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Exploring Genetic Variability for Grain Iron Content in Rice (*Oryza sativa* L.)

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ABSTRACT: An investigation of 72 rice genotypes for grain iron and yield was carried out during *Kharif* 2022-23. Based on the preliminary screening, twenty four genotypes were selected and raised in Randomized Block Design with two replications. Grain yield per plant exhibited positive correlation with tillers per plant, panicle length, 100-grain weight and grain breadth. While, grain weight exhibited positive significant correlation with grains per panicle indicating scope for increasing grain yield through such correlated response. In contrast, Fe content exhibited strong negative correlation with tiller number and grain yield per plant, While grain Zn (ppm) content is negatively associated with almost all major yield contributing traits indicating feeble scope for biofortification in rice without sacrificing grain yield. Some of high yielding varieties Kalingadhan 1202, Hasanta and Govinda were rich in grain iron content with maximum in Kalingadhan 1202 (76.10 ppm). Such genotypes had also shown high yield potential along with acceptable grain quality and may serve as potential donors in Fe biofortification programme.

Keywords: Rice, coefficient of variation, genetic variability and correlation.

INTRODUCTION

Iron is an essential element for blood production and is a constituent of several enzymes, some pigments and assist in DNA synthesis, nitrate and sulphate reduction and energy production within the plant. While, Fe acts as an important component of haemoglobin and myoglobin (Sperotto *et al.,* 2010) in our body system and its deficiency can exist with or without anaemia with functional deficits like reduced learning ability and delayed physical and mental growth (Bouis, 2003).

In India, rice is the staple food for more than 65% of the population, contributing approximately 40% of the total food grain production. The leading rice producing states are West Bengal, Uttar Pradesh, Punjab, Odisha, Andhra Pradesh, Bihar and Chhatisgarh. Over 33% of the world's populations are suffering from Fe deficiency anaemia (IDA) and upto 20% are Zn deficient (Garcia-Oliveira *et al.,* 2018). Under this scenario, hidden hunger has become a global challenge, with Fe and Zn being two highly prevalent nutritional deficiencies in humans (Rawat *et al.,* 2013; UNEP, 2021). But rice grain usually harbour very minimum amount of Fe (5-6 mg/kg) as compared to the target fixed (Fe: 40 ppm) to meet the recommended daily allowance (RDA) of 10-15 mg Fe/day (FAO/WHO, 2000 and Welch and Graham 2004). The Recommended Dietary Allowance (RDA) for all age groups of men and postmenopausal women is 8 mg/day; the RDA for premenopausal women is 18 mg/day. The median dietary intake of iron is approximately 16 to 18 mg/day for men and 12 mg/day for women. The biofortification strategies will need to be introduced in local, high-yield genetic backgrounds and it can be achieved by reorienting the traditional breeding strategy. Grain iron content is a complex trait with appreciably high G × E interaction which hinders progress in development of stable biofortified rice. On average, polished rice of high yielding varieties has concentrations of approximately 2 µg/g Fe (Trijatmiko *et al.,* 2016). These values are lower than the target values by biofortification programs, 10-15 µg/g Fe. Furthermore, a wide genetic variation for Fe has been reported for brown rice with concentrations varying from 0.4 to 147 µg/g for Fe (Zeng *et al.,* 2010; Swamy *et al.,* 2021). Iron content of brown rice ranged from 7.4 – 22.7 ppm in North East Land Races (NELR) of rice using ED-XRF (Rao *et al.,* 2014). However, a quest for truly stable nutrient dense donors with high genetic variability can pave the way for biofortification breeding. Therefore, an experiment was undertaken to assess the genetic variation and character association for Fe along with agromorphological and physico-chemical traits in a set of diverse germplasm of rice.

MATERIALS AND METHODS

The experimental material includes 72 test genotypes including 55 released varieties, 12 improved breeding lines and 5 local land races of rice germplasm. During rabi 2021 seventy two genotypes were evaluated for selection of iron and zinc content through qualitative (Prussian blue method) and quantitative (AAS method) screening methods. Based on the preliminary screening (Prussian blue method, AAS method), twenty four genotypes were selected for yield and yield contributing traits. The trial was raised during kharif summer 2022 in Randomized Block Design with two replications. Before planting, average soil pH was 5.8 and the average iron and zinc content of soil were 450 ppm and 0.52 ppm respectively. Observations were recorded on twelve agro-morphological traits along with grain yield and fourteen physico-chemical traits including grain Fe and Zn content. Slide calipre was used to determine length and breadth of 10 grains of each genotype. L/B ratios for grain were calculated taking respective mean values.

Based on grain length and grain breadth (L/B) ratio , rice genotypes were classified into seven grain types as per Govindaswamy (1985). After harvest of the crop, the rice grains were oven dried at 50°C for two hours to reduce the moisture content to 11-12 % and the dried rice grains were manually dehulled. Preliminary assessment of the grains for grain iron content was done by both qualitative (Prussian blue) and quantitative (Bagchi, 2010) methods respectively. Fe and Zn content were estimated using Atomic Absorption Spectrophotometer (AAS) at 248.3 nm and 213.9 nm respectively at NRRI, Cuttack. The variations in replications for each sample didn't exceed ± 5 ppm. Analysis of variance and covariance were done as per Singh and Choudhury (1985) using sample means of various traits under study. Estimates of the correlation coefficient for each pair of characters were computed as per Panse and Shukhateme (1985) to establish a genetic relationship among different characters.

RESULTS AND DISCUSSION

There exists a significant variability among all the quantitative and physico-chemical traits in rice. Hence exploring rice donors with moderate iron content but high seed yield would immensely help plant breeders to breed iron biofortified rice varieties.

A. Genetic variability of grain yield and yield contributing traits

For Fe biofortification, short plant type , plant with 125-140 days duration and acceptable grain quality and grain iron content with 60-65 ppm are the breeding traits in rice. A set of genotypes including tall plant types high Fe donors, improved breeding lines and important iron rich landraces in Odisha was purposefully selected during this research work. The mean performance of all 24 rice genotypes for grain yield and its component traits have been presented in Table (1 and 2). The days to maturity varied from 124.50 days in Tejaswini to 143.00 days in Mahalaxmi. Similarly Bhuban ,short plant type (107.00 cm) revealed 125 days of maturity with moderate iron content of 62.75 ppm accompanied with high grain yield of 4.67 tonns per ha. The variety Mahalaxmi also exhibited short plant type (107.50 cm) and of 143 days duration with moderate iron content 58.61 ppm and high grain yield (3.76 tonn/ha).

The tillers per plant, grains per panicle and 100 grain weight along with spikelet fertility (%) and harvest index directly determine the yield potential of rice genotypes. The genotype Jajati (17.60) revealed highest number of tillers per plant followed by Pratap (16.50). Khush (1993) emphasized the importance of moderate tillering types with large panicles bearing high grain numbers for the realization of high grain yield in rice. Longer panicle with high grain density (more grains per panicle) usually contributes significantly to grain yield. Here also more grains per panicle have been reported to accumulate moderate iron content, found in most of the test genotypes and maximum being revealed in Tanmayee (27.07 cm) and Pratibha (27.23 cm). The high grain weights mean the bold grain revealed significant yield with moderate iron content found in the rice genotypes Gouri and Meher. Grain filling depends upon effective translocation of photosynthates to the sink (seed). The activity of a number of enzymes related to the transport of photosynthates is needed for healthy and plumpy grains at physiological maturity. However its best known function is its structural role in the prosethetic groups of enzyme systems such as cytochromes, catalases and peroxidases. These enzymes are also the main components of chloroplasts and mitochondria (Mengel and Kirby 1987; Marschner, 1995b). Apart from these, iron is also involved in protein synthesis (Bennet, 1945; Perur *et al.,* 1961). In the present investigation, the fertility % in almost all the genotypes was 70-80% and the genotypes Gouri and Indravati exhibited more filled grains per panicle (>75%) with moderate Fe content at physiological maturity. Higher fertility % in the present set of genotypes can therefore be related to the selection history of the test genotypes.

The estimates of heritability aid the breeders in allocating resources necessary to effectively select for desirable traits and to achieve maximum genetic gain with less time and resources (Smalley *et al.,* 2004). Heritability was classified as low (below 30%), medium (30-60%) and high (above 60%). In the present investigation, high heritability was observed in flag leaf length followed by grains per panicle and grain yield per plant, whereas moderate heritability recorded in spikelet fertility followed by days to maturity. Grains per panicle, flag leaf length and grain yield per plant revealed high heritability with high genetic advance.

B. Genetic variability for Physico-chemical Traits

Grain length and grain breadth determine grain type of rice genotypes. Grain type score ranged from 2.0 to 5.0 (short bold to long slender grain type). Grain length/grain breadth ratio determines grain and kernel dimension as well as grain density. Improved grain density refers to degree of compactness of starch grain in kernel and leaving no space between kernel and hull. High grain length/grain breadth ratio was revealed in Kalingadhan 1202 with high iron content. Grain dimension is a primary consideration for consumers' preference. Usually, medium slender to long slender grain types fetch better price in the market and are also suitable for table rice. In the present study Kalingadhan 1202, Kalingadhan 1201 and Pratibha had revealed proportionally longer G/B ratio value of more than 4.0 with moderate to high iron content. These could be considered for consumers' preferences.

Amylose is a component of rice starch. The high amylose rice contains approximately >24% amylose content of the milled rice, the low amylose rice contains 10-19% and the waxy rice contains <5%. In the present study, Tejaswini, Govinda and Pradeep revealed high amylose content (>24%) that determines the non sticky nature of rice to be preferred by consumer. Apart from these, high amylose is inversely proportionate to the gylcemic index which is required for diabetes patient.

Usually, Fe content varies from 40.0-77.0 ppm depending upon the set of germplasm as test materials. Local landraces and wild rice, *Oryza nivara* are usually rich in grain Fe content. Sala *et al.* (2015) studied the genetic variability for iron and zinc content on segregating population of rice. Genotype with Fe content above the threshold limit of 30 ppm is considered as a Fe biofortified rice variety.In the present research work, considering both grain Fe content and high yield potential, Kalingadhan 1202, Bhuban, Pratibha, Gouri are the best Fe biofortified product with grain yield around 3.2-4.6 tonns/ha and grain Fe content more than 45.0 ppm.

High genotypic coefficient of variation was observed in VER (volume expansion ratio) followed by ASV (alkali spreading value) .Similar results were also reported by Williams *et al*. (2021); Adhikari *et al*. (2018). High heritability with high genetic advance was observed in alkali spreading value (ASV), gel consistency (GC), head rice recovery (HRR) and volume expansion ratio (VER). The similar findings of high heritability coupled with high genetic advance was reported by Limbani *et al*. (2017). Contradictory results have also been reported in some cases *i.e.* by Adhikari *et al*. (2018).

Similarly for qualitative characters the heritability (broad sense) ranged from 74.06% for amylose content to 98.97% for alkali spreading value (ASV). The genetic advance as percentage of mean at 5% selection intensity varied from 15.16 for optimum cooking time (OCT) to 159.90 in VER. Alkali spreading value revealed high heritability followed by volume expansion ratio (VER) and grain L/B ratio. High heritability with high genetic advance was observed in alkali spreading value (ASV), gel consistency (GC), head rice recovery (HRR) and volume expansion ratio (VER). Similar findings were in agreement with Babu *et al*. (2012); Dey *et al*. (2021) in rice.

C. Character association

The knowledge of the degree of association between yield and its component traits and within the component characters themselves, can improve the selection efficiency in plant breeding. The correlation studies (Table 4) reflected that the phenotypic correlation coefficients were higher than genotypic correlation coefficients for most of the characters under study. It indicated that the studied characters were much influenced by the environment.

In this present research, phenotypic and genotypic correlations between all possible pairs of twenty six characters were studied. The grain yield per plant revealed significant positive correlation with plant height, flag leaf length, grains per panicle both at phenotypic and genotypic level. The Fe (ppm) content exhibited significant negative correlation with grain yield per plant both at phenotypic and genotypic level respectively. Similarly, grains per panicle exhibited positive significant correlation with 100 grain weight both at phenotypic and genotypic level respectively. Also it has been observed that grain Fe (ppm) content is negatively correlated with grain zinc content both at phenotypic and genotypic level respectively. Similar results were also reported by Dhurai *et al*. (2014); Nandan *et al*. (2010); Ajmera *et al*. (2017); Shivakumar *et al*. (2018); Srijan *et al*. (2014); Lakshmi *et al*. (2020); Shivani *et al*. (2021); Prasad *et al*. (2017); Kishore *et al*. (2018) in rice.

D. Path coefficient studies

Plant selection based on correlation coefficients is often misleading due to the impact of third factor in the correlation between two variables. The most beneficial selection criteria was the traits with high positive correlation along with high direct effects (Pavan *et al.,* 2011). In the present investigation, Table (5 & 6) the plant height has the highest direct effect on grain yield per plant followed by flag leaf length and grains per panicle. Days to maturity, tillers per plant, panicle length, 100 grain weight had negative direct effect on grain yield. The grain length, grain breadth also had negative direct effect on grain yield per plant. Fe (ppm) content also revealed negative direct effect on grain yield. The partial similar results were also observed by Kishore *et al*. (2018); Islam *et al*. (2018); Tripathy (2021); Prasannakumari *et al*. (2020) ; Kiran *et al*. (2012).

Fig 1- Sample collection from EB-1, OUAT, BBSR

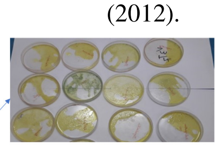

Fig 2- Qualitative assessment by Prussian blue stain

Fig 3- Sample digestion by microwave digester, NRRI, Cuttack

Fig 4- Fe & Zn estimation by AAS Method, NRRI, Cuttack

Table 1: Mean performance of yield and its related traits in 24 genotypes of rice.

Parents	DM	PH (cm)	FLL(cm)	FLW(cm)	TP	PL(cm)	GP	SF(%)	GYP (g)	100 GW(g)	HI (%)	GY (tons/ha)
Jajati	126.00	108.50	25.01	1.02	17.60	24.49	184.00	75.12	35.39	2.68	0.40	3.53
Manika	128.50	98.50	27.26	1.01	16.30	23.44	190.20	75.83	33.95	2.19	0.38	3.39
Sidhanta	125.50	84.50	32.26	1.16	12.40	19.10	133.10	72.63	34.14	2.00	0.41	3.41
Tanmayee	132.00	132.00	28.09	1.06	11.90	27.07	241.70	77.96	35.37	2.61	0.42	3.53
Bhanja	132.50	87.00	27.84	1.03	13.50	23.24	174.40	74.61	35.76	2.39	0.42	3.57
Pratibha	138.00	93.50	36.84	1.23	11.20	27.23	185.60	74.58	35.88	2.41	0.42	3.58
Mahalaxmi	143.00	107.50	28.23	1.04	14.00	23.95	197.40	77.48	37.64	2.34	0.47	3.76
Birupa	126.00	87.50	29.24	0.99	11.40	24.43	203.80	77.89	31.96	2.63	0.50	3.19
Bhuban	125.00	107.00	44.41	1.06	14.90	25.62	231.80	75.72	46.79	2.64	0.53	4.67
Uphar	134.00	108.50	25.73	1.01	13.90	24.71	215.40	72.84	33.19	2.45	0.46	3.31
Indravati	128.50	104.00	22.84	0.99	13.90	24.44	221.50	78.11	33.06	2.69	0.41	3.30
Kalingadhan 1202	136.50	97.50	29.47	1.03	12.70	24.54	160.40	75.21	35.08	2.11	0.42	3.50
Meher	130.50	82.50	31.10	1.00	15.70	26.06	221.10	78.01	32.40	2.76	0.47	3.23
Pratap	134.00	84.50	34.36	1.05	16.50	23.60	193.70	74.33	31.95	2.18	0.44	3.19
Pradeep	135.50	120.50	35.71	1.05	13.60	25.28	168.90	76.53	33.51	2.43	0.53	3.34
Kalingdhan 1201	138.50	92.50	41.47	1.07	15.90	24.50	160.10	75.38	32.61	2.33	0.45	3.26
Hema	128.50	87.00	35.31	1.55	15.90	23.34	144.60	75.11	32.86	2.60	0.47	3.28
Govinda	134.50	97.50	41.00	1.06	11.50	25.55	228.10	76.87	34.92	2.67	0.46	3.49
Tejaswini	124.50	93.50	37.80	1.04	14.30	23.05	118.70	70.69	33.96	2.18	0.49	3.39
Sebati	138.50	77.50	37.22	1.23	11.60	23.35	108.70	72.46	31.06	2.05	0.46	3.10
Gouri	136.00	89.00	26.47	1.02	16.30	22.81	240.10	78.34	33.82	2.80	0.49	3.38
Santeheap	138.50	104.50	34.31	1.03	13.00	23.31	166.90	73.45	34.38	1.99	0.46	3.43
Hasanta	133.00	104.00	35.24	1.09	11.40	24.00	186.30	74.15	33.01	2.11	0.44	3.30
Surendra	132.00	92.00	25.95	1.06	14.00	22.95	111.10	71.75	30.64	2.14	0.42	3.06
Grand Mean	132.48	97.54	32.22	1.08	13.89	24.17	182.82	75.21	34.31	2.39	0.45	3.43
CV	3.35	6.25	6.42	6.11	10.49	5.19	9.08	2.87	3.82	8.94	3.36	3.92
CD at 5%	9.18	12.62	4.28	0.14	3.01	2.59	34.35	4.46	2.71	0.44	0.03	0.28

DM = Days to maturity, PH = Plant height, FLL = Flag leaf length, TP = Tillers per panicle, PL = Panicle length, GP = Grains per panicle, 100 GW = Grain weight, GL = Grain length, GB = Grain breadth, GYP = Grain yield per plant

Table 2: Mean performance of physico-chemical traits in 24 rice genotypes.

Parents	Hulling (%)	Milling (%)	HRR (%)	GL (mm)	GB (mm)	Grain L/B	ASV	GC (mm)	Amylose (%)	KLC	VER	OCT (min)	Fe (ppm)	Zn (ppm)
Jajati	81.76	72.40	58.06	6.25	2.15	2.91	2.00	44.85	21.07	9.70	2.25	21.00	54.68	20.99
Manika	75.80	70.70	57.85	5.65	2.85	1.98	2.50	57.85	26.26	7.15	2.00	23.00	58.07	20.05
Sidhanta	71.25	61.64	59.85	5.27	1.77	2.96	2.00	34.75	23.60	7.00	9.25	22.00	57.81	27.67
Tanmayee	65.38	59.07	31.73	5.82	1.96	2.96	2.00	18.75	25.65	9.35	3.34	19.00	66.66	24.15
Bhanja	74.25	67.27	43.84	5.67	1.97	2.87	5.50	19.25	26.81	8.05	2.40	24.00	46.03	28.84
Pratibha	82.17	66.23	31.87	6.78	1.60	4.27	2.50	16.60	22.48	10.05	4.75	20.50	54.42	24.30
Mahalaxmi	78.90	73.45	46.78	5.53	2.05	2.68	3.16	44.00	26.29	9.50	2.75	22.00	58.61	20.90
Birupa	80.00	77.16	41.68	5.58	2.12	2.63	4.41	47.40	26.09	8.05	1.37	23.00	55.88	20.77
Bhuban	74.25	70.67	42.00	5.27	2.09	2.52	6.50	16.10	26.93	9.80	2.25	22.50	62.75	19.61
Uphar	71.96	64.19	51.99	5.90	2.11	2.80	2.00	20.00	27.93	8.05	1.60	24.50	64.67	19.18
Indravati	84.33	80.90	51.24	4.85	1.82	2.66	2.66	29.50	27.07	7.80	1.20	22.00	65.76	20.95
Kalingadhan1202	50.84	48.12	32.43	6.42	1.21	5.28	1.00	28.15	26.11	8.90	7.35	21.50	76.10	20.08
Meher	79.17	68.05	45.82	6.03	2.17	2.78	2.00	17.90	24.26	7.65	1.70	27.00	47.40	21.05
Pratap	78.07	66.81	53.27	5.09	1.81	2.80	2.50	23.55	31.64	6.65	2.00	25.00	51.08	23.41
Pradeep	71.71	65.37	51.06	7.15	2.00	3.59	2.00	20.60	32.10	9.10	1.55	23.00	62.82	19.96
Kalingadhan 1201	55.76	51.95	35.43	6.09	1.32	4.64	5.16	16.45	31.59	9.05	1.27	24.00	46.13	24.57
Hema	71.29	65.81	41.10	6.08	1.95	3.12	4.25	17.02	25.49	8.05	3.40	27.00	42.81	24.21
Govinda	86.45	77.16	44.73	5.42	1.63	3.32	6.08	18.25	32.10	6.90	9.75	24.50	72.94	27.21
Tejaswini	70.41	65.60	51.16	5.05	1.66	3.04	5.50	23.65	32.27	8.85	7.00	24.00	58.09	26.83
Sebati	72.55	60.69	50.66	5.27	1.78	2.95	2.00	19.60	30.30	8.90	10.00	23.00	46.80	24.63
Gouri	67.52	61.15	52.89	5.18	1.78	2.90	5.60	27.00	27.95	6.75	2.00	25.50	57.52	21.41
Santeheap	75.37	70.03	40.36	5.16	1.99	2.59	2.165	18.65	28.70	6.75	2.45	20.50	60.67	20.95
Hasanta	83.72	76.81	62.79	5.05	1.85	2.72	2.00	22.25	31.02	7.25	10.10	25.50	71.99	23.25
Surendra	73.56	69.84	53.17	5.80	1.74	3.32	2.50	17.45	30.28	8.55	10.00	25.00	68.47	24.65
Grand Mean	74.02	67.13	47.16	5.68	1.89	3.10	3.25	25.82	27.67	8.24	4.24	23.29	58.67	22.9
CV	6.12	5.21	5.88	5.56	6.59	8.09	5.11	6.36	6.32	5.72	8.89	4.19	7.78	6.40
CD at 5%	9.37	7.23	5.74	0.65	0.26	0.52	0.34	3.40	3.62	0.98	0.78	2.02	9.44	3.03

HRR = Head rice recovery, GL = grain length, GB = grain breadth, Grain L/B = grain length/breadth, ASV = alkali spreading value, KLC = kernel length after cooking, VER = volume expansion ratio, OCT = optimum cooking time

Table 3: Mean, range, PCV, GCV, heritability, genetic advance for different quantitative and physico-chemical traits in rice.

Sr. No.	Characters	Mean	Range	GCV	PCV	h^2 (Broad Sense)	Genetic Advancement 5%	Gen. Adv as % of Mean 5%
1.	Days to maturity	132.48	124.50-143.00	3.04	4.52	45.24	5.58	4.21
2.	Plant height (cm)	97.54	77.50-132.00	12.28	13.78	79.41	21.99	22.54
3.	Flag leaf length	32.22	22.84-44.41	17.46	18.61	88.09	10.88	33.77
4.	Flag leaf width	1.08	0.99-1.55	10.16	11.85	73.41	0.19	17.93
5.	Tillers per plant	13.89	11.20-17.60	11.58	15.62	54.95	2.45	17.69
6.	Panicle length	24.17	19.10-27.23	5.68	7.70	54.58	2.09	8.65
7.	Grains per panicle	182.82	108.70-241.70	20.75	22.65	83.92	71.60	39.16
8.	Spikelet fertility	75.21	70.69-78.34	2.06	3.53	34.27	1.87	2.49
9.	Grain yield per plant (g)	34.31	30.65-46.80	8.69	9.49	83.82	5.62	16.39
10.	100 grain weight (g)	2.39	1.99-2.80	8.83	12.57	49.40	0.30	12.79
11.	Harvest Index (%)	0.45	0.39-0.54	8.22	8.88	85.69	0.07	15.68
12.	Grain yield (tons/ha)	3.43	3.06-4.68	8.66	9.51	83.01	0.55	16.26
13.	Hulling (%)	74.02	50.84-86.46	10.46	12.12	74.54	13.78	18.61
14.	Milling (%)	67.13	48.12-80.90	10.91	12.09	81.43	13.61	20.28
15.	HRR	47.16	31.73-62.79	18.36	19.28	90.69	16.98	36.02
16.	GL (mm)	5.68	4.85-7.15	9.40	10.93	74.08	0.94	16.68
17.	GB (mm)	1.89	1.22-2.85	16.12	17.42	85.67	0.58	30.75
18.	Grain L/B	3.10	1.98-5.28	22.50	23.91	88.55	1.35	43.62
19.	ASV	3.25	1.00-6.50	50.21	50.47	98.97	3.34	102.91
20.	GC (mm)	25.82	16.10-57.85	44.64	45.09	98.00	23.50	91.04
21.	Amylose (%)	27.67	21.07-32.28	10.67	12.40	74.06	5.23	18.92
22.	KLC	8.24	6.65-10.05	12.38	13.64	82.41	1.91	23.17
23.	VER	4.24	1.20-10.10	78.12	78.62	98.72	6.77	159.90
24.	OCT (min)	23.29	19.00-27.00	8.25	9.25	79.50	3.53	15.16
25.	Zn (ppm)	22.90	19.18-28.85	11.39	13.07	76.01	4.68	20.46
26.	Fe (ppm)	58.67	42.81-76.10	14.51	16.47	77.68	15.46	26.35

Table 4: Correlation analysis for yield and yield contributing traits in rice.

	DM	PH	FLL	FLW	TP	PL	GP	100GW	GL	GB	Zn (ppm)	Fe (ppm)	GYP
DM	1.000	0.072	0.127	0.010	-0.144	0.119	0.012	-0.196	0.183	-0.323*	-0.074	0.102	-0.133
PH		1.000	-0.096	-0.267	-0.042	0.419*	0.399*	0.168	0.229	0.181	-0.372*	0.259	0.361*
FLL			1.000	0.335*	-0.040	0.110	-0.138	-0.136	0.016	-0.266	0.254	-0.307*	0.312*
FLW				1.000	-0.033	-0.113	-0.384*	-0.083	0.177	-0.149	0.320*	-0.329*	-0.059
TP					1.000	-0.102	0.077	0.208	0.040	0.254	-0.250	-0.360*	0.071
PL						1.000	0.422*	0.424*	0.371*	0.065	-0.275	-0.029	0.218
GP							1.000	0.662**	-0.070	0.251	-0.402*	-0.013	0.371*
100GW								1.000	0.162	0.161	-0.244	-0.216	0.224
GL									1.000	-0.064	-0.188	-0.037	-0.034
GB										1.000	-0.373*	-0.215	0.104
Zn (ppm)											1.000	-0.069	-0.204
Fe (ppm)												1.000	-0.431*
GYP													1.000

*and** indicate significance at 5% and 1% levels probability correlation analysis

DM = Days to maturity, PH= Plant height, FLL = Flag leaf length, TP = Tillers per panicle, PL= Panicle length, GP = Grains per panicle, 100 GW = Grain weight, GL = Grain length, GB = Grain breadth, GYP = Grain yield per plant

Table 5: Path coefficient analysis of yield and yield related traits.

	DM	PH	FLL	FLW	TP	PL	GP	100GW	GL	GB	Zn (ppm)	Fe (ppm)	GYP
DM	-0.250	-0.018	-0.031	-0.002	0.036	-0.029	-0.003	0.049	-0.045	0.080	0.018	-0.025	-0.133
PH	0.034	0.467	-0.045	-0.125	-0.020	0.195	0.186	0.078	0.107	0.084	-0.173	0.121	0.361*
FLL	0.031	-0.023	0.243	0.081	-0.010	0.027	-0.033	-0.033	0.004	-0.064	0.062	-0.074	0.312*
FLW	-0.0009	0.025	-0.031	-0.093	0.003	0.010	0.035	0.007	-0.016	0.013	-0.029	0.030	-0.059
TP	0.023	0.007	0.006	0.005	-0.163	0.016	-0.012	-0.034	-0.006	-0.041	0.041	0.058	0.071
PL	-0.012	-0.042	-0.011	0.011	0.010	-0.101	-0.043	-0.043	-0.037	-0.006	0.028	0.003	0.218
GP	0.003	0.114	-0.039	-0.110	0.022	0.121	0.287	0.190	-0.020	0.072	-0.115	-0.003	0.371*
100GW	0.025	-0.022	0.017	0.010	-0.027	-0.055	-0.086	-0.130	-0.021	-0.021	0.031	0.028	0.224
GL	-0.014	-0.017	-0.001	-0.013	-0.003	-0.028	0.005	-0.012	-0.076	0.004	0.014	0.002	-0.034
GB	0.075	-0.042	0.062	0.035	-0.059	-0.015	-0.059	-0.037	0.015	-0.234	0.087	0.050	0.104
Zn (ppm)	0.015	0.079	-0.054	-0.068	0.053	0.058	0.085	0.052	0.040	0.079	-0.212	0.017	-0.204
Fe (ppm)	-0.065	-0.165	0.195	0.209	0.229	0.018	0.008	0.137	0.024	0.137	0.044	-0.637	-0.431*
GYP	-0.133	0.361*	0.312*	-0.059	0.071	0.218	0.371*	0.224	-0.034	0.104	-0.204	-0.431*	1.000

*and** indicate significance at 5% and 1% levels probability respectively path coefficient analysis

DM = Days to maturity, PH = Plant height, FLL = Flag leaf length, TP = Tillers per panicle, PL = Panicle length, GP = Grains per panicle, 100 GW = Grain weight, GL = Grain length, GB = Grain breadth, GYP = Grain yield per plant

CONCLUSIONS

Selection becomes ineffective unless the presence of wide genetic variability of the trait of interest is ensured. Therefore, identification of donors for grain Fe content in rice is a prerequisite for biofortification breeding. Hence selection of semi-dwarf plant types with high tillering ability and compact panicles containing long slender grains may be rewarding for Fe biofortification breeding. In the present context Kalingadhan 1202, Hasanta and Govinda were rich in grain iron content and may serve as potential iron donor in breeding programme.

FUTURE SCOPE

With the increasing demand and consumer's preferences, rice breeding programme needs to focus on development of nutrient dense quality rice for value addition and thereby to eradicate malnutrition. High yielding nutrient dense cultivars can be bred selective breeding or through genetic modification. The ultimate objective is to isolate the Fe rich rice donor so as to utilize them in the further breeding programme. The genes and QTLs have been recently found out for the nutritional quality of rice. Besides, the different advanced genomic technologies such as SNPs array, genome sequencing, GWAS, transcriptome profiling etc could be strategically exploited to understand molecular mechanism.

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Conflict of Interest. None.

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