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Genetic Diversity with respect to thermal indices and grain yield in cultivated rice

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ABSTRACT

Rice (Oryza sativa L.) is the leading cereal crop of the world which is consumed by more than 55 % of the global population. To feed the increased population, as per an estimate, 50 % of more rice will be required by 2050. Keeping in view the present level of productivity growth this has been a challengingtask based on the existing approaches. In recent years along with conventional yield component traits, emphasis has been laid on some physiological and related meteorological indices to achieve a further gain in selection. This investigation aimed at studying genetic diversity in a set of 58 rice germplasm of Assam for some conventional yield traits as well as traits related to thermal indices. The investigation was carried out during the Kharif season of 2020 at the experimental field of Biotech Hub, Biswanath College of Agriculture. Data were recorded on eleven agro- morphological characters and three thermal indices. Analysis of variance indicated that GCV was highest for filled grains per panicle followed by total grains per panicle and yield per plant. Based on Mahalanobis' D2 - statistics, all the genotypes were grouped into six diverse clusters. The maximum number of genotypes wasincluded in cluster IV followed by cluster VI. The intra-cluster distance ranged from 8.57 in cluster I to 313.79 in cluster V. The maximum inter-cluster distance was exhibited between clusters V and VI (1082.8), followed by cluster III and VI (752.43). Cluster I and II (53.63) exhibited the minimum intercluster distance. Based on the per se performance of the genotypes and considering their location in diverse clusters, Luit (lowest days to 50 % flowering), BiriyaBhonga Bao (highest 100-grain weight, biological weight), Maizubiron (highest heat use efficiency), Konguti (highest total and filled grains per panicle) and Boga joha (highest GDD and HTU) were identified promising for undertaking hybridization programme. An efficient hybridization programme formulated among these parents is expected to yield desirable segregants for their further utilization in the breeding programme.

Keywords: *Rice, Genetic Diversity, Thermal Indices, Grain yield, Parents for hybridization*

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INTRODUCTION

Rice (*Oryza sativa* L) is a heat-loving hydrophyte and is the staple food crop for more than 55 % of the global population. It is the principal cereal crop in south-east Asian countries, where 90 % of the world's rice production is consumed (1). Rice is cultivated all over the world in highly diverse global rice environments from 50°N to 35°S and it is well adapted to areas from below sea level to as high as 3000 m from msl(2).

Rice production in the country of India has increased more than six-fold from 20.54 mt (3) in 1950 to 124 mt currently (4). The green revolution technology and the hybrids in recent years have contributed to a large extent to this achievement. However, it has been projected that 50 % more rice will be needed by 2050 to feed the growing population(5). This is very challenging for plant breeders. Conventionally, plant breeders aim at combining the grain yield and its component traits from different genetic backgrounds. However, conventional trait-based breeding has attained at the plateau of productivity, and here lies the need for searching for new traits and approaches.

Temperature plays a crucial role in crop growth and development. In other words, heat energy captured by the plant canopy has relevance in crop growth and yield. Genotypic variability in rice with respect to heat use efficiency has been reported (6). In this light, the temperature being a crucial factor of crop growth, there is the scope of investigating the diversity in crop genotypes concerning heat use efficiency as well.The heating unit is used in the assessment of the yield potential of a crop in different weather conditions and also can explain the direct and linear relationship between growth and temperature (7). To study the extent and comparative utilization of these resources, some weather-based agro-meteorological indices have been developed. Growing degree days (GDD), Helio-thermal units (HTU), and Heat Use Efficiency (HUE) are the most commonly used thermal indices that relate the crop growth and development.

Genetic diversity is the foundation of the genetic improvement of any crop based on hybridization. It is an important tool for a crop improvement programme, as it helps in the development of superior recombinants (8). Genetic diversity with respect to the traits of concern needs to be assessed before undertaking a crop improvement programme. Owing to the limitations of conventional trait-based breeding as experienced by the yield plateau, new traits need to be explored. Therefore, we realised that there is scope of investigating the diversity in ricegenotypes with respect to heat use efficiency. Attempts of scientific investigations in this aspect have been very meagre. Identification of genotypes exhibiting diversity with respect to thermal indices would help frame new criteria for genotypic selection and hybridization programme to overcome the yield plateau attained based on conventional trait-basedbreeding. Keeping this in view, we undertook an analysis of diversity for thermal indices and grain yield in a set of rice cultivars of Assam.

MATERIALS AND METHODS

The present experiment was carried out at the experimental field of Biotech Hub, Biswanath College of Agriculture, AAU, BiswanathChariali, during 2020-21. The experimental site is situated at latitude and E and 30'W longitude having an altitude of 104 m above mean sea level (MSL). The materials for the present investigation consisted of a set of fifty-eight winter rice cultivars representing different maturity durations, ecological habitats, and varietal groups, collected from farmers' fields indifferent parts of Assam. Sowing was done during June 2020. The observations were recorded on ten randomly sampled competitive plants from each plot in all three replications for nine quantitative traits *viz*., Plant height (PH), Panicle length (PL), Effective tillers per plant (ET), Total grains per panicle (TG), filled grains per panicle (FG), Spikelet fertility (SF), 100-Grain weight (GW), yield per plant (YP), and biological yield (BY). Observations on Days to fifty *percent* flowering (DF), and Days to maturity (DM) were recorded on a plot basis. The three thermal indices related to crop growth,*viz*., Growing Degree Days (GDD), Helio-thermal Unit (HTU), and Heat Use Efficiency (HUE) were calculated from both morphological and meteorological data. The weather parameters for the crop growing period were obtained from the meteorological observatory, Biswanath College of Agriculture. Growing degree days werecomputed with 10°C as the base temperature based onthe daily mean temperature with the help of the following formula:

GDD = Σ [(Tx + Tn) / 2 – Base temperature]

Tx= Daily maximum temperature
Tn= Daily minimum temperature.

Helio-Thermal Unit (HTU) is calculated by multiplying GDD with bright sunshine hours

HTU = GDD × n

Where, n = bright sunshine hour
Heat Use Efficiency (HUE) (kg ha-1 degrees-day) was calculated with the help of biomass (g/m2) per GDD by the following equation:

HUE (g/m2/°day) = Biomass (g/m2)/GDD (degree days).

All the collected data were subjected to analysis of variance as per RBD followed by testing of Wilk's criterion. Mahalanobis' D^2- analysis (9) was carried out to assess the genetic divergence among the set of 58 genotypes with respect to the yield, yield attributes, and meteorological indices. The inter se D^2 values were used for further clustering of genotypes based on Tochers' method followingRao(10) and Singh and Chaudhury(11).

Table 1: Analysis of variance of eleven agro-morphological and three agro-meteorological indices.

Sl.	Characters	Mean sums of squares			Treatment-F value	CV (%)
		Replica-tion	Treatment	Error		
1	Days to 50% flowering	2.11	844.15	4.33	194.89	1.89
2	Days to maturity	1.396552	761.34	3.033979	250.9389	1.22
3	Plant height	63.85613	1957.12	54.323999	36.0269	4.89
4	Panicle length	0.494504	27.24939	1.380075	19.7449	4.29
5	Effective tillers	0.095313	12.39688	0.381176	32.5227	6.71
6	Total grains per panicle	91.71719	5066.14855	85.502133	59.2517	7.1
7	Filled grains per panicle	3.049036	4814.3937	76.761052	62.7192	8.22
8	Spikelet fertility	49.81104	146.743477	33.290349	4.408	7.81
9	100-grain weight	0.001106	0.395131	0.000541	729.8051	1.06
10	Yield per plant	0.648347	87.279102	3.374354	25.8654	9.74
11	Biological yield	11.45254	510.382654	5.857197	87.1377	4.85
12	Growing Degree Days	2679.603	143463.994	2531.369	56.6745	1.99
13	Helio-thermal Unit	4641.528	7770806.85	29368.321	264.5983	1.5
14	Heat Use Efficiency	0.301318	8.764206	0.118994	73.6526	5.26

Analysis of variance and genetic diversity was computed by using the latest version of the software Indostat. The genotypes were grouped into different clusters, intra and inter-cluster distance, mean performances for characters, and their contribution to the divergence were also compared.The ranking was done based on cluster mean, highest (1st) to lowest (5th) except for DF and DM where the highest mean is given a score (5th) and the lowest mean is given a score (1st). The overall score is the summation of the rank number for all the characters.

RESULTS AND DISCUSSION

Analysis Of Variance

In the present investigation, analysis of variance indicated (Table 1) significant differences for all the eleven agro-morphological and three agro-meteorological traits under study as well. This means, there were highly significant differences among all the fifty-eight genotypes of rice under study and there was ample scope for the selection of desirable genotypes. Significant differences among rice genotypes for meteorological indices were also observed by Kumar*et al.* (12). The presence of significant variability in the genotypes under study for yield as well as the meteorological indicesindicatedthe scope of selection not only for the conventional yield traits but also for the meteorological indices. Significant variances for the above yield traits under study were also observed by Sarma*et al.* (13); Parashar *et al.* (14) and Das *et al.* (15) and several other workers.

Estimation of genetic divergence and clustering of genotypes

Following the analysis of variance, Wilk's criteria for genetic variability was assessed which indicated the worth of the data for further genetic diversity studies with D^2 statistics. In the present investigation, fifty-eight rice germplasmwastaken for diversity analysis which differed significantly displaying remarkable divergence with regard to the yield traits and thermal indices under study. All the entrieswere grouped into six different clustersfollowing Mahalanobis'sD^2 -analysis. The compositions of the clusters are presented in table 2, and Fig1 (Dendogram). Two entries were present in Cluster I, five entries in cluster II, eight in cluster III, twenty-seven were in cluster IV, eight in cluster V and nine entries were included in cluster VI. The genotypes within each cluster were closer to each other than the genotypes in different clusters. These clusters were formed by grouping all 58 rice genotypes in such a way that genotypes within each cluster had smaller D^2 -values than in other clusters.

The inter- cluster and intra- cluster D^2 values are

Table 2: Clustering Pattern of 58 rice genotypes evaluated for character associated with grain yield and thermal indices.

Cluster	Number of entries	Genotypes
Cluster I	2	Baismuthi, NV-1
Cluster II	5	XoruJahingia, Vasudev, Ranjit, Nagheri bao, Bishnuprashad
Cluster III	8	Hackey Nagaland, Sangmohini, Betguti, Boga aijung, Machuri, Gopinath, Boga joha
Cluster IV	27	SokNaka, Sokjonthi, InglongABara, Mala, NavinDhan, Maibee, Vandana, JoraDhan, Inglongkirijoha, NBR-1, Sekamoiphou, Maibelai, Jaya, Mukunda, ManiouriJoha, Sluna, Swarna sub-1, Joha, Bahadur, Sahabhagi, ManuharSali, Suwagmoni, BiyoiSali, SokBangtuk, Joybangla, Haccha, Bairing
Cluster v	8	Maizubiron, Karbidhan, SokRangpi, SokSoiSoi, MairenSanglok, Konguti, Luit, Kola Joha
Cluster VI	9	HatiSali, Bokul, Joldubi, BorJahingia, Black rice, Malbhog Dhan, Mohan, Karbisanglok, BiriaBhonga Bao

Table 3: Average intra and inter cluster distances for characters related to yield and thermal indices in 58 rice germplasms.

Clusters	Clusters I	Clusters II	Cluster III	Cluster IV	Cluster V	Cluster VI
Cluster I	**8.57**	53.63	263.79	135.31	514.36	205.25
Cluster II	53.63	**43.31**	228.06	208.36	523.65	277.02
Cluster III	263.79	228.06	**98.16**	299.66	251.16	752.43
Cluster IV	135.31	208.36	299.66	**184.15**	454.5	396.57
Cluster V	514.36	523.65	251.16	454.5	**313.79**	1082.8
Cluster VI	205.25	277.02	752.43	396.57	1082.8	**171.74**

NB: Diagonal values are the respective intra-cluster values of different clusters

Table 4: Cluster mean values of six clusters of fourteen different yield parameters and thermal indices in rice.

Cluster	DF	DM	PH	PL	ET	TG	FG	SF	GW	GY	BY	GDD	HTU	HUE	Over-all score	Rank
I	117	147.3	137.3	27.9	10.39	130.8	114.5	87.6	2.34	23.33	57.87	2601	11908	7.34	39	3rd
	(3)	(3)	(6)	(3)	(1)	(4)	(3)	(1)	(2)	(1)	(2)	(4)	(4)	(2)		
II	127.07	159.7	167.2	30.07	10.23	138	114.6	80.59	2.22	22.77	62.4	2741	13102	7.51	34	1st
	(5)	(6)	(2)	(1)	(2)	(2)	(2)	(3)	(4)	(3)	(1)	(1)	(1)	(1)		
III	117.1	149	152.6	26.76	9.74	137.1	111.9	80.36	1.77	19.13	55.58	2611	12017	7.02	51	4th
	(4)	(4)	(3)	(5)	(3)	(3)	(4)	(4)	(5)	(4)	(3)	(3)	(3)	(3)		
IV	104.46	137.8	140.4	26.34	9.03	122	98.66	79.79	2.23	17.65	44.02	2459	10896	5.98	65	5th
	(2)	(2)	(5)	(6)	(5)	(5)	(5)	(5)	(3)	(5)	(6)	(5)	(5)	(6)		
V	96.13	129.46	146.1	27.67	7.91	117.1	94.03	77.84	1.69	14.43	48.81	2325	10033	6.94	67	6th
	(1)	(1)	(4)	(4)	(6)	(6)	(6)	(6)	(6)	(6)	(5)	(6)	(6)	(4)		
VI	121.81	153.9	177.7	28.8	9.62	156.7	130.9	82.12	2.7	22.97	55.04	2665	12509	6.86	38	2nd
	(6)	(5)	(1)	(2)	(4)	(1)	(1)	(2)	(1)	(2)	(4)	(2)	(2)	(5)		

NB: the figures in parentheses are the rank of cluster with respect to mean values of the concerned traits.

Table 5: Three best genotypes with their per se performance and location in clusters along with GCV and contribution toward divergence for specific traits.

Traits	GCV	Rank of genotype	Genotype	*Per se* perfomance	Belonging to cluster
DF	15.22	1st	Luit	71	V
		2nd	Bairing	83.67	IV
		3rd	Joy bangla	86	IV
DM	11.14	1st	Luit	106	V
		2nd	Bairing	114.33	IV
		3rd	Haccha	119.33	IV
PH	16.72	1st	Biriyabhonga bao	192.79	VI
		2nd	Joldubi	192.31	VI
		3rd	Malbhog	192.1	VI
PL	10.74	1st	Bishnuprashad	33.3	II
		2nd	Biriyabhonga bao	32.98	VI
		3rd	Nagheri bao	31.88	II
ET	21.75	1st	Manipuri Joha	13.36	IV
		2nd	Sahabhagi	13.3	IV
		3rd	Borjahingia	12.48	VI
TG	31.30	1st	Konguti	211.84	V
		2nd	Joha	208.88	IV
		3rd	Biriyabhonga bao	201.88	VI
FG	37.30	1st	Konguti	185.86	V
		2nd	Joybangla	183.32	IV
		3rd	Joha	182.73	IV
SF	7.66	1st	Joybangla	90.81	IV
		2nd	Ranjit	90.47	II
		3rd	Baismuthi	90.2	I
GW	16.66	1st	Biriyabhonga bao	2.93	VI
		2nd	Mohan	2.92	VI
		3rd	KardiSanglok	2.77	VI
GY	28.06	1st	Ranjit	29.47	II
		2nd	Biriyabhonga bao	28.23	VI
		3rd	BorJahingia	27.55	VI
BY	26.02	1st	Biriyabhonga bao	73.73	VI
		2nd	Konguti	71.54	V
		3rd	Gopinath	70.37	III
GDD	8.60	1st	Boga joha	2801.3	III
		2nd	BiyoiSali	2793.5	IV
		3rd	Bokul	2787.5	VI
HTU	14.11	1st	Boga joha	13506	III
		2nd	BiyoiSali	13436	IV
		3rd	Bokul	13417	VI
HUE	25.91	1st	Maizuniron	9.35	V
		2nd	Konguti	9.13	V
		3rd	Haccha	9.03	V

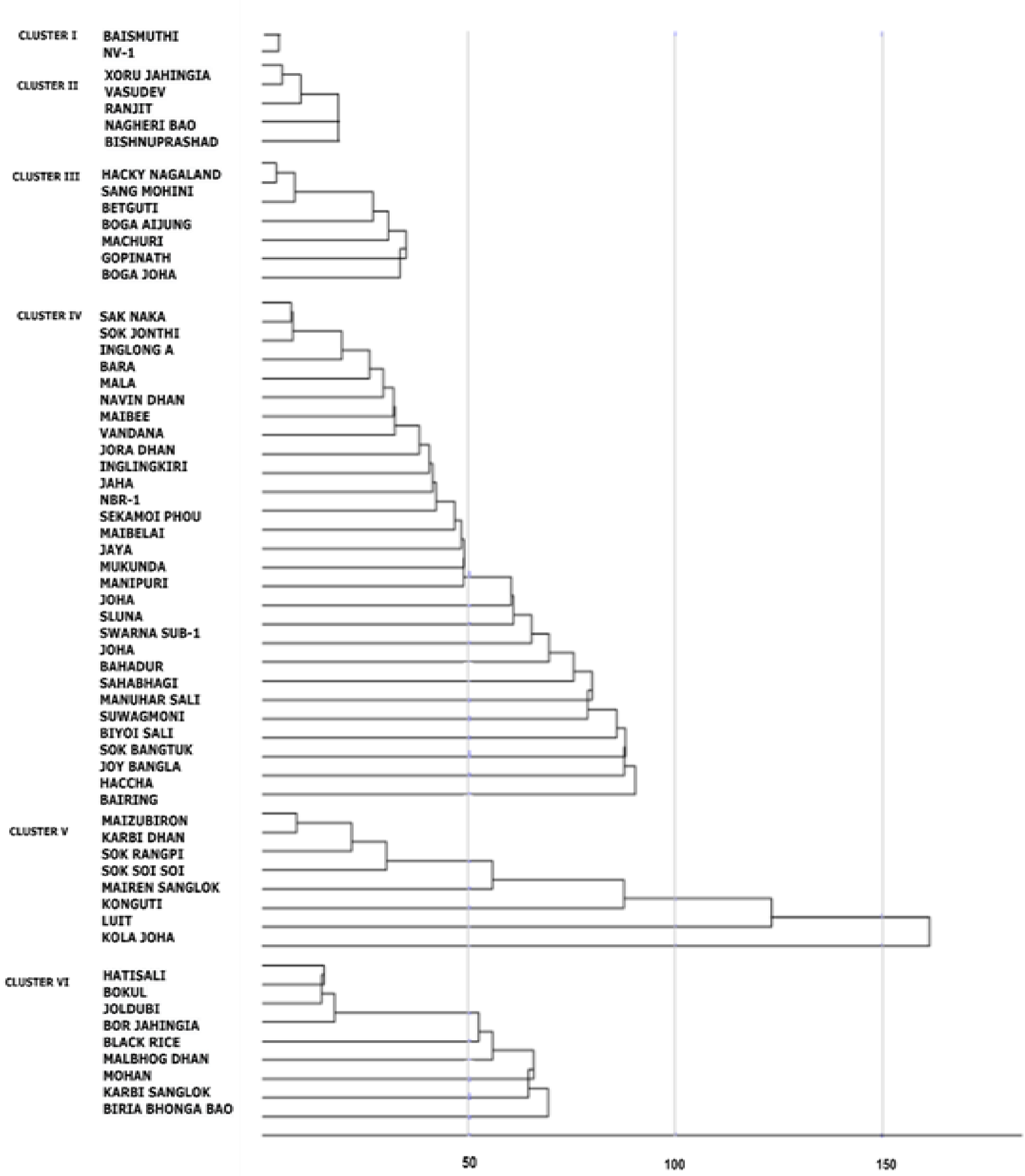

Fig 1: Dendrogram of 58 rice germplasm based on Cluster constructed by Tocher's method.

presented in Table 3 and Fig, 1. The intra cluster distances ranged from 8.57 in cluster I to 313.79 94 in the case of cluster V. The maximum inter-cluster distance was observed between clusters V and VI (1082.8), indicating maximum inter-varietal genetic diversity between the entries belonging to these two clusters. Thus, genotypes in these clusters may be utilized for inter-varietal hybridization programme and intercrossing between them would yield better recombinants. The second highest divergence was exhibited by cluster III and VI (752.43) which was followed by clusters II and V (523.65). Clusters that exhibited the minimum inter-cluster distance was in between I and II (53.63). Crosses made between the genotypes belonging to diverse clusters are likely to yielddesirable segregants. To get more variability and more heterotic effect selected parents should be from two different clusters having more inter-cluster distance.

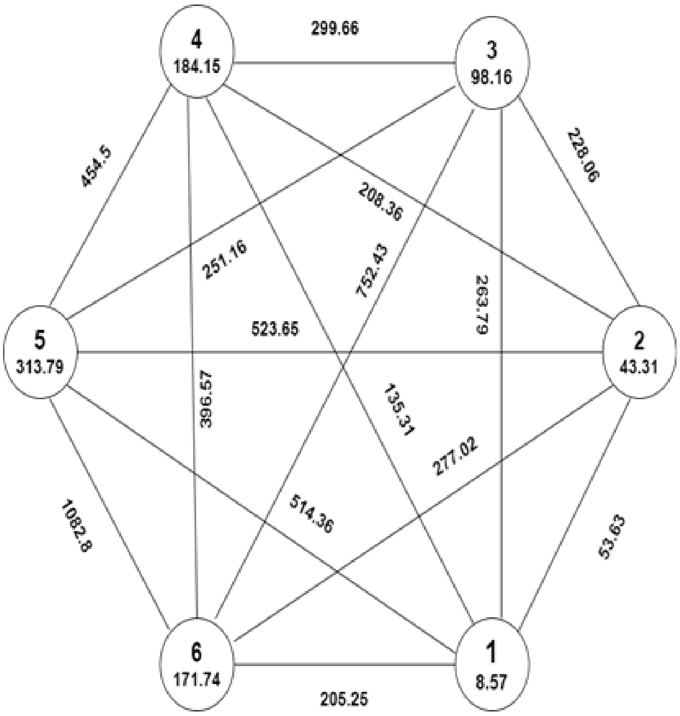

Fig 2: Mahalanobis' Inter se distance (Inter and intra –cluster D2 values.

Cluster mean values for different traits and Cluster ranking

Cluster mean values and their ranking is presented in Table 4. Based on accumulated ranking, clusters II, VI, and I, were ranked 1st, 2nd, and 3rd, respectively. Cluster II with 1st rank was also ranked first with respect to all the thermal indices,this indicated the importance of genotypes belonging to this cluster for the higher values of thermal indices. Moreover, cluster II being considerably diverse from other clusters, the importance of the thermal indices could be understood in exhibiting the diversity. Among the yield attributes, biological yield, grain weight, maturity duration, plant height, total grains and fertile grains per panicle were shown to contribute significantly towards divergence.

Genetic diversity and selection of parents for hybridization

Choice of parents based on*per se* performance along with cluster distances (Table 5) is one of the simplest ways the selection of superior genotypes (16). Genotypes with high *per se* performance would be useful as parents for selecting better offspring in any hybridization programme (17). Thus, it could be emphasised that undertaking a crossing programme between superior genotypes having high *per se* performance and belonging to the diverse clusters having higher *interse* D^2-value would yield desirable transgressive segregants for developing high-yielding varieties.

Genotypes identified for grain yield and yield attributes for hybridization

Based on the *per se* performance and *inter se*distance(Table 5), Luit (lowest days to 50% flowering), Konguti (highest effective tillers per plant) from cluster V can be utilized in a crossing programme with BiriyaBhonga Bao (maximum plant height, 100-grain weight, biological weight) from cluster VI, as cluster V and cluster VI had the maximum inter-cluster distance. Therefore, hybridization between BiriyaBhonga Bao with Luit would yield short-duration heteroticsegregants. Ranjit (Highest grain yield) from cluster II could be crossed with Luit (Lowest days to 50 % flowering) from cluster V to get high-yielding, early maturing segregants as cluster II with the best promising genotypes have the highest inter-cluster distance with cluster V.

Thermalindices, genotypic diversity and selection of genotypes for hybridization

Influence of components of meteorological indices like temperature on phenology and yield of crop plants can be studied under field conditions through accumulated heat units or Growing Degree Days (GDD). Plants require a definite range of temperature to complete different phenophases(18) and thermal accumulation study helps in estimating heat unit requirement and use by specific phases of the crop. Accumulation of heat units is related to phenological development from sowing to maturity. Different rice cultivars use different amounts of thermal units for their growth and development (19). The heating unit is used in the assessment of the yield potential of a crop in different weather conditions and also can explain the direct and linear relationship between growth and temperature (7). Heat and photoperiodic units are considered fundamental units used to examine the phenology of crops over climatic variations (20, 21). The helio thermal unit (HTU) is used to quantify the effect of temperature and describes the timing of different biological processes (22, 23). On the other hand, heat use efficiency (HUE) depicted the heating unit utilized to produce one unit of plant biomass (24). The quantification of Heat Use Efficiency (HUE) is useful for the assessment of the yield potential of a crop in different growing environments (25). Heat use efficiency, i.e., the efficiency of utilization of heat in terms of dry matter accretion, depends on crop type, genetic factors & sowing time & has great practical application (26). Temperature-based agro-meteorological indices such as growing degree days (GDD) and Heat Use Efficiency (HUE) are quite useful in predicting the growth and yield of different crop genotypes. Thus, it is imperative that genotypes differ with respect to thermal indices and the study of genetic diversity with respect to traits related with thermal indices could be meaningful.

In this investigation genotypic diversity with respect to three thermal indices was elucidated. The rice genotypes were not only diverse for the yield and yield attributing traits but also diverse with respect to thermal indices. Significance of variance, and considerable magnitude of genotypic coefficients of variation are indicative of the role of thermal indices in cultivar diversity respect to thermal indices. The clustering pattern, the ranking of clusters with respect to the thermal indices as discussed above further elucidated the importance of the meteorological indices in relation to genetic divergence. *Inter se* genetic diversity along with desirable values of thermal indices in conjunction with consideration of genotypic values for other yield traits could be a meaningful proposition for planning crop improvement programme. In this light several genotypes were brought out by analysing the above parameters for inclusion in the hybridization programme (Table 5). Maizubiron (Highest heat use efficiency) from cluster V could be crossed with BiriyaBhonga Bao from cluster VI. Again, Boga Joha (highest growing degree days and helio-thermal unit) from cluster II could be crossed with Maizubiron (highest heat use efficiency) from cluster V to get all the heterotic combinations for agro-meteorological indices. Also, Konguti (highest total and filled grains per panicle) and Luit (lowest days to 50 % flowering) from cluster V could be crossed with Boga Joha (highest growing degree days and helio-thermal unit) from cluster II to produce better recombinants as cluster II had the highest rank (1st), indicating the presence of most promising genotypes in it.The variety Maizubiron was identified with the highest mean value for heat use efficiency which belonged tocluster V and Ranjit belonging to cluster II had the highest grain yield per plant. So, there may be a crossing programme in between these genotypes to get segregants with better HUE and more grain yield per plant.

The elucidation of genetic diversity with respect to yield and the thermal indices, thus, could be a useful guide for breeding genotypes resilient to climate change. While considering the *inter se* genetic diversity, the *per se* performance of the genotypes for various traits should also not to be overlooked. Therefore, judicious planning to combine high-yielding attributes along with efficiency with respect to thermal indices could result in further yield improvement under changing climatic variables, particularly the temperature.

CONCLUSION

The study revealed significant variability and genetic diversity in the set of 58 rice cultivars of, Assam India with respect to grain yield and associated traits along with thermal indices. The findings indicated that genotypes exhibited considerable diversity with respect to thermal indices as well and, therefore,selection of genotypes based on genetic diversity and the *per se* values of thermal indices could be possible. Appropriate crossing programmes based on the selected genotypes were suggested for further improvement of rice genotypes based on yield, yield components, and thermal indices. Consideration of thermal indices in genetic diversity studies, and selection of genotypes for hybridization will add a new dimension in respect of breeding for efficiency of thermal indices.

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