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Research Article

Genetic variability and diversity analysis in selected rice (*Oryza sativa* L.) varieties

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Abstract
Rice is the staple diet for more than half of the world's population. To meet the demands of a growing population, yield levels are to be improved. The creation of variability is a must for improving yield and to design breeding programmes. Twenty-six improved rice varieties were subjected to the study genetic variability through nine different traits. Four traits namely, number of productive tillers per plant, flag leaf breadth, number of grains per panicle and 100 grain weight had high PCV and GCV. All the traits except panicle length exhibited high heritability with high GAM. To assess the genetic diversity in terms of spatial distance and quantification, Principal component analysis and D^2 analysis were done, respectively. In PCA, out of nine principal components, the first three PC's showed maximum cumulative variability. However, the traits *viz.,* days to 50 per cent flowering, plant height, flag leaf length, flag leaf breadth and panicle length were found to be essential characteristics creating variability. Based on D^2 statistics, 26 genotypes were grouped into six clusters. Cluster I was the largest group which comprised 13 genotypes followed by cluster II with seven genotypes. Cluster VI had the highest intra cluster distance. Maximum inter cluster distance was observed between clusters V and VI indicating a significant genetic diversity between these two clusters. The characters *viz.,* 100 grain weight, days to 50 per cent flowering, the number of grains per panicle and flag leaf breadth contributed maximum divergence among the genotypes. Therefore, these traits may be given more importance for the hybridization programme.

Keywords: Rice, variability, principal component analysis, genetic diversity.

INTRODUCTION

Rice is the staple diet for more than half of the worlds population. About 90 per cent of the population in Asia consumes rice as a staple food for which it is referred as the grain of life. Asia produces the majority of the world's rice and accounts for nearly 94 per cent of global production. In India, the area and production of rice during the year 2020 - 21 was about 45.8 million hectares and 124.37 million tonnes, respectively. In Tamil Nadu, the area and production of rice were about 2.04 million hectares and 6.9 million tonnes, respectively (Annual report, 2021). Ever increasing population urges to augment the productivity of rice crops and this can be achieved through the development of high yielding varieties. Selected varieties from the different background were employed for the study and variability was assessed which enabled for trait selection to improve yield.

Principal component analysis (PCA) gives component scores for the characteristics by condensing the dimensions of a multivariate data set to a small number of primary axes, creating an Eigenvector for each axis. The term "eigenvalues" describes how important

each component is to the overall variance, whereas "eigenvectors" describe how much each original variable contributes to each primary component (Jolliffe, 2002). The main advantage of PCA is the quantification of each dimension's significance for describing a data set's variability in more understandable and visually appealing dimensions by using linear combinations of variables that obtain the majority of the variation present in the initial set of variables (Burman *et al.,* 2021). In plant breeding, genetic diversity is more important because offspring from different parents show more heterosis and offer a wide range of variability in succeeding generations. Diversity not only results in inducing genetic variation but also provides new recombination of genes in the gene pool. To ensure effective use of genetic resources, it is crucial to have a better knowledge on the genetic diversity within as well as closely related crop varieties. Therefore, the present study was carried out with the above objectives to find out the genetically divergent genotypes.

MATERIALS AND METHODS

The present study was carried out at the research field of the Department of Plant Breeding and Genetics, Anbil Dharmalingam Agricultural College and Research Institute, Trichy during the *late samba* season of the year 2021 with an average maximum and minimum temperature of about 31.9°C and 22.8, respectively and total rainfall of about 849.6 mm during the trial period. The experiment was laid out in randomized blocks design with two replications which consisted of 26 selected rice varieties with different pedigree and from diverse regions of Tamil Nadu state namely Trichy, Ambasamudram, Aduthurai, Tirur, Vaigai Dam and Coimbatore (**Table 1**).

Each genotype was sown in a raised bed and 28 days old seedlings were transplanted in well puddled field with a spacing of 20 x 20 cm. Recommended package of practices was adopted for healthy crop maintenance. Totally nine biometrical traits were observed and recorded at appropriate stages following, SES (IRRI, 1996). Days to 50 per cent flowering was observed besides employing five randomly selected plants for recording observation for the traits *viz.,* plant height (cm), the number of productive tillers per plant, flag leaf length (cm), flag leaf breadth (cm), panicle length (cm), the number of grains per panicle, 100 grain weight (g) and single plant yield

Table 1. List of 26 rice varieties used in this study

S. No.	Name of variety	Pedigree of variety	Source of variety
1	ASD 16	ADT 31/CO 39	RRS, Ambasamudram
2	ASD 17	ADT 31/RATNA/ASD 8/IR 8	RRS, Ambasamudram
3	ASD 18	ADT 31/IR 50	RRS, Ambasamudram
4	ASD 20	IR 18348/IR 25863/IR 58	RRS, Ambasamudram
5	TKM 6	CO 18/GEB 24	RRS, Tirur
6	TKM 9	TKM 7/IR 8	RRS, Tirur
7	CO 51	ADT 43/RR272-1745	Department of Rice, Coimbatore
8	ADT 42	AD 9246/ADT 29	TRRI, Aduthurai
9	ADT 43	IR 50/White ponni	TRRI, Aduthurai
10	ADT (R) 45	IR 50/ADT 37	TRRI, Aduthurai
11	ADT 53	ADT 43/JGL 384	TRRI, Aduthurai
12	IR 64	IR5657-33-2-1/IR 2061-465-1-5-3	IRRI, Philippines
13	TRY (R) 2	RP 825-45-1-3/IR 36	ADAC & RI, Trichy
14	TRY 5	Mutant of TRY (R) 2	ADAC & RI, Trichy
15	ASD 19	Lalnakanda/IR 30	RRS, Ambasamudram
16	CO 52	BPT 5204/CO (R) 50	Department of Rice, Coimbatore
17	ADT 39	IR 8/IR 20	TRRI, Aduthurai
18	CO 53	PMK (R) 3/*Norungan*	Department of Rice, Coimbatore
19	VGD 1	ADT 43/*Seeragasamba*	ARS, Vaigaidam
20	CO 43	Dasal/IR 20	Department of Rice, Coimbatore
21	IWP	Selection from White Ponni	IRRI, Philippines
22	ADT (R) 46	ADT 38/CO 45	TRRI, Aduthurai
23	CO (R) 50	CO 43/ADT 38	Department of Rice, Coimbatore
24	TNAU Rice ADT 49	CR 1009/*Seeragasamba*	TRRI, Aduthurai
25	TRY 1	RP 578-172-2-2/BR-1-2-B-1	ADAC & RI, Trichy
26	TRY 4	ADT 39/CO 45	ADAC & RI, Trichy

(g). Analysis of variance and variability parameters were calculated by TNAU STAT (Manivannan, 2014) and R studio software version 5594.2.3.0 was used for PCA analysis. D^2 statistics were analyzed as per the method suggested by Mahalanobis (1936).

RESULTS AND DISCUSSION

The mean sum of squares of genotypes was found to be significant for all the traits under study indicating the presence of significant differences in the traits across the genotypes (**Table 2**). Of all the traits, the number of grains per panicle showed a wider variation of 297.50 (CO (R) 50) to 101.33 (ASD 17) with a mean value of 170.83. The highest and lowest value of plant height was observed in TKM 6 (134.17 cm) and ASD 20 (80.84 cm), respectively with a mean value of 104.37 cm. Minimum and maximum values for days to 50 per cent flowering were observed in ASD 17 (75 days) and CO 43 (113.5 days), respectively with an average value of 94.23 days.

Similarly, The maximum and minimum number of productive tillers per plant were produced by IR 64 (39) and ASD 17 (10) with a mean value of 23.54. Flag leaf length exhibited wide variation which ranges from 47.95 cm (CO 52) to 23.5 cm (ASD 17) with a mean value of 33.54 cm. Broader flag leaf breadth was recorded in TRY 1 (2.05 cm) and narrower leaf was observed in IWP & IR 64 (1.00 cm). The hundred grain weight was observed high in TRY 1 and CO 53 (2.38 g), while it was lowest in VGD 1 (0.70 g) with a mean value of 1.79 g. For the single plant yield, maximum yield was recorded by CO 53 (30.94 g) and minimum yield was observed in TKM 6 (14.61 g) with an average single plant yield of 20.01 g (**Table 3**).

Analysis of genotypes reported that the PCV was found to be marginally higher than the GCV for all the traits studied which reveals the environmental influence on the expression of characters. PCV and GCV were high for the traits *viz.,* the number of productive tillers per plant (31.02 %, 25.83 %), flag leaf breadth (23.63 %, 21.41 %), the number of grains per panicle (25.67 %, 20.08 %) and 100 grain weight (22.60 %, 22.51 %). Similarly, single plant yield recorded high PCV (23.27 %) but, GCV was found to be moderate (18.81 %). The traits days to 50

Table 2. Analysis of variance for yield and its attributing traits in selected rice varieties

Character	Mean sum of square		
	Varieties	Replication	Error
Days to 50% flowering	320.05*	11.08	5.56
Plant height	639.37*	286.33	17.11
Number of productive tillers per plant	90.28*	88.92	16.36
Flag leaf length	77.12*	13.57	10.58
Flag leaf breadth	0.22*	0.12	0.02
Panicle length	7.61*	6.53	1.37
Number of grains per panicle	3099.24*	741.41	745.69
100 grain weight	0.33*	0.01	0.001
Single plant yield	35.86*	0.60	7.52

*Significance at 5% level

Table 3. Estimates of genetic parameters for nine biometrical traits of 26 selected rice varieties

S. No.	Character	Mean	Maximum	Minimum	Coefficient of variation		h^2 (%)	GAM (%)
					PCV (%)	GCV (%)		
1	Days to 50% flowering	94.23	113.50	75.00	13.54	13.31	96.59	26.94
2	Plant height (cm)	104.37	134.17	80.84	17.36	16.90	94.79	33.89
3	Number of productive tillers per plant	23.54	39.00	10.00	31.02	25.83	69.31	44.29
4	Flag leaf length (cm)	33.54	47.95	23.50	19.75	17.20	75.88	30.87
5	Flag leaf breadth (cm)	1.46	2.05	1.00	23.63	21.41	82.13	39.97
6	Panicle length (cm)	23.55	27.39	19.33	9.00	7.50	69.49	12.88
7	Number of grains per panicle (g)	170.83	297.50	101.33	25.67	20.08	61.21	32.37
8	100 grain weight (g)	1.79	2.38	0.70	22.60	22.51	99.18	46.18
9	Single plant yield (g)	20.01	30.94	14.61	23.27	18.81	65.32	31.31

per cent flowering (13.54 %, 13.31 %), plant height (17.36 %, 16.90 %) and flag leaf length (19.75 %, 17.20 %) exhibited moderate PCV and GCV, while panicle length (9.00 %, 7.50 %) showed low PCV and GCV (**Table 3**). These results were in accordance in rice with Fathima *et al.* (2021), Bhargava *et al*. (2021) and Nikhitha *et al.* (2020) for plant height and the number of productive tillers per plant. For the number of grains per panicle, similar results were obtained in rice by Fathima *et al.* (2021), Bhargava *et al.* (2021) and Singh *et al.* (2021).

High heritability with high GAM was observed for days to 50 *per cent* flowering (96.59%, 26.94%), plant height (94.79%, 33.89%), the number of productive tillers per plant (69.31%, 44.29%), flag leaf length (75.88%, 30.87%), flag leaf breadth (82.13%, 39.97%), the number of grains per panicle (61.21%, 32.37%), 100 grain weight (99.18%, 46.18%) and single plant yield (65.32 %, 31.31 %). Similar findings were reported in rice by Bhargava *et al.* (2021) and Fathima *et al.* (2021) for plant height, the number of productive tillers per plant, the number of grains per panicle and single plant yield; Nikhitha *et al.* (2020) and Singh *et al.* (2021) for plant height. But panicle length exhibited high heritability (69.49%) and moderate GAM (12.88%) (**Table 3**) which were in accordance with Nikhitha *et al.* (2020), Bhargava *et al.* (2021) and Singh *et al.* (2021) in rice.

In the present study, PCA analysis revealed that out of nine quantitative traits studied, the first three principal components (PC1, PC2 and PC3) showed eigenvalue >1 and exhibited 75.28% cumulative variability among all the characters under study. Out of three principal components, PC1 alone exhibited for 47.40% of the total variability (**Table 4**) and the characters which contributed for the variation were days to 50 per cent flowering, plant height, flag leaf length, flag leaf breadth and panicle length. PC2 was mostly contributed by the number of productive tillers per plant which showed 16.32% of the total variation. More than 50% of the variation was explained by the first two PC dimensions, indicating a strong relationship between the characteristics under study (Subramanian *et al.,* 2019). In PC3, the number of productive tillers per plant and 100 grain weight exhibited more contribution towards the variation of about 11.57%. Similarly, the study of eight biometrical traits in 49 rice landraces revealed that 72.96% of the overall variation was contributed by the first three major principal components Raiza Christina *et al*. (2021).

The character 100 grain weight (-0.09) showed negative loading in PC1, while the other traits showed positive loadings towards the first principal component. In PC2, positive loadings were showed by days to 50 per cent flowering, the number of productive tillers per plant, flag leaf length and the number of grains per panicle, whereas other traits showed negative loadings towards PC2. In PC3, characters *viz*., days to 50 per cent flowering, flag leaf breadth and the number of grains per panicle showed negative loadings whereas, other characters showed positive loadings (**Table 5**).

The biplot diagram of the first two principal components depicted the interaction among the characters and also with each genotype (**Fig. 1**). The vector length of each character shows how much it contributed to the overall divergence; the longer the vector, the greater the contribution. The character 100 grain weight showed maximum vector length indicating its contribution to the total diversity followed by plant height, days to 50 per cent flowering and flag leaf breadth.

The direction of correlation between the traits is indicated by the angle between the trait vectors. A right angle (90^{o}) between the vectors indicates no correlation whereas, the acute angle (<90^{o}) indicates a positive correlation and obtuse angle (>90^{o}) indicates a negative correlation. Out of nine characters under study, the character *viz.,* flag leaf breadth, panicle length, plant height, flag leaf length, days to 50 per cent flowering and the number of grains per panicle showed a positive correlation with single plant yield whereas the number of productive tillers per plant, the number of grains per panicle, days to 50 per cent flowering and flag leaf length showed a

Table 4. Eigen values, percentage of variation and cumulative percentage for principal components

Principal components	Eigen values	Variance per cent	Cumulative variance per cent
PC1	4.27	47.40	47.40
PC2	1.47	16.32	63.72
PC3	1.04	11.57	75.28
PC4	0.89	9.92	85.21
PC5	0.58	6.41	91.62
PC6	0.25	2.82	94.44
PC7	0.22	2.49	96.93
PC8	0.21	2.34	99.27
PC9	0.07	0.73	100.00

Table 5. Contribution of first three principal components to variation in selected rice varieties

Parameters	PC1	PC2	PC3
Days to 50% flowering	0.41	0.13	-0.33
Plant height	0.42	-0.06	0.17
Number of productive tillers per plant	0.12	0.46	0.64
Flag leaf length	0.38	0.12	0.33
Flag leaf breadth	0.38	-0.25	-0.36
Panicle length	0.38	-0.19	0.10
Number of grains per panicle	0.30	0.30	-0.08
100 grain weight	-0.09	-0.67	0.44
Single plant yield	0.34	-0.35	0.07

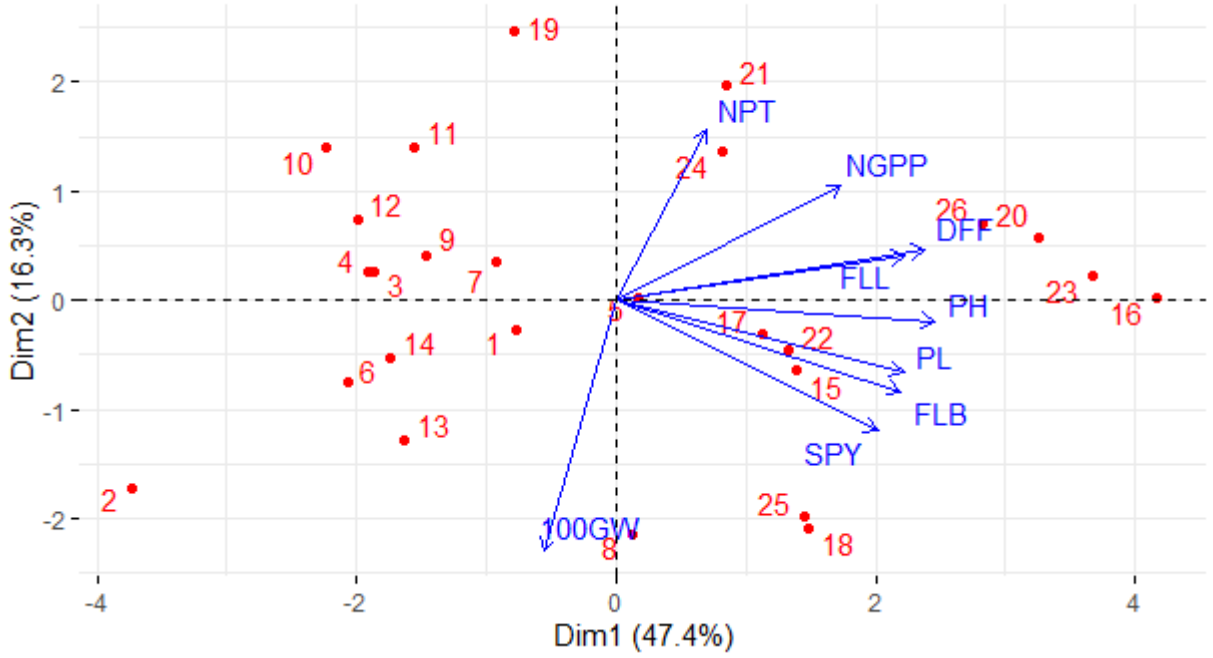

Fig. 1. Biplot diagram of principal components

negative correlation towards the 100-grain weight. There is no correlation between the panicle length and 100 grain weight.

The genotypes that are present along the trait vectors of the same quadrant generally exhibit superior performance for those characteristics. The genotypes (ADT 39, ADT (R) 46 and ASD 19) found in the particular quadrant along with other genotypes were performing best for flag leaf breadth, panicle length, single plant yield and plant height whereas, the genotyps (IWP and TNAU Rice ADT 49) were found to perform best for the number of productive tillers per plant. The genotypes (ASD 20, ASD 18, ADT 43, CO 51, IR 64 and ADT (R) 45) that were present in the opposite direction to these vectors performed poorly for all the traits.

The material which has to be evaluated for genetic diversity may include germplasm lines, strains and varieties. The genotypes are generally selected on the basis of phenotypic variability or geographical origin (Singh and Narayanan, 1993). Based on the considerable variability present in the tested varieties, D^2 analysis was made. Based on Euclidean distances using Tocher's method, 26 genotypes were grouped into six clusters (**Table 6**). Out of six clusters, cluster I was the largest which comprises 13 genotypes followed by cluster II which had seven genotypes. Clusters IV and VI had two genotypes each whereas, clusters III and V were found to be a solitary cluster. Similar results were obtained by Singh and Chaudhary (1977), Behera *et al.* (2018), Devi *et al.* (2019) and Singh *et al.* (2020). Maximum inter cluster distances were between clusters V and

Table 6. Cluster composition of 26 selected rice varieties (Tocher's method)

Clusters	Number of varieties	Name of varieties
I	13	ASD 18, ADT 43, CO 51, ADT 53, ADT (R) 45, ADT 39, ASD 19, ADT (R) 46, ASD 20, ASD 16, TRY 4, CO 43, CO 52
II	7	TKM 9, TRY 5, ASD 17, TRY (R) 2, ADT 42, IR 64, CO 53
III	1	CO (R) 50
IV	2	TKM 6, IWP
V	1	TRY 1
VI	2	TNAU Rice ADT 49, VGD 1

cluster VI (3193.54) indicating the genotypes falling in these clusters exhibiting the highest genetic diversity whereas, minimum inter cluster distances were observed between the cluster I and III (268.41) indicating the close association and similarity between the genotypes for most of the characters. Similarly, cluster VI had the highest intra cluster distance (290.88), whereas cluster IV showed the lowest intra cluster distance (119.36). These results were in accordance with Vennela *et al.* (2017) and Behera *et al.* (2018). The inter cluster distances was greater than the intra cluster distances, indicating that the parent's racial backgrounds varied significantly (**Table 7**).

The cluster mean values for different traits exhibited the differences between the clusters for all the traits. The cluster mean values for all nine traits were presented in **Table 8.** The cluster mean value for days to 50 per cent flowering ranged from 84.50 (cluster II) to 111.50 (cluster V). For plant height, cluster mean ranged from 95.45 (cluster II) to 132.36 cm (cluster IV). The number of productive tillers per plant ranged from 19.50 (cluster V) to 29.00 (cluster IV). Similarly, flag leaf length ranged from 30.90 (cluster VI) to 41.92 cm (cluster IV), whereas flag leaf breadth ranged from 1.06 (cluster IV) to 2.05 cm (cluster V) and panicle length ranged from 22.72

Table 7. Inter-cluster and Intra-cluster (diagonal) average of D^2 and D values (parenthesis) of 26 selected rice varieties

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI
Cluster I	200.94 (14.18)	615.67 (24.81)	268.41 (16.38)	439.57 (20.97)	868.86 (29.48)	1074.04 (32.77)
Cluster II		127.50 (11.29)	472.85 (21.75)	578.50 (24.05)	271.84 (16.49)	2780.18 (52.73)
Cluster III			0 (0)	555.53 (23.57)	405.14 (20.13)	1485.48 (38.54)
Cluster IV				119.36 (10.93)	884.06 (29.73)	1893.01 (43.51)
Cluster V					0 (0)	3193.54 (56.51)
Cluster VI						290.88 (17.06)

Table 8. Cluster means for nine characters in 26 selected rice varieties

CLUSTER	DFF	PH	NPT	FLL	FLB	PL	NGPP	100GW	SPY
I	95.46	103.20	23.81	34.74	1.49	23.57	179.45	1.66	20.43
II	84.50	95.45	22.14	28.94	1.35	22.72	142.52	2.23	20.81
III	110.50	126.30	23.50	38.85	1.92	27.39	297.50	1.87	21.29
IV	89.00	132.36	29.00	41.92	1.06	24.69	159.75	1.67	16.35
V	111.50	119.75	19.50	33.30	2.05	24.20	144.50	2.38	22.06
VI	108.75	96.61	23.25	30.90	1.51	22.99	174.75	0.90	16.51

Where, DFF- Days to 50 per cent flowering; PH- Plant height (cm); NPT – Number of productive tillers per plant; FLL- Flag leaf length (cm); FLB – Flag leaf breadth (cm); PL-Panicle length (cm); NGPP- Number of grains per panicle; HGW- Hundred grain weight (g); SPY- Single plant yield (g)

Table 9. Relative contribution of nine characters to genetic diversity in 26 selected varieties of rice

Character	Times ranked first	Contribution (%)
Days to 50% flowering	51	15.69
Plant height	8	2.46
Number of productive tillers per plant	4	1.23
Flag leaf length	1	0.31
Flag leaf breadth	16	4.92
Panicle length	1	0.31
Number of grains per panicle	17	5.23
100 grain weight	225	69.23
Single plant yield	2	0.62

(cluster II) to 27.39 cm (cluster III). The cluster mean for the number of grains per panicle ranged from 142.52 (cluster II) to 297.50 (cluster III). The 100-grain weight ranged from 0.90 (cluster VI) to 2.38 g (cluster V). Similarly, the cluster mean for single plant yield ranged from 16.35 (cluster IV) to 22.06 g (cluster V) (**Table 8**).

In addition to divergence, the performance of genotypes and characters that contribute most to divergence should also be taken into account as they seem beneficial for crop improvement. Based on data collected for nine yield and yield attributing traits in 26 genotypes using Mahalanobis D^2 analysis, genetic diversity was evaluated. Among all the nine traits, 100 grain weight exhibited the maximum contribution (69.23%) towards the diversity by taking the first rank for 225 times followed by days to 50 per cent flowering (15.69% ranked first for 51 times), the number of grains per panicle (5.23% ranked first for 17 times), flag leaf breadth (4.92% ranked first for 16 times), plant height (2.46% ranked first for 8 times) and the number of productive tillers per plant (1.23% ranked first for 4 times) (**Table 9**).

Many researchers have employed the Mahalanobis D^2 statistic for multivariate analysis, including analyses of the degree of divergence in agricultural germplasm collections and in varieties. The effectiveness of this model for examining genetic divergence in rice genotypes was described by Singh *et al.* (2006), Kuchanur *et al.* (2009), Shahidullah *et al.* (2009), Vennela *et al.* (2017), Meena *et al.* (2017) and Behera *et al.* (2018).

From the present study, it was concluded that the number of productive tillers per plant, flag leaf breadth, the number of grains per panicle and 100 grain weight showed high GCV, PCV, heritability as well as GAM. Hence, these traits should be taken into consideration at the time of selecting the genotypes for enhancing the yield. Based on the diversity studies, the traits *viz.,* 100 grain weight, days to 50 per cent flowering, the number of grains per panicle and flag leaf breadth were important traits that contributed maximum divergence to the genotypes. In PCA, the traits, days to 50 per cent flowering, plant height, flag leaf length, flag leaf breadth and panicle length contributed more for the variation. As a result, the current study can be used to identify the variables that contribute to the variability and choose the varieties to use as donors for the enhancement of characters in the future breeding programme.

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