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Research Article

EVALUATION OF RICE GERMPLASM FOR HEAT TOLERANCE

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Abstract- An experiment was conducted by utilizing the existing 98 breeding materials derived from crosses involving heat tolerant donors as one of the parents. The aim of the study was to assess the degree of genetic diversity for yield and its related traits in order to identify high temperature tolerant lines that could be utilized in hybridization programme. The 98 genotypes were grouped into 13 diverse clusters. Cluster III with three genotypes *viz.,* IR 86970 – 112 – 3, IR 86977 – 122 – 1 and IR 86991 – 103 – 2 involving three heat tolerant donors exhibited the maximum intra cluster distance of 162.33. The inter cluster distance was high between VI and XII (329.80), XIII and VI (265.50) and XII and V (263.45). Hybridization between the genotypes of these clusters and also between I and VI may offer scope for further selection. Total number of tillers per plant (44.03 %) and single plant yield (26.29 %) contributed more towards genetic divergence.

Key words-Rice, High temperature, genetic divergence, global warming, climate change.

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Introduction

More than half of the people on the globe depend on rice as their basic diet. It is expected that the world population will increase by about 2 billion in the next two decades and half of this increase will be in Asia, which accounts for 90% of world's production and consumption of rice [1]. For millions of Asians, 'RICE IS LIFE' and it is the staple food that provides 75 per cent of calories and 55 per cent protein in the average daily diet of the people [2]. An increase in rice production by 0.6-0.9% annually until 2050 is needed to meet the demand [3]

It is predicted that the carbon-di- oxide concentration (CO_2) in the atmosphere will double within this century compared to that at the beginning of last century and that the increase in CO_2 and other green house gases will cause global warming of 1.5 to 5.8^{0}C at the end of this century [4]. Such global environmental change is considered to have a tremendous impact on Asian rice production. Increment in carbon-di- oxide concentration in the atmosphere has a positive effect on biomass production but the total effect on rice yield depends on possible yield reduction associated with increasing temperature [5]. For every 75 ppm increase in CO_2 concentration, rice yield will increase by 0.5 t/ha, but the yield will decline by 0.6 t/ha for every 1^{0}C increase in temperature [5]. Predicted rate of increase in night temperature has a negative impact on rice production with significant yield losses [6].

It is estimated that food production in India must increase by five million metric tons per year in order to keep pace with population growth and to ensure food security. Hence, much of this extra production has to necessarily come from rainfed systems which are actually vulnerable to climate change [7]. As water is becoming a limiting factor, there is a gradual shift in crop cultivation from irrigated system to water saving technologies like direct seeded rice, aerobic rice, alternate wetting and drying etc., which would be more vulnerable to adverse effects of high temperatures. Hence, there is an urgent need to address high temperature induced yield losses and effort to breed rice for hot environments [7].

A knowledge on the extent of genetic diversity in the population handled by the breeder is very important to predict the outcome of breeding programme and it offers much scope for selection. Also, information on the nature of germplasm and extent of genetic divergence would help the plant breeder in choosing right parents for effecting hybridisation [8]. The D^2 technique developed by Mahalanobis in1936 [9] has been found to be a potent tool in quantifying the degree of divergence in germplasm. Generally, the grain yield is the targeted trait for improvement in rice productivity in favourable or unfavourable environments.

Breeding for heat tolerance in rice is an emerging area of study to address the issues elaborated earlier. A scrutiny of meteorological data over the past 15 years at Tamil Nadu Rice Research Institute, Aduthurai has revealed that the months April and May are prone to high temperature stress with the average maximum temperature reaching 37-38^{0}C. Farmers in the delta regions tend to grow summer rice for varied reasons if they have irrigation facilities. This crop will be prone to high temperature stress at booting or flowering or grain filling stages. Under this context, the present study was formulated using breeding lines derived from crosses involving heat tolerant donors with the objective to study the extent of genetic diversity in heat tolerant genotypes

Materials and Methods

The present investigation was carried out at the Tamil Nadu Rice Research Institute, Aduthurai of Tamil Nadu Agricultural University which is situated at 11^0 N latitude and 79.3^0 E longitudes with an elevation of 19.5 meters above the mean sea level. During the summer season temperature reaches upto 39^{0}C. The details of materials studied and methods followed are given hereunder. The material for the present study consisted of 98 heat tolerant genotypes (Source: IRRI, Philippines)and the seeds were obtained from Tamil Nadu Rice Research Institute, Aduthurai. The details are given in [Table-1]. All the 98 heat tolerant genotypes were sown in nursery bed during April 2010 and transplanted to the main field on the 28th day after sowing. The seedlings were planted in Randomized Block Design at South farm of Tamil Nadu Rice Research Institute, Aduthurai. Adopting a spacing of 20× 15 cm, the genotypes were replicated twice. In each replication, each genotype was planted in four rows with 12 seedlings or hills per row. The recommended normal crop management practices were followed.

Table-1 *List of experimental materials studied*

S.No.	HTL No.	Group name	Designation
1.	127	GHARIB/IR 2006-P12-12-2-2	IR 86958-30-1
2.	1035	SUPER BASMATI/IR 2006-P12-12-2-2	IR 86978-64-1
3.	790	IR 64/IR 2006-P12-12-2-2	IR 86970-166-3
4.	1310	CT 6946-9-1-2-M-1P/IRRI 123	IR 86991-83-2
5.	437	IR 6/IDSA 77	IR 86966-5-3
6.	1343	CT 6946-9-1-2-M-1P/IRRI 123	IR 86991-119-1
7.	765	IR 64/IR 2006-P12-12-2-2	IR 86970-117-2
8.	900	SUPER BASMATI/IDSA 77	IR 86977-104-1
9.	1651	KHAO HAHNG/IRRI 123	IR 87008-68-2
10.	1203	CT 6946-9-1-2-M-1P/IR 64	IR 86990-147-1
11.	183	GIZA 178/IDSA 77	IR 86960-91-3
12.	432	GR11/IR 2006-P12-12-2-2	IR 86964-95-3
13.	1196	CT 6946-9-1-2-M-1P/IR 64	IR 86990-141-2
14.	1307	CT 6946-9-1-2-M-1P/IRRI 123	IR 86991-82-2
15.	754	IR 64/IR 2006-P12-12-2-2	IR 86970-106-3
16.	1062	SUPER BASMATI/IR 2006-P12-12-2-2	IR 86978-98-1
17.	409	GR11/IR 2006-P12-12-2-2	IR 86964-56-1
18.	105	GHARIB/IR 2006-P12-12-2-2	IR 86958-1-1
19.	793	IR 64/IR 2006-P12-12-2-2	IR 86977-117-3
20.	1055	SUPER BASMATI/IR 2006-P12-12-2-2	IR 86978-81-3
21.	1342	CT 6946-9-1-2-M-1P/IRRI 123	IR 86991-115-3
22.	1236	CT 6946-9-1-2-M-1P/IR 64	IR 86990-141-2
23.	899	SUPER BASMATI/ IDSA 77	IR 86977-102-3
24.	442	IR 6/IDSA 77	IR 86966-13-2
25.	1213	CT 6946-9-1-2-M-1P/IRRI 123	IR 86991-18-1
26.	933	SUPER BASMATI/ IDSA 77	IR 86977-140-2
27.	1031	SUPER BASMATI/IR 2006-P12-12-2-2	IR 86978-61-3
28.	126	GHARIB/IR 2006-P12-12-2-2	IR 86958-29-3
29.	1047	SUPER BASMATI/IR 2006-P12-12-2-2	IR 86978-72-1
30.	1176	CT 6946-9-1-2-M-1P/IR64	IR 86990-98-3
31.	129	GHARIB/IR 2006-P12-12-2-2	IR 86958-30-3
32.	769	IR 64/IR 2006-P12-12-2-2	IR 86970-126-3
33.	880	SUPER BASMATI/ IDSA 77	IR 86977-62-2
34.	1007	SUPER BASMATI/IR 2006-P12-12-2-2	IR 86978-33-3
35.	449	IR 6/IDSA 77	IR 86966-21-1
36.	1039	SUPER BASMATI/IR 2006-P12-12-2-2	IR 86978-66-2
37.	791	IR 64/IR 2006-P12-12-2-2	IR 86970-167-1
38.	897	SUPER BASMATI/ IDSA 77	IR 86977-99-2
39.	1285	CT 6946-9-1-2-M-1P/IRRI 123	IR 86991-56-1
40.	608	IR 6/N 22	IR 86968-7-1
41.	971	SUPER BASMATI/IR 2006-P12-12-2-2	IR 86978-12-3
42.	343	GIZA 178/N 22	IR86962-67-1
43.	459	IR 6/IDSA 77	IR86966-33-3
44.	874	SUPER BASMATI/ IDSA 77	IR 86977-39-3
45.	875	SUPER BASMATI/ IDSA 77	IR 86977-40-3
46.	879	SUPER BASMATI/ IDSA 77	IR 86977-62-1
47.	438	IR 6/IDSA 77	IR86966-10-1
48.	1172	CT 6946-9-1-2-M-1P/IR64	IR 86990-94-2
49.	85	BINAM/IR 2006-P12-12-2-2	IR86955-13-2
50.	913	SUPER BASMATI/ IDSA 77	IR 86977-118-1
51.	1214	CT 6946-9-1-2-M-1P/IR64	IR 86990-165-3
52.	1669	KHAO HAHNG/IRRI 123	IR 87009-79-3
53.	893	SUPER BASMATI/ IDSA 77	IR 86977-95-1
54.	211	GIZA 178/IR 2006-P12-12-2-2	IR86961-31-1
55.	927	SUPER BASMATI/ IDSA 77	IR 86977-135-2
56.	1405	IR 2344-P1 PB-9-3-2B/IR64	IR 86992-40-2
57.	892	SUPER BASMATI/ IDSA 77	IR 86977-92-3
58.	1298	CT 6946-9-1-2-M-1P/IRRI 123	IR 86991-74-1
59.	1048	SUPER BASMATI/IR 2006-P12-12-2-2	IR 86978-72-2
60.	762	IR 64/IR 2006-P12-12-2-2	IR 86970-112-2
61.	770	IR 64/IR 2006-P12-12-2-2	IR 86970-145-1
62.	934	SUPER BASMATI/ IDSA 77	IR 86977-140-3
63.	888	SUPER BASMATI/ IDSA 77	IR 86977-87-2
64.	1008	SUPER BASMATI/IR 2006-P12-12-2-2	IR 86978-36-1
65.	1213	CT 6946-9-1-2-M-1P/IR64	IR 86990-165-2
66.	1489	IR 2344-P1 PB-9-3-2B/IR 64	IR 86992-127-3
67.	435	IR 6/IDSA 77	IR 86966-3-3
68.	764	IR 64/IR 2006-P12-12-2-2	IR 86970-117-1
69.	766	IR 64/IR 2006-P12-12-2-2	IR 86970-117-3
70.	1076	CT 6946-9-1-2-M-1P/IR64	IR 86990-17-2
71.	153	GIZA 178/IDSA 77	IR 86960-1-3
72.	1031	SUPER BASMATI/IR 2006-P12-12-2-2	IR 86978-61-3
73.	374	GR11/IR 2006-P12-12-2-2	IR86964-6-2
74.	909	SUPER BASMATI/ IDSA 77	IR 86977-115-3
75.	1043	SUPER BASMATI/IR 2006-P12-12-2-2	IR 86978-67-3
76.	1176	CT 6946-9-1-2-M-1P/IR64	IR 86990-98-3
77.	436	IR 6/IDSA 77	IR 86966-5-2
78.	1236	CT 6946-9-1-2-M-1P/IRRI 123	IR 86991-18-1
79.	309	GIZA 178/IR 2006-P12-12-2-2	IR86961-170-1
80.	1041	SUPER BASMATI/IR 2006-P12-12-2-2	IR 86978-67-1
81.	1666	KHAO HAHNG/IRRI 123	IR 87009-67-3
82.	434	IR 6/IDSA 77	IR 86966-3-2
83.	1061	SUPER BASMATI/IR 2006-P12-12-2-2	IR 86978-94-3
84.	885	SUPER BASMATI/ IDSA 77	IR 86977-86-2
85.	1466	IR 2344-P1 PB-9-3-2B/IR 64	IR 86992-99-3
86.	1305	CT 6946-9-1-2-M-1P/IRRI 123	IR 86991-78-2
87.	1038	SUPER BASMATI/IR 2006-P12-12-2-2	IR 86978-66-1
88.	448	IR 6/IDSA 77	IR 86966-18-3
89.	430	GR11/IR 2006-P12-12-2-2	IR86964-95-1
90.	785	IR64/IR 2006-P12-12-2-2	IR 86970-165-1
91.	1381	IR 2344-P1 PB-9-3-2B/IR 64	IR 86992-12-1
92.	936	SUPER BASMATI/ IDSA 77	IR 86977-141-3
93.	763	IR 64/IR 2006-P12-12-2-2	IR 86970-112-3
94.	859	SUPER BASMATI/ IDSA 77	IR 86977-23-2
95.	908	SUPER BASMATI/ IDSA 77	IR 86977-115-2
96.	918	SUPER BASMATI/ IDSA 77	IR 86977-122-1
97.	911	SUPER BASMATI/ IDSA 77	IR 86977-117-2
98.	1328	CT 6946-9-1-2-M-1P/IRRI 123	IR 86991-103-2

Results and Discussion

Rice is one of the most important cereal food crop which provides food to more than half of the world's population [10]. Increasing temperatures are global phenomenon although the level of temperature increment may vary between different regions. The IPCC (2007) [11] report predicts that the mean summer rainfall is expected to increase by about 10% for all of India by the end of century. South Asia will experience much larger seasonal variations due to heavy rainfall, there may be a decrease in the number of rainy days and temperature will increase for all months. The premonsoon seasons will experience an increase of > 1^0 C until the time slice 2010-2039 due to which there are likely incidences of extreme heat during the months of April and May [7]. In rice, extreme maximum temperature is particularly important during flowering which usually lasts for 2-3 weeks. Exposure to high temperature for a few hours can greatly reduce pollen viability and therefore cause yield loss [12]. Hence, there is an urgent need to address high temperature induced yield losses in rice to face a changing climate.

At IRRI multiple biparental mapping populations involving N 22 were initiated. The genotype N 22 was identified as an ideal donor of high temperature tolerant genes at flowering stage [13-15]. Some advanced breeding lines of the crosses are now in field trials in different countries including India. Accordingly, from more than 1500 lines (F_4) few genotypes were selected based on spikelet fertility. These selected genotypes formed the base material of study. A scrutiny of parents of these breeding lines show that Super Basmati, IR 64, Giza 178 were common parents in many crosses, while the donor lines were IR 2006-P 12-12-2-2, IDSA 77, IRRI 123, CT 6946-9-1-2-M-1, N22 etc.

The objectives were thus formulated to assess the extent of genetic diversity of these materials. A set of 98 heat tolerant genotypes were evaluated for ten yield and yield contributing characters and the data subjected to statistical analysis.

Genetic diversity

Genetic diversity is the most potent tool in the hands of plant breeder through which one can measure variation and make selection and without which crop improvement could not have taken place in the path of green revolution.

All the 98 genotypes were grouped into 13 clusters [Table-2] for the ten traits studied. In the present investigation, the cluster XIII with three genotypes *viz.,* IR 86970 – 112 – 3, IR 86977– 122 – 1 and IR 86991– 103 – 2 was found to possess the maximum intra cluster distance (162.33). All the three genotypes have different heat tolerant donors *viz.,* IR 2006 – P12 – 2 – 2, IDSA 77 and CT 6946 – 9– 1– 2– M– 1P and the other parent was also different *viz.,* IR 64, Super Basmati and IRRI 123. Hence, the presence of adequate genetic diversity among the genotypes is highly justified. These genotypes possessed moderate mean values for all the traits. The next best cluster with high intra cluster distance (139.04) was X, which had nine genotypes. The mean values of genotypes were found to be inferior for the traits *viz.,* total and productive tillers, panicle length, flag leaf length, number of filled grains per panicle and single plant yield when compared to those of cluster XIII. Hence, the genotypes in cluster XIII could be better utilized either directly or for hybridization.

Table-2 *Distribution of 98 rice heat tolerant genotypes into different clusters*

Cluster number	Number of genotypes	Genotypes
I	2	IR 86977-135-2, IR 86977-92-3
II	2	IR 86991-119-1, IR86964-95-1
III	39	IR 86958-30-1, IR 86978-64-1, IR 86970-166-3, IR 86991-83-2, IR 86966-5-3, IR 86970-117-2, IR 86977-104-1, IR 87008-68-2, IR 86990-147-1, IR 86960-91-3, IR 86964-95-3, IR 86990-141-2, IR 86991-82-2, IR 86970-106-3, IR 86978-98-1, IR 86964-56-1, IR 86958-1-1, IR 86977-117-3, IR 86978-81-3, IR 86991-115-3, IR 86990-141-2, IR 86977-102-3, IR 86966-13-2, IR 86991-18-1, IR 86977-140-2, IR 86978-61-3, IR 86958-29-3, IR 86978-72-1, IR 86990-98-3, IR 86958-30-3, IR 86970-126-3, IR 86977-62-2, IR 86978-33-3, IR 86966-21-1, IR 86978-66-2, IR 86970-167-1, IR 86977-99-2, IR 86991-561, IR 86970-117-3
IV	9	IR 86968-7-1, IR 86978-12-3, IR86962-67-1, IR86966-33-3, IR 86977-39-3, IR 86977-40-3, IR 86977-62-1, IR 86977-87-2, IR 86966-5-2
V	5	IR86966-10-1, IR 86990-94-2, IR86955-13-2, IR 86992-127-3, IR 86970-117-1
VI	2	IR 86990-165-2, IR 86978-61-3
VII	6	IR 86977-118-1, IR 86990-165-3, IR 87009-79-3, IR 86977-95-1, IR 86978-36-1, IR 86990-98-3
VIII	2	IR 86970-145-1, IR 86970-165-1
IX	2	IR 86977-23-2, IR 86977-115-2
X	9	IR86961-31-1, IR 86992-40-2, IR 86991-74-1, IR 86978-72-2, IR 86970-112-2, IR 86977-140-3, IR 86966-3-3
XI	15	IR86964-6-2, IR 86977-115-3, IR 86978-67-3, IR 86991-18-1, IR86961-170-1, IR 86978-67-1, IR 87009-67-3, IR 86966-3-2, IR 86978-94-3, IR 86977-86-2, IR 86992-99-3, IR 86991-78-2, IR 86978-66-1, IR 86966-18-3, IR 86992-12-1
XII	2	IR 86977-141-3, IR 86977-117-2
XIII	3	IR 86970-112-3, IR 86977-122-1, IR 86991-103-2

A comparison of inter cluster distances [Table-3] between the 13 clusters revealed that the maximum values of 329.80 was between clusters VI and XII both of which consisted of two genotypes each. The two genotypes of cluster XII were derived from the same cross *viz.,* Super Basmati / IDSA 77 and this cluster had high mean values for number of filled grains per panicle and hundred grain weight and ranked second in mean value for grain yield (36.29 g). On the other extreme, the genotypes of cluster VI were poor in performance for the traits *viz.,* total and productive tillers, panicle length, flag leaf length, breadth, number of filled grains per panicle and consequently the single plant yield (13.62 g). The parents of these two genotypes are different from each other.

Table-3 *Inter and intra cluster average distances in 98 heat tolerant genotypes in rice*

Clusters	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
I	**14.24**	47.59	151.27	122.01	159.42	222.88	85.57	64.61	71.13	134.68	132.46	126.44	104.53
II		**16.95**	150.86	139.88	156.79	221.66	83.13	36.69	84.97	142.31	143.37	119.54	105.81
III			**135.64**	150.30	115.65	143.98	125.59	144.74	119.48	138.30	131.00	245.19	196.33
IV				**134.57**	150.43	187.01	124.78	140.55	99.75	135.65	126.68	211.05	169.45
V					**84.76**	102.15	120.72	146.88	120.47	128.51	120.10	263.45	207.73
VI						**23.83**	176.38	213.68	166.36	163.84	152.16	329.80	265.50
VII							**87.20**	79.47	75.09	120.62	116.26	178.20	140.66
VIII								**29.43**	89.05	138.93	139.00	131.15	114.75
IX									**32.04**	106.63	97.06	175.33	131.16
X										**139.04**	123.97	225.70	180.73
XI											**117.39**	229.72	180.98
XII												**48.69**	128.73
XIII													**162.33**

Bold diagonal values shows intra cluster distance

The second high inter cluster distance of 265.5 was observed between the potent cluster XIII and the poor performing genotypes of cluster VI. Hence hybridization of genotypes between these clusters may give rise to transgressive segregants for most of these traits. The donors for heat tolerance in these clusters were CT 6946 – 9 – 1 – 2 – M 1P, IDSA 77 and IR 2006 – P12 – 12 – 2 – 2 while the other parents were IR 64 and Super basmati.

The third position of high inter cluster distance (263.45) occurred between cluster XII with favourable mean values for number of grains per panicle and hundred grain weight and cluster V possessing five genotypes which were found to be semi dwarf but late in duration. Four heat tolerant donors *viz.,* IDSA 77, IR 2006 – P12 – 2 – 2, CT 6946 – 9 – 1 – 2 – M 1 and IR 2344 – P1 PB – 9 – 3 – 2B were involved as one of the parents among these genotypes.

The relative contribution of characters [Table-4], [Fig-1] towards genetic divergence was assessed. The highest contribution towards genetic divergence was recorded by total number of tillers per plant followed by single plant yield, number of productive tillers per panicle and 100 grain weight. The characters like plant height, flag leaf length and panicle length contributed considerably for genetic diversity. Earlier studies indicated that 100 grain weight [16] [17] number of productive tillers per plant and single plant yield had contributed more towards genetic divergence in rice [18-22].

Table-4 *Contribution of characters towards diversity in heat tolerant genotypes*

Source	Times Ranked 1st	Contribution (%)
Days to 50 per cent flowering	66	1.38
Plant height	41	0.86
Total number of tillers per plant	2093	44.03
Number of productive tillers per plant	669	14.07
Panicle length	96	2.01
Flag leaf length	158	3.32
Flag leaf width	0	0.00
Number of filled grains per panicle	15	0.31
100 grain weight	365	7.67
Single plant yield	1250	26.29
TOTAL	4753	100

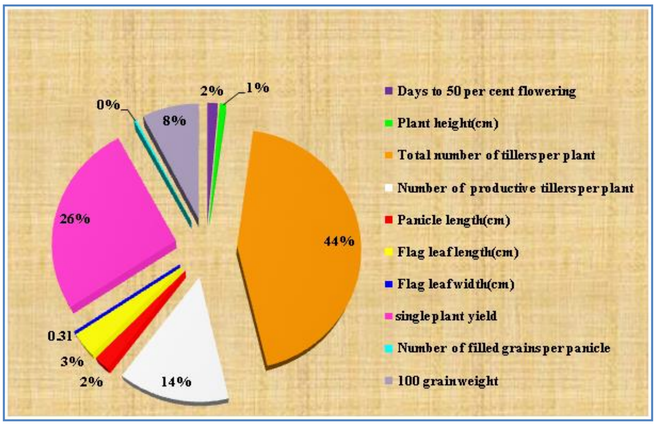

Fig-1 Chart showing the contribution of 10 characters for diversity in 98 heat tolerant genotypes of rice

Considering the mean performance of clusters [Table-5] for different traits, cluster I with two genotypes *viz.,* IR 86977 – 135 – 2 and IR 86977 – 92 – 3 was found to be highly productive for the traits like number of productive tillers per plant, panicle length, flag leaf length, width and single plant yield (37.92 g). It exhibited highest inter cluster distance with cluster VI which was the other extreme for these traits. Hence, hybridization between these four genotypes will also throw transgressive segregants which offer scope for further selection

Conclusion

It can be concluded that the three genotypes *viz.,* IR 86970 – 112 – 3, IR 86971 – 122 – 1, IR 86991 – 103 – 2 in cluster XIII which were adequately diverse among themselves can be selected directly for utilization.

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Table-5 *Cluster mean for different quantitative traits among 98 heat tolerant rice genotypes*

Clusters	D50F	PHT	TNT	NPT	PNL	FLL	FLW	NGP	100 GW	SPY
Cluster I	95.20	94.28	18.50	**18.02**	**28.52**	**38.40**	**1.62**	140.06	19.30	**37.92**
Cluster II	91.36	87.70	**18.52**	18.00	28.49	30.79	1.50	143.66	22.47	36.14
Cluster III	99.45	88.02	12.45	11.72	23.21	26.87	1.31	113.67	21.76	24.14
Cluster IV	100.71	**99.35**	14.70	14.14	23.43	33.57	1.18	123.99	19.34	27.23
Cluster V	**102.52**	**84.08**	11.85	11.24	21.47	29.65	1.58	105.69	23.62	20.52
Cluster VI	94.70	86.21	**8.46**	**8.03**	**19.13**	**19.72**	**1.08**	**87.50**	20.79	**13.62**
Cluster VII	97.87	88.31	14.83	14.07	25.31	28.59	1.52	129.72	20.38	27.90
Cluster VIII	98.73	84.33	17.23	16.90	25.86	28.51	1.22	141.98	22.32	34.87
Cluster IX	**90.55**	95.08	12.75	12.61	23.35	31.24	1.21	129.21	**17.72**	25.28
Cluster X	101.56	93.67	12.22	11.77	22.57	30.27	1.56	119.81	23.79	22.53
Cluster XI	101.93	94.32	10.77	10.16	21.66	30.86	1.34	117.57	20.05	21.07
Cluster XII	90.80	93.62	17.91	17.61	28.50	31.91	1.28	**176.18**	**25.67**	36.29
Clusters XIII	91.84	93.95	16.12	15.86	27.07	35.00	1.18	151.84	22.54	33.29

Bold numbers show the maximum and minimum values for their respective character

Also, they can be used as one of the parents in crosses with two genotypes of cluster VI for getting transgressive segregants, as these clusters possessed genotypes with poor performance for most of the traits. The heat tolerant donors involved in these genotypes as one of the parents are IDSA 77. Also, hybridization between two genotypes in each of cluster I and VI with maximum and minimum mean values respectively, for five traits including grain yield may offer scope for further selection. Among the different traits studied, total number of tillers per plant (44.03 %) and single plant yield (26.29 %) contributed more towards total genetic divergence.

Application of research

The extent of genetic diversity present among the genotypes evaluated in the present study indicated that this material may serve as good source for selecting the diverse parents for hybridization programme aimed at identifying desirable segregants for grain yield with high temperature tolerance or heat tolerance.

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Author Contributions

The authors declare that there is no conflict of interests regarding the publication of this paper and authors are equally contributed.

Abbreviations:

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