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SHORT RESEARCH ARTICLE

Use of thermal indices as selection criteria in breeding programme of rice (*Oryza sative* L.)

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Abstract

A set of 58 rice cultivars from Assam were studied to investigate the thermal indices and yield components as the selection criteria. Significant genetic variation was observed for the three thermal indices studied. Estimation of variability parameters indicated high heritability coupled with high genetic advance for the three thermal indices, *viz.,* Growing Degree Days (GDD), Helio-Thermal Units (HTU) and Heat Use Efficiency (HUE) along with grain yield and other yield components. Grain yield was observed to be contributed positively and significantly by the three thermal indices in specific growth intervals apart from other yield components.

Keywords: Rice, thermal indices, genetic parameters, character association, selection criteria

Rice (*Oryza sativa* L.) is a heat-loving hydrophyte, the staple food crop for more than half of the global population. It is the principal cereal crop in south-east Asian countries. It is projected that global rice production must be increased by more than 50% to feed the growing population by the year 2050 (Singh 2022). Owing to the presently experienced yield plateau, it is required to target further yield improvement by identifying newer traits associated with grain yield (Anand et al. 2016). Yield is dependent on various factors, like morpho-physiological traits and response to various environmental factors. Temperature and photoperiod are the major environmental factors that determine crop phenology, total photosynthesis, and ultimately yield (McMaster 2018). Many agro-meteorological indices influencing the crop's phenology, development and performance are known. The influence of temperature on phenology and yield of crop plants can be studied under field conditions through accumulated heat system and the growing degree days (GDD) (Chakraborty and Sastry 1983; Bisoin et al. 1995), Helio-Thermal Units (HTU) and heat use efficiency (HUE) are the most commonly used agro-meteorological indices (Chaudhari et al. 2019). The varietal differences for thermal indices have been noticed in earlier studies conducted by several researchers (Rajbogshi et al. 2016; Samanta et al. 2019; Ortiz 2022). A set of 58 rice genotypes from Assam (Table 1) were analysed for thermal indices, grain yield and yield components to elucidate the implication of thermal indices as selection criteria in rice breeding.

The present investigation was carried out during *kharif* 2020 on 58 winter rice genotypes of Assam using 3 replications in a randomized block design at the experimental field of Biotech Hub, Biswanath College of Agriculture, Biswanath Chariali, Assam. The observations were recorded on five conventional morphological traits *viz*., days to maturity (DM), panicle length (PL), number of effective tillers per plant (ET), no. of filled grains per panicle (FG) and yield per plant (YP) and three thermal indices during three growth phases *viz*., GDD between sowing to maximum tillering (GDD_{S-MT}), GDD between maximum tillering to days to flowering (GDD_{MT-DF}), GDD between days to flowering 21 and days to maturity (GDD_{DF-DM}), HTU_{S-MT}, HTU_{MT-DF}, HTU_{DF-DM}, HUE_{S-MT}, HUE_{MT-DF} and HUE_{DF-DM}. The recorded data were subjected to analysis of variance following Panse

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Table 1. A list of genotypes studied

Sl. No.	Genotypes	Sl.No.	Genotypes	Sl. No.	Genotypes	Sl. No.	Genotypes
1	Luit	16	Karbi Sanglok	31	Gopinath	46	Joldubi
2	Bairing	17	SokBangtuk	32	Mahshuri	47	Hatisali
3	Haccha	18	Aghoni Bora	33	Kon Joha	48	Nagheri Bao
4	Joy Bangla	19	SokJonthi	34	Manipuri Joha	49	Manohar Sali
5	Maibee	20	Jora Dhan	35	Mukunda	50	Malbhog Dhan
6	Dehangi	21	Navin Dhan	36	Hacky Nagaland	51	Suagmoni
7	Maizubiron	22	Sekamoi Phou	37	Baismuthi	52	XaruJahinga
8	MairenSanglok	23	Boga Aijung	38	Sona	53	Bahadur
9	Karbi Dhan	24	Jyotiprasad	39	Sang Mohini	54	BorJahinga
10	Madhab	25	Betguti	40	Gitesh	55	Bokul
11	Sok Soi Soi	26	Mala	41	Swarna Sub-1	56	Boga Joha
12	Inglong A Bara	27	Black Rice	42	Ranjit	57	BiroiSali
13	SokRangpi	28	Mohan	43	BiriyaBhanga Bao	58	Vasudev
14	Inglongkiri	29	Konguti	44	Kola Joha		
15	Sok Naka	30	Jaymati	45	Bishnuprasad		

and Sukhatme (1967). The mean sum of squares was subjected to the estimation of genetic parameters of variation as per Singh and Choudhury (1988). The weather parameters for the crop growing period were obtained from the meteorological observatory, Biswanath College of Agriculture. Growing degree days were computed with 10°C as the base temperature. The following standard formulae were used to compute the thermal indices.

GDD = Σ [(Tx + Tn)/2 – Base temperature], where, Tx= Daily maximum temperature and Tn= Daily minimum temperature.

HTU = GDD × n, Where, n = Bright sunshine hour

HUE (g/m²/°day) = Biomass (g/m²)/GDD

Analysis of variance revealed significant differences among the genotypes for all the fourteen variables, suggesting that the rice genotypes were not only diverse for the yield and yield attributing traits but also diverse with respect to the thermal indices. The magnitude of mean sums of squares (MSS) of the thermal indices was observed to be comparatively higher than the other traits. Similar higher values of MSS for thermal indices were also observed by Kumari (2019). The earlier reports that the total heat energy available to any crop is never completely converted to dry matter even under the most favourable conditions but the crop varieties differed in terms of GDD and HUE are supportive to the present findings. Thus, the present study is found to be quite relevant to further investigate the thermal indices in rice genotypes.

Genetic variability

A wide range of phenotypic and genotypic coefficient of variation was observed for all the characters under study (Table 2) with relatively higher magnitude of phenotypic coefficient of variation (PCV) than the genotypic coefficient of variation (GCV) for all the variables, which might be due to some degree of environmental factors influencing in phenotypic expression as also observed earlier (Adhikari et al. 2018; Naveen Kumar et al. 2021). The genetic coefficient of variation (GCV) was highest for HUE_{DF-DM} followed by HUE_{S-MT} and HUE_{MT-DF}. The effectiveness of selection for a character depends not only on the presence of variability but also on heritability. On the other hand, heritability should be coupled with genetic advances to arrive at a reliable genetic gain. High heritability coupled with high genetic advance as a percent of mean was observed for the variables *viz.,* ET, FG, GY, and GDD, HTU and HUE. Thus, it was indicated that selection would be effective, not only for the yield traits but also for the thermal indices as well. From the mean value (Table 2), it was observed that GDD, HTU were highest for the time period between sowing to maximum tillering, followed by GDD and HTU between days to flowering to days to maturity. Chaudhuri et al. (2019) also observed similar kinds of results. However, HUE was highest for the period between sowing to maximum tillering, followed by HUE between days to flowering to days to maturity.

Correlations

Character association studies at the genotypic level (Table 3) indicated that grain yield was not only directly influenced by its conventional yield components but also a function of thermal indices under study. A highly significant and positive association of grain yield was observed with GDD_{S-MT}, HTU_{S-MT}, HTU_{MT-DF}, HUE_{S-MT}, HUE_{MT-F} and HUE_{DF-DM} apart from its significant association with effective tillers per plant, panicle length and filled grains per panicle. Kumari (2019) also observed a positive association of grain yield with all

Table 2. Analysis of variance and genetic parameters of variation for five agro-morphological and nine thermal indices in 58 rice varieties

ANOVA						Genetic parameters of variation					
Sl. no.	Characters	Replication	Treatment	Error	F value	*Mean (m)*	*SE*	*GCV%*	*PCV %*	*h2(broad sense) %*	*GA (pm)*
1	DM	1.397	761.343	3.034	250.939	142.69	1.422	11.142	11.209	98.814	22.816
2	PL	0.095	12.397	0.381	32.523	9.20	0.504	21.748	22.759	91.31	42.809
3	ET	0.495	27.249	1.38	19.745	27.33	0.959	10.743	11.571	86.204	20.548
4	FG	3.049	4,814.39	76.761	62.719	106.54	7.154	37.3	38.196	95.365	75.036
5	YP	0.648	87.279	3.374	25.865	18.85	1.5	28.063	29.707	89.234	54.608
6	GDD S_{-MT}	1,152.21	2,58,604.50	1,233.46	209.657	1508.88	28.676	19.412	19.551	98.583	39.704
7	GDD_{MT-DF}	2,877.61	3,875.44	1,250.59	3.099	508.96	28.874	5.812	9.058	41.164	7.681
8	GDD_{DF-DM}	302.952	24,298.02	3,095.45	7.85	541.21	45.427	15.533	18.627	69.542	26.684
9	HTU_{S-MT}	10,169.15	57,07,523.10	22,747.38	250.909	5671.42	123.146	24.272	24.417	98.814	49.703
10	HTU_{MT-DF}	2,91,134.37	6,13,072.80	1,25,700.23	4.877	2547.00	289.483	15.825	21.076	56.378	24.477
11	HTU_{DF-DM}	1,32,982.54	4,89,795.87	1,56,560.31	3.128	3404.99	323.069	9.788	15.194	41.503	12.99
12	HUE_{S-MT}	0.085	5.622	0.165	34.086	4.23	0.332	31.867	33.281	91.686	62.858
13	HUE_{MT-DF}	0.842	41.194	1.97	20.913	12.32	1.146	29.353	31.487	86.907	56.37
14	HUE_{DF-DM}	0.563	58.68	2.919	20.103	12.04	1.395	35.809	38.518	86.427	68.577

Table 3. Estimates of genotypic correlation for characters related to yield and thermal indices

Traits	DM	ET	PL	FG	GY	GDD_{S-MT}	GDD_{MT-DF}	GDD_{DF-DM}	HTU_{S-MT}	HTU_{MT-DF}	HTU_{DF-DM}	HUE_{S-MT}	HUE_{MT-DF}	HUE_{DF-DM}
DM	1													
ET	0.203	1												
PL	0.238	0.276	1											
FG	0.175	0.259	0.169	1										
GY	0.314	0.564	0.266	0.727	1									
GDD S_{-MT}	1.000	0.202	0.236	0.173	0.311	1								
GDD_{MT-DF}	0.183	-0.123	-0.205	0.009	-0.054	0.193	1							
GDD_{DF-DM}	-0.962	-0.190	-0.280	-0.168	-0.305	-0.964	-0.391	1						
HTU_{S-MT}	0.992	0.178	0.220	0.183	0.289	0.994	0.221	-0.941	1					
HTU_{MT-DF}	0.498	0.294	0.212	-0.001	0.313	0.493	-0.181	-0.635	0.386	1				
HTU_{DF-DM}	0.120	-0.143	-0.234	-0.076	-0.093	0.117	0.293	0.018	0.198	-0.685	1			
HUE_{S-MT}	-0.406	0.399	0.072	0.539	0.723	-0.409	-0.204	0.382	-0.429	-0.008	-0.203	1		
HUE_{MT-DF}	0.270	0.576	0.282	0.695	0.976	0.264	-0.263	-0.222	0.236	0.347	-0.163	0.743	1	
HUE_{DF-DM}	0.672	0.514	0.340	0.634	0.895	0.671	0.067	-0.680	0.640	0.539	-0.099	0.366	0.849	1

Significant at 5% | Significant at both 1% & 5%

these thermal indices. Therefore, direct selection of the conventional yield traits and thermal indices may improve the grain yield. A negative and significant association of GDD_{DF-DM} with grain yield and other yield components along with HTU and HUE was observed. This indicated that lower GDD is associated with a higher yield. But further dissection of the traits into different phenophases indicated that GDD was positively correlated with days to maturity during sowing to maximum tillering, and HUE was negatively correlated with days to maturity. Since, sowing to the maximum tillering stage actually differentiates the duration of a genotype, it indicated that early maturing varieties would have higher heat use efficiency.

The present study elucidated the importance of thermal indices as selection criteria for yield improvement in rice. The information obtained on genetic parameters and genetic association with respect to thermal indices and yield components may pave the way to explore the utility of thermal indices as new selection criteria in plant breeding programmes. Heat use efficiency and other related meteorological parameters associated with the genotypic response thus, appear to be useful for genotypic selection in rice breeding programmes particularly in the context of climate change. Further geneticstudies with respect to these parameters would be helpful in establishing them as useful criteria for the crop improvement programme.

Author's Contribution

Conceptualization of research (MKS, DDS, PN); Designing of the experiments (MKS, DDS, MPN); Collection of experimental materials (DDS, MPN); Execution of lab experiments and data collection (DDS, ASNA, NSD, JT), Analysis of data and interpretation (DDS, ASNA); Preparation of the manuscript (DDS, MKS).

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