

# **Original Research Article**

## **Estimating Genetic Variability and Diversity for Vein Density, Photosynthesis and Yield in Rice Genotypes**

### **ABSTRACT**

The experiment was conducted to evaluate the variability and diversity of ninety-nine rice genotypes for photosynthesis, vein-related characters, and yield. The field trial was carried out in a wetland in Tamil Nadu Agricultural University, Coimbatore during Rabi, 2020. To investigate the genetic variability, efforts were made to estimate the percent of genotypic and phenotypic variation, heritability, and genetic advance likewise genetic diversity was estimated for twelve traits using Mahalanobis ( $D^2$ ) statistics. Analysis variance elucidates the existence of significant variation among the genotypes for all the twelve characters studied. The difference between GCV and PCV was narrow for all the characters studied which shows these characters are less influenced by environmental factors. The highest GVC and PCV was observed in yield and biomass simultaneously the high heritability in broad sense along with high genetic advance as percent mean was estimated in biomass, photosynthetic rate, yield, interveinal distance between major vein, leaf width, total number of veins, and total number of minor veins. These characters are considered to be inherent in nature and selection for improving these traits may be effective in the genetic improvement program. Based on the  $D^2$  value ninety-nine genotypes were diversified into five clusters in which Cluster II is the largest containing 37 genotypes followed by cluster I. The highest inter-cluster distance was estimated between cluster II and cluster IV whereas the highest intracluster distance was observed in cluster V indicating that genotypes in this cluster are highly diversified. Subsequently, the higher cluster means of most of the characters including vein characters, leaf width, and photosynthetic rate along with optimum yield and biomass fell in cluster II. Whereas in cluster IV the highest cluster means for biomass and yield was recorded. The traits biomass, yield, photosynthetic rate, interveinal distance between major veins, the total number of minor vein is the major contributors of total divergence in this population. Based on the trait contribution percentage for genetic diversity and genetic distance this study suggests that the genotypes from cluster II and cluster IV can be selected as parents for vein characters, photosynthetic rate, yield, and biomass for genetic improvement or trait improvement breeding programs.

**KEYWORDS:** Genetic Diversity, variability, Photosynthetic rate, Vein Characters, Yield and Biomass.

### **INTRODUCTION**

Rice is a leading food crop in the world. It is the most staple food for low and lower middle income countries, extended equally across all the income classes. Rice provides nearly 20% of daily calories and 13% dietary protein for more than 3.5 billion human population. Rice is an important cereal crop cultivated across 164.19 million hectares worldwide whereas in India rice occupies an area of 43.78million hectares with an average production of 118.4 million tonnes with a productivity of 2.98 tonnes per hectare ([www.agricoop.nic.in](http://www.agricoop.nic.in)). In addition, the human population is expected to reach 9.1 billion by the year 2050, i.e., 34% higher than today and most of this population will occur in developing countries. Adding to this, per capita consumption in daily diet has increased as a result of economic growth in the world also creates greater demand for food grain but the reality is the growth rate of cereal grain has reduced from

3.2% to 1.5 % since 1960's and 1970's (Lumpkin, 2011). The yields of major crops including rice have risen by around two-fold since the green revolution years through genetic improvement, management practice, control of pests and diseases, and a greatly increased fertilizer application rate. Consecutively, slowing down of compound yield growth is due to the optimization of mechanisms used to improve rice yield potential in the past, such as canopy architecture and Harvest Index (HI). However, it is predicted that further improvements will be required on the existing land area to meet the demand of future populations.

Evidence suggests that to meet the future food demand plant scientist have to improve the photosynthetic efficiency since it is the primary source for yield and biomass production of the crop plants. Therefore identifying the relationship of photosynthetic rate together with leaf anatomical traits is ideal for crop improvement since high-yielding varieties arise from high photoassimilate production and partitioning. Studies reports that vein densities are highly correlated with yield (Nawarathna *et al.*, 2017) and photosynthetic rate (Feldman *et al.*, 2017). Before planning for the plant breeding programs it is essential to owe knowledge on the magnitude of variability available in the existing population. Thus helps to encounter the donors for leaf vein density and photosynthetic rate for genetic mapping and yield improvement. Generally, genetic diversity is a principal source for the identification of ideal parents or desirable characters for the development of superior recombinants. Moreover, very little attention has been paid to quantifying the diversity of leaf vein traits and photosynthetic rate together with yield. Hence, it is hypothesized that large genetic variability in terms of vein density and photosynthetic rate in association with yield may exist in unexploited rice germplasm. This study was undertaken in diverse germplasm of association mapping panel that comprises of landraces, varieties, exotic genotypes, and improved genotypes that are collected from 13 countries. Therefore it helps to identify the appropriate parent for genetic crop improvement or plant breeding programs in rice.

## **MATERIALS AND METHODS**

The present investigation was carried out during Rabi 2020 with a set of diverse genotypes containing 98 rice accessions. All the accessions belong to an association mapping panel which are collected from different countries like Argentina, Bangladesh, Brazil, Bulgaria, Uruguay, China, Indonesia, Philippines, Colombia, Taiwan, Venezuela, and the US including India. The experiment was conducted in a randomized block design (RBD) with three replications in wetland, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. All the genotypes were sown in a raised bed and transplanted 14days old seedlings in the field with a spacing of 25cm between rows and plants. The crop was maintained with a standard package of practices recommended by TNAU. The observations on 12 quantitative traits were documented on the 5<sup>th</sup> leaf of primary tiller from randomly selected plants of each replication. The data recorded in 12 traits are photosynthetic rate, leaf width, leaf thickness, the total number of veins, major and minor vein width, the interveinal distance between major and minor vein, yield, and biomass.

The data obtained from each replication of the genotypes were subjected to basic statistical analysis that gives maximum, minimum, mean, standard deviation, and analysis of variance (ANOVA) using SPSS Statistics version 16.0 (SPSS Inc., Chicago, Ill., USA). The genetic parameters like genotypic variance, phenotypic variance, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), genetic heritability, genetic advance were calculated by the procedure given by Burton and De Vane (1953) and Johnson *et al.* (1955). While genetic diversity among 98 genotypes was quantified by Mahalanobis  $D^2$  statistics and genotypes were grouped into clusters by following the procedure given by Rao (1952).

## **RESULTS AND DISCUSSION**

The analysis of variance showed significant differences among the genotypes for all twelve characters indicating the existence of genetic variability in the population studied (Table 1.). In the current study, the maximum range of variation was observed in yield (4.40-82.16), biomass (20.77-93.37), total number of minor veins (25.67-68.67), total number of veins (37.33-79.67), interveinal distance between major vein (33.09-73.77) and photosynthetic rate (13.39-36) (Table. 2). Priyanka *et al.* (2019) has also recorded high variability for yield per plant and Jahn *et al.* (2011) reported similar photosynthetic variation in diverse rice varieties. Similar variability in vein characters was reported by Nawarathna *et al.* (2017). The range and mean value of all the characters reveal the possibility of diversity among ninety-nine genotypes. Such magnitude of diversity in the population gives the scope for further improvement in the crop and this population could be a source for the donor of desirable traits.

In the current study, the phenotypic coefficient of variation (PCV) has ranged from 9.85 to 38.74 % and the genotypic coefficient of variation (GCV) has ranged from 6.70 to 36.25 % (Table 2). The result shows that PCV is higher than the GCV (Table 2). However, the difference between PCV and GCV is narrow indicating that the variation is due to the inherent nature of the genotypes and negligible influence of environmental factors. Less difference between PCV and GCV was recorded in all the characters studied suggesting the minimal influence of environmental factors. Therefore the selection of genotypes based on the phenotypic performance of all the characters studied is effective in genetic improvement. This result was in agreement with Praveen *et al.* (2009) for yield and biomass. According to the GCV and PCV classification given by Sivasubramanian and Madhavamenon (1973), the highest genotypic and phenotypic coefficient of variation was recorded in yield (33.33% and 38.74%) and biomass (36.25 and 36.67%). Similar results were reported by Bupesh Kumar *et al.* (2017) for yield and Abebe *et al.* (2017) for biomass. While the lowest GCV and PCV were observed in the total number of major veins (6.70 and 9.85%) and interveinal distance between minor veins (7.73 and 9.89% respectively) this is due to the variation among all the genotypes for the total number of major veins (6.67 - 12.67) and interveinal distance between minor veins (13.57 - 22.27) were low (Table 2).

Heritability describes the reliability of the character to the environmental factors. According to Johnson *et al.* (1955) heritability was categorized into 3 classes as low (<30%), medium (30-60 %), and high (>60 %). Based on this characterization, heritability in a broad sense was recorded in all twelve characters. High heritability values were recorded in almost all the characters (ranging from 61.17 of Interveinal distance between minor veins to 97.52% for biomass) except the total number of major veins (46.24%) and leaf thickness (58.47%) that comes under the category of medium heritability (Table 2). Therefore these characters are considered to be less influenced by environmental factors. This result provides information about the phenotypic performance of these twelve characters to the environmental factors for the better selection of the genotypes from this population.

Heritability estimate alone is not sufficient to be effective for selection programs. Therefore, heritability along with genetic advance predicts the information about the genetic gain after the selection on the trait of interest. In the present study, the genetic advance was ranged from 0.27 % of leaf width to 35.73% for biomass. Moreover, genetic advance as a percent mean gives more accurate information than genetic advance. According to Johnson *et al.* (1955), genetic advance as percent mean was classified into low (<10%), medium (10-20%), and high (>20%). In the present study genetic advance as percent mean among 12 characters has ranged from 9.38 % (total number of major vein) to 73.75% (biomass) (Table 2).

**Table. 1. Analysis of Variance for 12 characters in rice genotypes.**

Source of variation	df	Mean Sum of Squares									Pn	Yield	Biomass
		Total Major vein	Total Minor vein	Total number of vein	Major vein width	Minor vein width	IVD b/w Major vein	IVD b/w Minor vein	Leaf width	Leaf thickness			
Replication	2	0.15	11.58	10.47	0.33	0.08	87.36	2.90	0.01	1.71	2.15	46.66	8.51
Genotypes	98	1.77*	121.50*	141.07*	1.21*	0.32*	196.74*	6.14*	0.08*	4.53*	46.96*	600.92*	933.25*
Error	196	0.50	12.84	14.91	0.19	0.05	12.47	1.07	0.01	0.87	2.88	62.92	7.88

\*Significant at 5% level; df = Degrees of freedom

IVD b/w Major vein= Interveinal distance between major vein; IVD b/w Minor vein= Interveinal distance between minor vein; Pn= Photosynthetic rate.

**Table 2. Estimation of genetic variability parameters for leaf anatomical traits, photosynthetic rate, yield and biomass**

Character	Mean	Range	Genotypic Variance	Phenotypic variance	GCV%	PCV%	Heredity in broad sense	Genetic advance	Genetic advance as % mean
<b>Total Number of Major Vein</b>	9.71	6.67 - 12.67	0.43	0.92	6.70	9.85	46.24	0.914	9.38
<b>Total Number of Minor Vein</b>	40.01	25.67 - 68.67	36.22	49.06	15.00	17.46	73.82	10.65	26.54
<b>Total Number of Veins</b>	49.88	37.33 - 79.67	42.05	56.96	13.00	15.13	73.83	11.48	23.02
<b>Major Vein Width</b>	7.00	4.84 - 9.03	0.34	0.53	8.37	10.42	64.92	0.97	13.87
<b>Minor Vein Width</b>	3.28	2.41 - 4.30	0.11	0.11	9.33	11.26	66.41	0.67	15.66
<b>Interveinal Distance between Major Vein</b>	45.70	33.09 - 73.77	61.41	73.90	17.15	18.81	83.12	14.72	32.21
<b>Interveinal Distance between Minor Vein</b>	16.82	13.57 - 22.27	1.69	2.76	7.73	9.89	61.17	2.10	12.46
<b>Leaf Width</b>	1.12	0.80 - 1.60	0.025	0.03	13.91	16.36	72.45	0.27	24.53
<b>Leaf Thickness</b>	14.44	11.67 - 17.74	1.22	2.09	7.65	10.10	58.47	1.74	12.05
<b>Photosynthetic rate</b>	25.67	13.39 – 36.00	14.69	17.57	14.96	16.35	83.62	7.23	28.17
<b>Yield</b>	40.18	4.40 - 82.16	179.34	242.25	33.33	38.74	74.03	23.74	59.06
<b>Biomass</b>	47.87	20.77 - 93.37	308.46	316.34	36.25	36.67	97.52	35.73	73.75

The highest genetic advance as percent mean was recorded in biomass, yield, interveinal distance between major vein, photosynthetic rate, total number of minor veins, leaf width, and the total number of veins while the estimates on moderate genetic advance as percent mean was recorded in minor vein width, major vein width, interveinal distance between minor vein and leaf thickness (Table.2). The above traits also fell into the category of high and moderate heritability. Shrivastava *et al.* (2015) recorded similar results on high heritability with high genetic advance as percent mean in yield and biomass and Acevedo-Siaca *et al.* (2021) for the photosynthetic trait. In this research, leaf architecture characters like total number of veins, total number of minor veins, interveinal distance between major vein and leaf width show high heritability along with high genetic advance as percent mean. These traits are considered as principle plant traits in maintaining hydraulic conductivity and photo-assimilate transport for the normal functioning of plants. Generally, rice leaves are diverse in leaf architecture and have strong genetic control over variation (Chatterjee *et al.*, 2016). Therefore these characters are found to be effective for the selection process for genetic improvement.

In the present study,  $D^2$  statistics was performed among ninety-nine genotypes, and based on the level of genetic distance genotypes were classified into five clusters by using the Tochers method. The clustering of ninety-nine genotypes into five groups was included in table 3. The maximum number of genotypes was grouped into Cluster II with 37 genotypes and cluster I with 29 genotypes. Compared to other clusters size, cluster III is the smallest containing 2 genotypes while cluster IV has 18 genotypes and cluster V has 13 genotypes. These results reveal that the genotypes with closer genetic distance/ association fall on the same clusters which are less divergent and the genotypes with diverse distance fall on different clusters.

**Table 3. Clustering of 99 rice genotypes into five clusters by Mahalanobis D2 statistics**

Cluster	Genotypes	No of genotypes
<b>Cluster I</b>	G1, G2, G3, G4, G5, G6, G7, G8, G9, G10, G11, G12, G13, G14, G15, G16, G17, G18, G19, G20, G21, G22, G23, G24, G25, G26, G27, G116, G132	29
<b>Cluster II</b>	G28, 29, G30, G31, G32, G33, G34, G35, G36, G37, G38, G39, G40, G41, G42, G43, G44, G45, G46, G47, G48, G49, G50, G71, G72, G74, G76, G83, G85, G87, G88, G91, G93, G94, G95, G118, G126	37
<b>Cluster III</b>	G134, G137	2
<b>Cluster IV</b>	G96, G97, G98, G100, G101, G111, G112, G113, G114, G115, G117, G119, G120, G121, G122, G123, G124, 135	18
<b>Cluster V</b>	G125, G127, G128, G129, G130, G131, G133, G136, G138, G139, G140, G141, G147	13

Inter and intracluster distance were computed and included in table 4. In this investigation, the intracluster distance ranges from 3.004 to 12.290. The highest intracluster distance was recorded in cluster V with a D value of 12.290 followed by cluster IV with a D value of 11.842. This result indicates the presence of genetic diversity among the genotypes in cluster V and also in cluster IV. While the minimum intracluster distance was observed in Cluster III with 3.004 which intimates the closer relationship among the genotypes in this cluster. The highest inter-cluster distance was observed between cluster IV and cluster II (12.52) followed by cluster V and cluster IV (12.32) (Table 4). This result indicates the existence of greater genetic divergence between the genotype in these clusters. From the present study, the result infers that the selection of parents from these diverse clusters (IV & II; V & IV) for hybridization programs

would give maximum heterogeneity in the segregating population. Chaturvedi and Maurya (2005) recommend selecting the parent from the clusters with high inter-cluster distance to get more variability and heterotic effect in the segregating generation. In contrast, the lower inter-cluster distance was noticed between cluster III and I (3.00) which suggests that the genotypes in these clusters are relatively closer than the other clusters. Therefore the selection of parents from these homogenous clusters for crossing programs may be avoided.

**Table 4. Inter and Intra-Cluster Distance (bold) among Five Clusters of Rice Genotypes**

	I	II	III	IV	V
I	<b>9.51</b>	11.26	7.78	12.26	11.52
II		<b>11.01</b>	9.30	12.52	11.95
III			<b>3.00</b>	11.120	9.47
IV				<b>11.842</b>	12.32
V					<b>12.29</b>

*Inter-cluster and Intra-cluster distance D value arranged in diagonal and bold*

Analysis of cluster means for 12 characters were included in table 5. The maximum cluster means for leaf anatomical traits like total number of major veins, the total number of minor veins, total number of veins, interveinal distance between major vein and interveinal distance between minor vein, major vein width, minor vein width, leaf width falls on the same cluster II which has optimum yield and biomass. However, leaf thickness, photosynthetic rate, yield, and biomass are relatively distributed. Cluster IV has recorded the highest cluster mean value for leaf thickness and biomass but lower cluster means for photosynthesis. This result reveals that the genotypes with higher leaf thickness would have higher biomass because the volume of leaf tissues and cell wall thickness will be more for these leaves. Though leaf thickness is an important constituent of leaf mass but a higher volume of leaf tissues and thickened cell wall causes resistance to diffusion of CO<sub>2</sub> that would result in reduced photosynthetic rate. Similar findings were reported by Zang *et al.* (2020).

In the case of yield per plant cluster, I possess a higher cluster mean of 48.068 followed by cluster IV with 39.501, and cluster III was observed to have a higher cluster for photosynthetic rate and lower cluster mean for minor veins, the total number of veins, interveinal distance between minor vein, major vein width, minor vein width, and leaf width. These results indicate that the genotype in this cluster has narrow leaf width, as a result of that, the vein counts, interveinal distance between minor veins, and width of the veins were low. A significant reduction in the number of minor and major veins for narrow leaves was documented by Kubo *et al.* (2016). Whereas in the case of cluster V minimum cluster mean of interveinal distance between major vein (41.149) and yield (31.178) was noticed. These findings serve as a diverse source for selecting the desirable genotypes for hybridization programs.

Percent contribution of individual characters of ninety-nine genotypes for total diversity is given in table 6. Among the traits studied, biomass has the highest percent (71.2843%) of contribution for total divergence followed by yield per plant (10.5133%), photosynthetic rate (6.2461%), the interveinal distance between major vein (4.2672%), and the total number of minor vein (2.06145). whereas other traits like the total number of veins, interveinal distance between minor veins, leaf thickness, and the total number of major veins have contributed least to total genetic divergence among ninety-nine genotypes.

## CONCLUSION

In this study considering the genetic distance and relative contribution of individual traits to the genetic diversity the genotypes in cluster II and cluster IV can be utilized for an effective crossing program to get a high heterotic effect on segregating population. These clusters have major contribution factors of divergence and the highest cluster mean for vein characters together with high photosynthetic rate and yield. This study recommends that the parents can be selected from clusters II and IV for photosynthetic rate, vein characters, yield, and biomass for crossing programs.

**Table 5. Cluster mean values of twelve characters of 99 rice genotypes**

Cluster	Total Major vein	Total Minor vein	Total number of vein	Major vein width	Minor vein width	IVD b/w Major vein	IVD b/w Minor vein	Leaf width	Leaf thickness	Pn	Yield	Biomass
<b>Cluster I</b>	9.644	37.425	47.069	6.854	3.147	41.469	16.400	1.053	14.625	24.323	48.068	42.185
<b>Cluster II</b>	9.973	44.559	54.532	7.211	3.458	52.067	17.297	1.228	13.927	27.087	37.892	48.249
<b>Cluster III</b>	8.833	35.667	44.500	6.707	2.905	41.763	16.258	0.983	14.873	28.647	32.688	40.780
<b>Cluster IV</b>	9.537	38.815	48.352	6.850	3.268	43.178	16.637	1.076	14.913	23.489	39.501	58.469
<b>Cluster V</b>	9.718	36.051	45.769	6.961	3.156	41.149	16.721	1.044	14.752	26.930	31.178	50.444

IVD b/w Major vein = Interveinal distance between major vein; IVD b/w Minor vein = Interveinal distance between minor vein; Pn = Photosynthetic rate.



**Table 6. Percent contribution of twelve characters for total divergence in 99 rice genotypes**

S.No	Character	Contribution %
1	Total Number of Major Vein	0.8452
2	Total Number of Minor Vein	2.0614
3	Total Number of Veins	0.0000
4	Major Vein Width	1.0513
5	Minor Vein Width	1.6698
6	Interveinal Distance between Major Vein	4.2672
7	Interveinal Distance between Minor Vein	0.2268
8	Leaf Width	1.1132
9	Leaf Thickness	0.7215
10	Photosynthetic rate	6.2461
11	Yield	10.5133
12	Biomass	71.2843

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

**References**

- Abebe T, Alamerew S, Tulu L. Genetic Variability, Heritability and Genetic Advance for Yield and its Related Traits in Rainfed Lowland Rice (*Oryza sativa* L.) Genotypes at Fogera and Pawe, Ethiopia. *Advances in Crop Science and Technology*. 2017; 5: 272
- Acevedo-Siaca LG, Coe R, Quick WP, Long SP. Evaluating natural variation, heritability, and genetic advance of photosynthetic traits in rice (*Oryza sativa*). *Plant Breed*. 2021;1-13.
- Annual Report.. Department of Agriculture, Cooperation & Farmers Welfare. Ministry of Agriculture & Farmers' Welfare, Government of India. 2021. [www.agricoop.nic.in](http://www.agricoop.nic.in)
- Bupesh Kumar, Amardeep Kour and Jay Laxami.. Genetic diversity for agro-morphological traits in rice germplasm. *Electronic Journal of Plant Breeding*. 2017; (4): 1216-1222.
- Chatterjee J, Dionora J, Elmido- Mabilangan A, Wanchana S, Thakur V, Bandyopadhyay A, et al.. The evolutionary basis of naturally diverse rice leaves anatomy. *PLoS ONE*. 2016; 11(10): e0164532.
- Chaturvedi HP, Maurya DM. Genetic divergence analysis in rice (*Oryza sativa* L.). *Advances Pl. Sci*. 2005; 18: 349-53

- Feldman AB, Leung H, Baraoidan M, Elmido-Mabilangan A, Canicosa I, Quick WP, Sheehy J, Murchie EH. Increasing leaf vein density via mutagenesis in rice results in an enhanced rate of photosynthesis, smaller cell sizes and can reduce interveinal mesophyll cell number. *Front. Plant Sci.* 2017; 8:1883.
- Jahn, CE, McKay JK, Mauleon R, Stephens J, McNally KL, Bush DR, Leung H, Leach, JE. Genetic variation in biomass traits among 20 diverse rice varieties. *Plant Physiology*. 2011. 155: 157–168.
- Johnson HW, Robinson F, Comstock RE.. Estimates of genetic and environmental variability in soybeans. *Agronomy journal*. 1955; 47: 314-318.
- Kubo FC, Yasui Y, Kumamaru T, Sato Y, Hirano HY.. Genetic analysis of rice mutants responsible for narrow leaf phenotype and reduced vein number. *Genes and Genetic Systems*, 91: 235–240.
- Lumpkin, T. A. 2011. Help for developing countries in a world of rising grain prices. *Acta Horti.* 2016; 916: 31-46
- Miao Ye, Zhengcan Zhang, Guanjun Huang, Zhuang Xiong, Shaobing Peng and Yong Li. High leaf mass per area *Oryza* genotypes invest more leaf mass to cell wall and show a low mesophyll Conductance. *AoB PLANTS*, 12: 4
- Nawarathna, R. N., Dassanayake, K. B. and Nissanka, S. P., Seneweera, S. and Salisbury, P. 2017. Is Phenotypic Variability in Leaf Vein Density in Rice Associated with Grain Yield?. *J Rice Res Dev*, 1(1):1-9
- Praveen Pandey, Anurag, P. J., Tiwari, D. K., Yadav, S. K. and Binod Kumar. Genetic variability, diversity and association of quantitative traits with grain yield in rice (*Oryza sativa* L.) *J. bio-sci*, 2009; 17: 77-82.
- Priyanka AR, Gnanamalar RP, Banumathy S, Senthil N, Hemalatha G.. Genetic variability and frequency distribution studies in F2 segregating generation of rice. *Electronic Journal of Plant Breeding*. 2019;10 (3): 988 – 994.
- Shrivastava, A, Mishra DK, Koutu GK. Estimation of genetic parameters of variability for yield and its attributing traits in parental lines of hybrid rice. *Plant Archives*. 2015; 15: 571-574.
- Sindhumole P, Veena V, Beena, R.. Genetic analysis and correlations in mid early genotypes of rice (*Oryza sativa* L.) under irrigated condition. *Electronic Journal of Plant Breeding*, 2015;6(3): 855-860.
- Sivasubramanian S, Madhavamenon P. Genotypic and phenotypic variability in rice. *Madras Agric J.* 1973;60: 1093-1096.