Mysore J. Agric. Sci., 52 (2) : 349-355, 2018

Evaluation of Genetic Variability, Heritability and Genetic Advance for High Zinc in Grain in F_3 Population of Rice (*Oryza sativa* L.) under Aerobic Condition

N. P. Thuy and H. E. Shashidhar
Department of Plant Biotechnology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
E-mail: npthuy2017@gmail.com

Abstract

A study was carried out using progeny from a cross between 'Gopaldoddiga' and 'ARB6' cultivars. Analysis of variance for the traits evaluated showed highly significant differences ($P < 0.001$) among the genotypes for all traits. Higher phenotypic and genetic coefficients of variation for all the characters except brown rice zinc, and high heritability coupled with high genetic advance for most of the traits indicates strong additive genetic control of these traits. Zinc content and grain yield were high for hybrid progenies namely, line GA 214-132 and line GA 214-217 and therefore can be recommended for planting under suitable aerobic conditions. These zinc enriched high yielding lines can be effectively utilized in rice biofortification programs across the globe.

Keywords: Biofortification, GCV, PCV, zinc, rice (*Oryza sativa* L.)

Rice (*Oryza sativa* L.), one of the most important cereal grains in the world today, serves as a staple food source for more than half of the world's population, especially for people in Asia (Gross and Zhao, 2014). Rice nutrient content varies depending on the cultivar and production conditions in addition to the processing method (Rohman *et al*., 2014).

Mukamuhirwa (2016) reported that rice contains mainly carbohydrates and contributes 20 per cent of the world's dietary energy. Calpe (2006) found that 100 g of raw white rice provides 361 kcal of energy and 6 g of proteins. Good proportions of thiamine, riboflavin, niacin and dietary fibers are found in rice. Some studies revealed that whole grains, especially from red and black rice are rich in polyphenols and insoluble fibers with nutraceutical and antioxidant benefits (Shao and Bao, 2015 and Zhang *et al.*, 2015) that play a role in preventing colorectal and intestinal cancer. Rice is considered as a potential food vehicle for the fortification of micronutrients since it rice is an essential part of daily diet for many. A study in Bangladeshi children and their care givers showed that rice was the main source of zinc intake, providing 49 per cent of dietary zinc to children and 69 per cent to women (Arsenault *et al.*, 2010). However, commercial varieties of rice are a poor source of essential micronutrients such as zinc (Zn) (Bouis and Welch, 2010).

In 2018, Harvest Plus reported Zn to be involved in more body functions than any other mineral. Zn is essential for survival normal growth and development, maintenance of body tissues, vision, immune system and functioning of more than 300 enzymes. Zn deficiency is reported to be associated with abnormal labor and fetal abnormalities in pregnant women, diarrhea, acute lower respiratory infections and cognitive capacity in children and delayed sexual maturity in adolescents. Harvest Plus (2018) estimated that over 17 per cent of the global population are at a risk of inadequate zinc intake and is as high as 25 per cent in Africa and 29 per cent in South Asia.

'Biologically fortified' or 'biofortified' refers to crops that have been nutritionally enhanced using agronomic practices, conventional breeding method and genetic modification (Garcia-Casal *et al.*, 2016). A fast and easy solution to prevent zinc deficiency in plants is through supplementation with fertilizers (Cakmak, 2008). However this method is limited by the costs involved in fertilizer applications and reduced availability of Zn to plants due to physical and chemical characteristics of soil. A promising and cost-effective alternative strategy is improving plant zinc use efficiency and grain zinc content by plant breeding or genetic engineering approaches (Henriques *et al.*, 2012). However, deregulation of genetically modified (GM) products for cultivation is still a major challenge (Swamy *et al.*, 2016). Breeding efforts could increase the Zn level by 6–8 mg kg^{-1} (Harvest Plus, 2014). Significant positive heterosis for grain Zn hasbeen reported. In a line × tester analysis involving six lines and eight testers and a total of 48 hybrids, it was interesting to note that 14 out of 48 hybrids showed significant positive heterosis for grain Zn over the standard micronutrient check variety Chittimutyalu. Two crosses (PR116 × Chittimutyalu and Mandya Vijay × Jalamagna) showed more than 50 per cent heterosis for grain Zn (Babu *et al*., 2012). Transgressive segregants were also observed for grain Zn (Stangoulis *et al.*, 2007).

The genetic biofortification strategy uses plant breeding techniques to produce staple food crops with higher micronutrient levels (Harvest Plus 2014). The world's first Zn enriched rice variety was released in 2013 by the Bangladesh Rice Research Institute (BRRI dhan 62), which is claimed to contain 20–22 mg Zn kg^{-1} of brown rice. Nonetheless, this is short of the target of 30 mg Zn kg^{-1} set by the Harvest Plus program (Shahzad *et al*., 2014).With the aim of further enrichment of Zn in commercial cultivars, present study was undertaken to evaluate genetic variability, heritability and genetic advance for high zinc in grain in F_3 population of rice under aerobic condition.

Material and Methods

The experiment was carried out during *kharif* 2015 using augmented design (Federer,1961) under aerobic condition at the field experimental plot of Department of Plant Biotechnology, University of Agricultural Sciences, GKVK, Bangalore. Ninety seven lines of F_3 population derived from *Gopaldoddiga* x ARB6 were sown in 10 blocks using Gopaldoddiga, ARB6, AM 143 and AM65 as checks under aerobic condition.

In all the plots, observations were recorded for days to 50 per cent flowering, days to maturity, plant height (cm), number of tillers per plant, number of productive tillers per plant, panicle length (cm) and grain yield per plant (g) at appropriate stages of the crop. Biomass of plant (g), harvest index (%), 100 grains weight (g) and brown rice Zn content (mg kg^{-1}) were recorded after harvest.

Grains of individual lines were harvested manually and hand threshed to avoid any contamination. The grains (0.5 g) were then manually dehusked. Unbroken, uniform grains were then washed in diluted hydrochloric acid followed by washing with double distilled water to remove any surface contaminants and dried in hot air oven at 70 °C for 72 hours. The Zn content in these grains was estimated using X-ray florescence (XRF) (Paltridge *et al*., 2012). Five grams of brown rice from each plant was subjected to XRF and content in mg kg^{-1} was calculated. The experimental data was compiled by taking mean values of three replications for each genotype.

The analysis of variance for different characters was carried out as suggested by Rana *et al.* (1991). Both phenotypic and genotypic co-efficient of variability (%) for all traits were estimated using the formulae of Burton and De Vane (1953). Heritability (%) and genetic advance (%) were worked out as per the method outlined by Hanson *et al.* (1956).

Results and Discussion

Analysis of Variance (ANOVA)

Analysis of variance indicated highly significant differences among the genotypes for all the characters studied ($P<0.001$) (Table I), suggesting genetic causes for the observed differences between various segregants. The effect of experimental blocks was insignificant for all traits (Table I), which suggested that environmental conditions were largely uniform in all 10 blocks. The performance of checks or F_3 population was influenced by two factors: the genetic properties it carries and the environment where it is cultivated; if the environment is uniform, the plant character will be influenced only by the genetic properties. Similar findings were reported earlier in rice by Bekele *et al.* (2013); Rashid *et al.* (2017) and Barokah *et al.* (2018).

Genetic variability parameters

Higher estimates (>15%) of GCV and PCV were observed for grain yield per plant, number of productive tillers, total number of tillers, harvest index, biomass per plant and 100 grains weight (Table II and Fig. 1). GCV and PCV estimates were moderate

TABLE I

Analysis of variance (mean sum of squares) for 10 different characters in F_3 population of Gopaldoddiga *X ARB6 in kharif-2015*

Source of Variation	Df	Mean Sum of Square: Day to 50 per cent Flowering		Plant Height		Total Number of Tillers		Number of Productive Tillers		Panicle Length	
Blocks (eliminating check + var)	9	1.85		12.96		3.29		4.39		3.07	
Progenies + Checks	103	208.14	***	344.32	***	114.07	***	101.74	***	23.26	***
Checks	3	2154.00	***	7213.78	***	442.30	***	397.29	***	334.19	***
Progenies	99	134.23	***	111.10	***	83.25	***	75.96	***	13.01	***
Checks vs. Progenies	1	1465.65	***	2124.92	***	2088.86	***	1689.63	***	74.40	***
Error	27	2.33		10.83		2.25		2.16		2.69	

Source of Variation	Df	Mean Sum of Square: Biomass per plant		Grain yield per plant		Harvest index		100 grains weight		Brown rice zinc	
Blocks (eliminating check + var)	9	3.16		1.48		0.002		0.04		2.60	
Progenies + Checks	103	135.16	***	147.18	***	0.06	***	0.32	***	31.02	***
Checks	3	1957.46	***	347.79	***	0.07	***	1.06	***	146.60	***
Progenies	99	79.62	***	98.16	***	0.03	***	0.26	***	22.59	***
Checks vs. Progenies	1	0.22		4251.41	***	2.86	***	4.45	***	493.35	***
Error	27	3.86		0.94		0.001		0.02		1.68	

* Significant at 5%; ** Significant at 1%; *** Significant at 0.1%; Df: Degrees of freedom.

TABLE II

Estimate of genetic parameters for different traits in F_3 population of Gopaldoddiga *X ARB6 in Kharif-2015*

Plant characters	Min.	Max.	Mean ± S.E	GCV(%)	PCV(%)	h^2(%)	GAM(%)
Day to 50% flowering	70.00	107.00	87.21 ± 1.18	11.45	11.58	97.71	23.32
Plant height (cm)	75.00	116.00	89.27 ± 1.07	9.75	10.43	87.50	18.79
Total number of tillers	8.00	39.00	25.94 ± 0.93	30.17	30.72	96.46	78.22
Number of productive tillers	7.00	38.00	24.30 ± 0.88	30.74	31.33	96.27	62.13
Panicle length (cm)	15.00	28.67	22.27 ± 0.37	12.54	14.54	74.37	22.27
Biomass per plant (g)	19.30	59.40	37.83 ± 0.91	20.01	20.67	93.68	39.89
Grain yield per plant(g)	8.40	40.10	22.60 ± 0.88	32.63	32.84	98.73	66.79
Harvest index (%)	23.23	79.42	59.01 ± 0.02	22.46	23.16	94.08	44.88
100 grains weight (g)	1.25	3.63	2.65 ± 0.05	15.78	16.78	88.49	30.58
Brown rice zinc (mg kg^{-1})	20.10	37.60	28.32 ± 0.48	14.04	14.76	90.37	27.49

* Significant at 5%; PCV = Phenotypic Coefficient of variation; GCV= Genotypic Coefficient of variation; h^2 % = Heritability percentage in broad sense; GAM: Genetic advancement as percentage of mean.

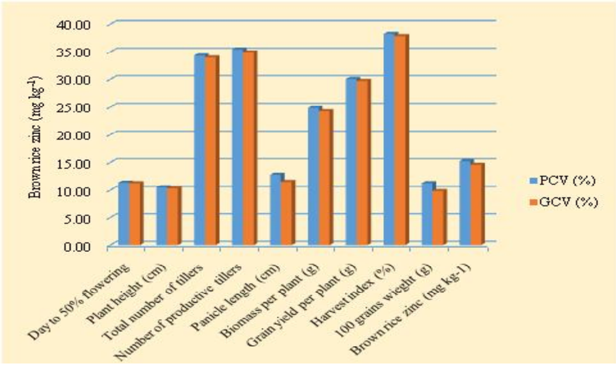

Fig. 1 : Graphical representation of phenotypic (PCV) and genotypic (GCV) coefficients of variation

(<15%) forbrown rice zinc, panicle length, day to 50 per cent flowering andplant height. PCV values were only slightly higher than GCV values under investigation for all the traits suggesting that these traits were under the strong influence of genetic control and less influence of the environment. Thus individual plant selection can be practiced for these characters. Similar results were reported in rice by Bisne *et al*. (2009); Akinwale *et al*. (2011); Govintharaj *et al*. (2016); Revathi *et al*. (2016); Yugandhar *et al*. (2017); Prasad *et al*. (2017); Abebe *et al*. (2017); Rajpoot *et al*. (2017); Ajmera *et al*. (2017); Nandeshwar *et al*. (2010); Shet *et al*. (2012); Kiran *et al*. (2013); Bekele *et al*. (2013); Tuhina-Khatun *et al*. (2015) and Mamata *et al*. (2018).

Moderate PCV and GCV values were observed for grain zinc content and are in agreement with previous reports; Purusothaman *et al*. (2010); Samak *et al*. (2011); Shashidhara *et al*. (2013), Sala *et al*. (2014), Anjali (2017), Ajmera *et al*. (2017); Madhubabu *et al*. (2017) and Shashidhara *et al*. (2017).

Heritability and Genetic Advance

The estimates of heritability act as predictive instrument in expressing the reliability of phenotypic selection, aiding in effective selection for a particular character. In this study, high estimates of broad sense heritability along with high genetic advance (expressed as per cent of mean) was observed for days to 50 per cent flowering, total number of tillers, number of productive tillers, panicle length, biomass

TABLE III

Transgressant lines selected from F_3 *population of* Gopaldoddiga *X ARB6 based on grain zinc content, grown in* kharif-2015

Superior plants	Day to 50 % flowering	Plant height (cm)	Total number of tillers	Number of productive tillers	Panicle length (cm)	Biomass per plant (g)	Grain yield per plant (g)	Harvest index (%)	100 grains weight (g)	Brown rice zinc (mg kg^{-1})
GA 240-450	99	78.2	34	31	21.67	30.2	8.4	27.81	2.95	37.6
GA 247-93	98	79	32	31	21	38.2	14.4	37.70	2.15	37.4
GA 214-132	78	93.6	20	18	18.33	41.6	23.9	57.45	2.96	37.1
GA 247-280	105	75	39	35	26	43	26.5	61.63	2.36	37.1
GA 191-209	73	104	16	14	27	40.1	30.7	76.56	3.21	36.7
GA 214-217	80	91.8	21	20	19.33	46.8	30.7	65.60	2.84	36.6
GA 254-9	96	80.4	32	30	20.67	42.2	24.6	58.29	2.3	36.6
GA 254-173	102	82.4	38	35	28.67	31.5	20.6	65.40	2.51	36.6
GA 254-19	100	77.2	36	32	23.33	43.5	28.7	65.98	2.84	36.6
GA 287-63	71	102.4	9	9	18.33	41.5	22.4	53.98	3.36	36.2
Gopaldoddiga (Parent-1)	72.5	101.1	8.3	8	24.12	26.26	6.74	25.67	2.72	29.71
ARB 6 (Parent-2)	99.7	80.6	21.2	20.1	18.68	27.84	12.54	45.04	1.96	22.3
AM 143 (Check-1)	102.1	75.4	23.3	22.3	20.88	41.23	16.07	38.98	2.12	21.12
AM 65 (Check-2)	103.3	134.62	16.6	15.9	31.89	56.32	20.73	36.81	2.23	23.47

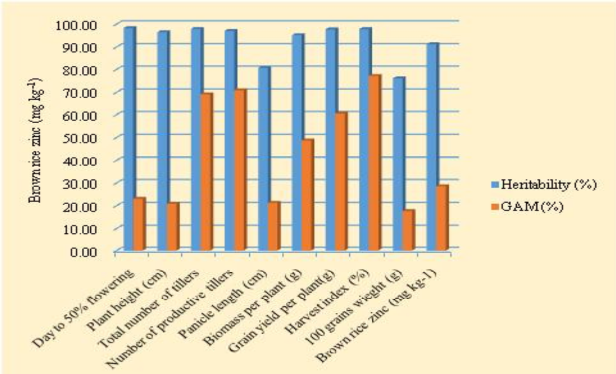

Fig. 2 : Graphical representation of heritability and genetic advancement as percentage of mean (GAM)

per plant, grain yield per plant, harvest index, 100 grains weight and brown rice zinc (Table II and Fig. 2). This indicates the presence of strong additive gene effects and potential for genetic improvement of these traits in future breeding programmes. From the results of the present study, it can be concluded that single plant selection could be effectively practiced as environment does not have any significant influence in the variation of these traits. High heritability and genetic advance as per cent of mean was earlier reported in rice by Babu *et al.* (2012), Bekele *et al.* (2013), Sadimantara *et al.* (2014); Soman *et al.* (2015); Limbani *et al.* (2017); Yadav *et al.* (2017); Sumanth *et al.* (2017) and Shamim *et al.* (2017).

Selected superior segregants in F_3 segregating generations

Ten progenies with high zinc content in grain, yield and yield *component* traits such as day to 50 per cent flowering, plant height, total number of tillers, number of productive tillers, panicle length, biomass per plant, grain yield per plant, harvest index and 100 grains weight, were selected from F_3 segregating populations (Table III). From the selection it was observed that high yielding progenies have higher brown rice zinc content per plant. As these progenies were still segregating, more generations need to be tested before releasing for multi-location trial.

References

Abebe, T., Alamerew, S. and Tulu, L., 2017, 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 Sci. Tech.*, **5** (2) : 1 - 8.

Ajmera, A., Kumar, S. S. and Ravindrababu, V., 2017, Evaluation of genetic variability, heritability and genetic advance for yield and yield components in rice genotypes. *Int. J. Pure App. Biosci.*, **5** (4) : 909 - 915.

Akinwale, M. G., Gregorio, G., Nwilene, F., Akinyele, B.O., Ogunbayo, S. A. and Odiyi, A. C., 2011, Heritability and correlation coefficient analysis for yield and its components in rice (*Oryza sativa* L.). *Afr. J. Plant Sci.*, **5** (3) : 207 - 212.

Anjali, P., 2017, Discerning phenotype and molecular markers-based association between grain number, zinc and iron bio-fortification of rice (*Oryza sativa* L.). *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci., Bangalore.

Arsenault, J. E., Yakes, E. A., Hossain, M. B., Islam, M. M., Ahmed, T., Hotz, C., Lewis, B., Rahman, A. S., Jamil, K. M. and Brown, K. H., 2010, The current high prevalence of dietary zinc inadequacy among children and women in rural Bangladesh could be substantially ameliorated by zinc biofortification of rice. *J. Nutr.*, **140** (9) : 1683 - 1690.

Babu, V. R., Shreya, K., Dangi, K. S., Usharani, G. and Nagesh, P., 2012, Genetic variability studies for qualitative and quantitative traits in popular rice (*Oryza sativa* L.) hybrids of India. *International J. Sci. Res. Pub.*, **2** (6) : 5.

Barokah, U., Susanto, U., Swamy, M., Djoar, D.W. and Parjanto., 2018, High-zinc rice as a breakthrough for high nutritional rice breeding program. *IOP Conference Series: Earth and Environmental Science*, **129** (1) : 012004.

Bekele, B. D., Rakhi, S., Naveen, G. K., Kundur, P. J. and Shashidhar, H. E., 2013, Estimation of genetic variability and correlation studies for grain zinc concentrations and yield related traits in selected rice (*Oryza sativa* L.) genotypes. *Asian J. Exp. Biol. Sci.*. **4** (3) : 7.

Bisne, R., Sarawgi, A. K. and Verulkar, S. B., 2009, Study of heritability, genetic advance and variability for yield contributing characters in rice. *Bangladesh J. Agril. Res.*, **34** (2) : 175 - 179.

Bouis, H. E. and Welch, R. M., 2010, Biofortification - a sustainable agricultural strategy for reducing micronutrient malnutrition in the global south. *Crop Sci.*, **50** : 20 - 32.

Burton, G. W. and De Vane, E. H., 1953, Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material. *Agronomy J.*, **45** (10) : 478 - 481.

CAKMAK, I., 2008, Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? *Plant and Soil,* **302** (1 - 2) : 1 - 17.

CALPE, C., 2006, Rice international commodity profile. *In FAO, Markets and trade division.*

FEDERER, W. T., 1961, Augmented Designs with One-Way Elimination of Heterogeneity. *Biometrics,* **17** (3) : 447 - 473.

GARCIA-CASAL, M. N., PEÑA-ROSAS, J. P., PACHÓN, H., DE-REGIL, L. M., CENTENO TABLANTE, E. AND FLORES-URRUTIA, M. C., 2016, Staple crops biofortified with increased micronutrient content: effects on vitamin and mineral status, as well as health and cognitive function in the general population. *In*: *Cochrane Database of Systematic Reviews,* John Wiley & Sons, Ltd.

GOVINTHARAJ, P., TANNIDI, S., SWAMINATHAN, M. AND SABARIAPPAN, R., 2016, Estimates of genetic variability, heritability and genetic advance for blast resistance gene introgressed segregating population in rice. *Int. J. Curr. Microbiol. App. Sci.,* **5** (12) : 672 - 677.

GROSS, B. L. AND ZHAO, Z., 2014, Archaeological and genetic insights into the origins of domesticated rice. *Proc. Natl. Acad. Sci. USA.,* **111** (17) : 6190 - 6197.

SHASHIDHARA, N., BIRADAR, H. AND HITTALMANI. S., 2017, Qualitative and quantitative genetic variations in the f_2 inter varietal cross of rice (*Oryza sativa* L.) under aerobic condition and parental polymorphism survey. *Int. J. Curr. Microbiol. App. Sci.,* **6** (4) : 2215 - 2225.

HANSON, C. H., ROBINSON, H. F. AND COMSTOCK, R. E., 1956, Biometrical studies of yield in segregating populations of Korean lespedeza. *Agron. J.,* **48** (6) : 268 - 272.

HARVESTPLUS, 2014, Biofortification progress briefs.

HARVESTPLUS 2018. Nutrition. http://www.harvestplus.org/what-we-do/nutrition.

HENRIQUES, A. R., CHALFUN-JUNIOR, A. AND AARTS, M., 2012, Strategies to increase zinc deficiency tolerance and homeostasis in plants. *Brazilian J. Pl. Physiol.,* **24** (1) : 3 - 8.

KIRAN, K. K., GURURAJA RAO, R. M. AND SURESH, K., 2013, Variability and frequency distribution studies in F_2 population of two crosses of rice (*Oryza sativa* L.). *Asian J. Bio. Sci.,* **8** (2) : 153 - 159.

LIMBANI, P. L., GANGANI, M. K. AND PANDYA, M. M., 2017, Genetic variability, heritability and genetic advance in rice (*Oryza sativa* L.). *Int. J. Pure App. Biosci.,* **5** (6) : 1364 - 1371.

MADHUBABU, P., SUMAN, K., RATHOD, R., FIYAZ, R., RAO, D., SUDHAKAR, P., SATYA, A., BABU, V. AND NEERAJA, C., 2017, Evaluation of grain yield, quality and nutrients content in four rice (*Oryza sativa* L.) genotypes. *Curr. J. Appl. Sci. Techn.,* **22** (1) : 1 - 12.

MAMATA, K., RAJANNA, M. P. AND SAVITA, S. K., 2018, Assessment of genetic parameters for yield and its related traits in F_2 populations involving traditional varieties of rice (*Oryza sativa* L.). *Int. J. Curr. Microbiol. App. Sci.,* **7** (1) : 2210 - 2217.

MUKAMUHIRWA, A., 2016, Responses of rice (*Oryza sativa* L.) genotypes to repeated drought stress under contrasting temperatures. *Introductory paper at the Faculty of Landscape Architecture, Horticulture and Crop Production Science (BIB14970803),* **2016** (1) : 1 - 38.

NANDESHWAR, B. C., PAL, S., SENAPATI, B. K. AND DE, D. K., 2010, Genetic variability and character association among biometrical traits in F_2 generation of some rice crosses. *Elect. J. Plant Breed.,* **1** : 758 - 763.

PALTRIDGE, N. G., PALMER, L. J., MILHAM, P. J., GUILD, G. E. AND STANGOULIS, J. C. R., 2012, Energy-dispersive X-ray fluorescence analysis of zinc and iron concentration in rice and pearl millet grain. *Plant and Soil,* **361** (1 - 2) : 251 - 260.

PRASAD, K. R., KRISHNA, K. V. R., BHAVE, M. H. V. AND RAO, L. V. S., 2017, Genetic variability, heritability and genetic advance in Boro rice (*Oryza sativa* L.) germplasm. *Int. J. Curr. Microbiol. Appl. Sci.,* **6** (4) : 1261 - 1266.

PURUSOTHAMAN, R., 2010, Genetic analysis for high Fe and Zn content in rice (*Oryza sativa* L.) grains. *M.Sc., (Agri.) Thesis* (Unpub.), TNAU, Coimbatore.

RAJPOOT, P., SINGH, P., VERMA, O. AND TRIPATHI, N., 2017, Studies on genetic variability and heritability for quantitative characters in rice (*Oryza sativa* L.) under sodic soil. *J. Pharmaco. Phytochem.,* **6** (4) : 1162 - 1165.

RANA, R. S., SAPRA, R. L., AGRAWAL, R. C. AND GAMBHIR, R., 1991, Germplasm evaluation; Augumented design. In: Plant genetic resources; documentation and information management. *National bureau of plant genetic resource,* New Delhi, pp. 37 - 44.

RASHID, M., NURUZZAMAN, M., HASSAN, L. AND BEGUM, S., 2017, Genetic variability analysis for various yield attributing traits in rice genotypes. *J. Bangladesh Agricult. Univ.,* **15** (1) : 15.

Revathi, S., Sakthivel, K., Manonmani, S., Umadevi, M., Ushakumari, R. and Robin, S., 2016, Genetics of wide compatible gene and variability studies in rice (*Oryza sativa* L.). *J. Genetics.,* **95** (2) : 463 - 467.

Rohman, A., Helmiyati. S., Hapsari, M. and Setyaningrum, D. L., 2014, Rice in health and nutrition. *IFRJ.*, **21** : 13 - 24.

Sadimantara, G. R., Muhidin and Cahyono, E., 2014, Genetic analysis on some agro-morphological characters of hybrid progenies from cultivated paddy rice and local upland rice. *Adv. Stud. Biol.*, **6** (1) : 7 - 18.

Sala, M. and Ananda Kumar, C. R., 2014, Variability studies for quality traits in rice with high iron and zinc content in segregating population. *Int. J. Sci. Res.*, **3** (12) : 1988 - 1990.

Samak, N. R., Hittalmani, S., Shashidhar, N. and Birada, H., 2011, Exploratory studies on genetic variability and genetic control for protein and micronutrient content in F_4 and F_5 generation of rice. *Asian J. Plant Sci.,* **10** (7) : 376 - 379.

Shahzad Z, Rouached, H. and Rakha A., 2014, Combating mineral malnutrition through iron and zinc biofortification of cereals. *Compr. Rev. Food Science Food Safety,* **13** (3) : 329 - 346.

Shamim, M. Z., Sharma, V. K., Manzar, H. and Bhushan, S., 2017, Grain yield components analysis in locally adapted rice varieties. . *Internat. J. Agricul. Envir. Biotechnol.*, **10** (4) : 435.

Shao, Y. and Bao, J., 2015, Polyphenols in whole rice grain: genetic diversity and health benefits. *Food Chemistry,* **180** : 86 - 97.

Shashidhara, N., Biradar, H. and Hittalmani, S., 2013, genetic variation in F3 and F_4 population of rice (*Oryza sativa* L.) for grain protein content (GPC), seed nutrients, yield attributing parameters and parental polymorphisms. *Bioinfolet*, **10** (2) : 572 - 580.

Shashidhara, N., Biradar, H. and Hittalmani, S., 2017, Qualitative and quantitative genetic variations in the F_2 inter varietal cross of rice (*Oryza sativa* L.) under aerobic condition and parental polymorphism survey. *Int. J. Curr. Microbiol. App. Sci.,* **6** (4) : 2215 - 2225.

Shet, R. M., Rajanna, M. P., Ramesh, S., Sheshshayee, M. S. and Mahadevu, P., 2012, Genetic variability, correlation and path coefficient studies in F_2 generation of aerobic rice (*Orzya sativa* L.). *Elec. J. Pl. Breed.,* **3** (3) : 925 - 931.

Soman, R., Gande, N., Kundur, J. P., Ambati, R., Ashwathanarayana, R., Bekele, D. B. and Shashidhar, H. E., 2015, Identification and validation of putative candidate gene markers for grain iron content in recombinant inbred lines of rice (*Oryza sativa* L.). *Int. J. Agric. Innov. Res.*, **3** (3): 923 - 930.

Stangoulis, J. C. R., Huynh, B. -L., Welch, R. M., Choi, E.-Y. and Graham, R. D., 2007, Quantitative trait loci for phytate in rice grain and their relationship with grain micronutrient content. *Euphytica,* **154** (3) : 289 - 294.

Sumanth, V., Suresh, B. G., Ram, B. J. and Srujana, G., 2017, Estimation of genetic variability, heritability and genetic advance for grain yield components in rice (*Oryza sativa* L.). *J. Pharmacognosy Phytochem.,* **6** (4) : 1437 - 1439.

Swamy, B. P. M., Rahman, M. A., Inabangan-Asilo, M. A., Amparado, A., Manito, C., Chadha-Mohanty, P., Reinke, R. and Slamet-Loedin, I. H., 2016, Advances in breeding for high grain Zinc in Rice. *Rice,* **9**.

Tuhina-Khatun, M., Hanafi, M. M., Rafii Yusop, M., Wong, M. Y., Salleh, F. M. and Ferdous, J., 2015, Genetic variation, heritability and diversity analysis of upland rice *(Oryza sativa L.)* genotypes based on quantitative traits. *Bio. Med. Res. Int.*, 1 - 7.

Yadav, R., Rajpoot, P., Verma, O., Singh, P., Singh, P. and Pathak, V., 2017, Genetic variability, heritability and genetic advance in Rice (*Oryza sativa* L.) for grain yield and it's contributing attributes under sodic soil. *J. Pharmacognosy Phytochem.,* **6** (5) : 3.

Yugandhar, P. R., Dahat, D. V., Barahte, K. K. and Suneetha, K., 2017, Study on variability, heritability and genetic advance for agro-morphological and grain quality parameters in restorer lines of rice (*Oryza sativa* L.). *Int. J. Pure App. Biosci.,* **5** (4) : 1202 - 1206.

Zhang, H., Shao, Y., Bao, J. and Beta, T., 2015, Phenolic compounds and antioxidant properties of breeding lines between the white and black rice. *Food Chem.,* **172** : 630 - 639.

(*Received :* May, 2018 *Accepted :* June, 2018**)**