another six as intermediate amylose rice (20-25% amylose) and the remaining four glutinous rice genotypes as the high amylose rice (>25% amylose). On the other hand, Allahgholipour *et al.* (2006) considered rice with 0-8% amylose as waxy or glutinous rice. In this context, about seventy four of the genotypes under study could be considered as glutinous. The amylose contents in some rice of Assam were recorded to vary from 0.95 to 1.25 per cent (Kandali *et al.,* 1995), from 0.679 to 1.892 per cent (Bahar, 2000) and from 0.92-1.19 per cent of starch (Bhagabati, 2000) and accordingly classed them as glutinous rice. Even a higher range of amylose contents (0.136-11.4%) for some glutinous rice of Assam was reported by Bhattacharjee (2006). A special class of rice locally known as *Chokuwa* rice (soft rice), indigenous to Assam needs no cooking and can be consumed after simply soaking in cold to lukewarm water. This rice is characterized by its semi glutinous character with amylose content ranging from 12 to 17 per cent (Barkakaty, 1975). Amylose contents in three of the *Chokuwa* rice varieties were reported to range between 15.02-16.95 per cent (Bhagabati, 2000). Nine of the glutinous rice genotypes used in the study, namely, Kola Ampakhi, Kmj Bora-10, Kmj Bora-80, Kmj Bora-90, Lothow Bora, Mon Bora-2, Nashinggeti Bora, Rupohi Bora-2 and Tuloxee Bora were found to have amylose contents in the range of 8.2-16.63 per cent, thus can be considered as *chokuwa* rice. Such variation in amylose contents among the genotypes facilitate the breeder to select genotypes in breeding programme in developing rice varieties with desired amylose level.

In present investigation, out of 99 local genotypes, 73 genotypes were found to have low GT (55–68°C, ASV: 5-7) and 22 genotypes showed intermediate GT (69-74°C, ASV: 3-5). The intermediate ASV indicated the medium disintegration and classified as intermediate GT which highly desirable for quality grain (Bansal *et al.,* 2006). Vanaja *et al.* (2003) also revealed that high-amylose rice varieties absorb more water, have low gelatinization temperature and produce more cooked material. Park *et al.* (2007) postulated that the crystalline regions of non-waxy (high amylose) rice starch restricted the hydration of amorphous regions whereas waxy (high amylopectin) rice starch consisted mostly of crystalline regions and thus could begin gelatinization at a lower temperature. Singh and Singh (2006) found the alkali spreading value between 2.5 to 7.0 with low variation in some of the scented varieties of rice. Out of 100 *ahu* rice genotypes of Assam, 97 genotypes showed low GT range (55–68ºC) with ASV 5.0-7.0 (Rathi *et al.,* 2010). The findings of the present study are, thus well comparable with these reports. In the present investigation, the range of fat content of 99 rice genotypes was 2.64-3.76 per cent and the values were found close to the findings of many earlier workers. Juliano (1977) recorded lipid content from 2.4 to 3.9 per cent in brown rice, 17.5-21.7 per cent in bran and 0.3 to 0.6 per cent in polished rice. The lipid content in glutinous rice of Assam was reported to vary from 2.22 to 3.62 per cent (Dutta and Baruah, 1978). Bhagabati (2000) recorded a little lower range of 3.34 to 3.51 per cent crude fat in glutinous rice varieties of Assam. The range of crude protein content in the rice genotypes including Ranjit was varying from 8.1 to 10.32 per cent. Juliano *et al.* (1964) reported the average protein content of brown rice in the range of 7.32 to 13.46 per cent for *indica* varieties. Kandali and Borah (1992) reported that the grain crude protein in 19 local rice varieties of Assam varied between 8.4 to 14.0 per cent on dry weight basis. The crude protein content of three glutinous rice varieties of Assam was found to vary from 9.96 to 10.39 per cent (Kandali *et al.,* 1995). Bhagabati (2000) revealed the crude protein content of nine different Assam rice varieties from 9.23 to 11.29 per cent. Thus the present findings conform to all these earlier reports. Lysine content of rice genotypes ranged from 2.71 to 3.39 g/100g protein and the value was comparable to the findings of Pathak (2008). However, the lysine content in rice genotypes used in the study was found to be lower than the reported values by Sekhar *et al.* (1982) and Begum *et al.* (1993). A wide variation in lysine content (1.73 to 7.13 g/16 g N) in milled rice grains of some Indian rice land races was reported by Banerjee *et al.* (2011). The average lysine contents in the rice land races were recorded as 4.62 g/16 g N which was much higher than the present findings. They observed that variation for lysine content was higher than that of protein content. These results indicated the existence of wide genetic variability for eating and nutritional quality parameters in among the genotypes studied. The variation in the lysine content of rice grains may primarily be due to genotype differences, genetic makeup of the genotypes, climatic condition, nutrient status of soil as well as the analytical methods used (Baishya *et al* 2010).

Various variability parameters studied are presented in the Table 2. The difference between GCV and PCV was less for all characters except GT, which indicate greater correspondence between phenotype and genotype, and less environmental influence and greater role of genetic factors on expression of grain quality traits. Similar results were obtained by Rathi *et al.* (2010) and Subbaiah *et al.* (2011). Among the grain quality parameters very high GCV and PCV was recorded for amylose content which indicate enormous variability for amylose content in the present study material and vast scope for region specific improvement of amylose content. However protein content and lysine content showed low PCV and GCV estimates, indicated limited scope for selection within the experimental materials. Babu *et al.* (2012) and Shejul *et al.* (2013) reported low PCV and GCV with low genetic advance for protein content; Rathi *et al.* (2010) and Arulselvi *et al.* (2007) reported high heritability with low genetic advance for starch content, which supports the present findings. High heritability with low genetic advance indicates that these characters were predominantly governed by non-additive gene action (dominance and epistasis). Vaneja *et al.* (2006) reported low GCV and PCV with high broad sense heritability and for grain length and kernel elongation ratio. Ogunbayo *et al.* (2014) reported similar finding for grain length. However, broad sense heritability includes both additive and non additive effects. Heritability estimates along with genetic advance is more reliable in selection of individuals than heritability estimate alone (Johanson *et al.,* 1955). High heritability coupled with high genetic advance as per cent of mean was recorded for amylose content, which indicates preponderance of additive gene action and can be improved through simple selection. High heritability with moderate genetic advance recorded for grain widening ratio. Low heritability along with moderate genetic advance was recorded for gelatinization temperature. High heritability with low genetic advance was recorded for starch content, gel consistency, grain length, grain elongation ratio, amylopectin, grain width, cooked grain length, cooked grain width, fat (%), protein (%) and lysine content (%).Heritability in conjunction with genetic advance would give a more reliable index of selection value (Johnson *et al.,* 1955). The high heritability estimates along with low genetic advance indicates that non-additive type of gene action and genotype-environment interaction plays a significant role in the expression of the traits. Thus the characters showing high heritability along with moderate or low genetic advance could be improved by intermating the superior genotypes of segregating population developed from combination breeding (Samadia, 2005).

In the present study, genotypic and phenotypic correlation coefficients were studied for grain quality characteristics are presented in Table 3. The genotypic correlation coefficients in most cases were higher than their phenotypic correlation coefficients indicating the major role of genetic factors for association (Pandey *et al*, 2012; Ehdaie *et al*, 1989; Ullah *et al*, 2012). Amylose content is negatively correlated with alkali spreading value (ASV), a measure of the time required for cooking. ASV is inversely proportional to GT. This indicate that rice varieties with high amylose content have high gelatinization temperature, amylose tends to act as a restraint to gelatinization because it diffuses out of the granules during swelling, making up the continuous phase (network) outside the granule (Hermansson and Svegmark, 1996). The GT affects the degree of cooking of rice because of the cooking gradient from the surface to the core of the grain. In the present study most of the genotypes possess low GT and GT correlates directly with cooking time, i.e. low GT favours fuel conservation, provided eating quality is not adversely affected. Park *et al.* (2007) postulated that the crystalline regions of non-waxy (high amylose) rice starch restricted the hydration of amorphous regions whereas waxy (high amylopectin) rice starch consisted mostly of crystalline regions and thus could begin gelatinization at a lower temperature. Generally gel consistency is negatively related with amylose content. Gel consistency decide either rice remain soft (gel consistency->than 60 mm gel length) or medium (gel consistency-41-60 mm gel length) or hard (gel consisteny-<than 40 mm gel length) after cooking. Odenigbo *et al.* (2013) reported negative correlation between amylose content and GC, but in present study there was no correlation observed between amylose content and GC. The negative correlation between grain elongation and amylose content was observed, which indicates that cultivars that elongate more during cooking would likely have a decreased content of amylose. This finding is similar with the finding of Oka *et al.* (2012). The negative correlation between amylose content and cooked grain width and grain widening ratio indicate that cultivars with low amylose content swell more and would have more grain widening ratio. Grain elongation showed positive correlation with GT, indicates that cooked grain elongation increases with increase in gelatinization temperature but high gelatinization temperature elongates less during cooking than low and intermediate gelatinizing rice. Therefore, here GT showed positive correlation with grain elongation. This finding was similar with the findings of Perez *et al.* (1987). Amylose content showed negative correlation with grain width and grain widening ratio, thus it is not possible to breed for low amylose content variety with fine grain. Amylopectin showed positive correlation with starch content, which is in conformity with the findings of Rathi *et al.* (2010) and Chakraborty *et al.* (2009), who reported positive correlations of starch content with amylopectin content. GT was negatively correlated with fat. The lysine content

Table 3. Genotypic (above diagonal) and phenotypic (below diagonal) coefficients of correlation between grain quality characteristics in Sali/winter rice from Assam, India

	MC	GL	GW	CGL	CGW	GLR	GWR	AC	AmC	SC	GC	ASV	FC	PC	LC
MC	1	0.0637	0.0111	0.019	0.0923	-0.0219	0.0942	0.0964	-0.0942	-0.1029	-0.1499	-0.098	-0.0144	0.0500	0.1231
GL	0.0219	1	-0.2774**	0.5596**	-0.0739	-0.3365**	0.1598	-0.0328	0.0334	0.046	-0.1085	-0.0267	0.1745	0.0602	-0.0806
GW	0.0021	-0.0546	1	-0.2203*	0.4404**	0.0331	-0.4928**	-0.0461	0.0476	-0.0141	0.1373	0.0031	0.0305	-0.2217**	0.1616
CGL	0.0113	0.3455**	-0.0866	1	0.3648**	0.5881**	0.5585**	-0.7291**	0.7293**	0.4947**	-0.2094*	0.5474**	0.1125	-0.0092	0.0815
CGW	0.0393	-0.0316	0.1225	0.3029**	1	0.4915**	0.5573**	-0.4871**	0.4899**	0.3285**	-0.066	0.3768**	0.0254	-0.1287	0.1629
GLR	-0.002	-0.0407	0.0006	0.1039	0.0566	1	0.4705**	-0.7861**	0.786**	0.5098**	-0.1413	0.6434**	-0.0281	-0.062	0.1741
GWR	0.0177	0.0283	-0.0745	0.2018*	0.1517	0.0246	1	-0.4325**	0.4341**	0.3197**	-0.1905	0.3609**	0.002	0.0674	0.0098
AC	0.4867**	-0.1679	-0.1455	-0.809**	-0.5638**	-0.8262**	-0.539**	1	-1	-0.6323**	0.1567	-0.8091**	0.0149	0.1000	-0.1725
AmC	-0.4774**	0.1723	0.1492	0.836**	0.5295**	0.8296**	0.625**	0.7255**	1	0.6326**	-0.1576	0.8085**	-0.0168	-0.1000	0.1724
SC	-0.1481	0.0669	-0.0127	0.4212**	0.6296**	0.1904	0.2653**	-0.6434**	0.701**	1	0.0284	0.3908**	0.1361	0.1127	0.0420
GC	-0.9713**	-0.711**	0.5543**	-0.5208**	-0.5702**	-0.2378*	-0.7115**	0.1592**	-0.1532**	0.7887**	1	-0.2335*	0.0951	-0.1593	0.1239
ASV	-0.076	-0.0489	-0.0082	0.7368**	0.3962**	0.1285	0.1672	-0.975**	0.9053**	0.3544**	-0.3809**	1	-0.2046*	-0.1072	0.1874
FC	-0.0024	0.027	0.0029	0.0317	0.0048	-0.0011	-0.0001	0.0347	-0.0387	0.0897	0.2823*	-0.0704	1	0.0504	-0.1061
PC	0.0158	0.0191	-0.0427	-0.0064	-0.0538	-0.0052	0.0117	0.468**	-0.4688**	0.1511	-0.9614**	-0.0752	0.0074	1	-0.7274**
LC	0.0107	-0.0078	0.0086	0.0132	0.0187	0.0041	0.0009	-0.217*	0.2181*	0.0151	0.2011*	0.0364	-0.0042	-0.0569	1

MC: Moisture content; GL: Grain length, GW: Grain width; CGL: cooked grain length; CGW: cooked grain width; GLR: grain elongation ratio after cooking; GWR: Grain widening ratio; AC: Amylose content; Amc: Amylopectin content, SC: Starch content; GC: Gel consistency; ASV: Alkali spreading value; FC: Fat content; PC: Protein content; LC: Lysine content.
* and **, Significant at 5% and 1% probability levels, respectively.

of the rice genotypes was found to be negatively correlated (*r*= -0.750) to the protein contents. Juliano *et al.* (1973) observed a negative correlation between the lysine content of protein and protein content of brown and milled rice only in samples with protein below 10 per cent. As protein content increased water-soluble nitrogen also increased as a percentage of brown rice. Lasztity (1996) reported that a negative correlation between protein and lysine content. He explained the negative correlation by the fact that increase in protein content is highest in the starchy endosperm and lower in the germ and aleurone layer. This suggests that the increased biosynthesis of the protein mainly produces storage proteins. Above discussion revealed that rice grain quality index can be improved by decreasing the breadth of the grain. The desired characters showing significant positive correlation can be improved with simple selection for one trait, while the desirable characters showing significant negative correlation compromise has to be done in deciding the extent of loss of one traits over other during selection.

Diversity Analysis

UPGMA Cluster analysis revealed the existence of two major clusters (A and B) with additional sub clusters within each major cluster in *indica* rice genotypes under study for grain quality data (Fig. 1). The cluster A comprised of short bold (8 genotypes), long bold (12 genotypes), basmati type (5 genotypes) with one medium slender and one long slender genotype and extra long slender. The cluster B comprised of short bold (12 genotypes), long bold (42 genotypes), basmati type (12 genotypes) with four medium slender and one extra long slender genotype. Average amylose content (AC) (23.50 %), grain length (8.0 mm), grain width (2.89 mm), cooked grain length (11.10), cooked grain width (4.83 mm), grain widening ratio (1.94) and fat percentage (3.35 %) of sub cluster A2 was greater than sub cluster A1 which have average amylose content 17.68 %, grain length 6.18 mm, grain width 2.48 mm, cooked grain length 8.86 mm, cooked grain width 4.56 mm, grain widening ratio 1.86 and fat percentage 3.10 %. A1 sub cluster was characterized by non waxy type amylose content; soft gel consistency, high protein percentage and majority of genotypes have medium type grain length. A2 sub cluster was characterized by very long grain type, intermediate GT, soft GC and low lysine content. B1 sub cluster comprised of three genotypes, these genotypes were characterized by waxy type genotypes, broad type grain width, high lysine, fat, moisture content and low protein content. B2 sub cluster comprised of 68 genotypes, these genotypes were characterized by waxy type amylose content, high GT, high cooked grain width, high grain widening ratio, high starch content and low moisture content.

Rice varietal improvement for grain quality is directed towards improving traits associated with consumer acceptance, nutritional quality and post harvest processing. All characters showed high broad sense heritability estimates except GT, which suggest that selection based on phenotypic performance, would be effective in improvement of these traits. Based on above discussion amylose content trait would be highly effective to be used in breeding programmes for improving cooking and eating quality. These local genotypes must not be left out, since they form a rich resource for incorporation into breeding programmes.

References

Anonymous (2014) Economic survey Assam, Directorate of Economics and Statistics, Assam Planning Development, Government of Assam, p 55.

AOAC (1970) Official methods of analysis. 10th Ed. Association of Official Analytical Chemists, Washington, D.C.

Al-Jibouri HA, PA Miller and HF Robinson (1958) Genotypic and environmental variances and covariances in an upland cotton cross of interspecific origin. *Agron J* **50**: 633–637.

Allahgholipour M, AJ Ali, F Alinia, T Nagamine and Y Kojima (2006) Relationship between rice grain amylose and pasting properties for breeding better quality rice varieties. *Plant Breed* **125**: 357-362.

Babu VR, K Shreya, KS Dangi, G Usharani and P Nagesh (2012) Genetic Variability Studies for Qualitative and Quantitative traits in Popular Rice (*Oryza sativa* L.) *Hybrids of India* **2**: 1-5.

Bahar B (2000) Biochemical characterization of some glutinous rice (*Oryza sativa* L.) varieties of Assam. M.Sc.(Agri.) Thesis, Assam Agricultural University, Jorhat.

Baishya, S, K Pathak, AM Baruah and S Rathi (2010). Starch and protein profile of hill rice cultivars of Assam. *Oryza* **47**: 237-242.

Banerjee S, G Chandel, N Mandal, BM Meenaand and T Saluja (2011) Assessment of nutritive value in milled rice grain of some Indian rice landraces and their molecular characterization. *Bangladesh J. Agril. Res.* **36**: 369-380.

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

Barkakati PK (1975) A study on the nutritive quality of some glutinous rice grown in Assam. An M. Sc. (Agri) Thesis to Assam Agricultural University, Jorhat.

Begum F, SK Biswas, B Banu, AK Khandaker, SF Banoo and NH Choudhury (1993) Protein quality of some rice varieties (Bangladesh). *Bangladesh J. Nutr.* **6**: 25-28.

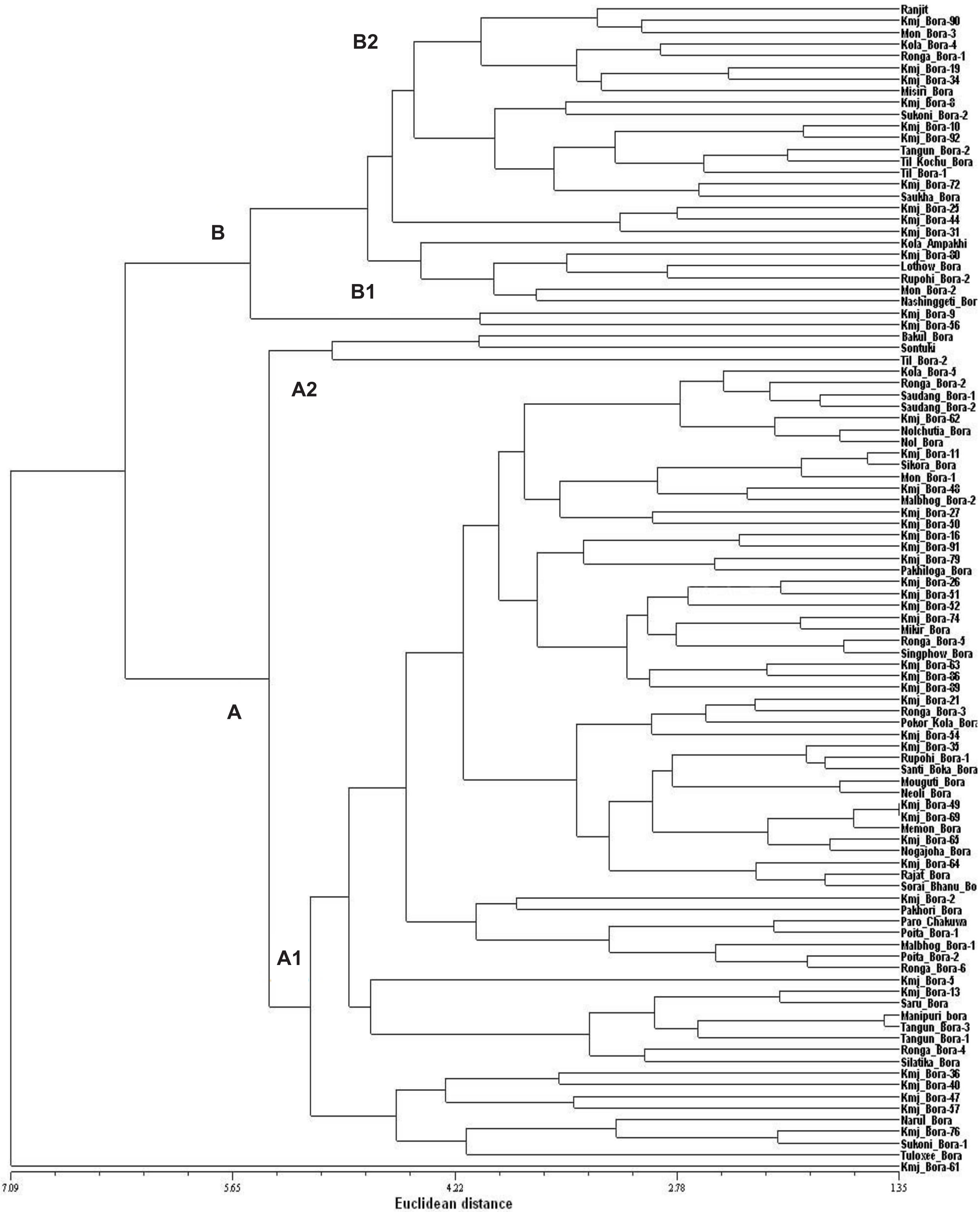

Fig. 1. UPGMA cluster analysis based on grain quality characteristics of local winter (Sali) rice of Assam, India.

Bhagabati RKM (2000) Biochemical and isozyme analysis of some glutinous and non-glutinous rice (*Oryza sativa* L.) varieties of Assam. M.Sc.(Agri.) Thesis, Assam Agricultural University, Jorhat.

Bhattacharjee S (2006) Allelic and functional diversity in few glutinous rice germplasm of Assam. An M.Sc. Thesis (Agri) Assam Agricultural University, Jorhat.

Cagampang GB, CM Perez and BO Juliano (1973) A gel consistency test for eating quality of rice. *J. Sci. Food Agric.* **24**: 1589-1594.

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

Chopra SL and JS Konwar (1976) Analytical Agricultural Chemistry (Kalyani Publisher, Ludhiana).

Chopra VL (2000) Plant breeding – Theory and practice 2nd ed. Oxford and IBH Pub. Co. Pvt. Ltd, New Delhi, p.10.

Dhanwani RK, AK Sarawagi, A Solanki and JK Tiwari (2013) Genetic variability analysis for various yield attributing and quality traits in rice (*O. sativa* L.). *The Bioscan* **8**: 1403-1407.

Dutta L and JN Barua (1978) Nutrient composition of glutinous and non-glutinous rice varieties grown in Assam. *Ind. J. Agric. Sci.* **48**: 610-613.

Hermansson M and K Svegmark (1996) Developments in the understanding of starch functionality. *Trend. Food Sci. Technol*. **7**: 345-353.

Johnson HW, HF Robinson and RE Comstock (1955) Estimates of genetic and environmental variability in soybean. *Agron. J.* **47:** 314-318.

Juliano BO, CM Perez (1984) Result of a collaborative test on the measurement of grain elongation of milled rice during cooking. *J. Cereal Sci*. **2**: 281-292.

Juliano BO (1971) A simplified assay for milled-rice amylose. *Cereal Sci Today* **16**: 334-338.

Juliano BO and CP Villareal (1993) Grain Quality Evaluation of World Rices. International Rice Research Institute, Manila, Philippines.

Juliano BO (1977) Rice lipids, II. *Riso* **25**: 3.

Juliano BO, GM Banitista, JC Dugay and AC Reyes (1964) Studies on the physiochemical properties of rice. *J. Agric. Food Chem.* **12**: 131-138.

Kandali R and RC Borah (1992) Screening of some local rice cultivars of Assam for crude protein and glutelin and correlation between protein and grain yield. *Oryza* **31**: 169-173.

Kandali R, SA Ahmed, RC Borah, CR Sarkar and AK Pathak (1995) Biochemical analysis of some varieties developed by the Assam Agricultural University, *JAAS* **42**.

Kumar I and GS Khush (1986) Genetic if amylose content in rice. *J. Genet,* **65**: 1-11.

Lasztity R (1996) Rice Proteins. *In: The Chemistry of Cereal Proteins*, Second Edition. CRC Press, Inc. p. 251.

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

Mertz ET, R Jambunathan and PS Misra (1965) *In: Protein quality*, Agric Experiment Stn Bull No 70 Purdue Univ. USA p 11.

Odenigbo AM, M Ngadi, C Ejebe, C Nwankpa, N Danbaba, S Ndindeng and J Manful (2013) Study on the gelatinization properties and amylose content of rice varieties from Nigeria and Cameroun. *Int. J. Nutr. Food Sci.* **2**: 181-186.

Ogunbayo SA, M Sie, DK Ojo, KA Saini, MK Akinwale, B Toulou, A Shittu, EO Idenhen, AR Popoola, IO Daniel and GB Gregoria (2014) Genetic variation and heritability of yield and related traits in promising rice genotypes (*Oryza sativa* L.). *J. Plant Breed. Crop Sci.* **6**: 153-159.

Oko A O, BE Ubi, AA Efisue and N Dambaba (2012) Comparative analysis of the chemical nutrient composition of selected local and newly introduced rice varieties grown in Ebonyi State of Nigeria. *Int. J. Agri. Forest.* **2**: 16-23.

Panse VG, PV Sukhatme (1957) Genectics and Quantitative characters in relation to plant breeding. *Indian J. Gen*. **17**: 312-328.

Park IM, AM Ibáñez, F Zhong, CF Shoemaker (2007) Gelatinization and pasting properties of waxy and non-waxy rice starches. *Starch Starke* **59**: 388-396.

Pathak K (2008) Starch and protein profiling of some hill rice (*Oryza sativa* L.) cultivars of Assam. An M.Sc. Thesis (Agri.) Assam Agricultural University, Jorhat.

Rathi S, RNS Yadav and RN Sarma (2010) Variability in Grain Quality Characters of Upland Rice of Assam, India. *Rice Sci.* **17**: 330-333.

Rohlf FJ (2000) NTSYSpc: Numerical taxonomy and multivariate analysis system. Version 2.1. Exeter Publications, New York, USA.

Scales FM and AP Harrison (1920) Boric acid modification of the Kjeldahl method for crop and soil analysis. *J. Indus. Engr. Chem*. **12**: 350-352.

Sekar KV, S Palanivel, S Bharathi and BJ Yogesh (2013) Available online through, **1**(4), 323–326. http://doi.org/10.7897/2321.

Sekhar BPS and GM Reddy (1982) Amino acid profiles in some scented rice varieties. *Theor. Appl. Genet.* **62**: 35-37.

Shejul MB, DB Deosarkar, HV Kalpande, SK Chavan, VD Deshmukh and U Dey (2013) Variability studies for grain quality characters in upland rice (*Oryza sativa* L.). *AJAR*, **8**: 4872-4875.

Shouichi Y, F Douglas, HC James and AG Kwanchai (1976) Laboratory Manual for Physiological Studies of Rice. Manila: IRRI: 69-77.

Sood BC (1978) Studies on Cooking and Nutritive Qualities of Cultivated Rice (*Oryza sativa* L.) with Special Reference to Genetics of Kernel Elongation, Aroma and Protein Content. Ph. D Thesis. IARI, New Delhi, India.

Subbaiah P V, MR Sekhar, KHP Reddy and NPE Reddy (2011) Variability and Genetic Parameters for Grain Yield and its Components and Kernel Quality Attributes in CMS Based Rice Hybrids (*Oryza sativa* L.). *Int. J. Appl. Biol. Pharm. Tech.* **2**: 603-609.

Tabkhkar N, B Rabiei and A Sabouri (2012) Genetic diversity of rice genotypes by microsatellite markers tightly linked to cooking and eating quality. *Australian J. Crop Sci.* **6**: 980-985.

Unnevehr LJ, B Duff and BO Juliano (1992) Consumer demand for rice grain quality. International Rice Research Institute, Manila, The Philippines/International Development Research Centre, Ottawa, Canada.

Vanaja T and Babu LC (2006) Variability in grain quality attributes of high yielding rice varieties (*Oryza sativa* L.) of diverse origin. *J. Trop. Agri.* **44**: 61-63.

Vanaja T, LC Babu, VV Radhakrishnan and K Pushkaran (2003) Combining ability for yield and yield components in rice varieties of diverse origin. *J. Trop. Agric.* **41**: 7-15.

Vanaja T, GJ Randhawa and K Mammootty (2006) Pedigree evaluation and molecular diversity of some true breeding rice (*Oryza sativa* L.) genotypes of Kerala**.** *J. Trop. Agric*. **44:** 42-47.

Varavinit S, S Shobsngob, W Varanyanond, P Chinachoti and O Naivikul (2003) Effect of amylose content on gelatinization, retrogradation and pasting properties of flours from different cultivars of Thai rice. *Starch-Stärke* **55**: 410-415.

Verma H (2013) Validation of molecular marker linked to grain quality in rice. An M.Sc. Thesis (Agri.) Assam Agricultural University, Jorhat.

Viratmath BC, AH Prasad, M Ramesha and MI Ahmed (2010). Hybrid Rice: Current Status and Future Prospects, Directorate of Rice Research, Hyderabad. pp. 19 Retrieved from http://www.rmp.co.in.

Wan XY, JM Wan, L Jiang, JK Wang and HQ Zhai (2006) QTL analysis for rice grain length and fine mapping of an identified QTL with stable and major effects. *Theor. Appl. Genet.* **112:** 1258-1270.

Samadia DK (2005) Genetic variability studies in Lasora (*Cordia myxa* Roxb.). *Indian J. Plant Genetic Res.* **18**: 236-240.

Pandey VR, PK Singh, OP Verma and P Pandey (2012) Inter-relationship and path coefficient estimation in rice under salt stress environment. *Int. J. Agril. Res.* **7**: 169-184.

Ehdaie, B and JG Waines (1989) Genetic variation, heritability and path analysis in land races of bread wheat from South Western Iran. *Euphytica.* **41**: 183-190.

Ullah MZ, MK Bashar, MSR Bhuiyan, M Khalequzzaman and MJ Hasan (2011) Interrelationship and Cause-effect Analysis among Morpho-physiological Traits in Biroin Rice of Bangladesh*.* *Int. J. Plant Breed. Genet*. **5**: 246-254.