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Assessment of Genetic Variability, Character Association and Path Analysis for Yield and Quality Traits in Zinc and Iron Rich Landraces of Rice

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ABSTRACT

Background: Rice is the staple food for billions of people globally and contains numerous essential nutrients. Among the nutrients, zinc and iron are vital for several growth metabolisms in plants and humans. Therefore, deficiency of these nutrients causes hidden hunger. However, understandingthe genetic variability of rice germplasm is required for improvement of grain yield, yield contributing and nutritional traits. The present study aimed to examine the variability, heritability, character association and path analysis in zinc and iron-rich rice landraces.

Methods: The present investigation was carried out with 37 genotypes of rice in a randomized block design with two replications during *Kharif* -2021 at Regional Agricultural Research Station (RARS), Maruteru.

Result: The studies on variability, heritability and genetic advance as percent mean results revealed moderate GCV and PCV coupled with high heritability and genetic advance as percent mean recorded for days to 50 per cent flowering, plant height, zinc content, iron content and grain yield plant^{-1} indicating scope for simultaneous improvement of these traits along with grain yield plant^{-1}. Character associations and path analysis revealed positive and significant association coupled with a high positive direct effect for grains panicle^{-1}, zinc content and productive tillers plant^{-1}, indicating the effectiveness of direct phenotypic selection for these traits in the improvement of grain yield plant^{-1}.

Key words: Correlation analysis, Iron, Path analysis, Quality traits, Rice grain yield, Variability, Zinc.

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple cereal food crop for more than 3.5 billion people globally and hence, is referred as “Global Grain” (Singh *et al*. 2020a). India is the second-largest producer after China and has a cultivated area of 43.78 million hectares with a production of 118.43 million tonnes and productivity of about 2705 kg^{-1} (FAOSTAT 2021). In rice production yield barriers have been overcome by high-yielding rice varieties, but micronutrient malnutrition is a severe threat to children aged under five and pregnant women.

Among the micronutrients, zinc (Zn) and iron (Fe) are vital for several cellular functions. In the recent past, proper attention has been given for improving rice grain Fe and Zn contents, as wide genetic variability for these essential micronutrients have been reported in rice germplasm (Singh *et al*. 2020b). Plant breeding-based bio-fortification has also been identified as the sustainable approach to improve grain micronutrient contents and curtail micronutrient malnutrition.

In this context understanding of the extent of genetic variability and the genetic relationship between the genotypes are important for successful plant breeding (Singh *et al*., 2020a). High heritability coupled with high genetic advance of the trait suggests a potent condition for its effective improvement through selection. Grain yield being a complex character, correlation coefficient analysis would help in analysis of the interrelationship between yield and yield component traits, while identification of the direct and indirect effects of the yield contributing characters on grain yield through path analysis would help in effective yield improvement. Studying the genetic variability, heritability, association amongst yield and quality-related traits and path analysis would therefore help in determining the effective selection criteria for improvement of grain yield and designing of effective breeding strategies.

In this context, the present investigation was undertaken to elucidate information on variability, heritability, genetic advance, character associations and path coefficients between grain yield, quality and nutritional traits in high zinc and iron landraces of rice.

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MATERIALS AND METHODS

The experimental material consisted of 35 zinc and iron rich rice landraces along with 2 checks. Seed of these accessions (Table 1) was collected from the ICAR- Indian Institute of Rice Research (IIRR), Hyderabad. Two local checks obtained from Regional Agricultural Research Station (RARS), Maruteru *viz*., MTU 7029 (Swarna) and BPT 5204 (Samba Mahsuri) were grown together with the 35 zinc and iron rich landraces during *kharif* 2021 in a randomized block design (RBD) with two replications. Twenty-eight-day old seedlings were transplanted in the main field with a spacing of 20 × 15 cm. All recommended practices were followed for raising a good crop and data was recorded on yield, yield attributing and quality traits.

Observations were recorded on five randomly sampled plants for grain yield plant^{-1} (g), plant height (cm), productive tillers plant^{-1}, panicle length (cm), grains panicle^{-1} and test weight (g). However, days to 50 per cent flowering was recorded on plot basis.

Energy-dispersive X-ray Fluorescence Spectrometry (ED-XRF) was used for analyzing the grain zinc and iron content in brown rice at IIRR Hyderabad. All remaining grain quality parameters, namely, hulling recovery (%), milling recovery (%), head rice recovery (%), water uptake (ml) and volume expansion ratio were estimated at Regional Agricultural Research Station, Maruteru Andhra Pradesh. The phenotypic and genotypic variances were estimated using the method of Burton and Devane (1953) and the variance components were used to compute the genotypic coefficient of variation (GCV) and phenotypiccoefficient of variationaccording to Falconer (1981). Broad sense heritability (Allard 1960) and expected genetic advance (Burton 1952) were also estimated as per the standard procedures.

Correlation coefficients were calculated based on the formulae suggested by Falconer (1981). The direct and indirect effects of different components on grain yield were estimated by path coefficient analysis as suggested by Dewey and Lu (1959) using the R software version 4.2.1 and SPSS 16.0software used for the statistical analysis in addition to correlation matrix and to depict frequency distribution, in the form of a histogram, respectively for the traits studied.

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) for yield, yield contributing and quality traits are presented in Table 2. The resultsrevealed highly significant differences among the genotypes for all the traits under study, indicating the existence of adequate variation in experimental material. Thus, there is a good opportunity to select better parental types to improve grain yield and quality.

A perusal of the results on mean performance and range of the yield component traits studied in the present investigation are presented in Table 3 . The character, grains panicle^{-1} (228.43) showed the maximum range of variation followed by water uptake (144.58 ml) and plant height (139.40 cm), while minimum range was observed for volume expansion ratio (3.55) (Table 2). Similar findings were reported earlier by Sharma *et al*. (2021) and Ravi Kumar *et al*. (2015) for grains panicle^{-1}; Singh *et al*. (2020a) for plant height and Devi *et al*. (2022) for water uptake. Grain zinc content was ranged from 17.52 to 36.42 with a mean of 27.04 ppm, while iron content ranged from 6.70 to 16.21 with an average of 11.45 ppm. These results are in accordance with the findings of Jasmine *et al*. (2022).

Genetic parameters

Variability is very essential for any character for improvement through plant breeding.The genotypic coefficient variation (GCV) phenotypic coefficient variation (PCV), heritability and genetic advance as per cent of mean were computed and analyzed for all characters studied in the present investigation. The results are presented in Table 3.

Table 1: Details of the experimental material studied.

Code	Genotype	Source/Origin
GM-7	Lalmala	Jammu Kashmir, India
GM-12	Raj Bangalo-1	West Bengal, India
GM-16	Futuyu-Red	China
GM-17	Futuyu	China
GM-18	Lalkada-1	Gujarat, India
GM-22	Pokkali-1	Kerala, India
GM-32	Ranbir basmati	Jammu Kashmir, India
GM-42	Pureline Selection	Nagaland, India
GM-44	Pureline Selection	Madhya Pradesh, India
GM-79	Pureline Selection	Madhya Pradesh, India
GM-80	Pureline Selection	Gujarat, India
GM-86	Pureline Selection	Maharashtra, India
GM-87	Pureline Selection	Madhya Pradesh, India
GM-88	Pureline Selection	Punjab, India
GM-91	Pureline Selection	Maharashtra, India
GM-93	Pureline Selection	Gujarat, India
GM-94	Pureline Selection	Gujarat, India
GM-117	Pureline Selection	Maharashtra, India
GM-120	Pureline Selection	Gujarat, India
GM-122	Pureline Selection	Kerala, India
GM-124	Pureline Selection	Gujarat, India
GM-125	Pureline Selection	Madhya Pradesh, India
GM-127	Pureline Selection	Madhya Pradesh, India
GM-128	Pureline Selection	Madhya Pradesh, India
GM-129	Pureline Selection	Madhya Pradesh, India
GM-155	Chakho selection	Manipur, India
GM-156	Panval-1	Maharashtra, India
GM-157	Leelabati	West Bengal, India
GM-163	Shalimar	Jammu Kashmir, India
GM-167	Kamad	Chhattisgarh, India
GM-169	Dehradun basmati 3-6	Uttarakhand, India
GM-172	Dehradun basmati 2-2	Uttarakhand, India
GM-173	Dehradun basmati 1-10	Uttarakhand, India
GM-175	Dehradun basmati 1-8	Uttarakhand, India
GM-178	Dehradun basmati 1-5	Uttarakhand, India
Check-1	MTU-7029	Andhra Pradesh, India
Check-2	BPT-5204	Andhra Pradesh, India

PCV was noticed to behigher than GCV value for all the traits studied indicating therole of environment. These results are supported by the findings of earlier workers Sudeepthi *et al*. (2020), Gunasekaran *et al.* (2017) and Kishore *et al*. (2015). Among the studied traits, productive tillers plant^{-1} had exhibited greater difference between phenotypic and genotypic coefficients of variation, compared to other traits, indicating higher influence of environment on the trait, resulting low heritability values for the trait. Moderate GCV and PCV (10-20%) were recorded for grain yield plant^{-1}, days to 50 percent flowering, plant height, zinc content, iron content, water uptake and volume expansion ratio. These results are in accordance with the reports of Sudeepthi *et al.* (2020) for grain yield plant^{-1}; Umarani *et al*. (2017) for days to 50 per cent flowering; Jasmine *et al*. (2022) for plant height, zinc and iron content. In contrast, low PCV and GCV values (<10%) were found for the traits namely, paniclelength, grains panicle^{-1}, test weight, hulling recovery, milling recovery and head rice recovery indicating low variability for these characters in the present experimental material. Similar findings were reported earlier by Singh *et al*. (2020a) for hulling recovery and milling recovery; Devi *et al*. (2022) for panicle length and head rice recovery.

Table 2: Analysis of variance for grain yield, yield components, quality and nutritional characters in rice landraces.

Source of variation	Df	Yield component traits					
		Days to 50% flowering	Plant height (cm)	Productive tillers plant^{-1}	Panicle length	Grains panicle^{-1}	Test weight
Mean sum of squares							
Replications	1	1.94	0.22	43.90	0.76	36.54	7.46
Genotype	36	243.23**	503.08**	2.90*	9.52**	778.36**	2.92**
Error	36	3.00	11.58	1.26	0.45	5.31	0.20

Source of variation	Df	Quality traits				Nutritional traits			
		Hulling recovery	Milling recovery	Head rice recovery	Water uptake	Volume expansion ratio	Zinc content	Iron content	Gran yield plant^{-1}
Replications	1	1.48	0.14	172.49	26.1	0.10	0.94	1.72	0.25
Genotype	36	39.37**	30.11**	13.05**	715.56**	0.28**	21.15**	4.38**	10.26**
Error	36	3.29	3.81	3.98	7.66	0.004	0.79	0.32	0.34

*, **Significantat 5 and 1 per cent levels, respectively.

Table 3: Genetic parameters for grain yield, yield components, quality and nutritional traits in rice landraces.

Characters	Mean	Range: Minimum	Range: Maximum	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heritability (%)	Genetic advance as per cent of mean
Yield component traits							
Days to 50 per cent flowering	77.21	65.00	120.00	14.19	14.36	97.56	28.88
Plant Height (cm)	139.40	92.00	165.00	11.24	11.50	95.35	22.63
Productive tillers plant^{-1}	12.74	9.00	16.00	7.10	11.33	39.29	9.17
Panicle length (cm)	25.40	22.14	31.02	8.37	8.79	90.82	16.44
Grainspanicle^{-1}	228.43	188.00	270.00	8.60	8.66	98.64	17.60
1000 seed weight (g)	20.01	16.72	23.52	5.82	6.24	87.03	11.65
Grain quality traits							
Hulling recovery (%)	74.89	64.33	82.74	5.67	6.16	84.57	10.74
Milling recovery (%)	66.90	56.96	74.22	5.41	6.15	77.49	9.82
Head rice recovery (%)	58.68	51.24	65.63	3.63	4.97	53.28	5.45
Water uptake (ml)	144.58	114.00	181.00	13.01	13.15	97.88	26.52
Volume expansion ratio	3.55	3.01	4.75	10.44	10.61	96.84	21.16
Nutritional traits and grain yield							
Zinc content (ppm)	27.04	17.52	36.42	11.80	12.25	92.74	23.41
Iron content (ppm)	11.45	6.70	16.21	12.42	13.39	86.08	23.74
Grain yield plant^{-1} (g)	22.07	17.72	27.58	10.08	10.43	93.42	20.08

In addition, heritability is a good index for the transmission of characters from parents to their offerings. In the present study, estimates of heritability for different characters ranged from 39.29 (productive tillers plant^{-1}) to 98.64 (grains panicle^{-1}). High heritability estimates (>60%) along with high genetic advance as percent mean (>20%) would be helpful in predicting genetic gain under selection than heritability estimates alone. In this study, high heritability coupled with high genetic advance as per cent mean was observed for days to 50 per cent flowering, plant height, zinc content, iron content, grain yield plant^{-1}, water uptake and volume expansion ratio indicating the preponderance of additive gene actionand hence, the effectiveness of simple phenotypic selection for improvement of these traits. These observations are in agreement with the reports of Devi *et al*. (2022) and Lakshmi *et al*. (2021) for days to 50 per cent flowering, plant height and water uptake; Sameera *et al*. (2015) for grain yield plant^{-1} and Jasmine *et al*. (2022) for zinc content and iron content. High heritability along with moderate genetic advance as per cent of mean was observed for panicle length, grains panicle^{-1} and test weight indicating the role of additive and non-additive gene effects for these characters. The results are in accordance with Perween *et al*. (2020) and Tiwari *et al.* (2020) for test weight; Sudeepthi *et al*. (2020) and Tejaswini *et al*. (2016) for panicle length.

Character association

The results on character associations between yield, yield components and quality characters are presented in Table 4. A perusal of these results revealed positive and significant association of grain yield with productive tillers plant^{-1}, grains panicle^{-1}, zinc and iron content, indicating scope for simultaneous improvement of these traits. The results are in agreement with the reports of Singh *et al.* (2020a) for grains panicle^{-1}, zinc and iron content and Ashok *et al*. (2016)and Devi *et al*. (2017) for productive tillers plant^{-1}.

Further, positive and significant associations were also noticed for days to per cent flowering with productive tillers plant^{-1} (Jasmine *et al*. 2022), head rice recovery (Singh *et al*. 2020a), water uptake (Ashok *et al*. 2016); plant height with zinc content, iron contentand hulling recovery (Singh *et al*. 2020a); productive tillers plant^{-1} with grains panicle^{-1},head rice recovery (Singh *et al*. 2020a) and water uptake (Devi *et al*. 2022), similar to the findings of earlier workers. Grain zinc content had recorded significant positive association with iron content implying the possibility of concurrent selection for both the micronutrients. These results are supported by the findings of Raza *et al.* (2019) and Sing *et al.* (2020a). Hulling recovery had a significant positive association with milling recovery and head rice recovery similar to the reports of Singh *et al*. (2020a).

In contrast, panicle length showed negative and significant associationwith grain yield plant^{-1}. The results are in conformity with the findings of Srivastava *et al*. (2017) for panicle length. Negative and significant associations were also observed for days to 50 per cent flowering with plant height, zinc and iron content (Singh *et al.* 2020a); plant

Table 4: Correlation for grain yield, yield components, quality and nutritional traits in rice landraces.

Characters	Plant height	Number of productive tillers plant^{-1}	Panicle length	Grains panicle^{-1}	Thousand seed weight	Hulling recovery	Milling recovery	Head rice recovery	Water uptake	Volume expansion ratio	Zinc content	Iron content	Grain yield plant^{-1}
Days to 50 per cent flowering	-0.465**	0.560**	0.159	0.062	0.047	-0.088	-0.185	0.330*	0.401*	0.523**	-0.539**	-0.538**	0.085
Plant height		-0.312	-0.093	-0.001	0.316	-0.094	-0.029	-0.270	-0.143	-0.577**	0.455**	0.417*	0.103
Number of productive tillers plant^{-1}			0.093	0.728**	-0.189	-0.212	-0.073	0.429**	0.462**	0.213	-0.362*	0.049	0.527**
Panicle length				-0.386*	0.128	0.135	0.011	0.375*	0.110	0.322	-0.341*	-0.238	-0.340*
Grains panicle^{-1}					-0.009	-0.199	-0.126	-0.175	-0.075	-0.133	0.075	0.232	0.570**
Thousand seed weight						0.069	-0.029	0.056	-0.003	0.010	0.167	0.028	-0.158
Hulling recovery							0.975	0.561**	-0.074	0.143	0.069	0.194	-0.142
Milling recovery								0.669**	0.076	0.009	0.161	0.305	0.059
Head rice recovery									0.132	0.555**	-0.064	0.023	0.132
Water uptake										0.026	-0.279	-0.092	0.020
Volume expansion ratio											-0.265	-0.436**	-0.025
Zinc content												0.5255**	0.371*
Iron content													0.338*

*, ** Significant at 5% and 1% levels, respectively.

Table 5: Path analysis for grain yield, yield components, quality and nutritional traits in rice landraces.

Characters	Days to 50 per cent flowering	Plant height	Number of productive tillers plant^{-1}	Panicle length	Grains panicle^{-1}	Thousand seed weight	Hulling recovery	Milling recovery	Head rice recovery	Water uptake	Volume expansion ratio	Zinc content	Iron content	Grain yield plant^{-1}
Days to 50 per cent flowering	0.127	-0.083	0.140	-0.033	0.019	-0.013	-0.023	-0.089	0.137	0.025	-0.036	-0.256	-0.007	0.085
Plant height	-0.059	0.178	-0.078	0.019	-0.005	-0.088	-0.024	0.014	-0.112	-0.009	0.040	0.217	0.005	0.103
Number of productive tillers plant^{-1}	0.071	-0.055	0.249	-0.019	0.231	0.052	-0.056	0.035	0.179	0.029	-0.016	-0.172	0.0006	0.527**
Panicle length	0.020	-0.016	0.023	-0.213	-0.122	-0.035	0.035	-0.005	0.156	0.006	-0.022	-0.162	-0.003	-0.340*
Grains panicle^{-1}	0.007	-0.0002	0.182	0.082	0.317	0.002	-0.053	0.063	-0.073	-0.004	0.009	0.036	0.003	0.570**
Thousand seed weight	0.005	0.056	-0.047	-0.027	-0.003	-0.278	0.018	0.014	0.023	-0.0002	-0.0007	0.079	0.0003	-0.158
Hulling recovery	-0.011	-0.016	-0.053	-0.028	-0.063	-0.019	0.265	-0.469	0.234	-0.004	-0.009	0.032	0.002	-0.142
Milling recovery	-0.023	-0.005	-0.018	-0.002	-0.040	0.008	0.258	-0.481	0.041	0.004	-0.0006	0.076	0.0042	0.059
Head rice recovery	0.041	-0.048	0.107	-0.080	-0.055	-0.015	0.149	-0.322	0.417	0.008	-0.038	0.030	0.0003	0.132
Water uptake	0.051	-0.025	0.115	-0.023	-0.023	-0.003	-0.019	0.036	0.231	0.001	-0.069	-0.126	-0.001	0.020
Volume expansion ratio	0.066	-0.103	0.060	-0.068	-0.042	-0.003	0.038	-0.004	0.231	0.001	-0.069	-0.126	-0.005	-0.025
Zinc content	-0.086	0.081	-0.090	0.072	0.024	-0.046	0.018	-0.007	-0.026	-0.017	0.018	0.476	0.007	0.371*
Iron content	-0.068	0.074	0.012	0.050	0.073	-0.007	0.051	-0.147	0.009	-0.005	0.030	0.250	0.013	0.338*

*, ** Significant at 5% and 1% level respectively,Diagonal values indicate direct effects, Residual effect = 0.367.

height with volume expansion ratio (Devi *et al*. 2022); productive tillers plant^{-1} with zinc content (Singh *et al.* 2020a); panicle length with grains panicle^{-1} (Lingaiah *et al*. 2020) and zinc content (Jasmine *et al*. 2022); volume expansion ratio with iron content, similar to the results of earlier workers, indicating the need for balanced selection, while effecting simultaneous improvement of the traits.

Path analysis

The results on path analysis of yield components and quality traits on grain yield plant^{-1} are presented in Table 5. A perusal of these results revealed low residual effect of (0.367) indicating that variables studied in the present investigation explained about 63.3 per cent of variability for grain yield plant^{-1} and therefore other attributes, besides the characters studied are also contributing for grain yield plant^{-1}.

A complete analysis of the direct and indirect effects also revealed a high (>0.3) positive direct effectfor head rice recovery, grains panicle^{-1} and zinc content. These findings are in conformity with reports of Shivangi *et al*. (2019) for head rice recovery; Singh *et al*. (2020a) for grains panicle^{-1} and zinc content.The traits grains panicle^{-1} and zinc content had also recorded high positive and significant association with grain yield plant^{-1}, indicating the effectiveness of direct selection for these traits in improvement of grain yield plant^{-1}. Further, the traits productive tillers plant^{-1}, hulling recovery percent, plant height, days to 50 per cent flowering and water uptake had recorded moderate to low positive direct effects on grain yield palnt^{-1}. The results are in agreement with the findings of Jasmine *et al.* (2022) for number of productive tillers plant^{-1}; Singh *et al*. (2020a) for days to 50 per cent flowering and plant height and Devi *et al*. (2022) for hulling recovery and water uptake. Negative direct effects were however; noticed for panicle length, test weight, milling recovery and volume expansion ratio, similar to the results of Singh *et al*. (2020a) for panicle length, test weight and milling recovery and Devi *et al*. (2020) for volume expansion ratio.

CONCLUSION

The study indicated high heritability and genetic advance as per cent of mean for grain yield plant^{-1}, zinc content, iron content, plant height and days to 50 per cent flowering indicating the effectiveness of direct selection for improvement of these traits. Among these, grains panicle^{-1} and zinc content were recorded high positive direct effect coupled with significant and positive correlation with grain yield plant^{-1}. Hence, these traits are identified as effective selection criterion for effecting grain yield improvement in the zinc and iron rich landraces of rice.

Conflict of interest: None.

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