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Descriptive Statistics and Heritability for Agronomic Traits and Grain Micronutrient Content in Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Author Avinash Kumar carried out the experiment and prepared the first hand manuscript. Author Ashutosh Kumar helped during conduct of experiment. Authors NKS, RK and Nilanjaya provided guidance during conduction of experiment. Authors MKS and S. K. Singh carried out the data analysis, proof reading and correction of manuscript, while resources and guidance for estimation of micronutrients was provided by the author Santosh Kumar Singh. All authors have read the manuscript thoroughly and approved it.

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ABSTRACT

In the present investigation, 10 parents and their 45 crosses (half diallel) along with 2 standard checks (Rajendra Nilam and Rajendra Mahsuri-1) were evaluated during *Kharif,* 2018 in Randomized Complete Block Design (RCBD) with 3 replications at Rice Farm Section, Dr. Rajendra Prasad Central Agricultural University (RPCAU), Pusa, Bihar. The objective of this study was to identify promising rice genotypes having desirable combination of morphological traits along with high grain iron and zinc content and high grain yield potential. The results of variability parameters indicated that ample amount of genetic variability was present for all the studied traits. Most of the

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traits showed high heritability coupled with high genetic advance indicating fruitfulness of selection for improvement of these traits. One genotype ($P_2 \times P_7$) with high grain iron (16.10 ppm) and grain zinc (26.40 ppm) content along with high yield (43.12 g/plant) was identified. Genotypes with high grain iron coupled with high grain yield ($P_7 \times P_9$, $P_8 \times P_9$, $P_5 \times P_7$ and $P_5 \times P_9$) and high grain zinc content coupled with high grain yield ($P_4 \times P_7$, $P_9 \times P_{10}$, $P_8 \times P_9$ and $P_5 \times P_7$) were also identified. These promising genotypes identified can be used further in breeding programmes to obtain superior segregants with high grain micronutrient content and high grain yield.

Keywords: Rice; diallel; GCV; PCV; heritability; genetic advance; biofortification.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population contributing over 20% of the total calorie intake of humans [1]. To fulfil the future food demand of ever-increasing world population, it is an urgent need to take necessary steps to increase the productivity of this crop [2]. Average daily intake of rice provides 20-80% of dietary energy and 12-17% of dietary proteins for Asians [3]. In India, rice is grown over an estimated area of *ca.* 44.50 million hectares with the production of 115.63 million tonnes and average productivity of 3.90 tonnes per hectare [4]. Micronutrient deficiencies or “hidden hunger” affect about 38% of pregnant women and 43% of preschool children worldwide and are most prevalent in developing countries. Biofortification is a combined approach of conventional plant breeding and modern biotechnological tools to enrich vital nutrients (minerals, vitamins and proteins) in staple crops [5,6]. Among micro-elements, iron (Fe) and zinc (Zn) mineral deficiency are the most common and widespread, affecting more than half of the human population. Fe serves as an important cofactor for various enzymes performing basic metabolism in humans. Fe is an essential element for blood production. About 70% of the body's iron is found in the Red Blood cells as haemoglobin molecule that is involved in transfer of oxygen from the lungs to the tissues [7]. Iron deficiency is one of the most prevalent micronutrient deficiencies, affecting around two billion people, globally [8]. Zn helps in protein synthesis and regulates immune system of the human body. Zinc deficiency is a major cause of stunting among children. About 165 million children with stunted growth run a risk of compromised cognitive development and physical capability [9]. Zn is one of the essential micronutrients that serves as cofactor for more than 300 enzymes involved in the metabolism of carbohydrates, lipids, proteins, and nucleic acids; hence it is important in normal growth and development of plants and animals. Some of these problems are more acute and clearly evident in developing countries where people depend on cereal based food for their daily diet and they cannot afford to diversify their meal by adding mineral rich fruits, vegetables, and meat. This problem could be tackled by biofortification that has potential to address even those who experience difficulty in changing their dietary habits because of financial, cultural, regional, or religious restrictions. Biofortification is also advantageous for governments because it is inexpensive and sustainable compared to nutritional supplement programs.

Genetic variability is the primary need for a sound plant breeding approach for realizing higher economic yield because selection and its success would depend on the availability of wider genetic variability and extent to which traits are heritable. Together with heritability, genetic advance gives estimates of realizable gain at a specific intensity of selection which is an important tool in plant breeding. Therefore, heritability estimates along with genetic advance are more helpful in selection for yield and yield components. Therefore, the present study was carried out with an aim to evaluate rice genotypes including their cross combinations with an ultimate aim to obtain genotypes with high grain Fe and Zn content along with high grain yield.

2. MATERIALS AND METHODS

10 diverse genotypes of rice showing variability for iron and zinc (Table 1) were selected from Harvest Plus Trial conducted at Department of Plant Breeding and Genetics, RPCAU, Pusa. These genotypes were mated in half diallel fashion to obtain 45 crosses during Kharif, 2017. These crosses along with their parents and 2 standard checks were evaluated during Kharif, 2018 in RCBD with 3 replications. Observations for 14 traits were recorded on 5 randomly selected plants in each entry except for days to

Table 1. List of parental genotypes

S.N.	Genotypes	S.N.	Genotypes
1	IR68144-2B-2-2-3-1 (P_1)	6	KALA JIRA JAHA (P_6)
2	HATI Bandha (P_2)	7	IR91175-27-1-3-1-3 (P_7)
3	TEVIRII (P_3)	8	R-RIZIH-7 (P_8)
4	NGOBANYO Red Cover (P_4)	9	MTU 1010 (P_9)
5	KHUSISOI-RI-SAREKU (P_5)	10	TEINEM RUISHENG MAA (P_{10})

50% flowering and days to physiological maturity where observations were recorded on plot basis. The estimation of micronutrients [10] by XRF (X-Ray Fluorescence Spectrometry) was carried out at Harvest Plus Division, ICRISAT, Hyderabad.

2.1 Statistical Analysis

The mean data recorded on 14 quantitative traits were subjected to estimate descriptive statistics like range, mean and coefficient of variation, heritability and genetic advance. The data was subjected to randomized block design analysis.

2.2 Estimation of Variance Components

Genotypic Variance (σ^2_g) = $\frac{\text{MSt}-\text{MSe}}{\text{No.of Replications (r)}}$

Environmental Variance (σ^2_e) = MSe

Phenotypic variance (σ^2_p) = $\sigma^2_g + \sigma^2_e$

Where,

MS_e = Mean Square Error, MS_t = Mean Square Treatment

In the present investigation three types of coefficient of variations were estimated, *viz.,* Phenotypic Coefficient of Variation (PCV), Genotypic Coefficient of Variation (GCV) and Environmental Coefficient of Variation (ECV). The formulae used to calculate PCV, GCV, ECV were given by Burton and De vane [11].

(i) PCV (%) $= \frac{\sigma_p{}^2}{X} \times 100$

(ii) GCV (%) $= \frac{\sigma_g{}^2}{X} \times 100$

(iii) ECV (%) $= \frac{\sigma_e{}^2}{X} \times 100$

Where,

σ^2_p= Phenotypic variance, σ^2_e= Environmental variance, σ^2_g= Genotypic variance, X= Mean of trait

Categorization of these coefficient of variation was done as proposed by Sivasubramanian and Madhavamenon (1973) [12]; <10% - Low, 10-20% - Moderate, >20% - High.

3. RESULTS

The analysis of variance revealed that mean sum of square due to treatment was highly significant for all the traits studied, indicating the presence of ample amount of variability. The mean, range and coefficient of variance of all traits are presented in Table 3. The mean performance of genotype along with that of check for quality traits and grain yield is presented in Table 4 and Figs. 1, 1(a), 2 and 2 (a). A wide range of variation was found for most of the traits among the genotypes. Days to 50% flowering ranged from 70.33 days (P_1×P_7) to 109 days (P_9×P_{10}). Days to physiological maturity ranged from 96.67 days (P_1×P_7) to 133 days (P_2×P_4). Plant height varied from 87.67 cm (P_4×P_{10}) to 185.67 cm (KHUSISOI-RI SAREKU). The data on flag leaf area ranged from 20.21 cm^2 (P_1×P_7) to 47.26 cm^2 (P_7×P_8). The canopy temperature among parents recorded in between 22.16ºC (MTU-1010) to 34.48ºC (P_3×P_6). The data recorded for chlorophyll content (SPAD) ranged between 28.07 (P_1×P_3) to 51.53 (P_4×P_5). The panicle length varied in between 22.17 cm (P_1×P_7) to 29.67 cm (P_2×P_3). The number of effective tillers per plant ranged from 4 (P_3×P_6) to 17 (P_7×P_9). The values for grains per panicle recorded in between 109 (P_3×P_6) to 197 (MTU-1010). The range of test weight was recorded in between 17.51 g (NGOBANYO RED COVER) to 25.05 g (P_3×P_{10}). The range of harvest index was found in between 38.01 per cent (P_2×P_8) to 59.49 per cent (P_1×P_3). Grain iron content the ranged from 8.89 ppm (P_6×P_7) to 16.92 ppm (P_7×P_9). The maximum and minimum grain zinc content in grains was reported in P_2×P_9 (30.77 ppm) and P_4×P_9 (19.22 ppm), respectively. For grain yield per plant, the range was from 26.75 g (P_3×P_6) to 50.81 g (P_7×P_9).

Table 2. Mean sum of squares for fourteen traits in rice

Sl. No.	Traits	Mean sum of squares		
		Replication DF = 2	Treatments DF = 56	Error DF = 112
1	Days to fifty percent flowering (d)	32.99	337.04**	13.60
2	Days to Physiological maturity (d)	0.60	275.15**	5.65
3	Plant Height (cm)	33.34	2020.58**	36.68
4	Flag leaf area (cm^2)	9.85	124.58**	5.96
5	Canopy Temperature (^0C)	5.84	17.58**	3.34
6	Chlorophyll Content (SPAD)	5.42	84.37**	6.95
7	Panicle length (cm)	1.36	12.22**	3.27
8	Effective Tiller per Plant (no.)	5.84	24.65**	2.40
9	Grains per Panicle (no.)	253.68	1468.85**	92.41
10	Test Weight (g)	1.42	7.21**	3.22
11	Harvest index (%)	15.88	72.61**	11.44
12	Grain Iron Content (ppm)	0.22	11.63**	0.09
13	Grain Zinc Content (ppm)	0.38	21.79**	0.13
14	Grain yield per plant (g)	19.45	90.99**	11.54

**, ** Significant at 5 and 1 per cent, respectively*

Table 3. Mean, range and Coefficient of Variance (CV) of parents and crosses for fourteen quantitative traits in rice

S. No.	Traits	Mean	Range		CV
			Min	Max	
1	Days to 50% flowering	89.08	70.33	109.00	2.88
2	Days to Physiological maturity	112.90	96.67	133.00	2.10
3	Plant height (cm)	127.2	87.67	185.67	4.76
4	Flag leaf area (cm^2)	36.43	20.21	47.26	6.70
5	Canopy Temperature (^0C)	30.70	22.16	34.48	5.95
6	Chlorophyll Content (SPAD)	39.70	28.07	51.53	6.64
7	Panicle length (cm)	25.64	22.17	29.67	7.06
8	Effective Tillers per Plant (No.)	10.0	4	17	16.11
9	Grains per Panicle (No.)	151	109.33	197.48	6.38
10	Test Weight (g)	22.34	17.51	25.05	8.04
11	Harvest index (%)	51.64	38.01	59.49	6.56
12	Grain Iron Content (ppm)	14.0	8.89	16.92	2.17
13	Grain Zinc Content (ppm)	24.2	19.22	30.77	1.51
14	Grain yield per plant (g)	37.67	26.75	50.81	9.02

Table 4. Mean performance of crosses, parents and checks for grain iron and zinc with grain yield per plant

Genotypes	Fe (ppm)	Zn (ppm)	GYPP
$P_1×P_2$	11.9	22.2	32.80
$P_1×P_3$	14.6	27.6	30.39
$P_1×P_4$	16.5	29.8	38.03
$P_1×P_5$	12.4	25.8	35.54
$P_1×P_6$	15.6	20.8	30.60
$P_1×P_7$	13.0	21.3	42.09
$P1×P_8$	13.0	24.7	39.72
$P_1×P_9$	15.5	28.7	39.87
$P_1×P_{10}$	13.4	28.9	35.15
$P_2×P_3$	13.5	25.8	31.47
$P_2×P_4$	16.8	22.8	34.42
$P_2×P_5$	13.2	20.1	38.28

Genotypes	Fe (ppm)	Zn (ppm)	GYPP
$P_2 \times P_6$	12.0	23.6	32.42
$P_2 \times P_7$	16.1	26.4	43.12
$P_2 \times P_8$	15.4	24.3	39.18
$P_2 \times P_9$	15.5	30.8	37.07
$P_2 \times P_{10}$	15.4	26.0	33.07
$P_3 \times P_4$	15.4	20.9	37.37
$P_3 \times P_5$	13.4	25.5	31.70
$P_3 \times P_6$	11.4	25.0	26.75
$P_3 \times P_7$	14.4	23.2	39.79
$P_3 \times P_8$	15.6	20.4	32.34
$P_3 \times P_9$	14.6	23.5	38.23
$P_3 \times P_{10}$	12.4	24.4	32.76
$P_4 \times P_5$	15.3	27.3	38.51
$P_4 \times P_6$	11.2	20.5	31.93
$P_4 \times P_7$	11.3	26.8	46.21
$P_4 \times P_8$	12.7	20.9	43.01
$P_4 \times P_9$	12.2	19.2	47.60
$P_4 \times P_{10}$	16.3	23.4	39.17
$P_5 \times P_6$	14.1	26.1	33.24
$P_5 \times P_7$	16.1	23.3	43.54
$P_5 \times P_8$	13.1	21.9	46.03
$P_5 \times P_9$	15.6	22.1	42.69
$P_5 \times P_{10}$	16.2	27.7	37.19
$P_6 \times P_7$	8.9	27.0	38.53
$P_6 \times P_8$	9.9	25.2	33.92
$P_6 \times P_9$	10.7	26.1	39.74
$P_6 \times P_{10}$	12.5	21.7	34.11
$P_7 \times P_8$	14.9	21.6	46.62
$P_7 \times P_9$	16.9	21.7	50.81
$P_7 \times P_{10}$	14.0	20.1	44.55
$P_8 \times P_9$	16.1	24.5	45.73
$P_8 \times P_{10}$	14.0	23.2	40.94
$P_9 \times P_{10}$	11.4	25.1	42.31
IR68144-2B-2-2-3-1	16.1	28.1	31.61
HATI BANDHA	16.4	22.7	29.90
TEVIRII	15.7	23.5	28.25
NGOBANYO RED COVER	13.0	21.8	39.75
KHUSISOI-RI-SAREKU	13.3	25.9	37.03
KALA JIRA JAHA	16.1	24.0	27.17
IR91175-27-1-3-1-3	15.9	25.1	42.89
R-RIZIH-7	11.3	24.8	40.43
MTU 1010	13.3	21.3	41.40
TEINEM RUISHENG MAA	12.1	23.4	32.90
RAJENDRA NILAM	16.5	27.1	38.27
RAJENDRA MAHSURI-1	15.4	26.2	39.17
Mean	14.0	24.2	37.67
C.V.	2.17	1.51	9.02
SEm±	0.17	0.21	1.961
C.D. 5%	0.49	0.59	5.50

3.1 Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV)

Genetic variability parameters for different traits are presented in Table 5 and Fig. 3. High PCV and GCV was found for effective tillers per plant (32.54 & 28.27) followed by plant height (20.77 & 20.22), moderate values of PCV and GCV was found for the traits days to 50% flowering (12.37 & 12.03), flag leaf area (18.52 & 17.26), chlorophyll content (14.42 & 12.80), grains per panicle (15.60 & 14.24), grain iron content (14.15 & 13.98), grain zinc content (11.11 & 11.09) and grain yield per plant (16.37 & 13.66) while, the lowest values of PCV and GCV was found for days to physiological maturity (8.66 & 8.40), canopy temperature (9.26 & 7.09), panicle length (9.76 & 6.74) and test weight (9.55 & 5.16). In case of harvest index PCV (10.93) and GCV (8.74) have shown moderate and low value, respectively.

3.2 Heritability and Genetic Advance

High heritability was found for days to 50 % flowering (94.56%), days to physiological maturity (94.08%), plant height (94.74%), flag leaf area (86.90%), chlorophyll content (78.78%), effective tillers per plant (75.49%), grains per panicle (83.24%), harvest index (63.98%) grain iron content (97.64%), grain zinc content (98.18%) and grain yield per plant (69.65%) while, moderate heritability was found for canopy temperature (58.64%) and panicle length (47.64%). Only one trait i.e. test weight (29.22%) has shown low heritability.

High genetic advance as per cent of mean was found for days to 50 % flowering (24.10%), plant height (40.54%), flag leaf area (33.15%), chlorophyll content (23.40%), effective tillers per plant (50.60%), grains per panicle (26.76%), grain iron content (28.46%), grain zinc content (22.64%) and grain yield per plant (23.48%) while moderate genetic advance as per cent of mean was found for days to physiological maturity (16.77%), harvest index (14.40%) and canopy temperature (11.19%). Panicle length (9.58%) and test weight (5.75%) showed low genetic advance as per cent of mean (Table 5 & Fig. 4).

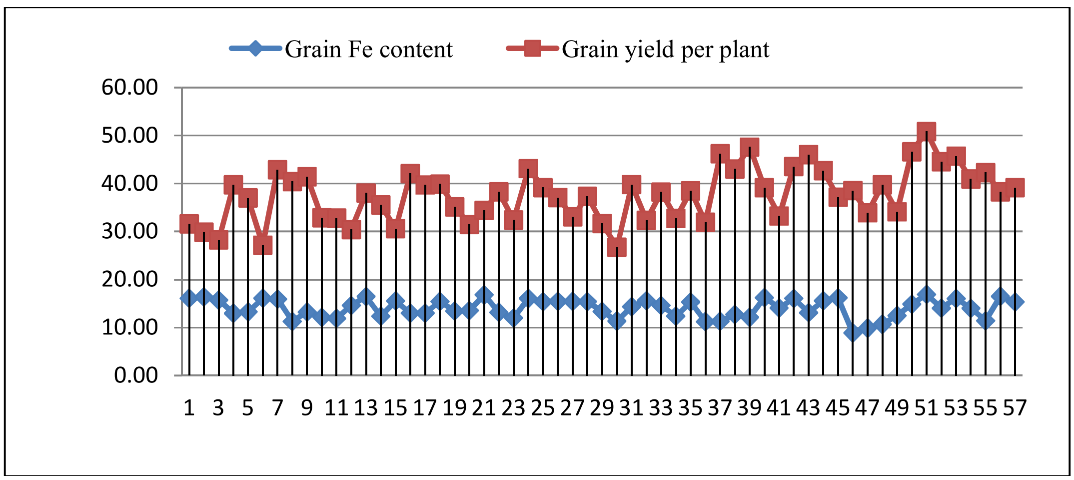

Fig. 1. Pattern of variation for grain Fe and yield per plant

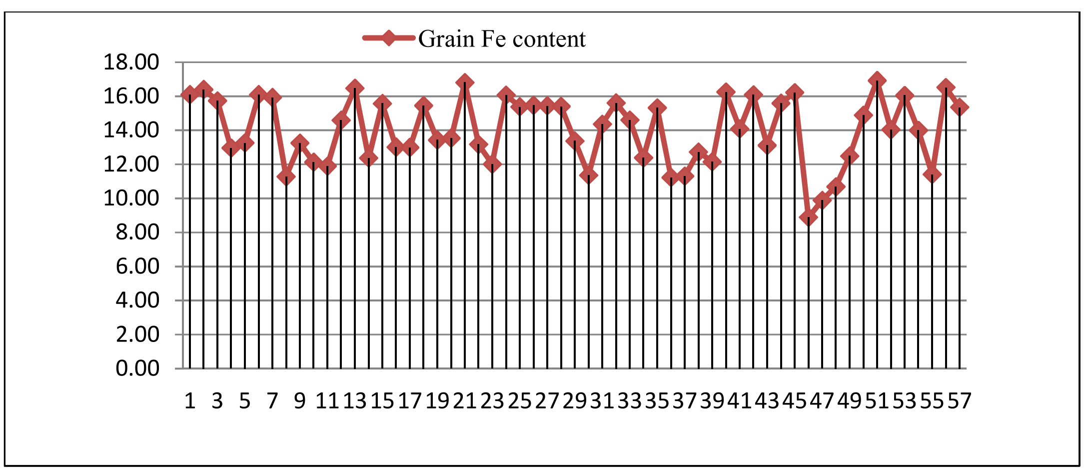

Fig. 1(a). Pattern of variation for Fe content

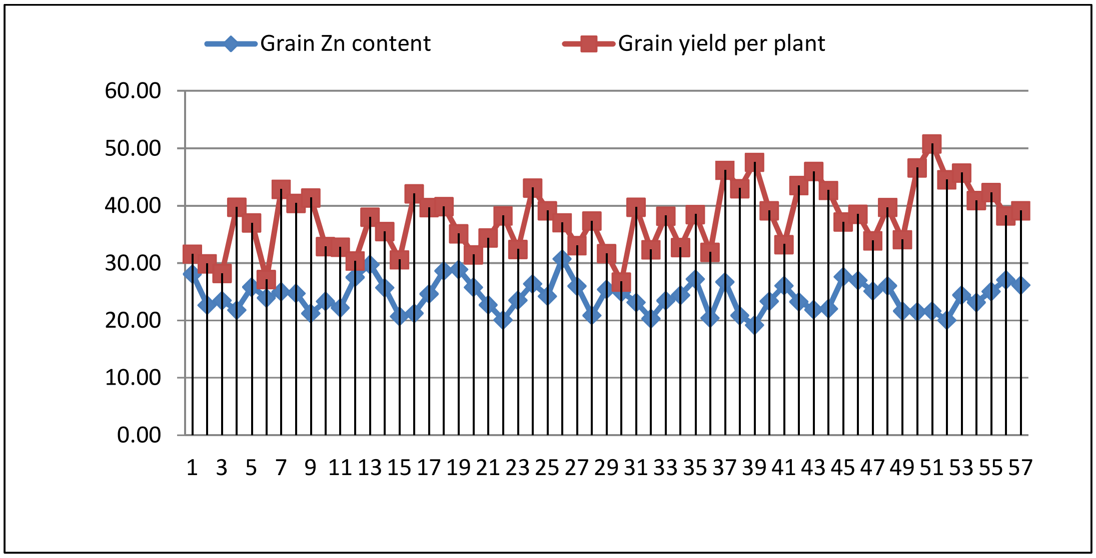

Fig. 2. Pattern of variation for grain zinc and yield per plant

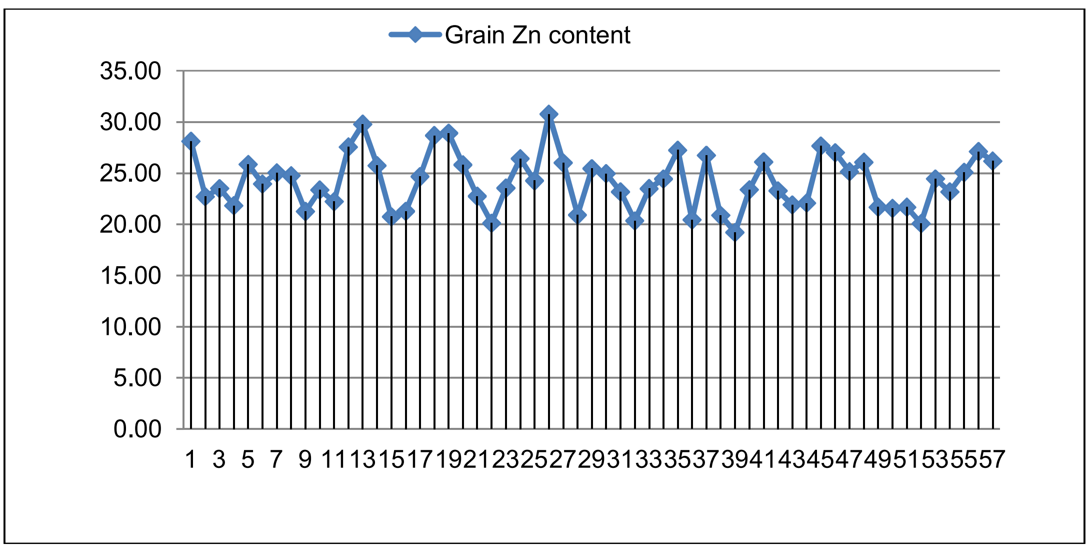

Fig. 2(a). Pattern of variation for zinc content

4. DISCUSSION

Phenotypic range describes the variability for the trait of interest, however, the phenotypic range for individual trait cannot be used as criteria to compare the variability of several traits with respect to each other. Therefore, we can conclude that effective tillers per plant showed maximum variation (4-17) with CV value of 16.11. This was followed by grain yield per plant (26.75 g to 50.81 g) with CV value of 9.02. Grain zinc content showed minimum variation (19.22 ppm to 30.77 ppm) with CV value of 1.51.

PCV for all the traits were higher than the respective GCV indicating role of environment in trait expression, however, the maximum difference between PCV and GCV was found with respect to test weight (9.55 & 5.16) indicating much influence of environment on expression of this trait.

Selection based on single criteria of heritability is not sufficient to predict the progress made through selection. A more robust selection criteria for selection to be effective towards changing the trait mean in progenies of selected individual is based on heritability coupled with genetic advance as per cent of mean. Days to 50 % flowering (94.56%, 24.10%), plant height (94.74%, 40.54%), flag leaf area (86.90%, 33.15%), chlorophyll content (78.78%, 23.40%), effective tillers per plant (75.49%, 50.60%), grains per panicle (83.24%, 26.76%), grain Fe content (97.64%, 28.46%), grain zinc content (98.18%, 22.64%) and grain yield per plant (69.65%, 23.48%) showed high heritability coupled with high genetic advance as per cent of mean. The high value observation for heritability for above traits may probably be attributed to additive gene action involved in expression of these traits. Since, these traits have high value for both the above mentioned criteria for effective selection, these traits could be targeted in selection to shift the respective value in desired direction, thereby improving the grain yield, the ultimate breeding objective.

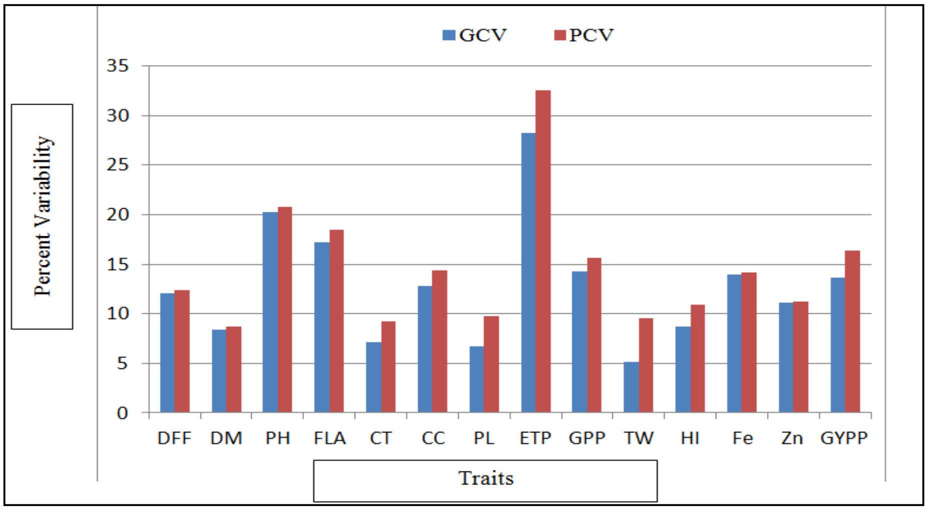

Fig. 3. Phenotypic (PCV) and genotypic (GCV) coefficient of variation for various traits in parents, their crosses and standard checks of rice

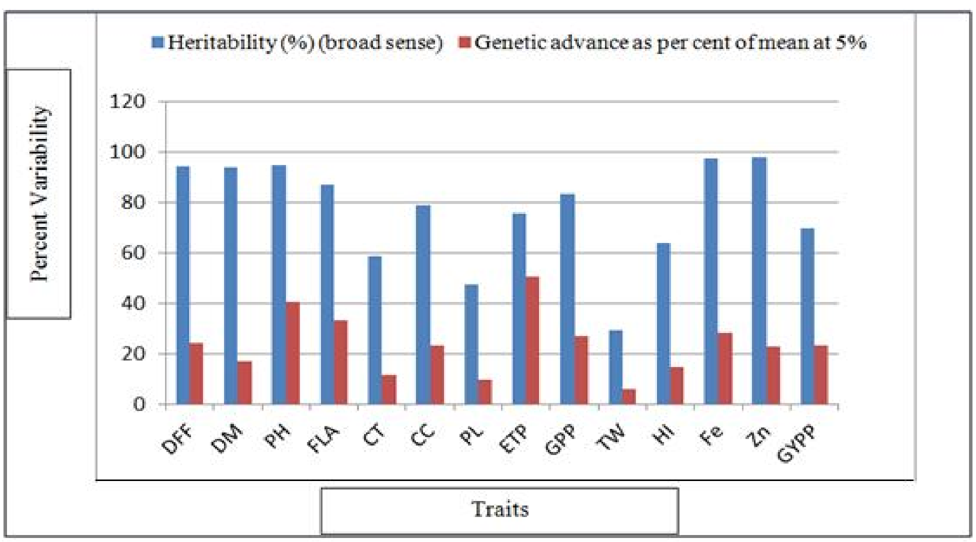

Fig. 4. Heritability and genetic advance as percent of mean for various traits in parents, their crosses and standard checks of rice

Where, DFF-Days to 50% flowering, DM-Days to physiological maturity, PH-Plant height, FLA-Flag leaf area, CT-Canopy temperature, CC-Chlorophyll content, PL-Panicle length, ETPP-Effective tillers per plant, GPP-Grains per panicle, TW-Test weight, HI-Harvest index, Fe- Grain iron content, Zn-Grain zinc content, GYPP-Grain yield per plant

Table 5. Estimates of genetic parameters for fourteen traits in rice

S. No.	Traits	Variance components		Coefficient of variation (%)		Heritability (%) (broad sense)	Genetic advance as per cent of mean at 5%
		Genotypic (σ^2g)	Phenotypic (σ^2p)	Genotypic	Phenotypic		
1.	Days to 50% flowering	114.82	121.42	12.03	12.37	94.56	24.10
2.	Days to physio. maturity	89.83	95.49	8.40	8.66	94.08	16.77
3.	Plant height (cm)	661.29	697.98	20.22	20.77	94.74	40.54
4.	Flag leaf area (cm^2)	39.54	45.49	17.26	18.52	86.90	33.15
5.	Canopy Temperature (^0C)	4.74	8.08	7.09	9.26	58.64	11.19
6.	Chlorophyll Content (SPAD)	25.80	32.75	12.80	14.42	78.78	23.40
7.	Panicle length (cm)	2.98	6.25	6.74	9.76	47.64	9.58
8.	Effective Tillers per Plant (No.)	7.41	9.82	28.27	32.54	75.49	50.60
9.	Grains per Panicle (No.)	458.81	551.22	14.24	15.60	83.24	26.76
10.	Test Weight (g)	1.33	4.55	5.16	9.55	29.22	5.75
11.	Harvest index (%)	20.38	31.83	8.74	10.93	63.98	14.40
12.	Grain Iron Content (ppm)	3.84	3.93	13.98	14.15	97.64	28.46
13.	Grain Zinc Content (ppm)	7.21	7.35	11.09	11.19	98.18	22.64
14.	Grain yield per plant (g)	26.48	38.02	13.66	16.37	69.65	23.48

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5. CONCLUSION

Based on the above studies five promising genotypes for high grain iron with high grain yield and high grain zinc with high grain yield were identified among the 45 hybrids (Table 4). The genotypes *viz.,* $P_7 \times P_9$, $P_8 \times P_9$, $P_5 \times P_7$, $P_2 \times P_7$ and $P_5 \times P_9$ were found promising for high iron and high grain yield whereas, $P_4 \times P_7$, $P_2 \times P_7$, $P_9 \times P_{10}$, $P_8 \times P_9$ and $P_5 \times P_7$ were identified for high zinc with high grain yield. These identified genotypes may be used in future breeding programmes to isolate desired segregants with high grain micronutrients and high grain yield that could be further evaluated at multi-locations for their potential release as biofortified rice varieties.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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