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Exploration of Genetic Variability and Trait Association in High Protein Landraces of Rice (*Oryza sativa* L.)

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Abstract

The present investigation was carried out at the Indian Institute of Rice Research farm, ICRISAT, Hyderabad with 31 genotypes of rice in a randomized block design with three replications, and observations were recorded on grain yield, yield components and quality characters. Analysis of variance revealed significant differences among the genotypes for all characters studied. The studies on variability, heritability and genetic advance as per cent mean thus revealed high GCV and PCV for grains panicle^{-1} and iron content. High heritability coupled with high genetic advance as per cent mean was recorded for plant height, ear bearing tillers plant^{-1}, grains panicle^{-1}, grain yield plant^{-1} and iron content indicating, the effectiveness of simple selection for improvement of these traits. The results on character associations and path analysis revealed positive and significant association coupled with high positive direct effect for ear bearing tillers plant^{-1}, panicle length, grains panicle^{-1}, and amylose content indicating the effectiveness of direct selection for these traits in the improvement of grain yield plant^{-1}. However, for test weight, days to 50 percent flowering, plant height, head rice recovery (%), and zinc content, indirect effects seemed to be the cause of correlation, while for days to maturity, protein and iron content, the use of restricted simultaneous selection model is suggested with restrictions imposed for nullifying the undesirable indirect effects in order to make use of the high positive direct effect observed for these traits on grain yield plant^{-1}.

Keywords: Correlation, Path analysis, Grain yield, Nutritional quality

Introduction

In India, rice occupies an area of 457 lakh hectares producing 1243.7 lakh tons with average productivity of 2717 kg ha^{-1} (www.Indiastat.com, 2020-21). In Telangana, it occupies an area of 10.6 lakh ha, with a production and productivity of 24.58 lakh tons and 2384 kg ha^{-1}, respectively (AAP 2019-20, www.agri.telangana.gov.in). Protein malnutrition is a serious health threat in children of developing countries (Gearing 2015). In India, 80 percent of children under the age of five are malnourished, (Sahu *et al*., 2015). The recommended calorie intake for children is 1000-1400 calories per day (200-300g rice) with protein accounting for 150-450 calories (Faizan and Rouster, 2020). In this context, even a one percent increase in the grain protein content of rice would contribute significantly to the dietary protein, presenting an affordable solution to the epidemic problem of malnutrition, particularly, in countries consuming rice as a staple food. Twenty percent of dietary protein, 3 percent of dietary fat, and other essential nutrients are provided by rice. Further, rice protein is said to be the best among cereal proteins because it has a better balance of important amino acids and is easier to digest. Rice has a higher protein digestibility corrected amino acid score (PDCAAS) of 0.81 (Nitrayová *et al*., 2018) which shows the presence of essential amino acids and overall protein quality, compared to other popular cereals. However, the protein content of milled rice grains is typically 6-7 % (Baniwal *et al.*, 2021), which is the lowest among cereals such as wheat (12-14 %) and maize (8-9 %). Therefore, efforts are needed to develop high-protein rice genotypes with good yields.

In this context, information on the extent of variability in the experimental material along with heritability and genetic advance of the traits would aid in the formulation of effective selection strategies. Studies on correlation and path analysis would further aid in the identification of effective selection criteria for the improvement of grain yield along with grain quality. The present investigation was undertaken in this background to elucidate information on the variability, heritability, genetic advance, character associations, and path coefficients of grain yield, yield components, and quality characters to aid in the formulation of effective selection criteria for grain yield and quality improvement of high protein rice landraces.

Materials and Methods

The experimental material consisted of 31 rice genotypes (**Table 1**) collected from the Indian Institute of Rice Research (IIRR), Rajendranagar, Hyderabad. Among the 31 genotypes, 30 are landraces and one check (CR DHAN 310), a popular high protein content (10.4) variety with excellent cooking quality traits. All 31 genotypes were sown at IIRR Farm at ICRISAT, Hyderabad during *Kharif* 2021 on separate raised nursery beds. All recommended package of practices were adopted to raise a healthy nursery and 30 days old seedlings were transplanted in the main field laid out in Randomized Block Design (RBD) with three replications. Each genotype was transplanted separately in 5 rows of 4.5 m length by adopting a spacing of 20×15 cm. All recommended package of practices were adopted throughout the crop growth period to raise a healthy crop. Observations were recorded on five randomly selected plants for

Table 1. Details of the rice genotypes studied in the present investigation

S No.	Genotype	Pedigree	Origin	S No.	Genotype	Pedigree	Origin
1	JAK 14	Land race	West Bengal	16	JAK 377-3	Land race	Maharashtra
2	JAK 17	Land race	Jharkhand	17	JAK 390	Land race	Maharashtra
3	JAK 25	Land race	Jharkhand	18	JAK 400	Land race	West Bengal
4	JAK 90	Land race	Uttar Pradesh	19	JAK 423	Land race	Maharashtra
5	JAK 108	Land race	Jharkhand	20	JAK 424	Land race	Maharashtra
6	JAK 120	Land race	Uttar Pradesh	21	JAK 440	Land race	Uttar Pradesh
7	JAK 124	Land race	Maharashtra	22	JAK 453	Land race	Uttar Pradesh
8	JAK 153	Land race	Jharkhand	23	JAK 486	Land race	Uttar Pradesh
9	JAK 163	Land race	Uttar Pradesh	24	JAK 513-1	Land race	Jharkhand
10	JAK 247	Land race	West Bengal	25	JAK 519	Land race	Uttar Pradesh
11	JAK 248-3	Land race	West Bengal	26	JAK 552	Land race	West Bengal
12	JAK 287	Land race	West Bengal	27	JAK 595-1	Land race	Uttar Pradesh
13	JAK 341-2	Land race	Maharashtra	28	JAK 611	Land race	Jharkhand
14	JAK 355	Land race	West Bengal	29	JAK 625	Land race	West Bengal
15	JAK 374	Land race	West Bengal	30	JAK 638	Land race	Jharkhand
31	CR DHAN 310	Naveen xARC 10075	Cuttack				

grain yield plant^{-1}; yield component traits, namely, plant height, ear bearing tillers plant^{-1}, panicle length, grains panicle^{-1} and test weight and quality characters, namely, head rice recovery (%), protein content, iron content, zinc content, and amylose content were recorded. However, days to 50 per cent flowering and days to maturity were recorded on a plot basis. In contrast, observations for test weight and all the quality traits studied were obtained from a random grain sample drawn from each plot in each genotype and replication using standard procedures. The data collected was subjected to standard statistical procedures (Panse and Sukhatme, 1967). The genotypic and phenotypic coefficients of variability were computed as per the formula proposed by Burton and Devane (1953). Categorization of the range of variation was followed as per Subramanian and Menon (1973). Heritability in a broad sense was estimated as per Allard (1960) and characterized as suggested by Johnson *et al.* (1955). The genetic advance was estimated as per the formula proposed by Lush (1940). The range of genetic advances as per cent of the mean was classified as suggested by Johnson *et al.* (1955). The correlation was worked out using the formulae suggested by Falconer (1964) and partitioning of the correlation coefficients into direct and indirect effects was carried out using the procedure suggested by Wright (1921) and elaborated by Dewey and Lu (1959). Characterization of path coefficients was carried out as suggested by Lenka and Mishra (1973).

Results and Discussion

The mean performance of 31 landraces studied in the present investigation for grain yield, yield components, and quality characters along with the estimates of the phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2 broad sense) and genetic advance as percent of the mean (GAM) are presented in **Table 2**. A perusal of the results revealed a maximum range for grains panicle^{-1} (63-207). Grain yield plant^{-1} also exhibited wide variation ranging from 14.30g to 24.17g with a mean value of 20.21g. The nutritional

Table 2. Variability, heritability, and genetic advance as per cent of mean for grain yield, yield components and quality traits in rice

S. No.	Character	Mean	Range	Coefficient of variation		Heritability (%)	Genetic advance as per cent of mean
				PCV (%)	GCV (%)		
1	Days to 50 per cent flowering	103	90-119	9.58	8.18	73.04	14.41
2	Days to maturity	133	120-149	9.97	6.4	39.28	8.27
3	Plant height (cm)	108.16	71.00-143.67	17.99	17.54	95.01	35.22
4	Ear bearing tillers plant^{-1}	11	6-14	18.38	16.71	82.71	31.31
5	Panicle length (cm)	23.5	20.16-7.12	10.86	6.34	34.08	7.62
6	Grains panicle^{-1}	118	63-207	32.55	25.03	60.11	39.64
7	Test weight (g)	19.53	15.60-24.84	17.17	9.99	33.83	11.97
8	Grain yield plant^{-1} (g)	20.21	14.30-24.17	13	11.9	83.8	22.44
9	Head Rice Recovery (%)	63.37	45.50-72.40	11.08	9.89	79.76	18.2
10	Protein content (%)	9.77	8.50-10.70	7.87	6.61	70.56	11.44
11	Iron content (ppm)	1.9	1.10-2.90	32	31.52	96.97	63.96
12	Zinc content (ppm)	19.4	14.90-24.00	16.34	12.58	39	19.97
13	Amylose content (%)	22.39	19.94-26.31	20.05	13.82	47.54	19.63

parameter, protein content ranged from 8.50 to 10.70 with an overall mean value of 9.77, while zinc content varied from 14.9 to 24.0ppm with a mean of 19.4ppm. The amylose content of the experimental material was noticed to range from 19.94 -26.31. with a mean value of 22.39 percent, while iron content ranged from 1.10 to 2.90ppm with a mean value of 1.90ppm. The test weight of the landraces studied ranged from 15.60 to 24.84g with a mean value of 19.53g. Further, the landraces were observed to be of short to late duration and their days to maturity ranged from 120.00 to 149.00 days with a mean value of 133 days. The landraces studied were noticed to possess semi-dwarf to tall plant height and it varied from 71.00 to 143.67cm with a mean value of 108.16cm.

High GCV and PCV values (>20) were recorded for grains per panicle, and iron content, indicating the existence of sufficient variation and hence, the effectiveness of selection is better for these traits in the landraces studied. The results conform with the reports of Singh *et al*., (2020). Plant height, ear-bearing tillers plant^{-1}, grain yield plant^{-1}, and zinc content exhibited moderate GCV and PCV values (10-20), while, days to 50 percent flowering, days to maturity and protein content had recorded low PCV and GCV values (<10). The results are in broad agreement with the findings of Sameera *et al*. (2016) and Sudeepthi *et al*., (2020). The other traits, namely, panicle length (Singh *et al*., 2020), test weight (Swarnajit *et al*., 2015), head rice recovery (%) (Babu *et al*., 2012) and amylose content (Suman *et al*., 2020) had recorded variable values of PCV and GCV, similar to the findings of earlier workers.

High heritability (>60) coupled with high genetic advance as per cent mean (>20) was noticed for plant height, ear-bearing tillers plant^{-1}, grains panicle^{-1}, grain yield plant^{-1} (Sudeepthi *et al*., 2020), and iron content (Singh *et al*., 2020), indicating the effectiveness of simple selection for improvement of the traits. High heritability coupled with moderate genetic advance (10-20) was noticed for days to 50 per cent flowering, head rice recovery (%) (Singh *et al*., 2020), and protein content (Kumar *et al*., 2006). The traits, days to maturity (Sudeepthi *et al*., 2020), panicle length, test weight, and zinc content recorded moderate heritability (30-60). Genetic advance as per cent mean was also noticed to be moderate (10-20) for test weight, zinc, and amylose content, while, it was low (<10) for days to maturity (Saha *et al*., 2019) and panicle length (Singh *et al*., 2018).

The results on character associations between yield, yield components, and quality characters are presented in **Table 3**. A perusal of these results revealed a positive and significant association of grain yield plant^{-1} with the yield component traits, namely, ear bearing tillers plant^{-1}, panicle length, grains panicle^{-1} and test weight and the quality traits, namely, amylose content and zinc content, indicating scope for simultaneous improvement of yield and quality traits through selection. The results are in agreement with the reports of Gunasekaran *et al.,* (2017) for ear-bearing tillers plant^{-1}and panicle length; Singh *et al.* (2020) for grains panicle^{-1}, test weight, and zinc content; and Hasan *et al.* (2020) for amylose content. Positive and significant associations were also observed for days to 50 per cent flowering with days to maturity (Saha *et al.,* 2019); ear-bearing tillers plant^{-1} with test weight (Singh *et al.,* 2020) and amylose content (Ashok, 2015); panicle length with zinc content (Singh *et al.,* 2020); test weight with ear bearing tillers plant^{-1}, panicle length and grains panicle^{-1}(Vennela *et al.,* 2021); and iron content with zinc content (Archana *et al*., 2018) indicating scope for simultaneous improvement of these traits. Negative and significant associations of grain yield plant^{-1} with protein content (Chattopadhyay *et al*., 2011) and panicle length (Srivastava *et al*., 2017). However, negative and significant associations were observed for days to 50 per cent flowering with test weight (Singh *et al.,* 2020); plant height with grains panicle^{-1} (Vennela *et al.,* 2021); panicle length with protein content (Chattopadhyay *et al*., 2011); and grains panicle^{-1} with protein content, indicating the need for balanced selection while effecting simultaneous improvement of the traits.

The results of path coefficient analysis of yield components and quality characters concerning grain yield per plant are presented in **Table 4** and **Figure 1**.

Table 3. Correlation coefficients for grain yield, yield components and quality characters in rice

Characters	Days to maturity	Plant height	Ear bearing tillers plant^{-1}	Panicle Length	Grains Panicle^{-1}	Test Weight	Head Rice Recovery (%)	Amylose Content	Protein content	Iron content	Zinc content	Grain yield plant^{-1}
Days to 50 per cent flowering	0.951**	0.057	-0.146	-0.124	0.098	-0.341*	0.1504	0.082	-0.123	0.352	0.104	0.072
Days to maturity		0.194	-0.074	-0.103	-0.238	0.102	0.3043	-0.117	-0.229	0.261	0.086	0.102
Plant height			-0.045	0.0218	-0.527**	-0.351	-0.022	-0.105	0.038	0.189	-0.025	-0.317*
Ear bearing tillers plant^{-1}				-0.036	0.119	0.540**	0.169	0.471**	-0.291	-0.159	0.171	0.530**
Panicle Length					0.496**	0.369**	0.2771	-0.259	-0.641**	0.32	0.577**	0.527**
Grains Panicle^{-1}						0.464**	0.2283	-0.11	-0.452	0.202	0.29	0.562**
Test Weight							-0.01	-0.024	-0.246	-0.211	0.227	0.544**
Head Rice Recovery(%)								0.2655	-0.3229	0.2002	-0.0529	0.278
Amylose Content									-0.159	0.0324	-0.076	0.390*
Protein content										-0.194	-0.194	-0.403*
Iron content											0.529**	0.1618
Zinc content												0.472**

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

The residual effect of 0.469 was observed indicating that variables studied in the present investigation explained about 53.10 per cent of variability for grain yield plant-1 and therefore other attributes, besides the characters studied, are contributing to grain yield plant-1. High positive direct effects of ear-bearing tillers plant-1 (Gunasekaran *et al.,* 2017), panicle length (Sudeepthi *et al*., 2020); grains panicle-1 (Archana *et al.*, 2018), and amylose content (Singh *et al.*, 2020) on grain yield plant-1 were noticed in the present study, similar to the results of earlier workers. These traits had also recorded high positive and significant association with grain yield plant-1, indicating the effectiveness of direct selection for these traits in the improvement of grain yield plant-1. Negative direct effects were, however, noticed for plant height, test weight (Lakshmi *et al.,* 2020), head rice recovery % (Ashok, 2015), and zinc content (Archana *et al.,* 2018), similar to the results of earlier workers. Plant height had also recorded a significant and negative association with grain yield plant-1, while test weight and zinc content had recorded a significant and positive association with grain yield plant-1. However, head rice recovery had recorded a non-significant association with grain yield plant-1. Further, days to 50 per cent flowering had recorded positive and non-significant association along with low and positive direct effects, indicating indirect effects as the cause of the correlation. Hence, consideration of indirect causal factors is suggested simultaneously for these traits. Further, days to maturity and iron content had recorded non-significant association coupled with a high positive direct effect, while protein content had recorded negative and significant association with a high positive direct effect, indicating the need for use of a restricted simultaneous selection model with restrictions imposed for nullifying the undesirable indirect effects to make use of the positive direct effects observed for these traits on grain yield plant-1. The results are in broad agreement with the reports of Archana *et al.,* (2018).

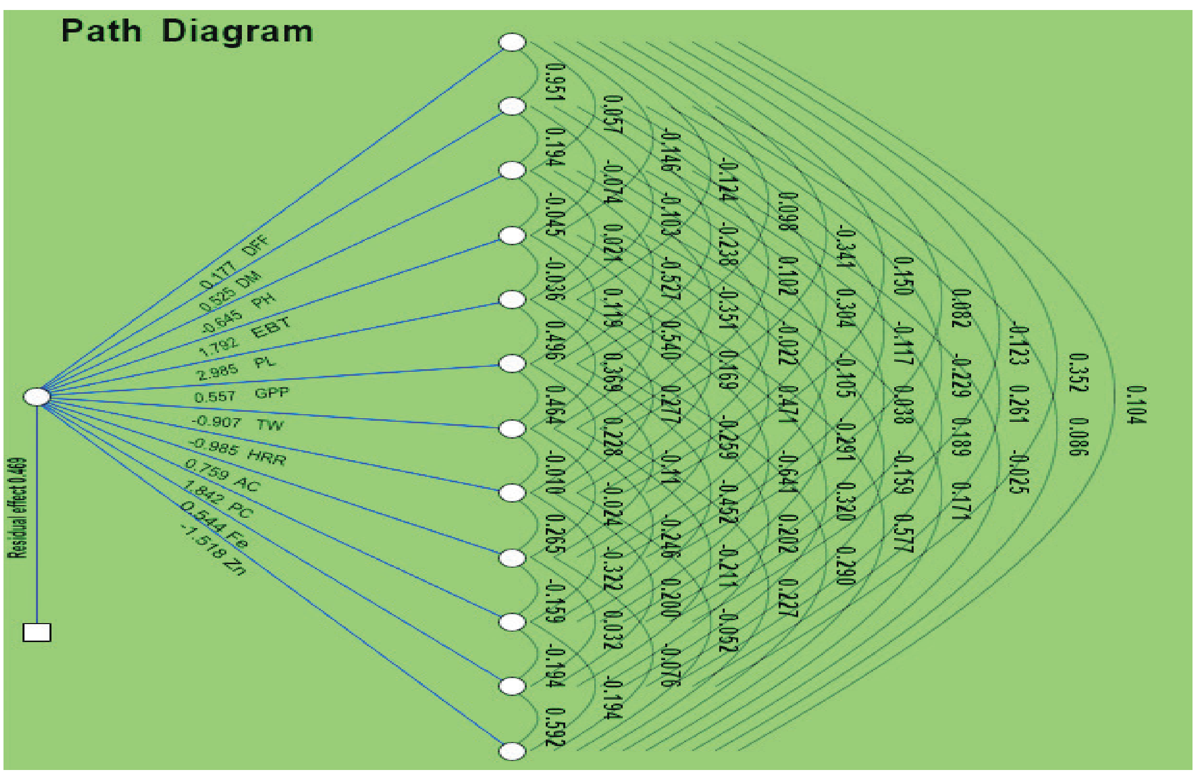

Figure 1: Path diagram of yield components and quality characters for grain yield plant-1

DFF= Days to 50 per cent flowering, DM= Days to maturity, PH= Plant height, EBT=Ear bearing tillers plant-1, PL= Panicle length, GPP= Grains panicle-1, TW= Test weight, GYPP= Grain yield plant-1, HRR=Head rice recovery %, AC=Amylose content, PC=Protein content, Fe = Iron content, Zn =Zinc content.

Table 4. Direct and indirect effects of yield components and quality characters on grain yield in rice

Characters	Days to 50 per cent flowering	Days to maturity	Plant height	Ear bearing tillers $plant^{-1}$	Panicle Length	Grains $Panicle^{-1}$	Test Weight	Head Rice Recovery (%)	Amylose Content	Protein content	Iron content	Zinc content	Grain yield $plant^{-1}$
Days to 50 per cent flowering	**0.177**	0.500	-0.037	-0.262	-0.372	0.055	0.292	-0.148	0.063	-0.227	0.192	-0.159	0.072
Days to maturity	0.168	**0.526**	-0.126	-0.133	0.309	-0.058	0.217	-0.300	-0.089	-0.422	0.142	-0.131	0.102
Plant height	0.010	0.102	**-0.646**	-0.081	0.065	-0.294	0.319	0.022	-0.080	0.071	0.103	0.039	-0.317*
Ear bearing tillers $plant^{-1}$	-0.026	-0.039	0.029	**1.792**	-0.109	0.066	-0.491	-0.167	0.358	-0.538	-0.086	-0.261	0.530**
Panicle Length	-0.022	0.054	-0.014	-0.065	**2.986**	0.277	-0.335	-0.273	-0.197	-1.181	0.174	-0.877	0.527**
Grains $Panicle^{-1}$	0.017	-0.054	0.341	0.213	1.481	**0.558**	-0.421	-0.225	-0.084	-0.833	0.011	-0.441	0.562**
Test Weight	-0.057	-0.126	0.227	0.969	1.103	0.259	**-0.907**	0.011	-0.019	-0.454	-0.115	-0.346	0.544**
Head Rice Recovery(%)	0.027	0.160	0.014	0.303	0.827	0.127	0.010	**-0.986**	0.202	-0.595	0.109	0.080	0.278
Amylose Content	0.015	-0.062	0.068	0.845	-0.773	-0.062	0.023	-0.262	**0.759**	-0.294	0.018	0.116	0.390*
Protein content	-0.022	-0.120	-0.025	-0.523	-1.914	-0.252	0.224	0.318	-0.121	**1.843**	-0.106	0.295	-0.403*
Iron content	0.063	0.137	-0.122	-0.285	0.959	0.011	0.192	-0.197	0.025	-0.359	**0.544**	-0.805	0.162
Zinc content	0.019	0.045	0.016	0.307	1.723	0.162	-0.207	0.052	-0.058	-0.358	0.288	**-1.519**	0.472**

*,**Significant at5 % and 1% levels, respectively

Conclusion

Grains panicle^{-1} exhibited high GCV, PCV, heritability, and genetic advance as per cent mean in addition to positive and significant correlation coupled with high positive direct effects and hence, is identified as effective selection criteria for improvement of grain yield plant^{-1} in the high protein landraces of rice. The study also revealed a negative correlation for grain yield plant^{-1} with protein content and hence, the need for balanced selection, while effecting simultaneous improvement for both traits.

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