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VARIABILITY AND CORRELATION STUDIES FOR GRAIN PHYSICOCHEMICAL CHARACTERISTICS OF RICE (*ORYZA SATIVA* L.)

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ABSTRACT

The analysis revealed significant differences among the genotypes for all the 10 quality traits indicating that sufficient variability is present in the material involved in the study.The high PCV was recorded for grain L/B ratio (17.54%, 34.21% and 8.64%) and gelatinization temperature (27.70%, 31.79% and 17.92%) in land races, new plant types and japonicas, respectively. High heritability (broad sense) along with high genetic advance as per cent of mean was observed for L/B ratio (34.60, 69.92 and 16.39) and gelatinization temperature (41.91, 62.26 and 28.13), respectively for land races, new plant types and japonicas. Grain length showed significant positive correlation with L/B ratio (0.851, 0.956) and grain elongation (0.832, 0.934) in land races and new plant types,while significant positive correlation with L/B ratio (0.748) 1000-grain weight (0.437) and amylose content (0.322)in japonica. Grain width showed significant positive correlations with 1000-grain weight (0.416) and protein content (0.448) in land races; with grain thickness (0.889, 0.563) and 1000-grain weight (0.331, 0.326) in newplant types and japonicas. Highest average iron content(15.44 μg/g) was estimated in new plant types, while zinc content was highest in land races (7.06 μg/g).This indicated that grain length, grain width and gelatinization temperature can be used for the improvement in grain quality in rice.

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for nearly one-half of the world population with an area of 165.2 m ha with production of 1018.1 m tonnes (FAO, 2013).It is widely cultivated throughout the world and is the third most important cereal in the world after wheat and maize in terms of cultivation.Grain quality, along with crop yield and resistance to insect-pest and diseases is an important criteria in most rice breeding programs (Khatun *et al*., 2003). Quality rice is not only in big demand for home consumption, but also have great export potential and can earn a lot of foreign exchange. The desired quality characteristics in rice include the total head rice recovery in milling, the physical attributes of grain size, shape and appearance, the cooking and eating characteristics, gelatinization temperature, grain elongation, gel consistency and aroma (Khush *et al*., 1979) by and large. Improvement in grain quality that does not lower the yield is need of the hour to benefit all the rice growers and consumers.Like grain yield, quality is not easily amenable to selection due to its complex nature.Therefore, efforts to enhance rice productivity with keeping grain quality must receive top priority (Dhurai *et al*., 2014). For planning and execution of a successful breeding program, the most essential pre-requite is the availability of substantial desirable genetic variability for important characters in the germplasmand the extent to which the desirable characters are heritable.Knowledge of correlation between different quality characters are basic and fore most endeavor to find out guidelines for selection of quality genotypes.In this regard a good number of works has been reported by many workers viz., Nayak (2001), Sreeparvathy*et al*. (2010), Bhadra *et al*. (2012) and Dhanwani *et al*. (2013). In the present investigation, an attempt was made to unravel the variability and correlation between quality parameters of local land races, new plant types and japonica rice for 10 important quality characters.

MATERIALS AND METHODS

Fifty seven genotypes involving 22 land races and 16 japonicas from Himachal Pradesh and 19 advanced lines of new plant types obtained from IRRI, Philippines were used in the present investigation. The experiment was conducted at the experimental farms of the Rice and Wheat Research Station, Malan, CSK Himachal Pradesh Agricultural University, Palampur. Single seedling was transplanting per hill in plot measuring 2.05 x 0.6 m in compact family block design with indica, japonica and new plant types as three different families with 3 replications for two consecutive years. The inter and intra-row spacing were 20 cm and 15 cm, respectively. All the observations for 9 quality characters viz., grain length (mm), grain width 9mm), grain thickness (mm), L/B ratio, 1000-grain weight (g), gelatinization temperature, grain elongation (mm), elongation ratio were recorded as per the procedure given in the Standard Evaluation System for Rice, IRRI, 2002. Protein content (%) was estimated by the standard Micro-kjehldahl method (AOAC, 1965), while Iron and zinc content was estimated using atomic absorption spectrophotometer (Varian model) after wet digestion of the samples (Piper, 1950).

The data were statistically analyzed for ANOVA as per Panse and Sukhatme (1984).The genotypic and phenotypic coefficients of variation were estimated following Burton and De Vane (1953).Heritability in broad sense (h^2bs) and genetic advance as per cent of mean were calculated as per Johnson *et al.* (1955).The genotypic and phenotypic correlations among 10 quality traits were calculated following Al-jibouri *et al.* (1958).

RESULTS AND DISCUSSION

Analysis of variance (Table 1) revealed significant differences among the genotypes with in families and among families (land races, japonicas and new plant type) for all the 10 characters studied indicating the presence of substantial variability among the genotypes. Similar results were reported by Dhanwani *et al.* (2013) and Dhurai *et al.* (2014).

The magnitude of phenotypic coefficient of variation (PCV)was higher than genotypic coefficient of variation (GCV) for all the characters studied indicating the influence of the environment on the manifestation of these characters.These observations were in agreement with the results of Nayak *et al.* (2001) and Sreeparvathy *et al.* (2010).

The GCV (Table 2) values ranged from 4.62 (grain thickness) to 23.74 (gelatinization temperature) in land races; 5.30 (elongation ratio) to 34.08 (L/B ratio) in new plant types and 3.69 (amylose content) to 15.62 (gelatinization temperature). The GCV has high for gelatinization temperature (23.74) in land races and for L/B ratio (34.08) and gelatinization temperature (31.79) in new plant types. This indicated the existence of wide genetic variability for these traits and direct selection for these traits will be fruitful. These results are in conformity with that of Bhadru *et al.* (2012) and Dhanwani *et al.* (2013).The GCV estimates were moderate for grain length (11.29), L/B ratio (17.10), 1000-grain weight (14.65), grain elongation (13.06), protein content (11.95) and amylose content (11.42) in land races andfor grain length (16.71), grain width (15.83), 1000-grain weight (12.04), grain elongation (14.71) and amylose content (11.10) in new plant types.Hence selection for these traits may be misleading if these are adopted for improvement. The moderate GCV for grain elongation and 1000-grain weight was also reported by Dhurai *et al.* (2014). Heritability (broad sense)estimates ranged from 17.0% (grain thickness) to 97.8% (grain elongation) in land races; 74.2% (protein content) to 99.3% (L/B ratio & grain elongation) in new plant types and 53.8 (grain thickness) to 97.5% (grain elongation) in japonicas. Heritability estimates were high (>80%) for all the traits except grain thickness (17.0%) in land races; protein content (74.2%) in new plant types and grain thickness (53.8%), 1000-grain weight (66.8%) and gelatinization temperature (76.0%) in japonicas.High heritability estimates for rice quality traits were also reported by Durai *et al.* (2014) and Gampala *et al.* (2015). Expected genetic advance as per cent of mean was highest for gelatinization temperature (41.91), L/B ratio (35.00) and 1000-grain weight (30.06) in land races and for L/B ratio (70.90), gelatinization temperature (62.26), grain length (33.60), grain width (33.21) and grain elongation (30.00) in new plant types.

Table 1: Analysis of variance for 10 quality traits in 57 rice genotypes

Source	D.F.	Grain length (mm)	Grain width (mm)	L/B ratio	Grain thickness (mm)	1000-grain weight(g)	Gelatinization Temperature	Grain elongation (mm)	Elongation ratio	Protein content (%)	Amylose content (%)
Land races											
Year (Y)	1	0.1144*	0.0283*	0.0845*	0.0885*	19.14*	0.01	0.0752	0.0012	8.54*	0.90
Replication (R)	2	0.0007	0.0011	0.0007	0.1052	7.04	1.48*	0.1099	0.0023	1.08	0.81
Yx R	2	0.0127	0.0035	0.0154	0.0416	1.06	0.00	0.1269	0.0004	0.19	0.96
Genotypes (G)	21	2.7859*	0.3371*	1.2286*	0.1028*	77.19*	3.10*	12.6291*	0.1087*	10.18*	37.85*
G x Y	21	0.0202	0.0059*	0.0082	0.0757	0.56	0.01	0.0319	0.0028*	0.031	0.32
Error	84	0.0140	0.0031	0.0069	0.0733	1.05	0.18	0.0485	0.0009	0.17	0.27
New plant types											
Year (Y)	1	0.0015	0.0674*	0.0241*	0.0061	14.49*	0.01	0.1250*	0.0051*	5.36*	1.20*
Replication (R)	2	0.0039	0.0009	0.0003	0.0204	2.82	1.08*	0.0024	0.0005	0.13	0.01
Y x R	2	0.0001	0.0041	0.0027	0.0078	0.48	0.01	0.0098	0.0003	0.22	0.67
Genotypes (G)	18	6.2907*	1.1421*	4.2673*	0.2971*	60.14*	12.90*	14.978*	0.0482*	4.34*	45.91*
G x Y	18	0.0397*	0.0046	0.0142*	0.0087*	0.77	0.01	0.0188	0.0029*	0.02	0.54*
Error	72	0.0206	0.0040	0.0052	0.0041	1.09	0.22	0.0136	0.0010	0.21	0.26
Japonica											
Year (Y)	1	0.0114	0.0040	0.0002	0.0060	0.02	0.01	0.0029	0.0016	6.57*	0.16
Replication (R)	2	0.0004	0.0102	0.0043	0.0162	9.32	0.50	0.0112	0.0009	0.39	0.28
Y x R	2	0.0017	0.0022	0.0013	0.0139	0.44	0.01	0.0004	0.0002	0.32	0.25
Genotypes (G)	15	0.5578*	0.2160*	0.1488*	0.0757*	39.67*	4.33*	2.464*	0.1296*	5.88*	8.94*
G x Y	15	0.0179*	0.0076*	0.0031*	0.0110*	2.63	0.01	0.0185	0.0017*	0.02	0.21
Error	60	0.0062	0.0028	0.0015	0.0065	2.19	0.22	0.0104	0.0007	0.14	0.23
Compact family											
Family (F)	1	15.2793*	10.2859*	17.2948*	1.8390*	351.02*	173.38*	13.4682*	0.4413*	23.77*	2523.12*
Year (Y)	2	0.0516*	0.0588*	0.0704*	0.0737	6276.84*	0.01	0.1228	0.0001	20.54*	1.21
F x Y	2	0.0331*	0.0257	0.0392	0.0136	4.16	0.01	0.0767	0.0041	0.06	0.59
Error	4	0.0029	0.0039	0.0247	0.0315	7.66	0.70	0.1527	0.0041	0.20	0.93

* Significant at 5% level

Table 2: Coefficient of variation, heritability (broad sense) and genetic advance as per cent of mean for 10 quality traits

Trait	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability broad sense (%)	Genetic advance
Land races				
GL (mm)	11.45	11.29	97.2	22.93
GB (mm)	9.77	9.31	90.8	18.18
L/B ratio	17.54	17.10	95.1	34.60
G Th. (mm)	11.20	4.62	17.0	3.70
1000-GW (g)	15.25	14.65	92.3	28.98
GT	27.70	23.74	73.5	41.91
GE (mm)	13.21	13.06	97.8	26.60
ER	7.52	7.28	93.7	14.69
Protein (%)	12.47	11.95	91.9	23.60
AC (%)	11.68	11.42	95.7	22.93
New plant type				
GL (mm)	16.89	16.71	97.9	34.09
GB (mm)	16.01	15.83	97.8	32.08
L/B ratio	34.21	34.08	99.3	69.92
G Th. (mm)	10.12	9.71	92.0	19.02
1000-GW (g)	12.98	12.04	86.2	23.04
GT	33.44	31.79	90.4	62.26
GE (mm)	14.76	14.71	99.3	30.21
ER	5.64	5.30	88.3	10.29
Protein (%)	9.47	8.16	74.2	14.47
AC (%)	11.38	11.10	85.1	22.29
Japonica type				
GL (mm)	5.88	5.55	89.0	10.77
GB (mm)	5.56	5.02	81.4	9.15
L/B ratio	8.64	8.28	91.9	16.39
G Th. (mm)	7.00	5.13	53.8	7.87
1000-GW (g)	8.79	7.19	66.8	12.09
GT	17.92	15.62	76.0	28.13
GE (mm)	6.35	6.27	97.5	12.73
ER	7.97	7.77	95.0	15.51
Protein (%)	9.89	9.07	84.2	17.15
AC (%)	4.10	3.69	80.8	6.82

Where, GL: Grain length (mm), GB: Grain width (mm), GTh: Grain thickness (mm), 1000-GW: 1000-grain weight, GT: Gelatinization Temperature, GE: Grain elongation (mm), ER: elongation ratio and AC: Amylose content (%).

Table 3: Phenotypic (P) and genotypic (G) correlation coefficients among ten quality traits in land races

Trait		Grain width (mm)	L/B ratio	Grain thickness (mm)	1000-grain wt. (g)	Gelatinization temperature	Grain elongation (mm)	Elongation ratio	Protein content (%)	Amylose content (%)
Grain length (mm)	P	**-0.362**	**0.851**	0.093	**0.573**	-0.082	**0.832**	-0.052	-0.037	-0.101
	G	-0.381	0.862	0.239	0.605	-0.094	0.841	-0.034	-0.039	-0.105
Grain width (mm)	P		**-0.786**	0.301	**0.416**	0.242	-0.242	0.098	**0.448**	-0.080
	G		-0.787	0.783	0.454	0.278	-0.258	0.096	0.486	-0.083
L/B ratio	P			-0.107	0.132	-0.178	**0.648**	-0.140	-0.282	-0.028
	G			-0.263	0.139	-0.109	0.662	-0.130	-0.301	-0.032
Grain thickness (mm)	P				**0.315**	0.132	0.172	0.146	0.170	-0.080
	G				0.875	0.377	0.428	0.365	0.476	-0.090
1000-grain wt (g)	P					0.145	**0.624**	0.207	0.309	-0.177
	G					0.190	0.650	0.212	0.331	-0.183
Gelatinization temperature	P						-0.015	0.081	0.053	**-0.737**
	G						-0.020	0.085	0.028	-0.866
Grain elongation (mm)	P							0.507	0.022	-0.020
	G							0.510	0.021	-0.023
Elongation ratio	P								0.102	0.143
	G								0.105	0.147
Protein content (%)	P									0.117
	G									0.121

Bold values are significant at 5 per cent level

A character exhibiting high heritability may not give high genetic advance Johnson *et al.* (1955) have shown that high heritability accompanied by high genetic advance is necessary to arrive at more reliable conclusion.

Table 4: Phenotypic (P) and genotypic (G) correlation coefficients among ten quality traits in new plant types

Trait		Grain width	L/B ratio	Grain thickness (mm)	1000-grain wt. (g)	Gelatinization temperature	Grain elongation (mm)	Elongation ratio	Protein content (%)	Amylose content (%)
Grain length (mm)	P	**-0.838**	**0.965**	**-0.721**	-0.012	-0.063	**0.934**	**-0.480**	0.143	**0.434**
	G	-0.864	0.972	-0.759	-0.010	-0.073	0.940	-0.472	0.181	0.442
Grain width (mm)	P		**-0.939**	**0.889**	**0.331**	0.132	**-0.839**	0.243	-0.143	**-0.456**
	G		-0.946	0.933	0.375	0.139	-0.853	0.284	-0.176	-0.464
L/B ratio	P			**-0.827**	-0.169	-0.103	**0.921**	**-0.404**	0.140	**0.455**
	G			-0.863	-0.187	-0.110	0.924	-0.420	0.174	0.462
Grain thickness (mm)	P				**0.527**	0.159	**-0.695**	0.289	-0.210	**-0.432**
	G				0.612	0.170	-0.724	0.330	-0.249	-0.442
1000-grain wt (g)	P					-0.069	0.014	0.035	-0.015	-0.093
	G					-0.081	0.017	0.037	-0.029	-0.111
Gelatinization temperature	P						-0.095	-0.059	-0.400	**-0.732**
	G						-0.105	-0.060	-0.466	-0.796
Grain elongation (mm)	P							-0.140	0.192	**0.458**
	G							-0.145	0.225	0.468
Elongation ratio	P								0.099	-0.086
	G								0.080	-0.096
Protein content (%)	P									**0.460**
	G									0.519

Bold values are significant at 5 per cent level

Table 5: Phenotypic (P) and genotypic (G) correlation coefficients among ten quality traits in japonica

Trait		Grain width (mm)	L/B ratio	Grain thickness (mm)	1000-grain wt. (g)	Gelatinization temperature	Grain elongation (mm)	Elongation ratio	Protein content (%)	Amylose content (%)
Grain length (mm)	P	-0.025	**0.748**	0.024	**0.437**	-0.300	0.099	**-0.622**	0.258	**0.322**
	G	-0.094	0.781	0.023	0.522	-0.339	0.084	-0.607	0.288	0.334
Grain width (mm)	P		**-0.680**	**0.563**	**0.326**	0.056	0.203	0.162	-0.247	0.096
	G		-0.694	0.841	0.420	0.050	0.231	0.234	-0.342	0.102
L/B ratio	P			**-0.362**	0.105	-0.252	-0.045	**-0.548**	**0.355**	0.161
	G			-0.516	0.118	-0.268	-0.065	-0.570	0.422	0.185
Grain thickness (mm)	P				**0.355**	-0.098	-0.039	-0.058	**-0.346**	-0.068
	G				0.593	-0.130	-0.043	-0.064	-0.487	-0.078
1000-grain wt (g)	P					0.200	0.166	-0.178	-0.100	-0.086
	G					0.234	0.188	-0.205	-0.188	-0.104
Gelatinization temperature	P						0.295	**0.440**	-0.054	**-0.778**
	G						0.352	0.507	-0.068	-0.852
Grain elongation (mm)	P							**0.716**	-0.121	-0.271
	G							0.740	-0.146	-0.291
Elongation ratio	P								-0.269	**-0.452**
	G								-0.302	-0.475
Protein content (%)	P									0.278
	G									0.321

Bold values are significant at 5 per cent level

Correlations

Land races

Grain length (Table 3) showed positive associations with L/B ratio (0.851), 1000-grain weight (0.573) and grain elongation (0.832), while significant negative association with kernel width (-0.362). These results are in conformity with the findings of Christopher *et al.*(1999)and Khatun *et al.* (2003). Grain width showed positive association with 1000-grain weight (0.416) and protein content (0.448) and negative association with L/B ratio (-0.786).L/B ratio was positively correlated with grain elongation (0.648), while 1000-grain weight was positively associated with grain elongation (0.624). Gelatinization temperature showed significant negative correlation with amylose content (-0.737) and grain elongation showed positive association of with elongation ratio (0.507).Khatun*et al.* (2003) and Allam *et al.* (2015) also reported negative correlation of gelatinization temperature with amylose content.

New plant types

Grain length exhibited positive significant associations with L/B ratio (0.965), grain elongation (0.934) and amylose content (0.434), and negative association with grain width (-0.838), grain thickness (-0.721) and elongation ratio (-0.480) (Table 4). Similar results for grain length and L/B ratio were reported by Christopher *et al.* (1999) and for negative association of grain length with elongation ratio by Amarawathi *et al.* (2008). Grain width had positive and significant association with grain thickness (0.889) and 1000-grain weight (0.331), and significant negative association with L/B ratio (-0.939), grain

Table 6: Iron (Fe) and Zinc (Zn) content present in rice genotypes.

Genotype	Fe content (μg/g)	Zn content (μg/g)
Land races		
Ram Jawain-100	20.36	6.08
LC Samloti-3	6.14	8.35
LC Rajiana-3	0.53	6.34
LC Yol-1	9.47	6.25
LC Serathana-1	5.07	6.99
KLC-6	12.19	6.56
LG-11	2.97	5.66
LG-15	12.21	8.19
LG-16	31.75	5.90
Kijun	22.61	7.89
Kalizhini	2.57	7.01
Lal Nakanda 41	4.75	4.89
TotuDhan	1.27	6.19
RJ-100	14.18	8.92
Japani	7.45	9.04
KrishanDhan	4.04	7.75
KalooDhan	8.10	7.43
Lal Zheeni	22.75	6.53
Zheeni	14.73	7.60
ChittiZheeni	31.87	4.89
Mukti	7.03	8.81
Chinna 988	3.81	8.03
	11.18	7.06
New Plant Types		
IR 68544 -29-2-1-3-1-1	0.28	1.21
IR 68544 -29-2-1-3-1-Y_n 1	27.63	2.91
IR 69353-70-3-1-1-3- Y_n1-4	0.42	1.49
IR 70749-45-2-3- Y_n1-2	27.48	5.30
IR 70544 -10-3-1-3- Y_n1-1	20.87	1.58
IR 71204 -78-3-3-Y_n1-1	25.33	2.43
IR 69853-70-3-1-1	28.79	5.09
IR 69137-34 -1-3-1	1.98	4.71
IR 65564 – 44 -5-1	14.15	3.40
IR 65600-87-2-2-3	22.27	2.56
IR 64683-87-2-2-3-3	14.60	4.67
IR 68450-36-3-2-2-3	18.07	1.97
IR 71146-40-7-2-1-2-1	21.94	2.57
IR 72870-21-2-1-2	21.37	4.04
IR 65600-27-1-2-2	5.60	1.97
IR 72780-120-1-2-2	20.60	6.93
IR 66159-189-5-5	4.11	4.77
IR 72884 -181-3-2-1	2.08	3.73
RP 2421	15.77	6.26
	15.44	3.56
Japonicas		
Koshihikari	12.60	6.17
Hinohikari	17.63	4.74
BhriguDhan	16.43	6.39
Matali	2.18	5.17
Jattoo	3.37	5.43
TeejuDhan	5.64	5.07
TiyunDhan	3.92	6.16
Desi Dhan	9.27	6.16
Kunjan – 4	2.70	7.20
Yunlen – 18	3.95	4.05
Deval – W	3.81	6.67
Deval – R	8.79	3.77
Hexi – 4	3.50	4.52
Fukunishiki	3.23	4.28
Won – 124	6.66	4.74
NaggarDhan	6.48	7.05
	6.89	5.47
Grand mean	12.90	5.45
CD(5%)	1.55	0.22

elongation (-0.839) and amylose content (-0.456).L/B ratio showed positive association with grain elongation (0.921) and amylose content (0.455), while significant negative associations with grain thickness (-0.827) and elongation ratio (-0.404). Positive association of L/B ratio with grain length and negative with elongation ration was also reported by Khatun *et al.* (2003) and Allam*et al.* (2015). Grain thickness exhibited significant positive association with 1000-grain weight (0.527) and negative with grain elongation (-0.695) and amylose content (-0.432). Gelatinization temperature showed significant negative correlation with amylose content (0.732), while amylose content exhibited significant positive association with grain elongation (0.458) and protein content (0.460). Negative association of gelatinization temperature with amylose content was also reported Tang *et al.* (1989) and Allam *et al.* (2015).

Japonicas

Grain length exhibited significant positive associations (Table 5) with L/B ratio (0.748), 1000-grain weight (0.437) and amylose content (0.322), while negative association with gelatinization temperature (-0.300) and elongation ratio (-0.622). Grain width had positive significant associations with grain thickness (0.563) and 1000-grain weight (0.326) and negative association with L/B ratio (-0.680).Sood and Siddiq (1980) andDeosarkar and Nerkar (1994) also reported similar kind of associations among rice quality parameters. L/B ratio exhibited significant positive associations with protein content (0.355) and significant negative with grain thickness (-0.362) and grain elongation (-0.548). Grain thickness showed significant positive correlation with 1000-grain weight (0.355), while gelatinization temperature exhibited significant positive correlation with grain elongation (0.440), while significant negative with amylose content (-0.778). Grain elongation exhibited positive significant association with elongation ratio (0.716), while amylose content showed significant negative association with elongation ratio (-0.452). Similar results were reported by Khatun *et al.* (2003)

In the three sets of genotypes, genotypic correlation coefficients followed the same trend as observed for phenotypic coefficient of correlations. However, the values of genotypic coefficients of correlations were generally higher than the corresponding phenotypic estimates for most of the characters studied, indicating that the characters are more sensitive to environmental variations, which diluted the expression of correlation between them at phenotypic level. These observations were in agreement with the results of Bai *et al.* (1992) and Nayak *et al.* (2001). The strong positive correlation of grain length with L/B ratio, 1000-grain weight and elongation ratio and negative correlation with elongation ratio, while negative association of gelatinization temperature with amylose content indicated that simultaneous improvement of these traits can be made with the selection of either of these traits and can be used as selection indices for the improvement in grain quality.

Iron (Fe) and zinc (Zn) content

Among three groups of rice, highest average iron content was estimated in new plant types followed by land races and lowest was in japonicas, whilezinc content was highest in land races followed by japonicas and least content was estimated in new plant types (Table 6).Among genotypes highest iron and zinc content was in the land races. This indicated that these land races can be involved in future breeding programmes for enhancing the Fe and Zn content in the rice varieties.

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