Int.J.Curr.Microbiol.App.Sci (2018) Special Issue-7: 4791-4801

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 Special Issue-7 pp. 4791-4801
Journal homepage: http://www.ijcmas.com

Original Research Article

Study of Yield Traits and Their Association under Zinc Deficient Condition in $F_{2:3}$ Mapping Populations of Rice (*Oryza sativa* L.)

Sandhya, Mukul, Deepika Singh and P. K. Singh*

Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.), India
**Corresponding author*

Keywords

Variability, Correlation, Heritability, Rice (*Oryza sativa* L), Zinc

A B S T R A C T

Genetic variability studies provide basic information concerning the genetic properties of the population based on which breeding methods could be formulated for further improvement of the crop. The estimates of heritability, coefficients of variability and genetic advance were computed in 21 $F_{2:3}$ progenies of a cross Kinandang Patong and A69-1 for 18 characters including zinc deficiency tolerance and yield contributing traits under zinc deficient condition during *kharif* 2016. The highest genotypic coefficient of variation (GCV) was found for leaf bronzing score. High heritability with high genetic advance was obtained in filled grains per panicle, grain yield per plant and plant height which is indicative of additive gene action. The correlation analysis revealed that the grain yield per plant had highly positive significant association with leaf bronzing score, number of productive tiller per plant, thousand grain weight and total dry matter. This implies that selection for these characters would lead to simultaneous improvement of grain yield high heritability coupled with high and moderate genetic advance was observed for all the plant traits observed. However zinc concentration in shoot (in minus zinc condition) was negatively significantly correlated with grain yield per plant.

Introduction

Zinc is one of the essential nutrients for plants and its deficiency is one of the major micronutrient constraints to crop production throughout the world (Reddy *et al.,* 2013). One third of the world population is at risk due to low dietary intake of Zn (Myers *et al.,* 2015), including 2 billion people in Asia and 400 million in sub-Saharan Africa (Institute, 2006). It was first diagnosed in on calcareous soils of northern India (Nene, 1966; Yoshida and Tanaka, 1969). Rice germplasm shows large variation in tolerance of Zn-deficient soils (Quijano-Guerta *et al.*, 2002; Wissuwa *et al.*, 2006) and in the ability to concentrate Zn in grains (Gregorio, 2002; Wissuwa *et al.,* 2008; Impa *et al.*, 2013).

However, "Khaira" disease was proved as d ue to zinc deficiency (Tanaka, 1970 and Quijano-Guerta *et al.,* 2002). Marschner, 1995 reported that Zn is involved in many physiological processes, including enzyme activation and protein synthesis. Zn deficiency affects rice most severely during the seedling stage, following 2-3 week after transplanting, when plant mortality may occur. Less severe symptoms include brown spot sand discoloration of the leaves and reduced plant growth. Surviving plants typically recover partially around weeks after transplanting, but delayed maturation and reduced yield are typical (Yoshida and Tanaka, 1969; Breemen and Castro, 1980; Wissuwa *et al.,* 2006). Although an adequate amount of Zn could be present in the soil, its availability to plants is dependent on soil conditions. Many factors, including high soil pH (>7) and high bicarbonate, as well as phosphate and organic matter content, contribute to sequestering Zn in the soil, resulting in rice Zn deficiency (Nene and Lantin, 1994; Dobermann and Fairhurst, 2000).

Rice yield and growth is very sensitive to zinc and it can be corrected by adding zinc compounds to the soil or plant, but the high cost associated with applying zinc fertilizers in sufficient quantities to overcome zinc deficiency places considerable burden on resource-poor farmers and it has therefore been suggested that breeding efforts should be intensified to improve the tolerance to zinc deficiency in rice cultivars (Quijano-Guerta *et al.,* 2002; Singh *et al.,* 2003 and Reddy *et al.,* 2013).

The development of new genotypes requires some knowledge about the genetic variability presents in the germplasm of the crop to build efficient breeding programme. The knowledge about genetic variability can help to know if these variations are heritable or non-heritable. The magnitude of variation due to heritable component is very important because, it would be a guide for selection of parents for crop improvement (Dutta *et al.,* 2013). Therefore, selection for high yield requires knowledge about genetic variability and good understanding of correlation between yield and yield components regarding to the genetic material that is on hand. Genetic variability for agronomic and quatitative traits is the key component of breeding programme for broadening the gene pool of rice (Konate *et al.,* 2016).

Heritability estimates provide authentic information about a particular genetic attribute which will be transmitted to the successive generations and constitute an efficient guide for breeders in the choice of parents for crop improvement programmes (Rafi and Nath, 2004). However, heritability in broad sense alone may not be helpful for selection based on phenotype, because it's influenced by environment. Thus, estimate heritability along with genetic advance conjointly are reliable helpful in predicting the gain under selection than heritability alone (Ogunbayo *et al.,* 2014). Moosavi *et al.,* (2015) reported that grain yield is a complex trait, quantitative in nature and a combined function of a number of constituent traits. Consequently, selection for yield may not be satisfying without taking into consideration yield component traits. Thus, positives correlated between yield and yield components are requires for effective yield component breeding increasing grain yield in rice (Ogunbayo *et al.,* 2014). So, it is important for plant breeders to understand the degree of correlation between yield and its components (Konate *et al.,* 2016).

Therefore, the objective of the present study was to assess and evaluate genetic variability of rice $F_{2:3}$ progenies based on agro-morphological traits and analyse the relationships between these traits.

Materials and Methods

A $F_{2:3}$ mapping population having 21 progenies was developed from Kinandang Patong (zinc deficiency sensitive) and A69-1 (zinc deficiency tolerant) parents by using modified single seed descent method. In the present study, 21 progenies of this mapping population along with parents were in the field during *Kharif* season 2016 at Research Farm of a sub-station, Central Soil Salinity Research Institute, Lucknow, (U.P.). Ten plants of each F_2 derived F_3 line were sown in three rows of 1 m length and one line gap with spacing of 15 cm between rows. All the genotypes were replicated thrice in RBD design. Six soil samples were collected from the experimental field at different locations to know zinc nutrient present in the soil. These soil samples were analyzed in soil science laboratory by using Atomic Absorption Spectrophotometer (AAS). Readings of these samples were ranged between 0.5ppm to 1.0ppm. Critical level of soil below which zinc deficiency might occur is 1.0ppm (Castro, 1977).

Recommended agronomic practices were followed throughout the crop growth period. This cross exhibited superior performance for biometrical traits in F_3 generations for almost all the economic characters studied including yield. Data were recorded five plants form each replication respectively for seedling survival (%), leaf bronzing score (0-9), days to 50 per cent flowering (days), days to maturity (days), number of productive tiller per plant, plant height (cm), panicle length (cm), filled grains per panicle, unfilled grains per panicle, thousand grain weight (g), grain yield per plant (g), total dry matter (g) in single plant, zinc concentration in shoot, root and leaf in plus zinc and minus zinc conditions observations. All field experiments were conducted on a highly Zn-deficient soil. The phenotypic evaluation of 21 $F_{2:3}$ progenies of the Kinandang Patong x A69-1 population was conducted in the same field plots. 2 WAT, the number of surviving plants per row was determined and surviving plants were scored for leaf bronzing. Leaf symptoms were scored based on classification according to (Wissuwa, *et al.,* 2006). The mean data for each character individually was subjected to statistical analysis. Standard statistical procedures were used for the analysis of mean variance, genotypic and phenotypic coefficients of variation (Burton, 1952), heritability (Lush, 1940) and genetic advance. Coefficient of correlation was determined using the technique outlined by Dewey and Lu (1959).

Results and Discussion

Analysis of variance and genetic parameters

It is evident from the analysis of variance that the treatment differences given to the 21 $F_{2:3}$ progenies were highly significant for the entire quantitative traits [Table-1]. This result is similar to (Rani *et al.,* 2001and Pallavi *et al.,* 2017). Genotypic coefficient of variation, phenotypic coefficient of variation, heritability in broad sense, genetic advance and genetic advance as percentage of means were estimated for yield and quality in $F_{2:3}$ generation as presented in Table 2. Expectedly phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) in all the characters studied. The difference between PCV and GCV is probably due to environmental effects. High heritability estimates for all the characters except seedling survival, leaf bronzing score, unfilled grains per panicle and zinc concentration in shoot (in minus zinc condition) suggesting that the environmental factors did not affect greatly the phenotypic performance of these traits. Highest PCV (80.77%) and GCV (62.14%) were observed for leaf bronzing score. PCV generally ranged between 3.18% for days to maturity to 80.77% for leaf bronzing score. Similarly, GCV ranged between 2.88% for days to maturity to 62.14% for leaf bronzing score. A similar finding of higher PCV than GCV for days to maturity and zinc score was also reported by (Vanitha *et al.,* 2016). Generally, heritability in broad sense estimate varied from 49% for zinc concentration in shoot (in minus zinc condition) and 98% for grain yield per plant. Similarly, genetic advance was ranged between 5.38% for days to maturity and 98.47% for leaf bronzing score. A joint consideration of GCV, heritability broad sense and genetic advance revealed that grain yield per plant (24.39, 98 and 49.75%) combined high GCV, high heritability broad sense and moderate genetic advance. Thus, high estimates of GCV and heritability could be good predictors of seed yield in rice. Hence selection based on the phenotypic performance will be reliable and effective. Furthermore, moderate to high heritability, GCV and GA% in a mean could be explained by additive gene action and their improvement could be achieved through mass selection [Khatun *et al.*, 2015] (Table 2).

Table.1 Analysis of variance (ANOVA) of 12 traits for zinc deficiency tolerance across the environment in a 21 progenies of $F_{2:3}$ population of a cross Kinandang Patong x A69-1

Source of variation	Replication	Treatment	Error
Degree of freedom	2	20	40
Seedling survival	0.357	4.673**	124.44
Leaf bronzing score	1.603	5.349**	4.22
Days to 50% flowering	0.007	14.661**	2.165
Days to maturity	0.142	14.773**	2.333
Number of productive tiller per plant	1.538	10.698**	0.402
Plant height (cm)	2.612	77.052**	7.292
Panicle length (cm)	3.133	25.718**	0.803
Filled grains per plant	1.535	64.914**	28.680
Unfilled grains per plant	3.612	5.454**	71.077
Thousand grain weight (g)	2.425	19.892**	1.385
Grain yield per plant (g)	2.216	148.543**	0.587
Total dry matter (g)	0.363	109.411**	2.170
Shoot (+Zn) mg per kg	0.165	3.958**	2.396
Shoot (-Zn) mg per kg	1.025	18.660**	2.647
Root (+Zn) mg per kg	2.474	16.187**	2.135
Root (-Zn) mg per kg	0.559	53.538**	1.021
Leaf (+Zn) mg per kg	3.043	31.908**	5.178
Leaf (-Zn) mg per kg	0.270	46.285**	1.233
Note: ** Significant at P<0.01			

Table.2 Phenotypic performance of 21 progenies of $F_{2:3}$ population of the cross Kinandang Patong x A69-1 for zinc deficiency tolerance

Trait	21 progenies of $F_{2:3}$ population							
	Range	**Mean± SE**	**CV%**	**F Ratio**	**h^2 (%)**	**GCV**	**PCV**	**G.A as % of mean**
Seedling survival	26.6-86.6	58.73± 6.44	18.99	4.67	55	21.01	28.33	32.12
Leaf bronzing score	0.0-9.0	3.98± 1.18	51.60	5.34	59	62.14	80.77	98.47
Days to 50% flowering	75.3-88.1	79.49±0.849	1.58	14.66	82	3.95	4.36	7.36
Days to maturity	108.3-123.0	113.42± 0.881	1.34	14.77	82	2.88	3.18	5.38
Productive tiller per plant	5.6-10.3	7.90± 0.366	8.02	10.69	76	14.42	16.51	25.97
Plant Height (cm)	89.6-145.4	119.01± 1.55	2.26	77.05	96	11.42	11.64	23.08
Panicle length (cm)	18.3-27.9	21.99± 0.51	4.07	25.71	89	11.69	12.38	22.75
Filled grains per panicle	83.0-183.0	116.09± 3.09	4.61	64.91	95	21.29	21.78	42.86
Unfilled grains per panicle	32.6-73.3	49.3±4.86	17.08	1.67	59	20.82	26.93	33.15
Thousand grain weight (g)	21.1-31.6	26.4± 0.679	4.44	19.89	86	11.15	12.01	21.35
Grain yield per plant (g)	15.2-35.9	22.041±0.354	2.78	231.85	98	24.39	24.64	49.75
Total dry matter (g)	25.6-61.68	37.59±0.850	3.91	109.41	97	23.56	23.88	47.87
Shoot (+Zn) mg per kg	29.0-36.6	33.841±0.893	6.14	22.50	87	16.38	17.72	31.20
Shoot (-Zn) mg per kg	16.0-29.0	24.095±0.855	4.57	3.95	49	4.54	6.44	6.59
Root (+Zn) mg per kg	32.3-43.6	35.761±0.843	4.08	16.18	83	9.19	10.06	17.30
Root (-Zn) mg per kg	15.0-31.0	24.809±0.544	3.80	61.41	95	17.04	17.52	34.15
Leaf (+Zn) mg per kg	33.0-71.0	48.174±0.939	3.37	111.45	97	15.57	16.31	30.62
Leaf (-Zn) mg per kg	16.0-33.3	27.190±0.641	4.08	46.28	93	15.86	16.38	31.65

CV (Coefficient of variance), SE (Standard error), h^2 (Heritability), GCV (Genotypic coefficient of variance), PCV (Phenotypic coefficient of variance), G.A (Genetic advance)

Table.3 Correlation Co-efficient among phenotypic traits studied in 21 $F_{2:3}$ progenies of Kinantong patong and A69-1

	SS	**LBS**	**DFF**	**DM**	**PTP**	**PH**	**PL**	**FGP**	**UGP**	**TW**	**TDM**	**S (+Zn)**
SS	**1.00**	-0.56***	0.02	-0.02	-0.17	-0.24	0.03	-0.30*	-0.05	0.21	-0.04	-0.01
LBS		**1.00**	-0.07	-0.07	0.06	0.25*	-0.01	0.28*	0.13	-0.02	0.18	-0.05
DFF			**1.00**	0.93***	0.10	-0.15	0.03	0.25*	-0.38**	-0.02	0.18	0.38**
DM				**1.00**	0.16	-0.06	0.07	0.29*	-0.46***	0.04	0.13	0.43***
PTP					**1.00**	0.08	0.08	0.19*	0.01	0.15	-0.09	0.09
PH						**1.00**	0.35**	0.37**	-0.15	0.38***	-0.00	0.03
PL							**1.00**	0.00	-0.12	0.34**	0.07	0.23
FGP								**1.00**	-0.17	-0.04	-0.09	0.07
UGP									**1.00**	-0.05	0.02	-0.43***
TW										**1.00**	-0.01	-0.03
S (+Zn)											**1.00**	0.05
S (-Zn)												**1.00**

Traits	S (-Zn)	R (+Zn)	R (-Zn)	L (+Zn)	L (-Zn)	GYP
Seedling Survival	0.58***	0.10	0.53***	-0.01	0.56***	-0.11
Leaf bronzing score	-0.71***	-0.07	-0.68***	-0.02	-0.59***	0.33**
Dayd to 50% flowering	0.22	-0.23	0.27*	-0.13	0.26*	0.19
Days to maturity	0.15	-0.16	0.22	-0.17	0.20	0.23
Number of Productive tiller per plant	-0.09	-0.08	-0.05	-0.08	-0.08	0.29*
Plant height	-0.27*	0.33**	-0.24	-0.18	-0.27	0.10
Panicle length	-0.01	0.37**	-0.03	-0.11	0.07	0.05
Filled grains per panicle	-0.27*	0.15	-0.08	-0.35**	-0.22	0.15
Unfilled grains per panicle	-0.26*	-0.01	-0.27*	0.26*	-0.14	0.05
Thousand grain weight	0.11	0.27*	0.09	0.24	0.27*	0.48***
Total dry matter	-0.13	-0.31*	-0.14	0.08	0.01	0.45***
Shoot (+Zn)	0.16	-0.21	0.16	-0.05	0.09	-0.15
Shoot (-Zn)	**1.00**	-0.11	0.86***	0.12	0.78***	-0.29*
Root (+Zn)		**1.000**	-0.02	-0.00	0.03	-0.09
Root (-Zn)			**1.00**	-0.03	0.82***	-0.21
Leaf (+Zn)				**1.00**	0.13	-0.12
Leaf (-Zn)					**1.00**	-0.02

Note: ***Significant at P<0.001, ** Significant at P<0.01, * Significant at P<0.05

Correlation studies revealed that grain yield per plant was positively significantly correlated with leaf bronzing score (0.33**), number of productive tiller per plant (0.29*), thousand grain weight (0.48***) and total dry matter (0.47***). Thus results suggest that selection to improve rice yield directed by phenotype of these traits may be effective (Ogunbayo *et al.,* 2014 and Suma *et al.,* 2014). Similarly, significant positive association of grain yield was observed with plant height (Shashidhar *et al.,* 2005 and Norain *et al.,* 2014), number of productive tillers (Shet *et al.,* 2018; Basavaraja *et al.,* 2011; Shanthi *et al.,* 2011; Norain *et al.,* 2014 and Suma *et al.,* 2014), thousand grain weight (Raju *et al.,* 2004 and Norain *et al.,* 2014), above-ground biomass and straw yield (Shashidhar *et al.,* 2005; Monalisa *et al.,* 2006; Pratap *et al.,* 2012). However, Grain yield per plant was negatively significantly correlated with zinc concentration in shoot (in minus zinc condition) (-0.29**). Similar findings were also recorded by (Wissuwa, *et al.,* 2006) for this trait (Table 3). Leaf bronzing score recorded significant positive correlation with plant height and filled grains per plant. Days to 50 per cent flowering recorded significant positive correlation with day to maturity, filled grains per plant, zinc concentration in shoot (in plus zinc condition) and zinc concentration in root (in minus zinc condition) at phenotypic level. Productive tillers per plant also showed positive correlation with filled grains per plant. Thousand grain weight were highly significant with plant height, panicle length, zinc concentration in root (in zinc plus condition) and zinc concentration in leaf (in minus zinc condition). Under the zinc deficient condition of field most of the trait was found with significant positive phenotypic correlation coefficients which indicated that a strong association among themselves and with grain yield per plant. Results are very close to the findings of (Ogunbayo *et al.,* 2014 and Wissuwa *et al.,* 2006). The results suggested that effective number of tillers and spikelet fertility may be taken into account in rice breeding programme for high yield and better improvement of the rice variety.

Among the twenty one rice progenies, 6 progenies recorded highest mean performance for the grain yield per plant along with lowest leaf bronzing score and highly tolerant to zinc deficient condition. These progenies which show good yields and other yield components would be more suitable for the direct selection and hybridization in order to make the desirable rice improvement programme.

References

Basavaraja, T., S., Gangaprasad, B. M., Dhusyantha, K. and Hittlamani, S. H. 2011. Correlation and path analysis of yield and yield attributes in local rice cultivars (*Oryza sativa* L.). Elect. J. Plant Breed., 2 (4): 523 - 526.

Breemen, N. V. and Castro, R.U. 1980. Zinc deficiency in wetland rice along a toposequence of hydromorphic soils in the Philippines. II. Cropping experiment. Plant Soil, 57: 215–221.

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

Castro, R.U. 1977. Zinc deficiency in rice: A review of research at the International Rice Research Institute. IRRI res.pap.ser., 9: 1-18.

Dewey, D.R., end K.H. Lu. 1959. A correlation and path coefficient analysis of components of crested wheatgrass seed production. Agron. J. 51:515-518.

Dobermann, A. and Fairhurst, T. 2000. Rice: nutrient disorders and nutrient management. International Rice Research Institute, Manila, Philippines.

Dutta P, Dutta P.N. and Borua P. K 2013. Morphological Traits as Selection Indices in Rice: A Statistical View. Univ. J. Agric. Res., 1(3):85-96.

Gregorio, G.B., Senadhira, D., Htut, T. and Graham, R.D. 2000. Breeding for trace mineral density in rice. Food Nutrition Bulletin, 21: 382-386.

Iftekharudduaula, K.M., Badshah, M.S., Hassan, M.S., Basher, M.K. and Akter, K. 2001. Genetic variability, character association and path analysis of yield components in irrigated rice (Oryza sativa L.). Bangladesh J. Pl. Breed. Genet., 14(2): 43-49.

Impa, S.M., Gramlich, A., Tandy, S., Schulin, R., Frossard, E. and Johnson Beebout, S.E. 2013.Internal Zn allocat ion influences Zn deficiency tolerance and grain Zn loading in rice (*Oryza sat iva* L.). Front. Plant Sci., 4: 534.

Institute, I.R.R. 2006. Bringing Hope, Improving Lives: Strategic Plan 2007-2015. Manila: International Rice Research Institute.

Khatun, T., Mohamed, M., Hanafi, Yusop, M.R. and Wong, M.Y. 2015. Genetic Variation, Heritability, and Diversity Analysis of Upland Rice (*Oryza sativa* L.). Genotypes Based on Quantitative Traits. BioMed Research International, 1-7.

Konate, A.K., Zongo, A., Kam, H., Sanni, A. and Audebert, A. 2016.Genetic variability and correlation analysis of rice (*Oryza sativa* L.) inbred progenies based on agro-morphological traits. African Journal of Agricultural Research, 11(35): 3340-3346.

Lush J L. 1940. Intra-sire correlation and regression of offspring on dams as a method of estimating heritability of characters. Proc. Ame. Soc. Anim. Prod. 33: 293-301.

Marschner, H. 1995. Mineral nutrition of higher plants. London, UK: Academic Press. London, UK. : 303.

Monalisa, M., Ali, M. D. and Sasmal, B. G. 2006. Variability, correlation and path co-efficient analysis in some important traits of low land rice. CropRes., 31: 153 - 156.

Moosavi M, Ranjbar G, Zarrini HN, Gilani A 2015. Correlation between morphological and physiological traits and path analysis of grain yield in rice genotypes under Khuzestan. Biol. Forum Int. J., 7(1):43-47.

Myers, S.S., Wessells, K.R., Kloog, I., Zanobetti, A. and Schwartz, J. 2015. Effect of increased concentrations of atmospheric carbon dioxide on the global threat of zinc deficiency: a modelling study. The Lancet Global Health, 3(10): 639-645.

Nene, Y.L. (1966). Symptoms, cause and control of Khaira disease of paddy. Bull. Indian Phytopathol Soc. 3: 97–191.

Neue, H.U. and Lantin, R.S. 1994. Micronutrient toxicities and deficiencies in rice. *In* AR Yeo, TJ Flowers, eds, Soil mineral stresses: approaches to crop improvement. Springer-Verlag, Berlin, Germany, 175-200.

Norain, M. N., Shamsiah, A., Abdul R. H., Nor, A. H., Haslinda, A. M. and Wan Aminuddin, W.A. 2014. Correlation Analysis on Agronomic Characters in F2 Population Derived from MR64 and Pongsu Seribu. J. Appl. Sci. Agric., 9 (18): 143 - 147.

Ogunbayo, S.A., Sie, M., Ojo, D.K., Sanni, K.A., Akinwale, M.G., Toulou, B., Shittu, A., Idehen, E.O., Popoola, A.R., Daniel, I.O. and Gregoria, G.B.

(2014). Genetic variation and heritability of yield and related traits in promising rice genotypes (*Oryza sativa* L.). J. Plant Breed. Crop Sci., 6(11):153-159.

Pallavi, S., Bapsila, L., Prashant, B., Deepika, S., Sandhya, and Singh P.K. (2017).Genetic variability and association analysis of rice lines derived from biparental progeny. International Journal of Genetics, 9(11): 318-321.

Pratap, N., Singh, P. K., Shekhar, R., Soni, S. K. and Mall, A. K., 2018. Genetic variability, character association and diversity analyses for economic traits in rice (*Oryza sativa* L.). SAARC J. Agri., 10(2): 83 - 94.

Quijano-Guerta, C., Krik, G.J.D, Portugal, A.M, Bartolome, V. and Mclaren, G.C. 2002. Tolerance of rice germplasm to Zn deficiency. Field Crops Res. 76: 183-130.

Rafi SA, Nath UK 2004. Variability, Heritability, Genetic advance and relationship of yield and yield contributing characters in dry Bean (*Phaselous vulgaris* L.). J. BioI. Sci. 4(2):157-159.

Raju, C. H. S., Rao, M. V. B. and Sudarshanam, A., 2004. Genetic analysis and character association in F_2 generation of rice. Madras Agric. J., 91: 66 - 69.

Rani, S.N., Prasad, G.S.V., Reddy, Bhaskar P. and Veni, Krishna B. 2001. Genetic variability for yield components in aromatic and quality rice germplasm. Indian J. Plant Genetic Resources, 14(2): 206-209.

Reddy, E.S.S., Verulkar, S.B., Saxena, R.R., Xalxo, S., Verma, S.K. and Deepthi, P. 2013. Identification of qtls for tolerance to zinc deficiency in rice (*Oryza sativa* L.). Internationl Journal of Science Innovations and Discoveries, 3(3):317-325.

Shanthi, P., Jebaraj, S. and Geetha, S. 2011. Correlation and path coefficient analysis of some sodic tolerant physiological traits and yield in rice (Oryza sativa L.). Indian J. Agric. Res., 45(3): 201 - 208.

Shashidhar, H. E., Pasha, F., Janamatti, M., Vinod, M. S. and Kanbar, A. 2005. Correlation and path co-efficient analysis in traditional cultivars and double haploid progenies of rainfed lowland rice. Oryza, 42: 156 - 159.

Shet, M. R., Rajanna, M. P., Ramesh, S., Sheshshayee, M. S. and Mahadevu, P. 2018. Genetic variability, correlation and path coefficient studies in F2 generation of aerobic rice (*Orzya sativa* L.). Elect. J. Plant Breed., 3(3): 925 - 931.

Singh, B., Natesan, S.K.A., Singh, B.K. and Usha, K. 2003. Improving Zn efficiency of cereals under Zn deficiency. Curr. Sci., 88: 36-44.

Suma, M. R., Manjunath, K. And Shashidhar, H. E. 2014. Correlation and path coefficient analysis of shoot, root morphological traits and micronutrient (Fe and Zn) content on grain yield in rice (*Oryza sativa* L.) under contrasting moisture regimes. The Bioscan, 9 (4): 1833 - 1841.

Suma, M. R., Manjunath, K. and Shashidhar, H. E. 2014. Correlation and path coefficient analysis of shoot, Root morphological traits and micronutrient (Fe and Zn) content on grain yield in rice (*Oryza sativa* L.) under contrasting moisture regimes. The Bioscan, 9(4): 1833 - 1841.

Tanaka, A. and Yoshida. S. 1970. Nutritional disorders of the rice plant in Asia. Int. Rice Res. Inst. Tech. Bull., 10: 31-40.

Vanitha, J., Amudha, K., Mahendran, R., Srinivasan, J., Robin, S. and Kumari, R.U. 2016. Genetic variability studies for zinc efficiency in aerobic rice. SABRAO Journal of Breeding and Genetics, 48(4): 425-433.

Welch, R.M. and Graham, R.D. 2004. Breeding for micronutrients in staple food crops from a human nutrition perspective. Journal of Experimental Botany, 55: 353–364.

Wissuwa, M, Ismail, A.M. and Yanagihara, S. 2006. Effects of zinc deficiency on rice growth and genetic factors contributing to tolerance. Plant Physiology, 142: 731–741.

Wissuwa, M., Ismail, A. and Graham, R. 2008. Rice grain zinc concentrations as affected by genotype, native soil-zinc availability and zinc fertilization. Plant Soil, 306: 37-48.

Yoshida, S. and Tanaka, A. 1969. Zinc deficiency of the rice plant in calcareous soils. Soil Sci. Plant Nutr., 15: 75-80.