Indian Journal of Traditional Knowledge
Vol 20(3), July 2021, pp 838-845

Morphological characterization of *sali* rice accessions of North East India

Rahul K Verma[a], Sanjay K Chetia[b], Amrit Tamuly[b], Vinay Sharma[c], P C Dey[b], P Sen[a] & M K Modi*[,a]

[a]Department of Agricultural Biotechnology, Assam Agricultural University, Jorhat, Assam, [b]Regional Agriculture Research Station, Titabar, Assam, [c]ICRISAT, Hyderabad, Telangana

E-mail: mkmodi@aau.ac.in

Received 21 April 2020; revised 06 March 2021

Rice is a major cereal crop of Assam, North East India. The local rice accessions grown in this region possess unique traits of breeder's choice i.e., tolerance to biotic and abiotic stresses. In the present investigation, 712 *sali* rice accessions of Assam were characterized using 20 qualitative and 13 quantitative traits. Among these, 19 qualitative traits showed distinct polymorphism except for the ligule colour. The maximum polymorphism was observed for apiculus colour followed by the colour of lemma palea and sterile lemma. The significant variation for the quantitative traits was recorded among the accessions. *Lakhi Bilash* and *Borkamal* were identified as the high yielding genotypes, which may be used further in breeding programmes. The cluster analysis using morphological traits based on the Euclidean distance matrix classified the accessions into the two distinct sub-groups. The high yielding accessions were grouped together in one cluster. A significant positive correlation was observed among the grain yield with the various panicle associated traits therefore, these may be used as selection criteria for development of high yielding rice varietiies.

Keywords: Diversity, Morphological traits, Pre-breeding, Rice accessions

IPC Code: Int Cl.[21]: A01G 22/22, A01H 6/46

Rice (*Oryza sativa* L.) is one of the major crops of North-East (NE) India and grown under diverse conditions. The traditional rice accessions of this region comprise several unique and beneficial alleles associated with various biotic and abiotic stresses such as cold, flooding, drought and salt tolerance[1]. In Assam, *sali* rice is a dominant crop, covering 71% of area with 73% of the total rice production. It is mainly cultivated in the months of June/July to November/December. The *sali* rice accessions are classified on the basis of grain shape i.e., coarse grain, medium size grain and grain quality *i.e*., scented rice, semi glutinous rice and glutinous rice. Therefore, the accessions are rich in diversity and may be utilized in crop improvement programmes for existing rice cultivars of Assam and NE India.

In the past, the green revolution improved the food grains production in our country[2]. It was achieved due to intensive use of high yielding varieties (HYV) and adoption of improved cultural practices in farming. The excessive use of HYV resulted in extinction of traditional cultivars from cultivation[3]. However, many of the local farmers in the extremes of NE regions are still cultivating these traditional accessions due to its adaptability with the local microclimate[4]. Therefore, it is essential to study and preserve the traditional genetic resources otherwise they may not be available in the future due to the emergence of HYV. The traditional accessions may be proved as valuable resources for improvement of yield, resistance to pests and pathogens, and agronomic performance of crop[5-7]. Several studies on characterization of traditional accessions have previously been conducted such as morphological characterization of 5285 accessions from China[8], genetic diversity in rice accessions of NE India[4], and phenotypic characterization of upland rice accessions of NE India using grain quality traits[9].

The phenotypic characterization of accessions is pre-requisite for an effective plant breeding program. It is an important tool for researchers in choosing suitable parental combinations for various breeding programmes. Although, many previous studies have been conducted on characterization of accessions however, very few studies using morphological traits have been reported using local rice accessions of Assam, NE India. Therefore, in order to effectively utilize these resources in breeding, the current research programme was proposed with the

*Corresponding author

objectives: i) to characterize *sali* rice accession of Assam, NE India using morphological traits and ii) to identify potential pre-breeding resources for crop improvement programmes.

Materials and Methods

The genotypes for the present investigation consisted of 712 *sali* rice accessions collected from Assam, North East India, including high yielding varieties, traditional varieties, advance breeding lines from India and International Rice Research Institute (IRRI) Philippines (Supplementary Table 1). A high yielding variety, Bahadur and a semi dwarf, short duration variety, IR-64 were used as checks for phenotypic evaluation of accessions under shallow lowland conditions. These accessions were grown at Regional Agricultural Research Station (RARS), Titabar, Assam during *Kharif* 2018. The 28 days old single seedling was transplanted using Randomized complete block design in three replications. The accessions were classified as the phenotypic sub-groups reported by the IRRI and the International Board for Plant Genetic Resources (IBPGR)[10]. A total of 20 qualitative (Table 1) and 13 quantitative traits (Table 2) were used for the present investigation. The qualitative traits are: Leaf colour, Basel leaf sheath colour, Flag leaf attitude, Culm attitude, Leaf senescence, Colour of ligule, Size of ligule, Colour of auricle, Size of auricle, Apiculus colour, Colour of node, Colour of internode, Stigma colour, Colour of lemma palea, Sterile lemma colour, Panicle attitude, Panicles shattering, Awning, Colour of awns and

Table 1 — Qualitative traits used for phenotypic evaluation according to descriptors reported by IRRI and the IBPGR.

S. No.	Descriptors	Observed phenotypic classes	Evaluation phase
1	Leaf colour	1,2, 3	Early flowering
2	Basel leaf Sheath Colour	1, 2, 3, 4, 5, 6	Booting
3	Flag leaf attitude	1, 2, 3, 4	Beginning of anthesis
4	Culm attitude	1, 2, 3	Booting
5	Leaf senescence	1, 5, 9	Caryopsis
6	Colour of ligule	1	Booting
7	Size of ligule	1, 2, 3	Booting
8	Colour of auricle	0,1, 2, 3, 4	Booting
9	Size of auricle	0, 1, 2, 3	Booting
10	Apiculus colour	1, 2, 3, 4, 5, 6, 7, 8	Booting
11	Colour of node	0, 1, 2, 3, 4	Milk development stage
12	Colour of internode	0, 1, 2, 3, 4, 5	Milk development stage
13	Colour of stigma	1, 2	Anthesis
14	Lemma palea colour	0, 1, 3, 4, 5, 7, 10	Ripening
15	Sterile lemma colour	1, 2, 3, 4, 5	Caryopsis
16	Panicle type	1, 2	Ripening
17	Panicles shattering	0, 1	Maturity
18	Awning	0, 1	Ripening
19	Colour of awns	0, 1, 2, 3	Ripening
20	Grain shape	1, 2, 3, 4, 5.	Maturity

Table 2 — Quantitative traits used for phenotypic evaluation according descriptors reported by IRRI and the IBPGR.

S. No.	Descriptors	Observed phenotypic classes	Evaluation phase
1	Days to flowering	Days taken from sowing to panicle emergence	After flowering
2	Plant Height	Average of six samples.	Maturity stage
3	No. of tillers	Average of six samples	Maturity stage
4	Effective booting tillers	Average of six samples	Maturity stage
5	Total No. of filled grains/panicle	Average of six samples	Maturity stage
6	Number of chaff /panicle	Average of six samples	Maturity stage
7	Spikelet fertility	Average of six samples	Maturity stage
8	Test Weight (100 grains)	Average of six samples	Maturity stage
9	Length of panicle	Average of six samples	Maturity stage
10	Single plant yield	Average of six samples	Maturity stage
11	Kernel Length	Average of six samples	Maturity stage
12	Kernel Breadth	Average of six samples	Maturity stage
13	L/B ratio	Average of six samples	Maturity stage

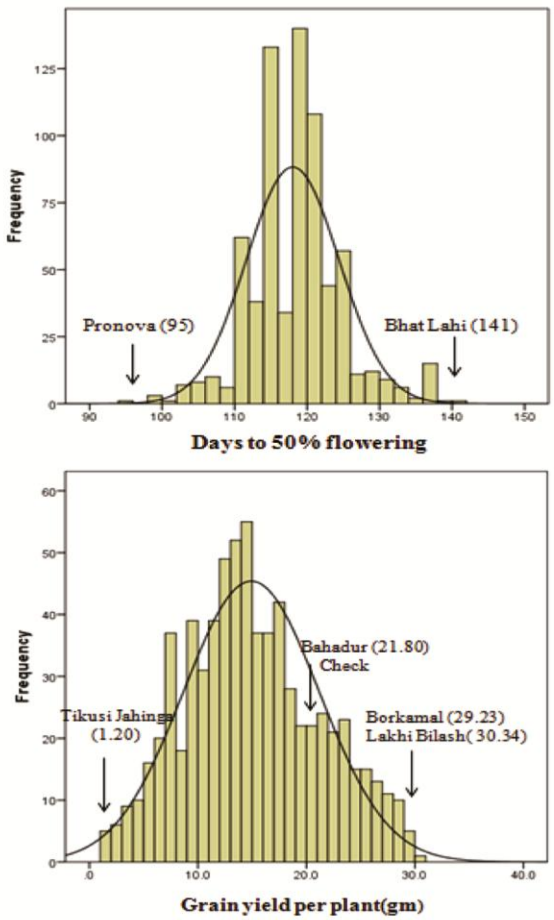
Grain shape. The quantitative traits are: Days to 50% flowering, Height of plant, Total number of tillers/plant, Total number of effective tillers/plant, Total number of filled grains/panicle, Total number of chaffs/panicle, Spikelet fertility, Length of panicle, Single plant yield, Length of kernel, Breadth of kernel, Kernel length to breadth ratio, Test grain weight (100 seeds). For the quantitative characters the statistical analyses and Pearson's correlation coefficient were performed by using SPSS software (Version 9, Chicago, USA). The diversity among the accessions was analyzed separately for the qualitative and quantitative traits based on Euclidean distances matrix using programme 'R'[11].

Results and Discussion

The usefulness of qualitative traits in phenotypic characterization of rice accessions is already reported by several resercher's[12]. In the present investigation, the *sali* rice accessions showed significant variation for the phenotypic traits recorded. The polymorphism was observed for 19 out of 20 qualitative traits studied except for the colour of ligule, which was observed white among the accessions. Only two alternative forms or types were observed for the traits such as stigma colour, awning, panicle type and panicle shattering. The white (91.70%) and purple (8.20%) genotypes were observed for stigma colour. The coloration in stigma is caused by deposition of anthocyanin, which is synthesized by a multistep biosynthetic pathway. It is generally accepted that anthocyanin colouration regulates drought tolerance in rice. The variation in the populations of *O. glumaepatula* for stigma colour is also reported[13]. Among the various genotypes, awns were observed only in 12.35% of genotypes whereas, 87.64% of genotypes were awnless. Most of the varieties derived from *O. sativa* are awnless due to domestication, whereas their ancestral species, *O. rufipogon* possess long awns. The 67.18% genotypes showed compact panicles while 32.86% showed open panicles. Shattering of panicles at maturity was observed in 6.80% genotypes whereas, 93.11% genotypes retained their panicles till harvesting. There are several causes of panicle shattering in rice among these the abscission of seed and disarticulation of spikelet is the most commonly reported[14]. In rice breeding, intensive effort may be needed to reduce the shattering of panicles before harvesting as it results in huge yield loss and has proven to be one of major reasons for low productivity.

The three alternate forms were observed for the traits such as leaf colour (13.34% light green, 43.67% medium green, 42.83% dark green), culm attitude (44.52% erect: 1.2% semi erect: 54.07% intermediate), size of ligule (6.8% Acute to acuminate: 91.15% cleft: 1.8% truncate) and senescence of leaf (56.03% early: 20.5% intermediate: 15.73% late). Whereas, the maximum polymorphism was observed for the traits such as apiculus colour (7% white: 1.1% green: 10.11% purple apex: 18.96% purple: 57.86% straw: 3.6% brown: 0.56% red apex: 0.7% black), lemma palea colour (2.8% yellowish: 41.99% gold and gold furnaces: 31.34 % brown farrow: 2.5% brown tawny: 7.4% reddish to light purple:11.51% purple farrow : 20.08% white), sterile lemma colour (83.84% white: 4.7% red: 8.1% light purple: 2.9% purple: 0.14% brown), colour of internode (85.67% absent: 4.92% whitish: 1.40% purple line: 3.09% light purple: 1.12% purple: 3.79% pale yellow), basal leaf sheath colour (5.05% whitish: 65.73% green: 16.43% mixture of white and green: 1.82% purple lines: 8.84% light purple: 1.96% purple), flag leaf attitude 43.11% erect: 21.20% semi erect: 8.56% horizontal: 26.68% Droping), colour of auricle (0.70% absent: 88.48% whitish: 0.42% yellowish green: 7.86% light purple and 2.38% purple) and grain shape (1.96% round: 22.47% semi-round: 65.55% semi elongated: 8% elongated) therefore, these are the most informative traits and used for assessment of diversity among the accessions. Similarly, the maximum variation was reported for the qualitative traits among aromatic[15] and upland rice accessions[16]. The cluster analysis based on qualitative traits using the Euclidean distance matrix clustered the accessions into two major sub-groups (Fig. 1). A total of 626 accessions formed cluster 1 including the high yielding varieties 'Bahadur' and 'IR64' whereas, the remaining 86 accessions formed cluster 2 including a flood tolerant cultivar 'FR-13-A'. The clustering of accessions may be useful in selecting appropriate genotypes for breeding programme.

The phenotypic evaluation of the 712 *sali* rice accessions showed normal distribution of 13 quantitative traits under lowland conditions (Fig. 2). Gain yield is a polygenic trait and is also affected by plant height and flowering time[17]. The average days to 50% flowering was 118 days recorded among the accessions (Table 3). The high yielding check cultivar 'Bahadur' flowered at 130 days resulted high grain



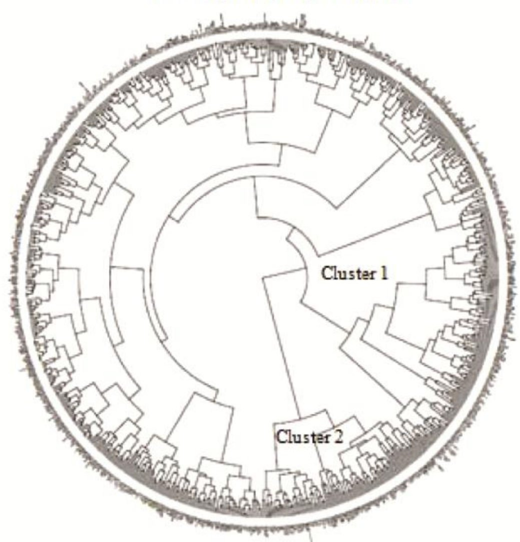


Fig. 1 — Clustering of 712 *sali* rice accessions based on Euclidean distance matrix, grouping using 20 qualitative traits: 626 accessions were grouped into cluster 1 and 86 accessions into cluster 2

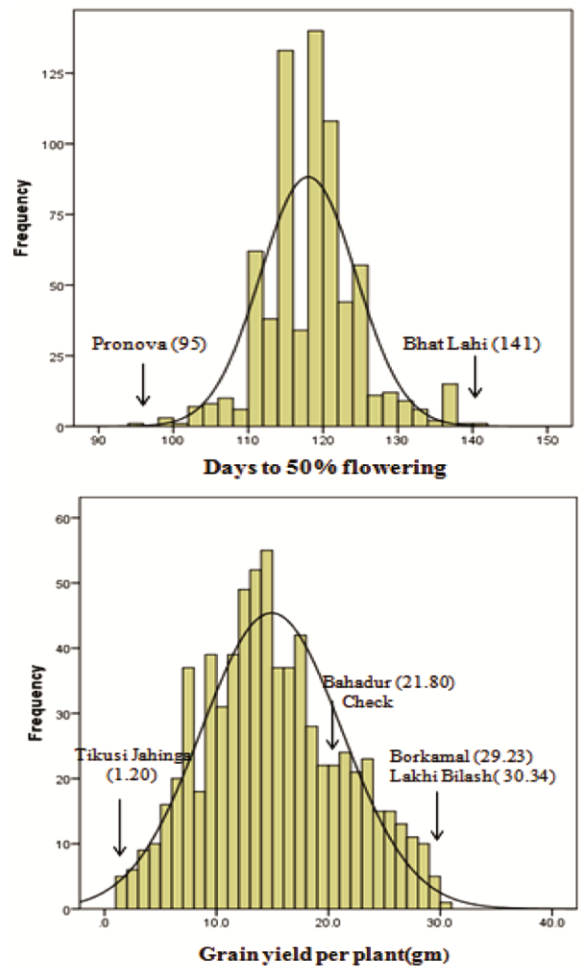


Fig. 2 — Phenotypic evaluation of the 712 *sali* rice accessions showed normal distribution of the traits. Days to 50% flowering, Single plant yield under lowland conditions of Assam

yield of 21.80 gm/plant. The maximum flowering duration of 141 days was observed in 'Bhat Lahi' with low grain yield of 8.60 gm/plant as some of the *sali* rice accessions were photoperiod sensitive therefore longer in growth duration. Whereas, 'Pronova' was recorded as the earliest flowering genotype of 95 days only resulted in grain yield of 17.60 gm/plant. The wide degree of variation was observed for this trait due to variability in response to environmental factors among the accession.

In rice, the height of plant is also associated with the grain yield. The mean plant height of 123.43 was recorded among these, 'JOHA-5' was the tallest genotype of 157.20 cm in height and grain yield of 11.60 gm/plant whereas, 'FG-28' had the shortest stature of 68.40 cm resulted in grain yield of 18.80 gm/plant. Plant height is a polygenic trait and dependent on many genetic and environmental factors[18]. The short to medium plant height is a desirable phenotype to overcome lodging of crop at maturity which results in significant yield loss under

Table 3 — Mean values of quantitative traits recorded among the selected genotypes

S.No.	Genotype	DTF	PH	NOT	EBT	NOG/P	NOC/P	SF	TW (100 seeds)	PL	GY	KL	KB	L/B ratio
1	Lakhi Bilash	120.00	131.00	10.40	8.95	121.00	12.20	90.84	3.00	28.30	30.34	6.90	3.00	2.30
2	Borkamal	124.00	117.40	9.80	8.60	104.29	20.00	83.91	3.00	27.00	29.23	6.20	3.00	2.07
3	Katari Bhog	115.00	131.80	6.96	3.25	114.62	22.00	83.90	4.00	28.10	16.20	7.10	2.80	2.50
4	Dinesh	119.00	135.00	9.60	5.40	110.67	36.40	75.25	4.00	25.86	25.20	8.20	3.00	2.73
5	Taraboli	123.00	129.20	8.20	6.80	147.06	24.40	85.77	2.80	22.14	28.00	6.20	3.20	1.94
6	Borgathu	119.00	138.00	7.20	6.20	193.55	52.80	78.57	2.40	23.76	28.80	4.70	3.30	1.42
7	Lothabor	123.00	129.20	10.20	8.60	120.43	11.60	91.21	2.80	24.92	29.00	6.30	2.80	2.25
8	Malbhog-2	118.00	140.40	10.20	7.40	157.66	30.20	83.92	2.40	28.44	28.00	7.50	2.80	2.68
9	Tsuknari	124.00	130.60	9.60	6.80	129.60	12.40	91.27	3.20	29.02	28.20	6.60	3.10	2.13
10	Monipuri-2	121.00	132.40	10.60	8.60	101.74	28.40	78.18	3.20	24.24	28.00	6.20	2.50	2.48
11	IRRI-2	132.00	116.60	11.80	7.80	111.38	38.80	74.16	3.20	23.92	27.80	6.40	2.90	2.21
12	IET-12170	123.00	119.00	6.60	7.40	114.86	37.40	75.44	3.20	24.96	27.20	6.80	3.00	2.27
13	Bahadur- Check	130.00	104.00	8.65	6.54	134.89	28.00	82.81	2.40	23.46	21.80	6.10	2.70	2.26
14	IR-64- Check	114.00	82.00	6.88	4.20	116.54	7.20	94.18	2.80	22.80	13.00	7.50	2.60	2.88
	Genotype mean	118.03	123.43	9.44	6.91	83.95	24.48	75.77	2.84	25.04	14.92	6.41	2.87	2.26
	Maximum	141.00	157.20	30.80	15.00	429.17	116.00	98.6	4.00	33.12	30.34	8.60	3.60	3.40
	Minimum	95.00	68.40	3.20	1.20	5.68	2.20	11.67	1.20	12.80	1.20	4.20	2.10	1.29
	S.D.	6.41	12.05	2.84	2.03	48.18	17.24	15.08	0.47	2.38	6.26	0.66	0.30	0.37

DTF- Days to flowering, PH- Height of plant (cm), NOT- Total no. of total tillers per plant, EBT- Total no. of effective tillers per plant, NOG/P- Total no. of filled grains per panicle, NOC/P- Total no. of chaffs per panicle, SF- Spikelet fertility(%), TW- Test grain weight of 100 grains (gm), PL- Length of panicle (cm), GY- Single plant yield per plant(gm/plant), KL-Length of kernel(mm), KB- Breadth of kernel (mm), L/B- Length breadth ratio.

field conditions[19]. The mean productive tillers of 6.91 were observed among the accessions. Among these, ‘Ali Raj’ had maximum number of productive tillers of 15 and single plant yield of 24.80 gm whereas, ‘Tikusi Jahinga’ had the minimum number of productive tillers and single plant yield of 1.20 and 2.50 gm/plant respectively. The average value of panicle length was 25.04 and ‘Genow’ had the longest panicle of 33.12 cm consisted of 181.25 grains/panicle whereas; ‘Domaroru’ had the shortest panicle of 12.80 cm with 27.70 grains/panicle. The panicle length, total tillers per hill, spikelets number per panicle and height of plant are the main contributors to grain yield in rice[20]. However, the grain yield mainly depends on the number of filled spikelets, which is an important yield attributing trait. The average spikelet fertility of 75.77% was recorded among these, ‘Dol bao’ had the lowest spikelet fertility of 13.98% due to maximum number of unfertilized seeds (116.00) per panicle whereas; highest spikelet fertility of 98.60% was recorded in ‘Ulpi bao’ due to minimum number of unfertilized seeds (2.20) per panicle. The spikelet sterility is the primary cause of yield loss under drought stress at reproductive stage in rice[21]. Therefore, may be targeted for development of drought tolerant rice variety.

Grain weight is directly associated with yield in plants[22]. The average value of 2.84 was recorded for 100 grain weight among the accessions. The maximum value of 4.00 gm was recorded for ‘Dinesh, and Katari Bhog’. It may be due to increase in the grain size in ‘Dinesh’ (kernel length- 8.20 mm, kernel breadth- 3.00 mm) and ‘Katari Bhog’ (kernel length- 7.10 mm and kernel breadth-2.80 mm) resulted in high test weight due to accumulation of more starch in the kernels. The grain yield of 25.20 gm/plant and 16.20 gm/plant were recorded in ‘Dinesh and Katari Bhog’, respectively.

The average grain yield of 14.92 gm per plant was recorded. The highest grain yield of 30.34 gm/plant was recorded in a tall (131 cm), medium duration (120 days) rice accession ‘Lakhi Bilash’. It may be due to long panicles (28.30 cm) associated with high spikelet fertility (90.84%) and test weight (3.00 gm/100 seed). A medium duration (124 days), tall cultivar (117.40 cm) ‘Borkamal’ had a grain yield of 29.23 gm/plant. Whereas, the grain yield of 21.80 gm/plant was recorded in high yielding check cultivar ‘Bahadur’ under lowland conditions. The accessions ‘Lakhi Bilash’ and ‘Borkamal’ showed significantly high grain yield over the check cultivar ‘Bahadur’ under similar field conditions therefore, these two accessions may be successfully utilized in breeding programme for development of high yielding rice verities. In addition to that, there are some high yielding genotypes i.e., Taraboli (28.00 gm/plant), Borgathu (28.80 gm/plant), Lothabor (29.00 gm/plant), Malbhog-2 (28.00 gm/

plant), Tsuknari (28.20 gm/plant), Monipuri-2-nachenraiachujhu (28.00 gm/plant), IRRI-2 (27.80 gm/plant) and IET-12170 (27.20 gm/plant) may be exploited further for crop improvement programme.

Grain shape is the important quality trait associated with the yield. It is a qualitative trait which follows quantitative inheritance and evaluated according to the grain dimensions. The grains of wild rice are small, round and are advantageous for dispersal by natural vectors. The *sali* rice accessions are mainly characterized as coarse or medium size grain. The average value of 2.26 was recorded for the kernel length to kernel breadth ratio. The highest value of 3.40 (elongated shape) was observed for 'Beji Lahi' while the lowest value of 1.29 (round shape) was observed for 'Dholamula-3'. Out of 712 rice accessions studied the grain shape was observed as semi elongated (67.41%), semi round (21.34%), elongated (9.5%) and 1.68% as round in shape. The variation in grain shape may be resulted due to the cumulative effect of multiple genes and environmental conditions[16]. The characterization of rice based on grain shape is reported in traditional rice accessions of Tamil Nadu[23].

The cluster analysis based on quantitative traits using Euclidean distance matrix classified the accessions into two major clusters (Fig. 3). 504 accessions formed cluster 1 including high yielding genotypes i.e., *Lakhi Bilash, Borkamal, Dinesh, Borgathu, Lothabor Malbhog-2, Tsuknari, IET-12170* and *IRRI-2, Bahadur and IR64'*. Whereas, the remaining 208 genotypes were grouped into cluster 2. Similarly, 782 rice accessions were characterized on the basis of 29 morphological and 8 agronomical traits[24]. The *sali* rice varieties mainly covers the low-lying flood plains areas of North East India, in the Brahmaputra and Barak Valley regions therefore, the accessions may be phenotyped for flooding in the future to identify flood tolerant cultivars which may be used in breeding programme.

Correlation coefficient

The duration of 50% flowering showed positive correlation with total number of filled grains per panicle and single plant yield (Table 4). As, the

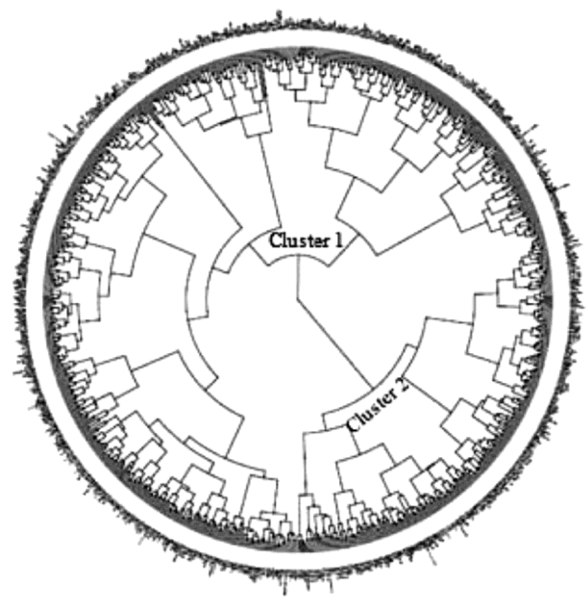


Fig. 3 — Clustering of 712 sali rice accessions based on Euclidean distance matrix, grouping using 13 quantitative traits: 504 accessions were grouped into cluster 1 and 208 in cluster 2

Table 4 — Pearson's correlation coefficient for various quantitative traits

	DTF	PH	NOT	EBT	NOG/P	NOC/P	SF	TW 100 grain	PL	GY	KL	KB	LB ratio
DTF	1												
PH	-.158**	1											
NOT	-.015	.002	1										
EBT	.006	.042	.865**	1									
NOG	.213**	-.049	-.090*	-.082*	1								
NOC	.230**	-.009	-.158**	-.161**	.101**	1							
SF	-.140**	-.019	.120**	.126**	.320**	-.864**	1						
TW_100 grain	-.076*	.166**	-.068**	-.041	-.168**	-.108**	.036	1					
PL	.026	.281**	-.055	.000	.251**	.115**	.021	.154**	1				
GY	.213**	.047	-.008	.042	.224**	-.030	.106**	.075*	.098**	1			
KL	-.066	.094*	-.047	-.061	-.212**	.045	-.123**	.352**	.012	.041	1		
KB	-.033	.112**	-.331**	-.272**	-.132**	.011	-.060	.298**	.191**	.095*	-.209**	1	
LB ratio	-.017	-.005	.202**	.157**	-.036	-.005	-.012	.038	-.094*	-.025	.752**	-.788**	1

DTF- Days to flowering, PH- Height of plant (cm), NOT- Total no. of total tillers per plant, EBT- Total no. of effective tillers per plant, NOG/P- Total no. of filled grains per panicle, NOC/P- Total no. of chaffs per panicle, SF- Spikelet fertility (%), TW- Test grain weight of 100 grains (gm), PL- Length of panicle (cm), GY- Single plant yield per plant(gm/plant), KL- Length of kernel(mm), KB- Breadth of kernel (mm), L/B- Length breadth ratio.

medium to long duration varieties synthesize more carbohydrate and therefore produce more filled grains which may contribute to high grain yield. A significant negative correlation was observed among the flowering duration with fertility of spikelet and grain weight[25-27]. Another yield component trait, effective booting tillers showed positive correlation with fertile spikelets and grain yield. The positive correlations among the various yield component traits *i.e*., spikelet fertility, total number of filled grains and grain yield is already reported in rice[28]. In rice formation of grains in the panicle is a critical process and dependent on many parameters *i.e*., climatic conditions, type of soil, genotypes, fertilizer application, damage caused by insect and pest attacks[29]. The majorities of yield component traits were interrelated on each other and contributed towards high grain yield therefore may be used for selection of desirable genotypes in breeding programme.

Conclusion

In the present investigation, the 712 *sali* rice accessions were characterized based on morphological traits and clustered into two sub-groups. The significant phenotypic variation was recorded among the accessions for the various morphological traits recorded under shallow lowland conditions. *'Kataria Bhog'* and '*Dinesh*' were high in test grain weight whereas, '*Lakhi Bilash'* and '*Borkamal*' were identified as the high yielding genotypes. In future, the accessions may be phenotyped for submergence stress in order to identify flood tolerant genotypes. The identified genetic resources may be used in crop improvement programmes for development of high yielding rice varieties suitable for low land rice growing areas of Assam and NE India.

Acknowledgement

The authors acknowledge DBT- NECAB, Jorhat, India for providing the financial assistance, Chief Scientist, RARS, Titabar for providing the logistic support to the field work and Debashish Panda, Distributed Information Centre (DIC), Department of Agricultural Biotechnology, Assam Agricultural University, Jorhat for data analysis.

Conflicts of Interest

The authors declare no conflict of interest.

Authors' contribution

Conceptualization of research (MKM); Designing of the experiments (MKM, SKC, PCD, PS, RKV); Contribution of experimental materials (SKC); Execution of field experiments and data collection (RKV, AT, VS); Analysis of data and interpretation (RKV, VS); Preparation of manuscript (RKV,VS, MKM).

References

1 Hore D K, Rice diversity collection, conservation and management in north eastern India, *Genet Resour Crop Evol*, 52 (2005) 1129-40.

2 Maji A T & Shaibu A A, Application of principal component analysis for rice germplasm characterization and evaluation, *J Plant Breed Crop Sci*, 4 (2012) 87-93.

3 Doebley J F, Gaut B S & Smith B D**,** The molecular genetics of crop domestication, *Cell*, 127 (2006) 1309-1321.

4 Vanlalsanga S, Singh P & Singh Y, Rice of Northeast India harbor rich genetic diversity as measured by SSR markers and Zn/Fe content, *BMC Genet*, 20 (2019) 79.

5 Brush S B, In situ conservation of landraces in centers of crop diversity, *Crop Sci*, 35 (2) (1995) 346-354.

6 Hoisington D, Khairallah M, Reeves T, *et al*., Plant genetic resources: what can they contribute toward increased crop productivity? *Proc Natl Acad Sci*, 96 (11) (1999) 5937-5943.

7 Mandel J R, Dechaine J M, Marek L F, *et al*., Genetic diversity and population structure in cultivated sunflower and a comparison to its wild progenitor, *Helianthus annuus* L, *Theor Appl Genet*, 123 (5) (2011) 693-704.

8 Yawen Z, Shiquani S, Zichao L, *et al*., Ecogeographic and genetic diversity based on morphological characters of indigenous rice (*Oryza sativa* L.) in Yunnan, China, *Genet Resour Crop Evol*, 50 (2003) 567-577.

9 Vanlalsanga S & Singh Y, Genetic diversity and population structure in upland rice (*Oryza sativa* L.) of Mizoram, North East India as revealed by morphological, biochemical and molecular markers, *Biochem Genet*, 57 (3) (2019) 421-442.

10 International Rice Research Institute [IRRI], *Descriptors for Rice Oryza sativa* L. The International Rice Research Institute, Manila, Philippines, (1980).

11 Team R C, R development Core Team: R:A language and environment for statistical computing, (2012) http://www.mendeley.com/research/r-language-environment-statistical-computing-96/%5Cnpapers2://publication/uuid/A1207DAB-22D3-4A04-82FB D4DD5AD57C28.

12 Kurlovich B S, Species and intraspecific diversity of white, blue and yellow lupins, *Plant Genet Resour News l*, 115 (1998) 23-32.

13 Veasey E A, Silva E F, Schammass E A, *et al*., Morpho-agronomic genetic diversity in American wild rice, *Braz Arch Biol Technol*, 51 (2008) 99-108.

14 Li W & Gill B S, Multiple genetic pathways for seed shattering in the grasses, *Funct Integr Genom*, 6 (2006) 300-309.

15 Bisne R & Sarawgi A K, Agro-morphological and quality characterization of BadshahBhog group from aromatic rice germplasm of Chhattisgarh, *Bangladesh J Agr Res*, 33 (2008) 479-492.

16 Nascimento W F, Silva E F &Veasey E A, Agro-morphological characterization of upland rice accessions, *Sci Agric*, 68 (6) (2011) 652-660.

17 Wei X, Xu J, Guo H, *et al*., DTH8 Suppresses flowering in rice, Influencing plant height and yield potential simultaneously, *Plant Physiol*, 153 (4) (2010) 1747-1758.

18 Cheema A A, Awan M A & Iqbal J, Improvement of plant height architecture in basmati rice, *Pak J Agric Res*, 8 (1987) 371–374.

19 Abbasi F M, Sagar M A, Akram M, *et al*., Agronomic and quality traits of some elite rice genotypes, *Pak J Sci Ind Res*, 38 (1995) 348-350.

20 Yadav S K, Pandey P, Kumar B, *et al*., Genetic architecture, interrelationship and selection criteria for yield improvement in rice, *Pak J Biol Sci*, 14 (2011) 540-545.

21 Liu J K, Liao D Q, Oane R, *et al*., Genetic variation in the sensitivity of anther dehiscence to drought stress in rice, *Field Crop Res*, 97 (2006) 87-100.

22 Bai X F, Luo L J, Yan W H, *et al*., Quantitative trait loci for rice yield-related traits using recombinant inbred lines derived from two diverse cultivars, *J Genet*, 90 (2011) 209-215.

23 Savitha P & Kumari U, Indigenous knowledge of traditional landraces in rice *in situ* conservation of Tamil Nadu, India, *Indian J Tradit Know*, 15 (2) (2016) 321-329.

24 Sarawgi A K, Rao L V S, Parikh M, *et al*., Assessment of variability of rice (*Oryza sativa* L.) germplasm using agro-morphological characterization, *J Rice Res*, 6 (1) (2013) 15-28.

25 Hasan M J, Kulsum M U, Akter A, *et al*., Genetic variability and character association for agronomic traits in hybrid rice (*Oryza sativa* L.), *Oryza*, 8 (3) (2013) 110-115.

26 Bhadru D, Lokanadha R D & Ramesha M S, Correlation and path coefficient analysis of yield and yield contributing traits in rice hybrids and their parental lines, *Electron J Plant Breed*, 2 (1) (2011) 112-116.

27 Parimala C, *Combining ability and heterosis in rice* (*Oryza sativa* L.), PhD Thesis, (Professor Jayashankar Telangana State Agricultural University, Hyderabad, India), (2016).

28 Anis G B, Namaky R A, Ashkar I M, *et al*., Yield potential and correlation analysis of somerice hybrids for yield and its component traits, *J Anim Plant Sci*, 30 (2) (2016) 4748-4757.

29 Yoshida S, Physiological aspects of grain yield, *Annu Rev Plant Physiol*, 23 (1972) 437-464.