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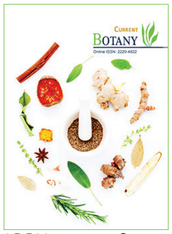
Research Article



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Genotypic diversity evaluation for nutritional and grain quality attributes in cultivated rice varieties of Assam

Kangkana Thakur[1], Mridusmita Kalita[2], Daizi Durba Saharia[2], Nayanika Sarma[2], M. K. Sarma[2], Sofia Banu[1]*

[1]Department of Bioengineering and Technology, Gauhati University, Guwahati-781014, Assam, India, [2]Department of Plant Breeding and Genetics, Biswanath College of Agriculture, Biswanath Chariali, Biswanath-784176, Assam, India

ABSTRACT

A set of fifty rice genotypes mostly of indigenous type and a few improved varieties grown by farmers of Assam were studied to screen for nutritional content, grain characteristics and yield potential. Based on the grain classification system, two cultivars were categorised as small (1.5-2), eleven were medium (2.1-2.5), fourteen had medium slender (2.6-3.0) grain, and eighteen were of slender (>3.0) type; Mahsuri had the highest grain yield per plant (49.64 g). The glutinous type, 'Bora' group of cultivars had comparatively the lower content of amylose (2.45-2.76%) with corresponding higher level of amylopectin (97.24-97.55%). A wide variation was observed for protein content, ranging from 3.5% in Amona Bao to 12.26% in Vandana. Manipuri Joha and Badol Sali were found to have the greatest concentrations of iron (466.88 mg/100 g) and zinc (44.8 mg/100 g), respectively. Grain length breadth ratio, volume expansion ratio, iron and protein content showed significant positive correlation with grain yield. High heritability in the broad sense was observed for the traits grain weight, grain length and breadth, length: breadth ratio, volume expansion ratio, iron and zinc. The cultivars were categorized into six clusters based on the Mahalanobis D^2 analysis, with cluster VI (739221) exhibiting the highest intra-cluster distance and cluster V with cluster II (27774001) exhibiting the highest inter-cluster distance. The genotypes belonging to the diverse clusters along with the desirable per se performance might be chosen for inclusion as parents in the hybridization program. Comprehensive understanding of the nutrients and grain characteristics and their relationship with grain yield would pave the way for further genetic improvement of quality and yield of rice.

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***Corresponding author:**
Sofia Banu
E-mail: sofiabanu2@gmail.com

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INTRODUCTION

The northeast Indian state of Assam is abode to a large array of rice germplasm representing different seasonal groups, quality classes and ethnic preferences. 'Rice is the life' for the people of the region, particularly, the state of Assam. It covers more than 90% of the cultivated area and provides the staple food, nourishment, and security of livelihood. There are a total of thirteen cultivated groups of rice varieties known to exist in the region, which are distributed throughout the six agroclimatic zones (Das, 1997). There is significant variance in terms of morpho-physiological and quality norms within each group. *Sali* rice (winter rice), *Boro* rice (summer rice), *Bao* rice (deepwater rice), and *Ahu* rice (autumn rice) are the four primary types of rice cultivars grown in Assam. These cultivars differ in terms of various attributes including, morphological features, yield attributes, grain quality, colour, stickiness, and aroma (Parasar *et al.*, 2017). Farmers in Assam have been cultivating and conserving a vast variety of rice landraces for a very long time. These diverse landraces are utilized to prepare a variety of dishes and show compositional differences in terms of nutrition. Aromatic Joha rice is used to make Kheer, Pulao, and other special dishes. Chokuwa rice is semi-glutenous soft rice that is used to make "instant rice," '*Bao*' rice is deep water rice that is the only alternative to flood-prone areas. Bora variety known for its sticky nature attributed by low amylose content is associated with varieties of traditional uses, which is found nowhere else in the mainland of India. Bora rice is glutinous rice that is used to prepare traditional cakes and breakfast items (Das *et al.*, 2018). Assam's main food crop, rice accounts for 95.51% of the state's total food grain production. There has been a global interest recently to look for sources with higher concentrations of nutrients like protein, zinc, iron, and important essential amino acids. The malnutrition due to protein deficiency, iron deficiency, and zinc deficiency are widespread in the rice eating populations. It is, therefore, important to identify sources for the specific nutritional elements amongst the traditional rice varieties. Nutrient profiling of rice germplasms is crucial for developing future plans for enhancing or fortifying the nutrient content, especially in the areas of protein, lysine, iron, and zinc (Sharma *et al.*, 2017). Grain yield has always been the priority in rice breeding. Therefore, the nutritional characteristics in rice must be considered along with other grain quality and yield attributes. Again, grain yield being a complex trait having contributions by many component traits, a detailed study of the interrelationship of different yield and yield contributing traits is necessary. This helps in identifying the traits that directly or indirectly influence the overall productivity of the crop and improves the efficiency of genetic selection in plant breeding programs (Sarma *et al.*, 2022). The nutritional profiling and identification of genetic stocks for different nutritional attributes amongst the indigenous rice genotypes will open new avenues for breeding new rice varieties that are nutrient-rich and high yielding. Therefore, to find potential donors from the existing indigenous gene pool of Assam rice, we have attempted to characterise a set of indigenous rice germplasm for various nutritional, grain and yield attributes along with their genetic parameters of variation and genetic diversity.

MATERIALS AND METHOD

A field experiment was conducted with 50 traditionally grown rice cultivars of Assam comprising Joha, Bora, Chokuwa, Bao and Hill rice, collected from farmers' fields from hills as well as plains of the state (Table 1). The experiment was laid out in a randomised block design with three replications and the crop was raised as per standard package and practice. Five plants were randomly taken from each plot to record the observations on the grain characteristics, *viz*., 100 grain weight, grain yield per plant, grain length, grain width, and length: breadth ratio. Observations on the grain characteristics were recorded as per the standard evaluation system for rice by IRRI (IRRI, 2013). The grain samples on maturity were harvested and checked for moisture content. Volume expansion ratio was recorded by using the formula suggested by Sidhu *et al.* (1975) using 5 g of rice grain. A sample of 50 g for each of the variety was dehusked separately by passing through a Satake paddy dehusker to yield brown rice. The grains were ground with the help of an electrical grinder and sieved with a BS 60 mesh size and stored in an airtight container for chemical analysis. To determine the amylose and amylopectin content, the method of Juliano (1972) was used. Protein estimation was done by folin phenol reagent following Lowry method (Lowry *et al.*, 1951). Iron and Zinc analysis was done by Atomic Absorption Spectrophotometer (AAS) (Model-Thermo Fisher Scientific AASIce 3500) using Flame Technique, carried out in the food quality control laboratory, Department of Food Engineering and Technology, Tezpur University, Assam.

Statistical Analysis

The mean data were subjected to the analysis of variance (Panse & Sukhatme, 1967) and the mean sum of squares, obtained from the analysis of variance, was subjected to estimation of genetic parameters of variation (Singh & Choudhary, 1988). Estimates of variability parameters, heritability and genetic advance were calculated using standard methods (Burton & Devane, 1953; Johnson *et al.*, 1955). The mean data set was subjected to diversity analysis using Mahalanobis' D^2 -analysis (Mahalanobis, 1928) and clustering was done by Tocher's method by R software using Factoextra. The Performance Analytics package of R was used to plot the correlation analysis using FactoMineR. In addition, the ggplot2 package was used for graphical representation.

RESULTS AND DISCUSSION

The set of 50 rice cultivars were studied for grain length, grain breadth, grain length: breadth, grain weight and grain yield alongside the biochemical traits *viz*., amylose, amylopectin, protein content (PC), Iron (Fe) and Zinc (Zn) content. For any crop improvement programme, it is important to understand the relative contribution and association of the component attributes on the grain yield to furnish a reliable guide for selection (Saran *et al.*, 2023).

Grain Characteristics

The grain shape along with the relative length and breadth of rice grain (L: B ratio) is one of the important factors governing the consumers' acceptance of rice varieties. Again, the correlation of amylose content and grain size is considered to govern the taste, cooking, and nutritional quality of rice, ultimately determining its consumer preference and market price (Ferdous *et al.*, 2018). Among the 50 studied rice cultivars, the highest grain weight was shown by Bokul Bora (3.43) followed by Malbhoog (2.8); highest grain length: breadth ratio was shown by Amona Bao (3.9), Bioi Sali (3.48) followed by Mashuri (3.39). Considering length breadth ratio, two cultivars were categorized as small (1.5-2). 11 were medium (2.1-2.5), 14 were with medium slender (2.6-3.0) and 18 were slender (>3.0) grain; Highest grain yield was shown by Mahsuri (49.64) followed by Bahadur (36.7). Volume expansion ratio (VER) is considered as the most important trait governing the cooking quality in rice. The higher the VER, more will be the quantity after cooking; less will be the energy content per unit volume (Suganthy *et al.*, 2023). The highest VER was recorded in Prasadbhog (3.38) and lowest in Boga Joha (1.25).

Amylose and Amylopectin Content in Studied Cultivars

Assam rice varieties are unique with the diverse range of amylose: amylopectin ratio in endosperm, associated with the varieties of traditional uses, which is found nowhere else in mainland India. They are used in preparing specialty products suiting the taste of the local people (Das *et al.*, 2018). Based on the amount of amylose and amylopectin present, rice cultivars can be categorized as either glutinous or non-glutinous. Juliano (1972) stated that the amylose concentration can be used to categorize types into four classes: waxy (0-2%), VL (very low, 5-12%), L, (low, 12-20%), I (intermediate, 20-25%), and H (high, 25-33%). In the studied germplasm, the highest amylose content was recorded in Vandana (26.5%)

Table 1: List of genotypes with grain traits and biochemical traits

Genotype	100GWt (g)	GL (mm)	GB (mm)	GL: GB (mm)	VER (mm)	Fe (mg/100 g)	Zn (mg/100 g)	amylose (g/100 g)	amylopectin (g/100 g)	Protein (g/100 g)	GY
BokulBora	3.43	9	4.1	2.2	1.65	2.8	5.16	2.4	97.6	6.89	10.27
Kola Bora	1.9	8.28	2.78	2.99	1.59	11.9	3.27	2.6	97.3	6.23	24.39
Boga Joha	1.55	8.25	2.46	3.35	1.25	61.1	4.18	19.06	80.94	8.71	14.64
Malbhoog	2.8	8.44	2.56	3.3	3.37	12.5	4.22	18	92.81	6.08	16.26
Ranjit	2.17	8.81	3.22	2.74	1.56	11.3	4.69	22.66	77.34	6.18	26.46
Luit	2.43	8.28	2.63	3.15	3.18	4.9	4.94	25.32	80.52	8.8	20.63
Kokua Bao	2.46	9.1	2.96	3.08	1.47	3.2	5.22	22.71	77.02	7.23	25.22
MaguriBao	2.1	8.17	3.38	2.43	2.65	47.3	5.56	21.07	78.93	6.24	11.96
AmpakhiBora	2.42	7.87	3.37	2.34	1.86	86.2	7.47	2.45	94.55	8.84	23.46
Mahshuri	2.04	8.8	2.53	3.49	1.85	148	6.31	20.54	79.46	6.01	49.64
Ronga Sali	2.32	7.29	2.7	2.7	1.77	6.1	6.28	18.21	81.79	6.39	30.17
PrasadBhog	2.14	7.78	2.63	2.96	3.42	3.8	6.95	23	70.45	5.6	24.49
KutkutiSali	2.3	6.65	2.99	1.89	1.47	3.5	5.25	22.03	77.97	7.95	23.11
BioiSali	2.25	7.52	2.27	3.48	1.73	123	6.47	17.47	82.53	5.55	19.33
Joy Bangla	2.11	8.13	3.46	2.35	1.67	59.9	3.36	24.15	75.85	5.24	23.06
Siyal Sali	2.06	7.97	3.96	2.9	1.51	118	6.48	22.88	77.12	5.7	13.52
Kola Joha	1.93	8.55	2.21	3.87	1.85	5.24	3.76	14.61	85.39	7.39	30.91
Nol Bora	2.28	7.9	3.27	2.42	1.74	54.9	4.09	2.76	97.24	5.09	20.64
Panindra	2.32	7.88	2.85	2.77	1.49	66.4	3.19	22	80.3	7.3	21.55
NegheriBao	2.21	7.2	2.2	2.1	1.52	48.5	4.01	23.4	78.6	5.32	19.48
SulsuliBao	2.37	8.2	2.67	3.08	1.76	4.67	3.52	22.24	77.76	5.09	20.73
Kati Neuli	2.76	8.47	3.27	2.6	1.66	7.2	3.62	22.45	77.55	5.46	13.67
Manipuri Joha	2.16	8.64	2.61	3.31	1.62	467	5.97	9.45	85.82	6.74	24.23
Bahadur	1.63	7.71	2.46	3.14	2.85	424	4.47	24.89	75.11	9.7	36.71
Kunkuni Joha	2.25	7.97	3.77	2.43	1.66	9.25	4.08	20.66	77.34	8.9	27.33
Bora	2.8	8.44	2.56	3.3	1.74	6.3	4.48	10.05	89.92	7.9	16.26
Ronga Bao	2.81	8.58	2.52	2.53	1.67	24.1	4.72	26.37	73.63	6.71	21.89
Gethu	1.72	6.61	3.01	2.28	1.39	23.4	4.32	20.01	79.99	5.74	20.71
Suagmoni	2.32	7.29	2.7	2.7	2.55	19.6	4.9	21	90.27	5.51	30.17
Baismuthi	1.9	7.54	2.73	2.79	1.35	15.1	5.06	19.7	80.3	8	16.31
Kumol Dhan	2	8.45	3.2	2.64	1.7	0.86	3.31	9	91	8.49	35.4
TTB 404	1.8	7.5	1.5	3.76	1.53	4.56	8.43	22.52	77.48	8.03	27.14
KajoliChakua	1.9	8.3	2.41	3.41	1.9	220.5	15.8	11.68	88.32	10.6	36.77
Solpuna	1.44	7.4	2.9	2.55	1.56	6.88	1.4	21.5	78.5	7.23	17.8
Vandana	2.2	9.1	2.4	3.79	1.6	8.18	21.33	26.57	73.43	12.3	13.48
Hurupi Bao	2.28	6.6	3.4	1.94	1.82	7	16.67	19.91	80.09	10.6	15.67
Maibee	2.46	9.17	2.93	3.13	1.39	4.19	3.21	19.17	80.83	3.87	27.37
Amona Bao	2.92	9.88	2.5	3.95	1.94	7.13	2.21	19.48	80.52	3.5	9.8
Til Bora	2.4	8	3.1	2.58	2.87	9	3.9	1.57	98.43	4.04	23.64
Gandhari	1.89	7.43	3.1	2.78	1.68	4.23	1.6	18.32	81.68	5.3	24.65
Keteki Joha	1.63	8.1	2.7	2.44	1.46	7.69	21.33	19.59	80.41	12.3	31.09
Bishnuprasad	2.1	8.6	3.1	2.77	2.9	8.31	2.5	21.43	78.57	10.3	23.94
Dehangi	2.44	8.03	2.86	2.81	1.58	5.02	1.54	21.82	78.18	6.7	37.4
Maizubiron	1.84	7.41	2.15	3.44	1.69	8.21	3.76	17.05	82.95	3.94	15.64
Nepali Chakuwa	3.2	9.01	2.81	3.2	2.8	6.08	41.5	12.51	87.49	6.3	18.6
Swarna Joha	2.48	8.6	3.7	2.32	1.63	5.95	10.02	18.42	81.58	6	29.87
Badol Sali	1.98	7.2	3.21	2.4	1.73	8.65	29.8	24.6	75.4	8.11	23.67
BorJahingya	2.9	9.22	3.1	3.12	3.21	7.26	3.7	22.36	77.64	5.5	36.9
Hakky	1.64	7.83	2.54	3.09	1.34	5.15	2.8	15.46	84.54	4.4	16.2
Sok soi soi	1.8	9.27	3.75	2.45	1.64	3.7	3.1	19.48	80.52	5.8	28.7

and Rongali Bao (26.3%) and the lowest 2.4% in Bokul Bora and 2.6% in Kola Bora. The presence of high amylopectin in the endosperm of Bora rice varieties makes them sticky. The amylose content in the Bora rice varieties ranged from 2.4% to 2.7%. Glutinous or sticky nature of the rice is attributed to the higher concentration of amylopectin. The semi-glutinous group called Chokuwa showed low amylose with 9% in Kumol dhan and 12.51% in Nepali Chokuwa. Another class of rice called Joha known for its small grain and special aroma showed a medium range of amylose content ranging from 9.41% in Manipuri Joha to 20.66% in Kunkuni Joha. Manipuri Joha exhibits both aromatic and glutinous characteristics. Joha rice exhibiting special cooking quality attributed is used in the preparation of Kheer and Pulao in the state of Assam and is considered as a counterpart of Basmati rice (Saikia *et al.*, 2021). The Bao or deep water rice varieties of Assam exhibited a range of amylose content, 26.3% in Ronga Bao to 19.7% in Amona Bao. The Hill rice of Assam grown in the two Hilly districts Karbi Anglong and Dima Hasao showed low to intermediate range from 15.46% in Hakky to 21.82% in Dehangi. One variety, Vandana recorded the highest presence of amylose (26.57%) among all the studied cultivars in the experiment, which is in accordance with Baishya *et al.* (2010). The 23 genotypes categorized under normal Sali rice in the study showed intermediate amylose content lying in the range of 25.32% in Luit and the lowest in Bioi Sali with 17.47%. Figure 1 shows the concentration and absorbance curve for amylose content in the study.

Protein Content (PC) in Studied Cultivars

PC has an impact on the texture of cooked rice as the highly scattered protein bodies associated with starch granules would prevent starch from expanding and restrict the softening effect of cooking. Since rice typically contains less protein than other grains, protein deficiency is the main concern for rice-eating nations (John *et al.*, 2023). Many reports on variability in protein content in rice are available. A range of 6.7-11.0% protein in brown rice was observed in 74 varieties from India by Guha and Mitra (1963). Amongst the 50 rice cultivars under study, the protein content showed a good range of 3.5% in Amona Bao to 12.26% in Vandana. In Bora cultivars the highest protein content was recorded in Ampakhi Bora (8.86%) and lowest in Nol Bora (5.09%). Earlier studies have reported waxy type of rice had more amount of protein than non-waxy types (Hasan *et al.*, 2022). High content of protein in Bora varieties was earlier recorded by Kalita and Hazarika (2022). Amongst the three Chokuwa cultivars under investigation, the highest content was observed in Kajoli Chokuwa (10.62 %). In the Joha cultivars, the range lied from 6.74% in Manipuri Joha to 11.26% in Keteki Joha. The protein content in Bao cultivars ranged from 3.5% in Amona Bao to 10.6% in Hurupi Bao. Protein in the studied five Hill cultivars ranged from 3.94% in Maizubiron to 12.26% in Vandana. This result corroborated with the findings of Baishya *et al.* (2010) in Hill rice. The normal Sali varieties showed a range 9.7% in Bahadur and the lowest in 5.46% in Kati Neuli. Figure 2 shows the concentration and absorbance curve for protein content in the study.

Iron and Zinc content in Studied Cultivars

Micronutrient deficiency is considered as one of the emerging challenges to food and nutrition security, particularly in developing countries and there is a growing realization of a food-based approach for addressing this. Among the minerals, Zn and Fe deficiency are widespread (Walsh *et al.*, 1994). Therefore, these key nutritional components are of important consideration for the rice eating populations. Zn and Fe were recorded to be highest in Manipuri Joha (466.88 mg/100 g) and Badol Sali (44.8 mg/100 g) respectively, corresponding to the results of Vanlalsanga *et al.* (2019). In Bora cultivars, Ampakhi Bora recorded the highest Fe (86.2 mg/100 g) and Zn content (7.47 mg/100 g). Bokul Bora recorded the lowest Fe (2.8 mg/100 g) and Kola Bora recorded the lowest Zn content (3.27 mg/100 g). Among the Chokuwa cultivars under investigation highest Fe content was observed in Kajoli Chokuwa (220.5 mg/100 g) and the highest Zn content was observed in Nepali Chokuwa (15.5 mg/100 g). In the Joha cultivars the Fe content ranged from 466.8 mg/100 g in Manipuri Joha to 5.24 mg/100 g in Kola Joha. The highest Zn content was recorded to be 21.33 mg/100 g in Keteki Joha and lowest in Kola Joha (3.76 mg/100 g). The Fe content in Bao cultivars ranged from 48.47 mg/100 g in Negheri Bao to

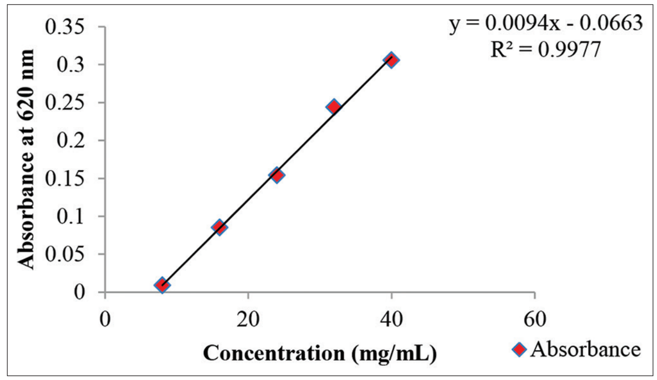

Figure 1: Amylose concentration and absorbance curve

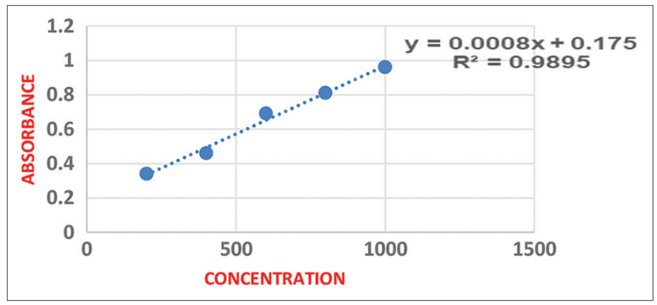

Figure 2: Protein concentration and standard curves

4.67 mg/100 g in Sulsuli Bao. The Zn content was recorded to be highest in Maguri Bao (5.56 mg/100 g) and lowest in Amona Bao (2.21 mg/100 g). Fe and Zn in the Hill cultivars were reported to be highest in Maizubiron (8.18 mg/100 g) and Vandana (21.33 mg/100 g) respectively. The normal Sali varieties showed a range 423.85 mg/100 g in Bahadur to 3.5 mg/100 g in Kutkuti Sali for Fe content. The highest Zn content was recorded to be 44.8 mg/100 g in Badol Sali and lowest in Solpuna (1.4 mg/100 g). These findings were much higher than the results recorded by Lavanya and Pinky (2019), Pathak *et al.* (2017) and lower than one reported by Das *et al.* (2018). Barplots showing the variability of nutritional composition across all the traits is presented in Figure 3.

Study of Genetic Parameters

There was good agreement of the values of genotypic and phenotypic variance, presented in Table 2, indicating relatively less influence of environment in expression of these traits. Highest genotypic coefficient of variation (GCV) along with phenotypic coefficient of variation (PCV) was observed for grain yield, grain breadth followed by Fe content. More than 80% (high) heritability in broad sense was observed for all the traits except protein content, amylose, amylopectin content, and grain yield. In order to quantify the genetic gain obtained from selection, along with heritability, estimation of genetic advance is important. Genetic advance as *per cent* of mean was highest for 100 grain weight (85.32). Genetic advance in quality trait was seen to be high for Fe (72.4), Zn (69.4), followed by amylose (38.04%) contents. Thus, the traits, *viz.*, grain yield, grain breadth along with Fe and Zn were found promising for

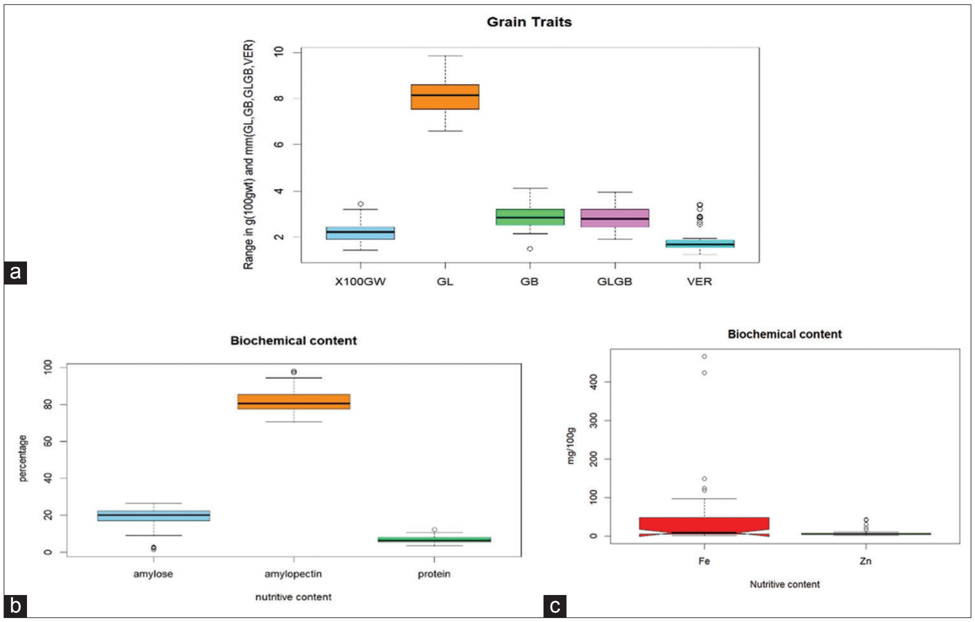

Figure 3: Barplots showing the variability of grain traits and nutritive content across the studied genotypes. a) 100 G Wt is expressed in g; GL, GB, GL: B and VER in mm, b) amylose, amylopectin and protein in g/100 g and c) Fe and Zn is expressed in mg/100 g

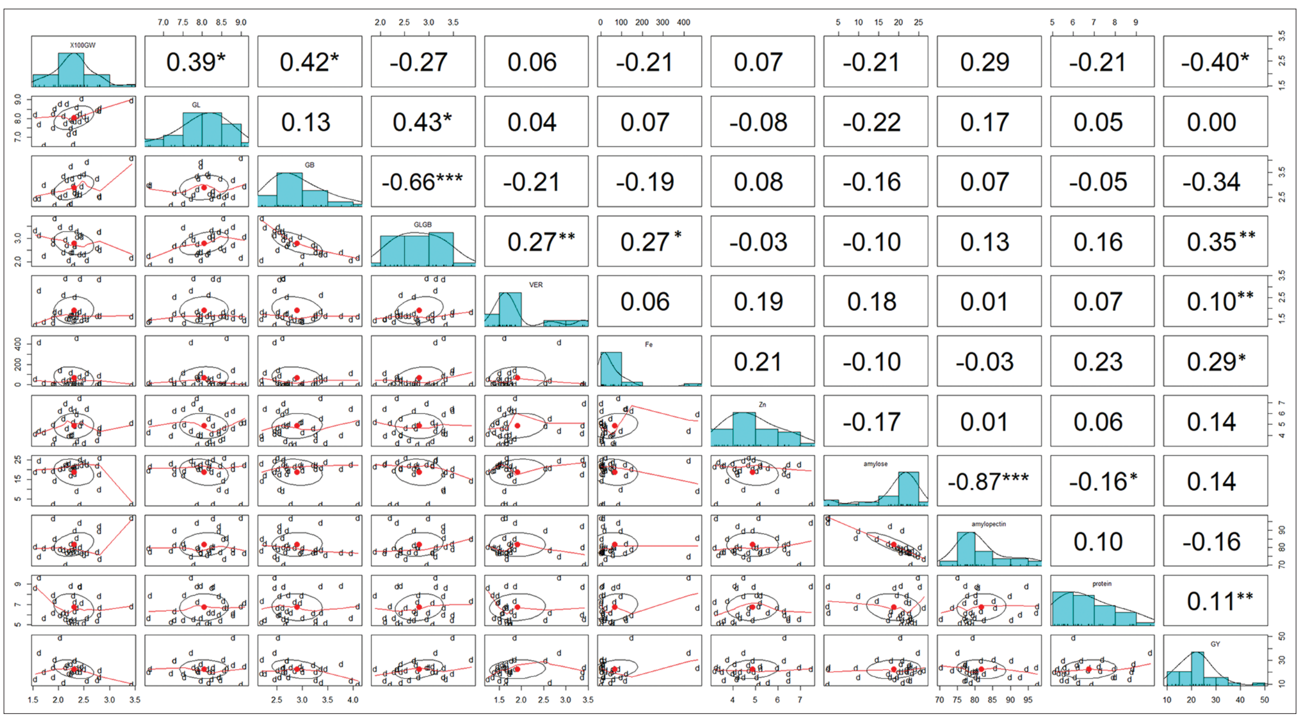

Figure 4: Correlation table showing positive and negative association among the studied traits. The distribution of each variable is shown on the diagonal. Each significance level is associated to a symbol: p-values (0.001, 0.01, 0.05) <=> symbols (***, **, *)

Table 2: Genetic parameters of variation of grain traits and biochemical traits

Characters	100 GW	GL	GB	L: B	VER	amylose	amylopectin	protein	Fe	Zn	GYP
Mean	2.2	7.46	2.99	2.66	1.88	19.3	80.7	7.6	65.55	6.34	20.99
SE	0.07	0.23	0.08	0.11	0.07	0.05	0.05	0.08	0.09	0.08	1.06
Range	3.12-1.29	9.43-3.16	8.5-1.4	4.14-1.02	1-3.7	1.5-26.91	73.08-98.4	3.5-12.3	1.3-485.8	1.13-21.62	51.4-7.8
GCV	17.02	11.22	24.2	18.36	11.57	9.36	7.01	10.74	19.7	15.23	38.24
PCV	17.76	12.285	24.35	20.1	12.58	9.27	7.02	12.51	19.8	15.5	39.48
h2 (broad sense) %	89.43	96.5	93.94	87.5	85.7	77.97	77.97	65	88.7	81.5	75
GAM	85.32	46.4	65	65.9	20.27	27.21	65	36.54	72.42	69.94	31.6

obtaining further genetic gain on selection. Similar findings were reported by Kumar *et al.* (2023), and Faysal *et al.* (2022).

Correlation of the Studied Traits with Grain Yield

In the present investigation, correlation studies of six grain traits and five chemical traits indicated significant positive correlation of grain yield with grain length breadth ratio, volume expansion ratio, Fe, and PC (Figure 4). Negative significant association was noted between grain yield and 100-grain weight. The traits with positive significance with yield also showed positive correlation amongst them. Grain length breadth ratio showed significant positive correlation with grain length, volume expansion ratio and Fe content. This is in support with the experimental findings of Anuradha *et al.* (2017) which indicated that long grained varieties were found to contain a higher concentration of Fe. Amylose recorded negative association with PC (significance level at 0.05) and strong negative correlation with amylopectin (significance level at 0.001). These results are in support of our experimental findings where the Bora cultivars with low amylose showed high PC. Grain length exhibited significant negative correlation with amylose. The reports are in support with this result where the Bora class of variety with slender grain recorded very low presence of amylose (Ferdous *et al.*, 2018). Again, positive association was shown by amylose and negative association by amylopectin with grain yield. Undesirable negative association observed in grain yield with grain weight might be due to its positive association with traits, which in turn exhibited a negative association with grain yield. Recombination breeding may be suggested for breaking such undesirable linkage.

Genetic Diversity Study

Mahalanobis D^2 analysis was used to assess the genetic diversity amongst the 50 cultivars under study using the software program R (Figure 5). A dendrogram was obtained that delineates a hierarchy between groups and subgroups based on the different similarity levels. A total of six clusters were formed among the land races with cluster IV having the highest entries of 19, followed by cluster V with 15 entries, cluster VI with five entries, cluster III and II with three entries each and cluster I with two entries. Manipuri Joha and Bahadur were grouped in the cluster that records the highest Fe content of 466.8 and 423.8 (mg/100 g) amongst the studied cultivars along with similar Zn content. Mahsuri, Bioi Sali and Siyal Sali grouped under cluster II had the same range of Zn content i.e., 6.3, 6.47 and 6.48 (mg/100 g) with slender grain type (>3 mm). Similarly, Badol Sali, Nepali Chokuwa and Kajoli Chokuwa categorized under cluster III showed the same range of high PC. All the Hill

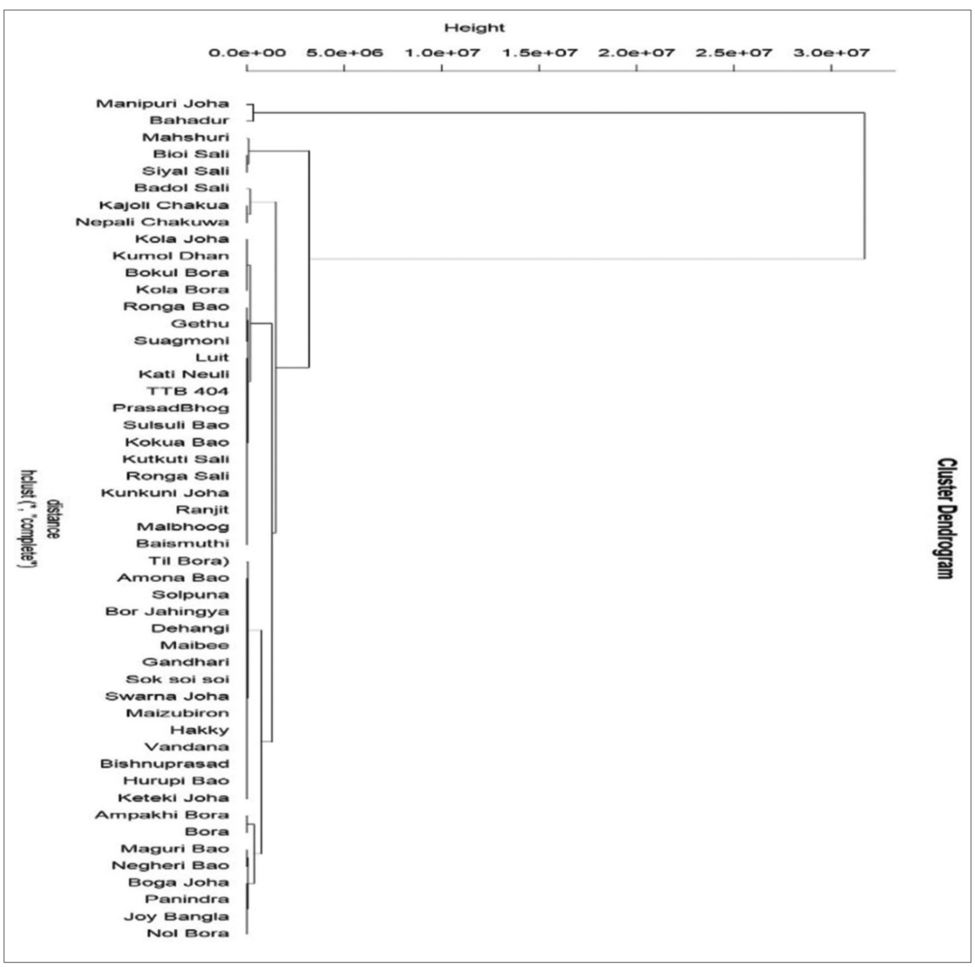

Figure 5: Dendrogram of 50 rice genotypes based on Mahalanobis's Euclidean Distance

Table 3: Inter and intra cluster distance amongst the clusters

Clusters	Entries	Cluster1	Cluster2	Cluster3	Cluster4	Cluster5	Cluster6
Cluster1	2	146936.2	565576.7	787519.7	927842.3	22264550	845563.3
Cluster2	3	565576.7	36354	1744269	1127287	27774001	983325
Cluster3	3	7875198	1744629	195723.2	1319410.3	15988317	1163445
Cluster4	19	927842.3	1127287	1319410	116466.6	22769233.2	8622341
Cluster5	15	22264550	27774001	15988317	22769233.2	354500.6	1055376
Cluster6	8	845563.3	983325	1163445	8622341	1055376.4	739221

varieties under study were found to be grouped under cluster V alongside a few Sali accessions. The cultivars with intermediate amylose content were grouped together in cluster V. The Bora group of cultivars specially known for their sticky nature and the scented Joha were not grouped together but dispersed under the cluster IV, V and VI. The reason might be that other governing traits such as Fe, Zn, and grain size which are seen to be contributing more toward diversity. Rest, it can be assured from the clustering that the same group of cultivars tends to stay together due to their similarity in origin. Cluster analysis to study intra and inter-cluster distances between groups is an effective tool used for classifying genotypes in plant breeding (Latif *et al.*, 2011). The intra and inter-cluster distance amongst the six clusters are also presented in Table 3. The highest intra-cluster D^2-value was recorded in cluster VI (739221), followed by cluster V (354500.6). The highest intra-cluster distance in cluster V indicated the presence of relatively wide variation amongst the entries within it. Highest inter cluster distance was recorded between cluster V and II (27774001), followed by Cluster IV and V (22769233.2). Such type of clustering was used by many workers with respect to morphological as well as molecular variation in various crops including rice (Manasa *et al.*, 2023; Hasan *et al.*, 2022; Parasar *et al.*, 2017; Sarma *et al.*, 2022). The total diversity deciphered into *inter se* distance between various clusters would have an implication in rice breeding. As the range of variability generated in a segregating generation depends on the genetic distance of the parents, the observed diversity pattern would be of value to the rice breeders (Bhargavi *et al.*, 2023).

CONCLUSION

Variability is the prerequisite in the breeding programme. On the other hand, selection to be effective, the traits must contribute towards the variability. The present study comprising of 50 indigenous rice varieties from Assam presents an insight into the diverse landraces of the state which could be the basis for planning an effective hybridization programme and selection of genotypes for the further rice improvement programme. The nutritional parameters, *viz.*, Fe and PC, showed a good degree of variability, suggesting the possibility of employing these accessions as parents for quality enhancement initiatives. Cultivars like Mashuri, Manipuri Joha, Bahadur, Kajoli Chokowa, Vandana, Bokul Bora were found superior in grain yield, Fe, PC, amylose respectively. The present study grouped the 50 rice cultivars of Assam into six diverse clusters and delineated a few important traits contributing towards total variability. Genotypes belonging to diverse groups along with possessing better *per se* performance for specific traits may be identified and hybridized for obtaining desirable segregants for further rice improvement for grain yield and nutritional qualities.

AUTHORS' CONTRIBUTION

Original draft preparation, investigation, acquisition of data, analysis and interpretation of data was performed by Kangkana Thakur. Substantial revision and correction of the article was done by Sofia Banu. The article was reviewed by Mridusmita Kalita, Daizi Saharia and Nayanika Sarma. The study design was critically reviewed and revised by MK Sarma. All authors read and approved the final manuscript.

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