Response of Assam Rice Varieties to Low Temperature Stress

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Low temperature induced injury, slow growth and prolongation of crop duration are some of the most important problems of *boro* rice cultivation in Assam and other eastern states of India. Any variety to be ideally fitted to the *boro* rice season must have cold tolerance at the vegetative stage of growth. In the present study, a set of rice varieties, randomly drawn from Assam rice collection, was evaluated for their response to low temperature stress at germination, post-germination and seedling growth stages. Several varieties, both modern and traditional, distributed across different classes and sub-classes of Assam rice germplasm, exhibited desired degree of tolerance to low temperature stress at one or the other stages of growth. Sufficient genetic diversity was observed among the varieties with Eucledian coefficient of dissimilarity ranging from 0.60 to 8.61 and average being 3.88 across the 56 genotypes. In this study, no ecotype-specific clustering was observed among the Assam rice varieties.

Key Words: Rice (*Oryza sative* L.), Low temperature stress, Genetic diversity, Assam rice germplasm, Boro rice

Introduction

Low temperature is a major climatic problem for growing rice in 25 countries (Kaneda and Beachell, 1974). More than 15 million hectares of rice throughout the world suffers from cold damage at one or the other stage of growth. In South and Southeast Asia alone, low temperature limits production of modern rice cultivars on an estimated area of 7 million ha (Kaw and Khush, 1985). It is one of the most serious constraints to cultivation of *boro* rice crop in the entire eastern India including Assam (Thakur, 1995; Chatterjee, 1995; Pathak *et al.*, 1999). In Assam, *boro* rice is adversely affected by low temperature in its vegetative stage with the impacts such as poor germination, stunted seedling growth and poor vigor, seedling chlorosis and mortality and prolongation of duration (Pathak *et al.*, 2003). These factors have direct bearing on the grain yield per unit area. Moreover, stunted seedling growth makes manual uprooting and transplanting operations very cumbersome. Hence, identification of genotypes with desired degree of tolerance to low temperature stress has become very important for recommendation of suitable varieties to the farmers and also for utilization in the breeding programs. Though, about 4000 accessions of rice germplasm are being maintained in Assam (Pathak, 2001) no effort has, so far, been made to systematically evaluate the varieties for their response to low temperature stress. The present study was undertaken to evaluate a set of rice varieties of Assam for their response to low temperature stress and to understand the nature and extent of genetic diversity among the varieties in relation to their response to cold.

Materials and Methods

Altogether, 56 rice genotypes were taken for the study. Of these, 53 *indica* varieties, both modern and traditional, chosen randomly from different classes and sub-classes of Assam rice, were collected from Regional Agricultural Research Station, Titabar and three *japonica* varieties were collected from College of Bioresource Sciences, NIHON University, Japan. The field and laboratory experiments were carried out in the Assam Agricultural University, Jorhat during 2005-06 to assess their response to low temperature stress at germination, post-germination and seedling growth stages using several cold tolerance indices.

Twenty healthy seeds of each variety were placed on filter paper moistened with distilled water in a 50 mm diameter Petri dish and incubated at 17°C in the dark by wrapping the Petri dishes with black polythene bags for a period of 168 hours with an interruption at 96 hours after initiation of the incubation process. The black polythene bags were removed after 168 hours and the germinated seeds were exposed to normal daylight and temperature for 48 hours for allowing the etiolated plumules to turn green. At germination and post-germination stages, response of the varieties was estimated based on the observations on rate of germination (RG) index following the method of Krishnasamy and Seshu (1989) and plumule length and plumule greening following McWilliam *et al.* (1979). According to the methods, RG index (%) = $(N_{96}/ N_{168})'$ 100 where, N_{96} =

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number of seeds germinated in 96 hours (as against 72 hours in the original method) and N_{168} = number of seeds germinated in 168 hours. The plumule length was measured on 5 germinated seeds from the point of plumule emergence to the tip of the plumule after 168 hours of germination at 17°C. Plumule greening was visually scored as the average performance of the 5 germinated seeds on a 1 to 9 scale, where 1 = dark green; 3 = light green; 5 = pale green; 7 = pale white with a tinge of greenness and 9 = plumule brown or dead.

Pre-germinated seeds of each variety were also sown on well-puddled seedbeds in two replications in Randomized Block Design (RBD) on 26 December 2005 when the average temperature fell below 20°C. On 30 days after sowing (d), seedlings were assessed for leaf yellowing, electrolyte leakage and chlorophyll content following the methods described by IRRI (1996), Patterson *et al.* (1976) and Arnon (1949), respectively. The weekly average temperature during the period of experimentation was 15.8°C-16.8°C.

The mean data of each of the characters were subjected to analysis of variance and calculation of genotypic and phenotypic correlation coefficients among the parameters in all possible combinations. Diversity among the varieties was studied through cluster analysis using unweighted pair group method using arithmetic average (UPGMA). Since observed traits were measured in different scales, the data were standardized with STAND module to have a mean of zero and variance of one. Euclidean distance was computed by running SIMINT with standardized data following Sneath and Sokal (1973). The phenetic representation of genetic relationship among the genotypes as revealed by Euclidean distance was produced through cluster analysis using UPGMA.

Results and Discussion

Analysis of Variance

The analyses of variance revealed the existence of significant variation among the varieties for all the characters except chlorophyll b. The varieties were randomly chosen from diverse classes and sub-classes of rice germplasm conserved at the Regional Agricultural Research Station, Titabar that staggers to a volume of more than 1000 accessions. The result reflects the variation in the rice germplasm stock of Assam. Earlier works have already established that the indigenous rice germplasm of the region is endowed with wide genetic diversity and represents a wealth of valuable gene systems (Sharma *et al.*, 1971; IRRI, 1974 and Das *et al.*, 1981).

Germination Index

Germination index, measured to assess the varieties' tolerance to low temperature stress at germination, varied from 0-100% (Table 1). Among 56 varieties, only two *viz.*, Satkora lahi, and Ranjit scored 100 per cent for the index. These two varieties were, however, statistically *at par* with the varieties, Sail borak (97.5%), Gitesh (97.22%), Basundhara (95%), Jahinga (92.5%), Khoirajuli (92.5%), Kumol sali (92.5%) and Disang (92.5%). Other 14 varieties, belonging to different classes of rice, scored 80 or more for the index and differed significantly from the rest of the varieties. On the other end, 11 varieties *viz.*, Khoiya boro, Kolagoria, Akitakomuchi, Dusri ahu, Iharsal, Jagli boro, Majeni chembi, Kolamanik, Kola boro, Mokon boro, with a germination index score of 0 and Koshihikari (*japonica*) with a score of 5, were the worst in their response to low temperature stress at germination (Table 1).

Seventeen varieties including five traditional *boro* rice varieties of Assam scored 20% or less for rate of germination index. This clearly indicates that the traditional *boro* rice varieties of Assam are highly susceptible to low temperature stress at germination which is quite contrary to expectation. Because, the traditional *boro* rice varieties of Assam are being grown under low temperature from a very long past they are believed to possess desired degree of tolerance to low temperature stress at this stage. However, it did not appear so. Nevertheless, good performance during germination is important to guarantee fast establishment and uniform crop stand (Krishnasamy and Seshu, 1989) which was not observed in case of most of the traditional varieties from *boro* as well as other classes of rice varieties of Assam.

It is also important to note that the varieties recording high score for germination index (> 80) belong mostly to the traditional *sali* and modern varieties. The *sali* rice varieties are, normally, sown during June-July when Assam experiences reasonably high temperature. It can, therefore, be assumed that environment-neutral mutant should be abundantly available in the rice germplasm of Assam and mass screening of the state's rice germplasm should allow identification of varieties with desired degree of low temperature tolerance at germination. The fact that several popular modern varieties like Ranjit, Basundhara and Gitesh showed desired degree of tolerance should

Table 1. Mean performances of the varieties for various cold tolerance indices

Varieties	Germination index (%)	Plumule length (mm)	Plumule greening score (1-9)	Leaf yellowing score (1-9)	Electrolyte leakage (C.per cent)	Chlorophyll a (ml/g)	Chlorophyll b (ml/g)	Total Chlorophyll (ml/g)
Guni ahu	80.00	4.50	3.00	4.00	6.44	1.68	0.79	2.47
Iharsal	0.00	4.00	5.00	4.00	4.86	2.28	1.39	3.67
Kolagoria	0.00	5.00	1.00	3.00	2.66	1.93	0.35	2.28
Bongaldoria	28.89	1.33	4.00	5.00	2.70	2.15	0.39	2.54
Dusri ahu	0.00	0.50	6.00	5.00	2.56	1.98	0.98	2.96
Gorupotia ahu	25.00	1.00	6.00	5.00	4.14	1.27	0.81	2.08
Malbhog	29.71	1.17	7.00	6.00	3.36	2.07	1.07	3.14
Goalbhog	50.00	1.17	5.00	4.00	5.08	1.71	1.04	2.75
Dubaichenga	84.61	8.33	1.00	5.00	2.50	2.40	0.73	3.12
As 313/4	13.33	3.50	4.00	3.00	2.35	2.83	0.59	3.42
Garumoina	47.50	4.17	1.00	5.00	3.16	2.37	0.71	3.09
Garem-1	60.00	4.67	6.00	5.00	6.20	2.01	0.38	2.39
Majeni chembi	0.00	1.67	7.00	4.00	1.79	2.00	0.38	2.39
Bairing	11.11	4.17	4.00	5.00	2.43	2.03	0.60	2.63
Bizor-2	20.00	1.17	6.00	4.00	2.84	2.17	0.28	2.45
Sorainokhia bora	32.50	8.50	6.00	5.00	5.33	1.60	0.36	1.96
Saudang bora 2	27.50	4.67	5.00	4.00	2.69	1.69	0.37	2.07
Ranga bora 2	56.11	8.17	5.00	5.00	4.61	1.76	0.60	2.36
Ranga bora	45.00	7.33	6.00	4.00	3.79	1.90	0.51	2.41
Khamti bora	20.00	4.83	8.00	5.00	3.15	1.41	1.22	2.63
Til bora	87.50	9.83	1.00	4.00	3.55	1.27	1.13	2.40
Jahinga	92.50	4.17	4.00	5.00	3.76	1.93	0.33	2.27
Satkora lahi	100.00	11.83	1.00	4.00	5.38	1.60	0.63	2.23
Sarkari lahi	87.50	10.67	3.00	4.00	6.78	1.28	0.75	2.03
Sail borak	97.50	9.67	6.00	6.00	2.73	2.03	0.60	2.63
Khoirajuli	92.50	5.00	3.00	5.00	2.76	1.10	0.06	1.15
Kanaimuluk	75.00	6.67	3.00	6.00	4.68	1.76	0.63	2.39
Baterueeri-2	32.50	5.00	8.00	6.00	6.43	1.58	1.09	2.66
Ahom Sali	28.16	4.33	3.00	5.00	4.60	1.49	0.77	2.26
Nirokadam	51.47	6.17	1.00	4.00	2.74	1.58	0.89	2.47
Khaja Sali	72.50	3.50	4.00	5.00	4.08	0.97	0.56	1.53
Dholamukh sali	90.57	7.50	1.00	4.00	3.18	1.59	0.34	1.93
Kumol Sali	92.50	3.50	4.00	4.00	3.11	1.98	0.63	2.61
Manohar Sali	30.00	3.33	1.00	4.00	5.48	1.57	0.50	2.07
Sial Sali	15.83	6.00	1.00	3.00	5.50	2.47	0.82	3.30
Hati Sali	41.94	4.83	2.00	4.00	3.79	1.98	0.54	2.52
Nolchuti	57.50	9.50	1.00	5.00	4.03	2.16	0.61	2.77
Kolamanik	0.00	2.50	4.00	5.00	4.71	0.66	0.56	1.22
Mokon boro	0.00	1.67	4.00	3.00	2.24	1.10	0.19	1.30
Jugli boro	0.00	1.33	5.00	5.00	3.13	1.60	0.31	1.91
Gaji boro	11.11	2.67	8.00	4.00	3.67	1.74	0.33	2.07
Khoiya boro	0.00	2.92	5.00	4.00	3.43	2.27	1.89	4.16
Kola boro	0.00	7.17	1.00	3.00	3.29	2.23	1.41	3.64
Lahi boro	52.50	10.00	1.00	4.00	2.52	1.32	0.45	1.77
Mahsuri	62.50	5.00	3.00	5.00	2.80	1.13	0.69	1.82
Bahadur	60.13	7.83	4.00	5.00	3.59	0.94	0.48	1.42
Prafulla	65.00	6.17	5.00	4.00	3.97	2.23	0.66	2.89
Gitesh	97.22	11.67	1.00	4.00	6.63	2.03	0.56	2.59
Keteki joha	65.00	6.83	2.00	4.00	2.59	1.99	0.67	2.66
Disang	92.50	5.83	1.00	5.00	3.14	1.39	0.38	1.77
Luit	59.50	6.17	1.00	5.00	5.69	1.20	0.36	1.56
Ranjit	100.00	13.00	3.00	5.00	3.56	1.80	0.47	2.27
Basundhara	95.00	10.17	1.00	5.00	3.71	0.76	0.24	1.00
Akitakomuchi	0.00	7.33	1.00	1.00	4.08	2.53	0.52	3.05
Nekken 2	55.00	7.50	1.00	1.00	3.77	2.17	0.62	2.79
Koshihikari	5.00	8.00	2.00	2.00	3.06	2.08	0.60	2.67
$CD_{0.05}$	7.89	1.97	1.79	1.85	1.73	1.03	NS	1.49

make the situation quite easy for breeding varieties with low temperature tolerance at germination.

In the present study, the varieties were assessed for germination index at low temperature following method of Krishnasamy and Seshu (1989) with small modification. The number of seeds germinated at 96 hours was taken in the study as the initial count instead of the count at 72 hours used in the original method. Considering the fact that only two varieties showed germination at 72 hours in the first trial of the present study the period for initial germination was extended to 96 hours for allowing better discrimination of the tested varieties for their response to low temperature stress at germination. More experiments will have to be conducted with diverse varieties to confirm the requirement of extending the time or otherwise.

Post-germination Evaluation

Plumule length varied from as low as just 0.5 mm (sign of germination only) to as high as 13 mm (Table 1). Ranjit with the highest plumule length (13 mm) was statistically at par with Satkora lahi (11.83 mm) and Gitesh (11.7 mm). Following these, other good performing varieties for plumule length were Sarkari lahi (10.67 mm), Basundhara (10.2 mm), Lahi boro (10.0 mm), Til bora (9.8 mm) and Sail borak (9.7mm) which were at par with Satkora lahi and Gitesh. The worst variety, Dusri ahu showed just sign of germination and was at par with 10 other varieties *viz,* Gorupotia ahu, Bizor-2, Malbhog, Goalbhog, Bongaldoria, Jagli boro, Majeni chembi, Mokon boro, Kolamanik, Gaji boro, recording plumule length less than 2.7 mm.

The *boro* rice varieties performed poorly for plumule length. At least three of them (Jagli boro, Mokon boro and Gaji boro) found place among the poorest of the varieties. Of course, Lahi boro and Kola boro could find place among the better performing varieties indicating variation among the *boro* varieties in this count. In this case also, the traditional *sali* varieties, *viz.*, Satkora lahi, Sarkari lahi, and Sail borak and the modern variesties, *viz.*, Ranjit, Basundhara and Gitesh performed better. Of course, early germination of these varieties might have positive impact on this trait as reflected from the significantly positive correlation between the two parameters (Table 2).

Altogether 18 varieties *viz.*, Akitakomuchi, Nekken 2, Koshihikari, Til bora, Sial sali, Luit, Disang, Nolchuti, Gitesh, Garumoina, Manohar sali, Nirokadam, Dalamukh sali, Lahi boro, Kola boro, Dubrichinga, Kolagoria, Satkora lahi scored 1 for plumule greening in a scale of 1-9. The worst among the varieties were Khamti bora, Baterueeri-2 and Gaji boro with average score of 8 which were at par with Malbhog, Majeni chembi, Gorupotia ahu, Garem-1, Dusri ahu, Bizor-2, Sorainokhia bora, Ranga bora and Sail borak with score of 6-7 (Table 1). Plumule greening has been suggested as a selection criterion for chilling tolerance in a range of di- and monocotyledonous species (McWilliam *et al.*, 1979) including rice (Sthapit and Wilson, 1992; Sthapit and Witcombe, 1998). In the present study, all the three *japonica* varieties, known to be cold tolerant, had score of 1 confirming the usefulness of the parameter to screen rice varieties for tolerance to low temperature stress.

Notably, only two *boro* rice varieties, Lahi boro and Kola boro, were found to be tolerant to low temperature stress with plumule greening score of 1 indicating that the traditional *boro* rice varieties as a class could not generally be considered cold tolerant contrary to the general belief. On the other hand, several traditional *ahu, sali* and modern varieties exhibited high degree of clod tolerance indicating that the varieties with tolerance to low temperature stress might be randomly distributed across the classes and subclasses of Assam rice germplasm.

The plumule greening score had significant correlation ($r = -0.48$) with plumule length. It was, of course, as expected since ability of a variety to rapidly synthesize chlorophyll under chilling stress should lead to its quicker plumule growth as reported earlier also (Sthapit and Wilson, 1992).

Evaluation at Seedling Stage

Leaf yellowing is one of the earliest symptoms of cold temperature damage in rice during the vegetative stage (IRRI, 1982). In the present study, the *japonica* varieties Nekken 2 and Akitakomuchi scored 1 for leaf yellowing in the scale of 1-9 and appeared to be the most tolerant to low temperature stress during seedling stage of growth. Six more varieties *viz.*, Koshihikari (*japonica*), Kolagoria, Sial sali, Mokon boro, Kola boro and As 313/4, with score 3 (Table 2), were at par with the top ranking *japonica* varieties. Among the 53 *indica* varieties of Assam, only 5 varieties exhibited high degree of tolerance to low temperature stress with leaf yellowing score less than 3. Again, these 5 varieties belong to different growing seasons and classes leaving no scope to consider any class of varieties to be superior to the others in respect of their response to low temperature stress at the seedling stage of growth like that in the germination and post-germination stage. In the study, however, none of the varieties scored 9 for leaf yellowing indicating that temperature lower than what was experienced during the period of study would have probably allowed better discrimination among the varieties at the seedling stage of growth.

Among numerous screening procedures applied to evaluate chilling sensitivity at various stages of growth, the most widely used technique consists of direct exposure of plants to chilling followed by visual damage assessment though some subjectivity, is sometimes associated with visual rating systems. Leaf yellowing score is one of such techniques most widely used for screening rice plants for their response to low temperature stress at the vegetative stage of growth. However, a reliable laboratory based screening technique would certainly be of significant utility for evaluation of large number of varieties and breeding materials. In this context, plumule greening may be considered as a useful method. The significant positive correlation ($r = 0.30$) of this parameter with leaf yellowing score (Table 2) enhances its importance as a screening criterion for low temperature tolerance as it would be easier to employ this criterion much earlier at the laboratory without the influence of temporal variation of field temperature.

The variety with the least electrolyte leakage (1.79 %) was Majeni chembi which was *at par* with 25 more varieties drawn from different classes and subclasses of Assam rice. The variety showing the highest electrolyte leakage (6.78%) was Sarkari lahi. This variety was *at par* with 9 other varieties *viz.*, Gitesh, Guni ahu, Baterueeri-2, Garem 1, Luit, Sial Sali, Manohar Sali, Satkora lahi and Sorainokhia bora (Table 1). This result, however, did not show correspondence with the result obtained with the application of leaf yellowing score. This was reflected by non-significant correlation coefficient ($r_g = 0.06$) between the two parameters (Table 2). Even, the *japonica* varieties Akitakomuchi, Nekken 2 and Koshihikari with electrolyte leakage of 4.08%, 3.77% and 3.06%, respectively seemed susceptible to low temperature stress based on this parameter though the same varieties exhibited very high degree of cold tolerance at post-germination and seedling stages of growth based on plumule greening and leaf yellowing score, respectively.

At low temperature, chlorophyll content tended to decrease in rice leaves (Baruah and Medhi, 1993). Yoshida *et al.* (1996) reported that chlorosis, where the newly emerging leaves lack chlorophyll, is a symptom of cold injury at the seedling stage of rice. The variety As 313/4 (2.83 ml/g of fresh weight) and Kolamanik (0.66 ml/g of fresh weight) recorded the highest and lowest amount of Chlorophyll a content. The best variety As313/4 was *at par* with 27 other varieties. With 4.16 ml/g of fresh weight, Khoiya boro hade the highest total chlorophyll content which was at par with 14 other varieties *viz,* Akitakomuchi, Iharsal, Kola boro, As 313/4, Sial Sali, Malbhog, Dubrichinga, Garumoina, Koshihikari, Dusri ahu, Prafulla, Saudang bora 2, Sorainokhia bora and Nekken 2 (Table 1). This result, unlike the one obtained with electrolyte leakage, maintained very good correspondence with the result obtained with leaf yellowing score, which was also reflected by significant correlation ($r_g = -0.30$) between the two parameters. Apparently, in this study, electrolyte leakage could not prove itself as a suitable parameter for evaluating a variety for its tolerance to low temperature stress.

Table 2. Estimates of genotypic correlation coefficient (r_g) (upper diagonal) and phenotypic correlation coefficient (r_p) (lower diagonal) for cold tolerance parameters

Traits	Germination index (%)	Plumule length (mm)	Plumule greening score	Leaf yellowing score	Electrolyte leakage	Chl. a	Chl. b	Total Chl.
Germination index	1	0.61**	-0.35**	0.39**	0.26	-0.40**	-0.85**	-0.46**
Plumule length	0.59**	1	-0.54**	-0.10	0.28	-0.01	-0.10	-0.05
Plumule greening score	-0.32*	-0.48**	1	0.52**	-0.05	-0.06	0.33*	0.09
Leaf yellowing score	0.26	-0.08	0.30*	1	0.06	-0.55**	0.51**	-0.17
Electrolyte leakage	0.20	0.22	-0.02	0.13	1	-0.32*	0.47**	-0.03
Chlorophyll a	-0.20	-0.09	0.03	-0.30*	-0.07	1	0.62**	0.95**
Chlorophyll b	-0.20	-0.09	0.07	-0.14	0.05	0.19	1	0.84**
Total Chlorophyll	-0.25	-0.11	0.06	-0.30*	-0.02	0.84**	0.69**	1

*Significant at 5 per cent level of significance, **Significant at 1 per cent level of significance

Diversity in the Rice Varieties

The Eucledian coefficient of dissimilarity between 56 rice genotypes in all possible combinations based on 8 morpho-physiological parameters used for evaluation of rice varieties for their response to low temperature stress showed that the average dissimilarity coefficient was 3.88 across all the 56 genotypes. Maximum coefficient of dissimilarity was observed between Basundhara and Khaiya Boro (8.61). These two varieties differed greatly for almost all the traits except leaf yellowing score and electrolyte leakage. The difference between these two varieties was particularly wide for germination index, plumule length and plumule greening score indicating that these parameters mainly contributed to place the two varieties so apart from each other. The minimum coefficient of dissimilarity was observed between Kumol sali and Jahinga (0.60).

The diversity analysis based on Eucledian distance separated the 56 varieties into two distinct clusters and placed one variety Mokon boro distinctively away from both the groups of varieties. The larger cluster 'A' comprised of 46 genotypes and the smaller cluster 'B' comprised of 9 genotypes (Fig. 1). The larger cluster A could further be classified into two sub-clusters 'A_1' and 'A_2' comprised of 31 and 15 varieties, respectively. All these clusters and sub-clusters included the varieties from all the rice seasons and classes. Incidentally, all the three *japonica* varieties fell in the smaller cluster 'B' along with six *indica* varieties drawn from all the three rice seasons of Assam. The result clearly exhibited the closer relationship among the *japonica* varieties in respect of their response to low temperature stress. At the same time, the result also clearly indicated that there was no cohesive relationship among the varieties of any specific class or

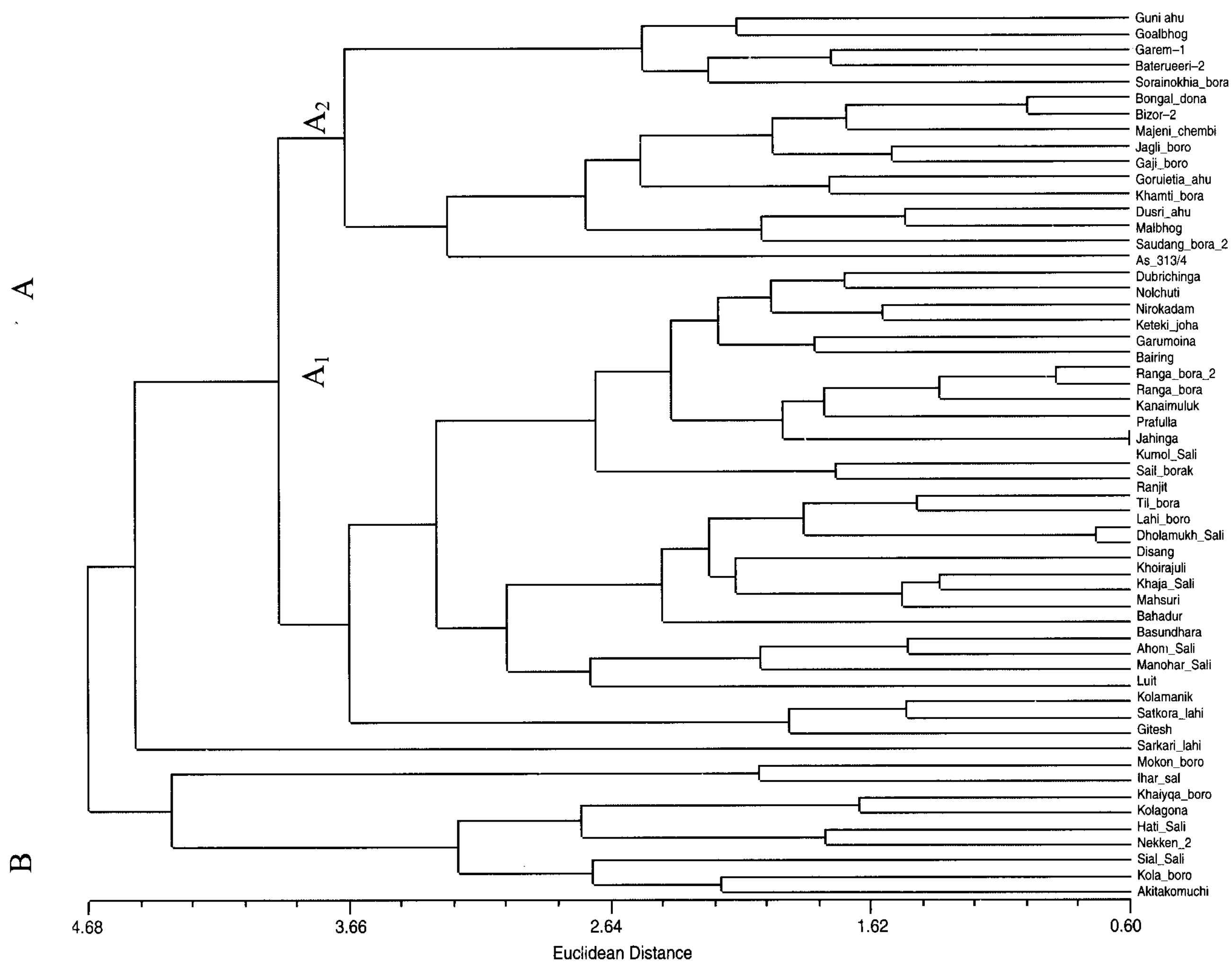

Fig. 1: *Dendrogram of 56 rice varieties based on Euclidean distance*

sub-class of Assam rice in respect of their response to low temperature stress. Even, the traditional *boro* rice varieties of Assam, which constitute a small seasonal group based on their cultivation by the farmers, over generations, in the low temperature affected *boro* season, did not fall in the same cluster.

Conclusion

Among the 53 rice varieties of Assam, the varieties showing tolerance to low temperature stress at different growth stages were found to be distributed across different seasons, classes and sub-classes leaving little scope to consider any class of varieties to be particularly good in respect of their response to low temperature stress. This clearly suggests that a thorough search in the rice germplasm of Assam would allow to identify varieties with desired degree of tolerance to low temperature stress at early growing stages for utilization in the breeding program for improvement of the *boro* rice of Assam. It has also been observed that same set of varieties did not show tolerance to low temperature stress at different stages of growth indicating that different gene systems might be involved with the varietal response to low temperature stress at different growth stages needing use of multiple parental sources for breeding varieties with tolerance to low temperature stress at different stages of growth. The varieties Ranjit, Gitesh, Basundhara and Disang among the improved varieties and Satkora lahi, Sail borak, Sial Sali, Kolagoria, Lahi boro, Kola boro, Mokon boro etc. among the traditional varieties were found to be tolerant to low temperature stress at more than one stage of growth. All the three *japonica* varieties proved themselves to be highly tolerant to low temperature stress at post-germination and seedling stages of growth.

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