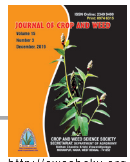
Journal of Crop and Weed, 17(1): 115-121 (2021)
ISSN- O : 2349 9400 ; P : 0974 6315



http://cwssbckv.org
www.cropandweed.com

Studies on genetic analysis and brown spot resistance in rice (*Oryza sativa* L.) under aerobic condition

*B. SRINIVAS, D. PADMAJA, Y. CHANDRAMOHAN, T. KIRAN BABU, S. THIPPESWAMY AND S. LAXMAN

Regional Agricultural Research Station, Polasa, Jagtial, Telangana – 505 529
Professor Jayashankar Telangana State Agricultural University

Received : 10.12.2020 ; Revised : 22.01.2021 ; Accepted : 25.01.2021

DOI : https://doi.org/10.22271/09746315.2021.v17.i1.1413

ABSTRACT

20 rice cultures were evaluated under aerobic condition at Regional Agricultural Research Station, Jagtial during kharif, 2016. High heritable estimates were observed for all the 7 traits studied under this aerobic condition. High values of heritability and genetic advance values for important yield attributes viz., effective bearing tillers/M^2 (59.70, 28.23), 1000 grain weight (95.00, 37.74) and number of grains panicle^{-1} (75.90, 57.52) indicated that these traits were under the control of additive genes. Except 1000 grain weight, all the traits exhibited significant and positive correlations with yield and late maturity was identified as preferable for increasing the yields under aerobic situations. Genotypes from cluster I and IV could be used as parents in crossing programmes for development of varieties suitable for rainfed situation. Present experimental material exhibited greater divergence for 1000 grain weight (41.05%) and days to 50% flowering (28.00%). JGL 28815 and JGL 28833 were identified as resistant lines for brown spot disease and needs further screening to be used as potential donors.

Keywords: Aerobic cultivation, brown spot resistance, correlations, genetic divergence and rice

Rice, an important food crop in India grabs major share in total cultivated area being cultivated in 43.79 m.ha with a production of 116.48 m.t and productivity of 2.65 t ha^{-1} (www.indiastat.com, 2018-19). Different methods of paddy cultivation are under practice in the country of which transplanting under puddled condition is the most common one. It requires 5000 liters of water for production of 1kg of rough rice (Bouman, 2009). In Asia, 50% of water used for irrigation is being consumed by rice only (Barker *et al.,* 1999). Countries from South Asia, South East Asia and West Africa are adapting the aerobic method of rice cultivation in larger areas (Kumar and Ladha, 2011). Factors like depletion of ground water levels, huge labour requirement for major operations like nursery raising, transplanting and weeding, increasing methane emissions and severe pest and disease incidence triggered the shifting of method of paddy cultivation from transplanting situation to direct seeding method. Aerobic paddy cultivation is a dry direct seeding method being practiced in many parts of the country under rainfed situation where water availability is a major concern. Cultivating rice under aerobic conditions is similar to cultivation of irrigated dry crops like cotton, maize, turmeric *etc*. and addresses the issues like water and labour scarcity, pest problems and environmental pollution. At present, most of varieties that have been bred for transplanting method of cultivation are being used for aerobic situation (Zhao *et al.,* 2010). Varieties which perform better in transplanted condition may or may not yield better under aerobic situations, therefore to understand the extent of transmission of a trait to its progeny through generations, understanding various genetic parameters, correlation studies and amount of genetic divergence present in given set of lines under aerobic condition are very important to frame the breeding methodologies and to identify the potential genotypes to be used in crossing for the development of varieties for aerobic condition. Brown spot disease, a major reason for great Bengal famine during 1942 in rice is caused by *Helminthosporium oryzae* and results in greater yield loss. The average yield losses in low land rice areas of South and Southeast Asia are 5% and can go up to 45% in severe infected conditions (Rice Knowledge Bank, IRRI). Incidence of this disease is most common in aerobic rice cultivation and high humid conditions (86-100%) and the temperatures prevailing during rainy season increases the severity. Therefore, developing brown spot resistant varieties could be one of the breakthroughs for success under aerobic method of cultivation. Hence the present investigation is aimed at identifying potential genotypes with high yield having brown spot resistance and to study the correlation of important yield traits with grain yield under aerobic conditions.

MATERIALS AND METHODS

Present investigation was conducted with 20 rice genotypes at Regional Agricultural Research Station, Polasa, Jagtial, Telangana located at 18°50’20.24" N

Email: srinu.bdd@gmail.com

latitude, 78°56′54.20" E longitude and 249 m above the mean sea level during *kharif*, 2016. These genotypes were sown in red sandy loam soil high in P and low in N levels. The land was prepared for sowing in the same manner as in case of dry crops like cotton, maize, red gram *etc*. The entries were evaluated in randomized block design replicated thrice. Seeds were sown by dibbling method with the seed rate of 30 kg/acre and plot size of 10 M^2. Fertilizers were applied @ 120 kg Nitrogen, 60 kg Phosphorous, and 40 kg Potassium ha^{-1}. During the crop period a total of 741.4 mm rainfall was received against the normal (720.3 mm) which is 3% excess compared to the normal rainfall. Complete phosphorous and half of the total recommended potassium were applied as basal and remaining potassium was applied at panicle initiation stage as top dressing. Nitrogen was applied in three splits at 15, 35 and 55 DAS. Data were recorded at maturity on 5 random plants for each entry in each replication for effective bearing tillers/M^2, plant height and panicle length. Whole plot was taken into consideration for recording grain yield and days to 50% flowering. Random sample of 5 panicles for each entry from each replication was used to record the grain number and test weight.

Statistical analysis

The analysis of variance (ANOVA) was done according to Panse and Sukhatme (1985). According to Sivasubramanian and Madhavamenon (1973), phenotypic and genotypic coefficients of variation were classified into low (< 10%), medium (10-20%), and high (> 20%). Heritability (h^2) in broad-sense for yield and other traits was done following Singh and Chaudhary (1985) and categorized into low (0-30%), moderate (31-60) and high (> 60%) as per Robinson *et al.* (1949). Expected genetic gain was calculated as genetic advance following the procedure suggested by Johnson *et al.* (1955) and classified as high (> 20%), moderate (10-20%) and low (< 10%). Association of different traits with the yield were estimated according to Johnson *et al.* (1955) and the genetic divergence for traits studied in the present experimental material was estimated using Mahalanobis (1936) D^2 statistics. Allotment of rice cultures into different clusters was carried out following Tocher's method (Rao, 1952).

Scoring of brown spot disease

The symptoms of brown spot disease were identified as small circular dark brown spots on leaf. Oval shaped larger lesions with grayish colour in the center are the peculiar identification symptom. Most spots have a light yellow halo around the outer edge. Scoring of disease incidence was done depending on the affected leaf area and 0 to 9 scale is given as detailed below as per Standard Evaluation System, IRRI (2013).

SCALE	Affected leaf area
0	No incidence
1	Less than 1%
2	1-3%
3	4-5%
4	6-10%
5	11-15%
6	16-25%
7	26-50%
8	51-75%
9	76-100%

RESULTS AND DISCUSSION

The lack of stability in yield of major rice varieties is the prime limitation in achieving the highest yields under aerobic ecosystem (Sandhu *et al.,* 2019). Thus, exploitation of variability present in the present day high yielding upland rice varieties is the primary requirement to develop varieties that yield high under aerobic situation. Phenotypic and genotypic coefficient of variation presented in Table 1 indicated the presence of good amount of variability for the 7 traits studied in 20 genotypes. This variability was studied as heritable and non heritable variation. Days to 50% flowering, plant height and panicle length exhibited low levels of PCV and GCV values, therefore for improvement of these characters in desirable direction, creation of variability through hybridization followed by selection in segregating generations is the best practice. Whereas, the important yield attributes *viz.,* effective bearing tillers per M^2 and 1000 grain weight recorded moderate values and number of grain per panicle recorded high values. Hence simple selections based on phenotypic superiority would improve these traits. The dependent trait grain yield also exhibited higher values for both PCV and GCV. Highest values for PCV than GCV for all the traits could be due to greater interaction of environment factors like climate, soil *etc*. with genotypes therefore consideration of environment into account is more practical while selecting for the characters in positive direction. Similarly, Kumar *et al.* (2012) noticed low GCV and PCV values for days to 50% flowering and panicle length, moderate values for plant height and number of grains per panicle and high values for effective bearing tillers/M^2 and grain yield under aerobic situation. Ramanjaneyulu *et al.* (2014) and Vanitha *et al.* (2015) reported similar findings for yield and various yield parameters like plant height, productive tillers/ plant, panicle length and 1000 grain weight in rice under aerobic condition. Genetic analysis under aerobic situation revealed very narrow differences between PCV and GCV values for all the traits indicating the phenotypic expression of a trait is of its genotypic value hence direct selection for superior phenotypic value would certainly improve the character. Ojah *et al.* (2019) also reported the lower differences between PCV and GCV values for traits in rice under aerobic condition.

Heritability is the measure of relative degree of transmission of a trait from parental population to its progeny. Amount of heritable variation of a character transmitted from parents to offspring is the key for improvement of that trait. All the seven characters studied exhibited high level of heritability (Table 1) estimates which implies that these traits are genetically unchanged as they are less influenced by environment and hence the job is easy for a breeder to improve these traits by mere selection. Gururaja *et al.* (2019) reported high heritable values for plant height, number of effective bearing tillers/M^2, number of grains per panicle and grain yield under dry direct rice seeding method. Heritability of a trait of an individual depends not only upon the nature gene action governing it but also on the population and environmental fluctuations the trait is subjected to and hence its values depends on magnitude of all these components and any change in these components will alter the heritability values (Kaul and Bhan, 1974). Genetic advance is the genetic gain in selected individuals over parental population resulting from the application of selection pressure and the values facilitate the breeder to design appropriate breeding programme for improvement. All the traits recorded moderate to high values of genetic advance (Table 1). Days to 50% flowering (11.80), panicle length (15.66) and plant height (18.69) showed moderate values whereas, grain yield recorded highest value (77.83) followed by number of grains per panicle (57.52), 1000 grain weight (37.74) and effective bearing tillers per M^2 (28.23). Selection of best individual based on both heritability and genetic advance estimates is more reliable rather than selections based on individual values of either heritability or genetic advance alone (Johnson *et al.,* 1955). Greater values for three genetic components *viz.,* GCV, heritability and genetic advance specify the action of additive genes that control the expression of characters. Important yield contributing characters *viz.,* effective bearing tillers per M^2, 1000 grain weight and number of grains per panicle showed higher values for these three genetic components indicating the role additive genes controlling these traits; thus these characters can be improved by practicing simple selection breeding method. Yield being a complex and dependent trait also exhibited higher values for these genetic components. The remaining traits, days to 50% flowering, plant height and panicle length recorded moderate levels of heritability with high genetic advance values. The findings of Gururaja *et al.* (2019), Kumar *et al.* (2012) and Ojah *et al.* (2019) are similar to the results illustrated in the present investigation.

Association of six independent traits with yield and correlations among them is depicted in Table 2. In the present study except 1000 grain weight, all the characters exhibited significant and positive correlations with yield. So, boosting of yield levels can be achieved simply by improving the yield attributes *viz.,* effective bearing tillers/M^2, plant height, panicle length and number of grains per panicle. Similar association of grain yield with plant height, effective bearing tillers/M^2, panicle length and number of grains per panicle was observed by Ramanjaneyulu *et al.* (2014) in their genetic studies of rice under aerobic condition. Khalid *et al.* (2015) and Srijan *et al.* (2018) reported similar results. In general, early maturity is a preferable trait, but in present investigation, the trait days to 50% flowering is positively correlated with yield implies that long duration genotypes with other desirable traits could be a better choice for yield maximization under aerobic situation. Association among the traits found significant in most of cases either in positive or negative direction. The correlations among the panicle related characters indicated that increased test weight associated with less number of grains per panicle, whereas, long panicles recorded more grain number. Panicle length recorded negative correlation with test weight implies that accommodation of finer grains in long panicles and coarse grains in short panicle. Correlation studies also indicated accommodation of the traits like higher number of productive tillers per plant, number of grains per panicle and long panicles in taller plants, thus improvement of anyone of the trait results in simultaneous improvement of the other, but plant height recorded negative correlation with test weight. Days to 50% flowering exhibited positive association with panicle length and number of grains per panicle and negative association with test weight. Thus using present material under aerobic condition, development of long duration rice cultures with long panicles and fine grains could be possible.

Mating between the parents having more divergence for a trait yields potential offsprings rather than less divergent parents. The degree of divergence among the genotypes for a given set of traits can be explained by grouping them into different clusters. Genetic diversity among the genotypes is not a reflection of their geographical distribution. Nayak *et al.* (2004) and Mishra *et al.* (2018) reported no parallelism of genetic

Table 1: Genetic parameters for seven characters in rice

Character	Mean	Range		GCV	PCV	h2 (Broad sense)	GA in % over Mean
		Min	Max				
Days to 50% flowering	100.60	87.67	114.67	5.91	6.10	94.00	11.80
Effective bearing tillers/M^2	243.18	146.67	330.67	17.74	22.96	59.70	28.23
Plant height (cm)	79.22	67.47	93.87	9.52	9.99	90.80	18.69
Panicle length (cm)	20.11	16.67	23.63	8.85	10.29	73.90	15.66
1000 grain weight (g)	20.53	12.02	25.15	18.79	19.28	95.00	37.74
Number of grains/panicle	116.72	74.67	216.67	32.06	36.80	75.90	57.52
Grain yield (kg/ha)	2365.33	1033.33	4663.33	39.76	41.85	90.30	77.83

Table 2: Estimates of correlation coefficients of various characters with yield

Character		Days to 50% flowering	Effective bearing tiller/M^2	Plant height	Panicle length	1000 grain weight	Number of grain panicle^{-1}	Grain Yield
Days to 50% flowering	P	1	-0.1042	0.1754	0.3515**	-0.3411**	0.3723**	0.245
	G	1	-0.1081	0.1889	0.4331**	-0.3603**	0.421**	0.2747*
Effective bearing tillers/M2	P		1	0.4586**	0.2167	0.0855	-0.0017	0.5591**
	G		1	0.5415**	0.3484**	0.0791	-0.0291	0.6654**
Plant height	P			1	0.5614**	-0.4548**	0.5854**	0.6891**
	G			1	0.6213**	-0.5205**	0.639**	0.723**
Panicle length	P				1	-0.368**	0.4655**	0.432**
	G				1	-0.4502**	0.4985**	0.5287**
1000 grain weight	P					1	-0.6527**	-0.0623
	G					1	-0.7321**	-0.0792
Number of grains/panicle	P						1	0.4721**
	G						1	0.543**

P: Phenotypic correlation coefficients, G: Genotypic correlation coefficients
** Significant at 1 per cent level, * Significant at 5 per cent level

Table 3: Allotment of 20 genotypes into different clusters

Cluster	No. of genotypes	Genotype
I	12	JGL 20171, JGL 20777, JGL 21002, JGL24423, JGLH6, JGLH37, MTU 1010, RDR 1140, RDR 1144, RDR 1151, RDR 1172, RDR 1188
II	5	JGL 21820, JGLH1, RDR 1158, JGL 28813, JGL 28815
III	1	Varalu
IV	1	JGL 23834
V	1	JGL 28833

Table 4: Average intra (diagonal) and inter cluster distances (Tocher method) for 20 rice genotypes

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V
Cluster I	4.38	8.53	6.52	12.68	9.41
Cluster II		5.3	9.18	7.76	7
Cluster III			0	10.05	11.32
Cluster IV				0	9.94
Cluster V					0

Table 5: Cluster means for 7 traits of 20 rice genotypes

Cluster	Days to 50% flowering	Effective bearing tillers/M^2	Plant height (cm)	Panicle length (cm)	1000 grain weight (g)	Number of grains panicle^{-1}	Grain yield (kg/ha)
Cluster I	99	236	75.2	19.5	22.97	99	2121
Cluster II	104	282	87.3	21.5	17.48	157	3403
Cluster III	88	242	78.8	19.3	20.43	80	1523
Cluster IV	97	231	93.9	21.9	12.02	180	2277
Cluster V	115	147	72.6	19.6	15.15	107	1033
% Contribution of character	28	0	8.95	3.68	41.05	6.84	11.58

Table 6: Scoring of 20 rice genotypes for Brown spot SES, IRRI (2013)

S.No	Entry name	Brown spot score (0-9)
1	JGL 20171	7
2	JGL 20777	5
3	JGL 21002	7
4	JGL 21820	5
5	JGL23834	8
6	JGL 24423	8
7	JGLH1	7
8	JGLH6	6
9	JGLH37	6
10	MTU 1010	6
11	Varalu	9
12	RDR 1140	7
13	RDR 1144	7
14	RDR 1151	6
15	RDR 1158	5
16	RDR 1172	8
17	RDR 1188	9
18	JGL 28813	6
19	JGL 28815	3
20	JGL 28833	3

diversity of genotypes with their geographical distribution. However, in self pollinated crops like rice there is every possibility of presence of genetic variation in genotypes collected from different eco-geographical regions (Kavurikalpana *et al.,* 2018). Phenotypic divergence does not reflect the actual divergence. Crosses between phenotypically divergent parents may not generate elite progenies. Timothy (1963) reported the similar results in his studies on crosses between phenotypically divergent Mexican, Brazillian and Andean maize collections. Applying selection pressure in a population in varying environments and genetic drift over the period results in greater diversity than the diversity attained by virtue of geographical isolation of that population (Murty and Arunachalam 1966). 20 genotypes were grouped into 5 clusters (Table 3) with highest number of genotypes (12) allotted to cluster I followed by cluster II (5 genotypes). Remaining clusters *viz.,* III, IV and V were accommodated with single genotype each. Higher the distance between the clusters more is the divergence between them. The highest distance (12.68) was observed between clusters I and IV (Table 4) followed by III and V (11.32), III and IV (10.05), IV and V (9.94), I and V (9.41) and II and III (9.18). Hence parents from these divergent clusters can be used in crossing programme for developing high heterotic hybrids and thereby chance of obtaining desirable transgressive segregants in succeeding generations can be increased. Cluster means (Table 5) provides useful information for breeders to choose suitable parents based on character means of respective clusters. As correlation data indicated positive association of yield with the duration of the crop and plant height, JGL 28833 (Cluster V) with highest number of days to flowering and JGL 23834 (Cluster IV) with highest mean value for plant height can be mated with the genotypes from cluster II with highest mean value for grain yield to develop high yielding varieties with desirable morphological features suitable for aerobic situation. In the present experimental material, the trait 1000 grain weight contributed highest (41.05%) towards total divergence (Table 5) followed by days to 50% flowering (28%) and grain yield (11.58%), whereas, least divergence was observed for panicle length (3.68%) and effective bearing tillers/M^2 (0%). Thus, development of varieties with different grain segments like coarse, fine and super fine and different maturity groups could be possible. Hence, chance of obtaining transgressive segregants with long duration and fine grain nature is more by crossing JGL 23834 (Cluster IV) of low test weight (12.02 g) with JGL 28833 (Cluster V) of long duration nature (115 days to 50% flowering) and similarly possibility of getting segregants with long duration and coarse grain nature is more by crossing JGL 28833 with genotypes of cluster I which recorded highest mean value for test weight. Kumari *et al.* (2016) and Tripathi *et al.* (2017) studied the genetic diversity among the rice genotypes under aerobic conditions and reported similar results.

Brown spot incidence is very common in aerobic rice cultivation causing severe yield losses. The optimum temperature for growth and conidial germination has been found to be 27-30°C and 25-30°C, respectively (Ou, 1985). Many efforts have been made towards searching for resistance to brown spot (Chakrabarti, 2001; Nagai and Hara, 1930). The present investigation is aimed at the identification of resistant lines under field screening. Brown spot incidence was measured in 0 to 9 score as per SES, 2013 in 20 rice genotypes at dough stage. Score was taken for each entry from all the three (3) replications and then averaged (Table 6). Genotypes exhibited greater variation for the incidence from highly susceptible to resistant. JGL 20777, JGL 21820, and RDR 1158 recorded moderately resistant reaction while JGL 28815 and JGL 28833 exhibited resistant reaction as they recorded least damage score of 3, whereas, remaining genotypes showed moderate to highly susceptible reaction. Satija *et al.* (2005) in their studies identified 15 resistant rice cultures which recorded less than 5% damage. JGL 28815 could be the best source to develop brown spot resistance and high yielding varieties as this entry fall in cluster II having high means for yield and important yield attributes like effective bearing tillers/M^2, panicle length and number of grains per panicle. Breeders can make best use of JGL 28833 exhibiting resistant reaction for brown spot and long duration in nature to generate high yielding resistant culture as it was evident by significant positive correlation of maturity period (days to 50% flowering) with yield. JGL 20777 (Cluster I), JGL 21820 and RDR 1158 (Cluster II) exhibited the moderate resistant reaction and also recorded highest mean for yield and one or other yield contributing traits.

The present investigation of genetic analysis of rice under aerobic condition revealed higher PCV values than GCV values and important yield contributing characters exhibiting high heritable estimates. The important yield attributing traits *viz.,* effective bearing tillers/M^2, 1000 grain weight and number of grains per panicle recorded both high heritability and genetic advance values. Except 1000 grain weight, all the traits exhibited significant and positive association with yield. Genotypes from cluster I and IV can be used in crossing programme for development of high yielding varieties suitable for aerobic condition. JGL 28815, JGL 28833, JGL 20777, JGL 21820 and RDR 1158 were identified as good sources for brown spot resistance.

REFERENCES

Barker, R., Dawe, D., Tuong, T.P., Bhuiyan, S.I. and Guerra, L.C. 1999. The outlook of water resources in the year 2020: Challenges for research on water management in rice production. *Assessment and orientation towards the 21st century.*, 96-109.

Bouman, B. A. M. 2009. How much water does rice use? *Rice Today.,* **8**: 28–29.

Chakrabarti, N.K. 2001. Epidemiological and disease management of brown spot of rice in India. In: Major Fungal Diseases of Rice. *Recent Advances, Kluwer Academic Publishers.,* 293-306.

Gururaja, M., Diwan, J. R., Mahantashivayogayya, K., Ramesha M.S., Nidagundi, J. M., Kisan, B. and Lokesha, R. 2019. Genetic variability studies on early maturing direct seeded rice (*Oryza sativa* L.) genotypes for yield component traits. *Int. J. Pure App. Biosci.,* **7** (3): 377-382.

Indiastat. 2018-19. Agriculture production. *http://www.indiastat.com.*

IRRI, Rice Knowledge Bank, Los Baños, Philippine.

IRRI. 2013. Standard Evaluation System for Rice, Los Baños, Philippine.

Johnson, H.W., Robinson, H.F. and Comstock, R.E. 1955. Estimates of genetic and environmental variability in soybean. *Agron. J.,* **47:** 314-318

Kaul, M.L.H. and Bhan, A.K. 1974. Studies on some genetic parameters of rice (*Oryza sativa* L.). *Theor. Appl. Genet.,* **44:** 178-183

Kavurikalpana, Thirumeni, S. and Shashidhara, N. 2018. Genetic divergence analysis for quantitative traits in rice (*Oryza sativa* L.). *Int J. Agri. Env. Biotech.*, **11**(3): 469-473.

Khalid, A., Osman, Ahmed, M., Mustafa, Yassir, M.A., Elsheikh. and Atif, E. 2015. Influence of different sowing dates on growth and yield of direct seeded rice (*Oryza sativa* L.) in semi-arid zone (Sudan). *Int. J. Agron. Agric. Res.,* **6**(6): 38-48.

Kumar, S., Singh, D., Satyendra, Sirohi, A., Kant, S., Kumar, A., Pal, K. and Mukesh, K. 2012. Variability, heritability and genetic advance in rice (*Oryza sativa* L.) under aerobic condition. *Environ. and Eco.,* **30**(4): 1374-1377.

Kumar, V. and Ladha, J. K. 2011. Direct seeding of rice: recent developments and future research needs. *Adv. Agron*., **111:** 297-413.

Kumari, M., Suresh Babu, G. and Nithin, B. P. 2016. Genetic diversity analysis of rice (*Oryza sativa* L.) germplasm under aerobic condition. *Bangladesh J. Bot*., **45**(3): 727-732.

Mahalanobis, P.C. 1936. On the generalized distance in statistics. *Proceedings of the National Institute of Sciences of India.* **(2):** 49–55.

Mishra, A.K., Singh, P.K., Kumar, R., Kumar, P., Singh, R., Kumar, P., Kumar, A. and Kumar, A. 2018. Genetic divergence study in advanced indica rice (*Oryza sativa* L.) lines for yield and quality attributes. *Int.J.Curr.Microbiol.App.Sci.,* **7:** 2924-2933.

Murty, B. R. and Arunachalam, V. 1966. The nature of divergence in relation to breeding system in some crop plants. *Indian J. Genet.,* **26**: 188-198.

Nagai, I. and Hara, S. 1930. On the inheritance of variegation disease in a strain of rice plant. *Jap. J. Genet.*, **5**: 140-144.

Nayak, A., Chaudhary, R. D. and Reddy, J. N. 2004. Genetic divergence in scented rice. *Oryza*., **41**: 79-82.

Ojah, H., Talukdar, P., Sarma, D. and Goswami, R. 2019. Genetic variability for yield and yield contributing traits of rice under aerobic condition in Assam, India. *Int.J.Curr.Microbiol.App.Sci.,* **8**(7): 1530-1537.

Ou, S.H. 1985. Rice Diseases. *2nd edn. CMI, Kew, England*, 370.

Panse, V.G. and Sukhatme, P.V. 1985. Statistical methods for agricultural workers, *2nd edition ICAR, New Delhi,.* 361.

Ramanjaneyulu, A.V., Gouri shankar, V., Neelima, T. L. and Shashibhusahn, D. 2014. Genetic analysis of rice (*Oryza sativa* L.) genotypes under aerobic conditions on alfisols. *SABRAO J. Breed. Genet.,* **46** (1) 99-111.

Rao, C.R. 1952. Advance Statistical Methods in Biometrical Research. *John Wiley and Sons, New York*.

Robinson, H.F., Comstock, R.E. and Harvey, P.H. 1949. Estimation of heritability and the degree of dominance in corn. *Agron. J.,* **41:** 353-359

Sandhu, N., Yadaw, R.M., Chaudhary, B., Prasai, H., Iftekharuddaula, K., Venkateshwarlu, C., Annamalai, A., Xangsayasane, P., Battan, K.R., Ram, M., Cruz, T., Pablico, P., Maturan, P.C., Raman, K.A., Catolos. M. and Kumar, A. 2019. Evaluating the performance of rice genotypes for improving yield and adaptability under direct seeded aerobic cultivation conditions. *Front. Pl. Sci.* **10:** 1-6

Satija, Anita, Chahal, S.S. and Pannu, P.P.S. 2005. Evaluation of rice genotypes against brown leaf spot disease. *Pl. Dis. Res. (Ludhiana)*., **20**: 163-164.

Singh, R.K. and Chaudhary, B.D. 1985. Biometrical methods in quantitative genetic analysis. *Kalyani Publishers*, *New Delhi*. 318 p.

Sivasubramanian, S. and Madhavamenon, P. 1973. Genotypic and phenotypic variability in rice. *Madras Agric. J.,* **60**:1093-1096

Srijan, Kuldeep Singh Dangi, Senguttuvel, P., Sundaram, R. M., Srinivasa Chary, D. and Sudheer Kumar, S. 2018. Correlation and path coefficient analysis for grain yield in aerobic rice (*Oryza sativa* L.) genotypes.*The J. Res. PJTSAU*., **46**(4) 64-68.

Timothy, D. H. 1963. Genetic diversity, heterosis and the use of exotic stocks in maize in Columbia. *In Stat. Genet. Pl. Breed. Symp. Raleigh,* 1961., 581-91.

Tripathi, A., Kumar, S., Kumar, M., Singh, Kumar, A. and Karnwal, M.K. 2017. Phenotypic assessment of rice (*Oryza sativa* L.) genotypes for genetic variability and varietal diversity under direct seeded condition. *J. Appl. Nat. Sci.,* **9**(1): 6 – 9.

Vanitha, J., Usha Kumari, R., Amudha, K. and Robin, S. 2015. Genetic evaluation of rice genotypes for zinc deficiency tolerance and yield traits under aerobic condition in rice. *Electron J. Plant Breed.,* **6** (1): 191-195.

Zhao, D. L., Atlin, G. N., Amante, M., Sta Cruz, M. T. and Kumar, A. 2010. Developing aerobic rice cultivars for water-short irrigated and drought-prone rainfed areas in the tropics. *Crop Sci.*, **50**: 2268–2276.