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Correlation and path coefficient analysis of quality traits in selected rice (*Oryza sativa* L.) germplasm accessions

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Abstract
Studies on character association and path-coefficient analysis were conducted on forty eight rice genotypes for grain quality traits on grain yield. Analysis of variance revealed considerable variability among the genotypes for all the characters studied. The correlation analysis indicated that grain yield was significantly associated with kernel breadth at genotypic level. Results of path-coefficient analysis revealed kernel length had the highest positive direct effect on grain yield followed by length breadth ratio after cooking, width of milled grain, elongation index and gel consistency. This study revealed that genetic improvement of grain quality in rice is admissible by selecting characters having high positive correlation and positive direct effect on grain yield.

Keywords: correlation, path coefficient, analysis, selected rice

Introduction
Rice is the staple food for two thirds of the Indian population. It contributes 43 per cent of caloric requirement and 20-25% of agricultural income. In India, rice is grown in an area of 43.5 million ha (23% of gross cropped area) with an annual production of 90 million tons (Viraktamath and Sundaram, 2010) [20]. Rice and agriculture are still fundamental to the economic development of most of the Asian countries. In much of Asia, rice plays a central role in politics, society and culture, directly or indirectly employs more people than any other sector. A healthy rice industry, especially in Asia’s poorer countries, is crucial to the livelihoods of rice producers and consumers alike.
Landraces are the local or traditional varieties of a domesticated plant species which have developed over time through adaptation to their natural environment (Jones *et al*., 2008) [5]. The demand for productive and homogenous crops has led to development of a small number of standard, high yielding varieties. This has consequently resulted to tremendous loss of heterogeneous traditional cultivars through genetic erosion. Landraces preserve much of this lost diversity and are known to harbor great genetic potential for breeding new crop varieties that can cope with environmental and demographic changes. There are more than 400,000 rice varieties worldwide but the major categories include; indica, japonica, basmati and glutinous. These varieties differ in their grain qualities which include: milling quality, grain shape, cooking quality, nutritional quality and aroma. These traits are crucial determinants of cooked rice grain quality (Shahidullah *et al*., 2009) [18].
Increased and stable rice production is required for increasing population during the era of climate change. New adaptation strategies are needed to develop new varieties to meet these challenges. In order to meet the fastest growing demand for rice grain, development of high yielding genotypes with desirable agronomic traits for diverse ecosystem is therefore a necessity (Islam *et al*., 2015) [4]. Quality trait is complex in nature, which is influenced by the environment. Grain quality characters are interrelated among themselves which in turn decides the final cooking and eating characteristics. Understanding the relationship between yield and its components is of the paramount importance for making the best use of the relationships in selection (Sarawgi *et al*., 1997) [17]. The data obtained from correlation coefficient can be augmented by path analysis. Path coefficient analysis splits the genotypic correlation coefficient into the measure of direct and indirect effects. Therefore, the present investigation was undertaken to study the association among different quality attributing characteristics in rice.

Materials and Methods

The current research study was conducted at College of Agriculture, Indira Gandhi Agricultural University, Raipur, Chhattisgarh during *kharif* 2015. The experimental material comprised of forty eight rice accessions. Rice genotypes used in this study are listed in the Table1. Seeding was done in the well prepared seed beds in the last week of June. The seedlings were transplanted into well puddled field twenty one days after seeding. Each accession was planted in two rows, with row length of one meter and row-row distance of 25 cm using randomized block design (RBD) with two replications. Measurements of different qualitative characteristics of these collected landraces at different stages of growth were recorded following the guidelines of test for Distinctness, Uniformity and Stability of Rice (*Oryza sativa* L.) PPV & FR Authority, GOI, 2007. The data were collected on five randomly selected plants from each accession. Recommended cultural practices as used for growing rice crop were used throughout the experiment.

Observations on grain characteristics *viz.*, grain length, grain width, L/B ratio of grain kernel length, kernel breadth, kernel L/B ratio, were recorded from 10 randomly selected kernels. Required quantities (100 g) of harvested seeds were used to record the hulling percentage, which were properly cleaned before starting the experiment. Hulling percentage was computed as below.

$$\text{Hulling percentage} = \frac{\text{Weight of the dehusked kernel}}{\text{Weight of paddy}} \text{ X } 100$$

The brown rice obtained after dehulling was milled and the weight of polished rice was recorded. Milling percentage was calculated as below.

$$\text{Milling percentage} = \frac{\text{Weight of polished kernel}}{\text{Weight of paddy}} \text{ X } 100$$

The milled samples were sieved to separate whole kernels from the broken ones. Full rice and three-fourth kernels were taken as whole milled rice for computation. Head rice recovery (HRR) was calculated in percentage as below.

$$\text{Head Rice Recovery} = \frac{\text{Weight of whole polished kernel}}{\text{Weight of paddy}} \text{ X } 100$$

The polished rice samples were analysed for quality traits *viz*., kernel length after cooking, kernel breadth after cooking, L/B ratio of cooked kernel, elongation ratio and elongation index. Alkali spreading values were determined as per procedure described by Jennings *et al.* (1979). Gel consistency was analysed based on the method described by Cagampang *et al*. (1973). Amylose content was determined by the method developed at International Rice Research Institute, Philippines (Jenning *et al*., 1979). Correlation coefficient was computed as per the procedure outlined by Karl Pearson (1932) and path coefficient analysis was carried out as suggested by Dewey and Lu (1959) [3].

Table 1: List of rice genotypes used in the current study

S.No.	Name	Source (Village/Block/Distt.)	S. No.	Name	Source (Village/Block/Distt.)
1	Lokti Machhi	Bade Rajpur/Bade Rajpur/Bastar	25	Farsa phool	Koyalibeda/Koyalibeda/Bastar
2	Atma Sital	Antagarh/Antagarh/Bastar	26	Jay Bajrang	Fingeshwar/Fingeshwar/Raipur
3	Lokti Machhi	Narayanpur/Narayanpur/Bastar	27	Gilas	Enhoor/Durgkondal/Bastar
4	ADT:27	Rajim/Fingeshwar/Raipur	28	Khatia pati	Odan/Palari/Raipur
5	Anjania	Pandarbhattha/Bemetara/Durg	29	Mani	Rajim/Rajim/Raipur
6	Kanak Jira	Dadesara/Durg/Durg	30	Khatriya pati	Odan/Palari/Raipur
7	Jhumera	Martara/Bemetara/Durg	31	Girmit	Kokodi/Kirnapur/Balaghat
8	Kakeda (I)	Kuamalji/Pandariya/Bilaspur	32	Lanji	Deverda/Baldevgarh/Tikamgarh
9	Dubraj II	Chandkhuri/Arang/Raipur	33	Banreg	Khutgaon/Deobhog/Raipur
10	Bhulau	Gidhpuri/Palari/Raipur	34	Ruchi	Kusumi/Kusumi/Sarguja
11	Rani kajar	Garra/Palari/Raipur	35	Safed luchai	Nagajhare/Barghat/Seoni
12	Sundar mani	Kodohatha/Deobhog/Raipur	36	Kanthi deshi	Vijaipali/Barghat/Seoni
13	Bhado kanker	Turanga/Pusaur/Raigarh	37	Piso III	Barghat/Barghat/Seoni
14	Jhumarwa	Charbhatha/Fingeshwar/Raipur	38	Kakdi	Kukanar/Darma/Bastar
15	Bishnu	Bishnupur/Baikundpur/Sarguja	39	Gajpati	Kosamghat/Ghar Ghoda/Bastar
16	Basa Bhog	Pratappur/Pratappur/Sarguja	40	Gadur sela	NA/Mohala/Rajnandgaon
17	Krishna Bhog	Mohgaon/Mandla/Mandla	41	Aadan chilpa	Kesherpal/Bastar/Bastar
18	Hira Nakhi	Khekha/Bichhiya/Mandla	42	Unknown	NA/NA/NA(CG)
19	Lokti Maudi	Abujhmad/Abujhmad/Bastar	43	Saja chhilau	Kanker/Kanker/Bastar
20	Kariya bodela bija	Kodo/Abujhmad/Bastar	44	Parmal Safri	Tilda/Tilda/Raipur
21	Gganja Kali	Kudum Kala/Ghar Ghoda/Raigarh	45	Safri	Varasioni/Waraseoni/Balaghat
22	Banas KupiII	Jhilwada/Waraseoni/Balaghat	46	Narved	Muraina/NA/Muraina
23	Dhangari Khusha	Darrabhatha/Saraipali/Raipur	47	Nagbel	Dev Bhog/Dev Bhog/Raipur
24	Bhaniya	Fashakar/Durgkondal/Bastar	48	Mudariya	Abhanpur/Abhanpur/Raipur

Results and Discussion

Table 2: Analysis of Variance (ANOVA) for grain quality traits in rice

SV	DF	MSS						
		HP	MP	HRR	KL	KB	KLBR	KLAC
Replication	1	1.69*	0.21	0.22**	0.013	0.06	0.01	0.28**
Treatment	47	68.73**	80.63**	125.83**	4.494**	0.2**	1.17**	7.25**
Error	47	0.29	10.47	0.01	0.012	0.01	0.02	0.01

SV	DF	MSS						
		KBAC	**LBRAC**	**ER**	**EI**	**AC**	**GC**	**GY**
Replication	1	0.1*	0.01	0.03**	0.023	4.08*	6*	101465.01**
Treatment	47	0.28**	0.58**	0.12**	0.152**	34.42**	424.74**	8927.39**
Error	47	0.01	0.01	0.003	0.008	0.67	0.78	6130.45

Analysis of variance was significant for all the traits among the entries, indicting the presence of considerable genetic variation in the experimental material (Table 2). In the present study, the grain yield per plant showed positive and significant association with grain width (Table 3). This result was in agreement with the earlier findings of Premkumar *et al* (2015), Jyothula and Nitu Singh (2010) [13] and Krishna Veni and Shoba Rani (2007) [9]. A significant negative association was observed between grain length and grain yield per plant and this was in accordance with the findings of Muhammad *et al* (2002) [12]. These associations can be well utilized as an indicator to affect selection strategies to improve the grain yield along with grain quality.

Amylose content is positive and significant correlated with grain length breadth ratio and kernel length breadth ratio. Hulling percent is positive and significantly correlated with amylose content whereas is negatively significant with gel consistency. This result is similar with the findings of Khatun *et al*. (2003) [8], Kaur *et al*. (2011) [7].

Length of milled grain is positively correlated with milling percent and which is in accordance with the finding of Ratna *et al.* (2016) [16]. Width of milled grain is positive and significantly correlated with kernel breadth. Grain length after cooking is positively and significantly correlated with grain length and this finding is in accordance with the Oladi *et al*. (2014) [11].

In this study, grain length after cooking and elongation ratio are interdependent as evidenced by the positive significant association between them. Selection of either of the trait will ultimately enhance the mean performance of the interdependent trait. Similar association was reported by Nirmaladevi *et al*. (2015) [14], Khatun *et al*. (2003) [8], Sood and Siddiq (1980) [19], Deosarkar and Nerkar (1994) [2], and Christopher *et al.* (1999) [1].

The amylose content is a chemical quality trait that determines the texture of cooked rice. Varieties with intermediate amylose content and soft gel consistency are preferred by most rice consumers. The non-significant positive association between these two chemical quality traits namely gel consistency and amylose content was found. Thus it showed that chances of selecting desirable intermediate values of gel consistency lead to automatic selection of intermediate and desirable level of amylose content. This result is similar with the findings of Nirmaladevi *et al*. (2015) [14].

Path analysis partitions the genotypic correlation coefficient into direct and indirect effects, indicates the relative significance for each component character to the dependent trait. It forms the best method to evaluate the cause and effect relationship in order to get the developmental relationship between them.

Path coefficient analysis using single plant yield as a dependent variable and grain quality traits were considered as independent variable. The grain quality traits *viz.*, grain width, grain length breadth ratio, kernel length, amylose content, gel consistency, hulling percent, head rice recovery, length breadth ratio after cooking and elongation ratio showed high and positive direct effects on single plant yield (Table 3). Nandan *et al*. (2010) and Mohana Krishna *et al*. (2009) were also reported high positive direct effect for hulling percentage and kernel L/B ratio on single plant yield.

Hulling percentage and milling percentage exerted a high positive indirect effect through kernel breadth. Similar finding is reported by Premkumar *et al*. (2016) [15]. Head rice recovery showed high indirect positive effects through grain length, kernel length, milling percent, length of milled grain and grain length after cooking.

Conclusion

From the present study, it can be concluded that the characters *viz*., hulling percent, kernel length breadth ratio, elongation ratio, gel consistency could be used as a important selection indices for the genetic improvement of grain quality characters in rice. Hence it may be possible to combine grain yield and quality by specific breeding programme like biparental mating. This will braek the linkage between unrelated traits and leads to more recombination

Table 2: Genotypic correlation coefficients of grain quality traits on single plant yield in rice

	GL	GW	GLBR	KL	KB	KLBR	AC	GC	HP	MP	HRR	LMG	WMG	MGLBR	GLAC	GWAC	LBRAC	ER	EI	GY
GL	1																			
GW	-0.045	1																		
GLBR	0.208*	-0.902**	1																	
KL	-0.011	0.116	-0.11	1																
KB	0.002	0.217*	-0.389**	0.158	1															
KLBR	-0.016	-0.316**	0.535**	0.158	-0.833**	1														
AC	0.181	-0.281**	0.335**	-0.055	-0.139	0.277**	1													
GC	0.104	0.174	-0.097	0.113	-0.187	0.189	0.156	1												
HP	-0.062	0.039	-0.001	-0.047	-0.036	0.108	0.451**	-0.265**	1											
MP	0.1	0.069	-0.072	-0.123	0.109	-0.127	-0.032	0.047	-0.042	1										
HRR	0.177	0.192	-0.187	-0.019	-0.09	-0.014	-0.119	0.075	-0.144	-0.044	1									
LMG	-0.082	-0.121	0.091	0.191	0.121	-0.074	0.154	-0.092	-0.01	0.235*	-0.039	1								
WMG	-0.194	-0.083	0.003	0.005	0.479**	-0.253*	-0.06	-0.137	0.072	0.168	-0.076	0.04	1							
MGLBR	0.182	0.086	-0.017	0.029	-0.315**	0.177	0.157	0.144	-0.116	-0.073	0.03	0.255*	-0.880**	1						
GLAC	0.229*	-0.065	0.083	-0.007	-0.052	0.048	-0.027	-0.041	-0.075	0.016	0.119	-0.269**	-0.204*	0.103	1					
GWAC	0.065	-0.167	0.220*	0.026	-0.091	0.166	0.134	-0.154	0.136	-0.124	-0.155	0.081	-0.041	0.132	0.226*	1				
LBRAC	-0.017	0.141	-0.191	0.002	0.059	-0.128	-0.17	0.119	-0.127	0.092	0.199	-0.213*	0.013	-0.144	0.177	-0.890**	1			
ER	0.085	0.001	0.021	-0.135	-0.097	0.086	-0.082	-0.003	0.08	-0.152	-0.084	-0.838**	-0.063	-0.189	0.620**	0.15	0.141	1		
EI	-0.082	0.017	-0.097	-0.032	0.391**	-0.244*	-0.127	-0.009	-0.009	0.087	0.021	-0.404**	0.740**	-0.769**	-0.004	-0.466**	0.527**	0.333**	1	
GY	-0.280**	0.247*	-0.116	-0.019	-0.119	0.087	-0.125	-0.169	0.1	-0.16	-0.049	-0.046	0.082	-0.046	0.071	0.039	0.06	0.068	0.049	1

GL-Grain length, GW-Grain width, GLBR-L/B ratio of grain, KL-Kernel length, KB-Kernel breadth, KLBR-Kernel length breath ratio, AC- Amylose content, GC- Gel consistency, HP- Hulling percent, MP- Milling percent, HRR-Head rice recovery, LMG- Length of milled grain, WMG-Width of milled grain, MGLBR-Milled grain L/B ratio, GLAC-Grain length after cooking, GWAC-Grain width after cooking, LBRAC-L/B ratio after cooking, ER-Elongation ratio, EI- Elongation index, GY- Grain yield

Table 3: Direct (diagonal) and indirect effects of grain quality traits on grain yield per plant in rice

Character	GL	GW	GLBR	KL	KB	KLBR	AC	GC	HP	MP	HRR	LMG	WMG	MGLBR	GLAC	GWAC	LBRAC	ER	EI	GY
GL	-12.962	-2.338	-11.393	-12.845	6.704	-11.917	-2.477	-3.464	5.484	3.223	-4.524	-12.754	-0.908	-11.027	-11.109	-4.635	-9.823	7.532	6.411	-0.280**
GW	0.511	2.835	-0.843	0.486	1.116	-0.273	0.602	0.932	-0.696	-1.206	-0.518	0.319	1.105	-0.311	0.325	0.118	0.312	-0.011	0.402	0.247*
GLBR	11.664	-3.946	13.271	11.611	-9.130	12.443	1.185	1.580	-3.929	-0.118	5.601	11.866	-1.309	11.491	10.475	4.527	9.133	-6.998	-6.906	-0.116
KL	48.754	8.428	43.047	49.201	-25.607	45.618	11.494	12.699	-18.595	-10.129	18.609	48.357	3.367	41.807	42.605	17.401	37.717	-27.799	-23.874	-0.019
KB	14.900	-11.346	19.819	14.993	-28.808	22.591	-2.010	3.234	-6.171	2.583	11.072	16.288	-18.230	22.388	13.117	4.853	11.262	-11.596	-20.045	-0.119
KLBR	-45.209	4.731	-46.106	-45.594	38.562	-49.175	-7.186	-11.236	18.006	5.866	-20.687	-46.062	8.383	-45.131	-39.777	-16.323	-34.751	27.697	29.900	0.087
AC	0.164	0.182	0.077	0.200	0.060	0.125	0.857	0.173	-0.154	-0.117	-0.027	0.145	0.275	0.005	0.111	0.033	0.087	-0.118	0.046	-0.125
GC	0.543	0.668	0.242	0.525	-0.228	0.465	0.411	2.033	-0.524	-0.381	0.191	0.489	-0.006	0.418	0.360	0.337	0.190	-0.343	-0.484	-0.169
HP	-3.355	-1.947	-2.347	-2.997	1.698	-2.903	-1.420	-2.045	7.929	6.454	0.893	-3.384	-0.514	-2.942	-2.001	-0.748	-1.834	3.221	2.245	0.1
MP	2.710	4.637	0.097	2.244	0.977	1.300	1.494	2.040	-8.871	-10.899	-4.123	2.734	2.637	1.350	0.938	-0.284	1.073	-3.415	-0.860	-0.16
HRR	0.626	-0.328	0.757	0.679	-0.690	0.755	-0.057	0.168	0.202	0.679	1.795	0.707	-0.297	0.771	0.818	0.599	0.586	-0.194	-0.613	-0.049
LMG	-49.790	-5.699	-45.246	-49.737	28.612	-47.401	-8.576	-12.167	21.596	12.694	-19.922	-50.604	-1.006	-45.242	-42.983	-16.698	-38.714	31.386	27.106	-0.046
WMG	1.176	6.545	-1.656	1.149	10.625	-2.862	5.390	-0.053	-1.089	-4.062	-2.774	0.334	16.790	-7.030	1.076	-1.064	2.026	0.800	10.269	0.082
MGLBR	32.467	-4.186	33.045	32.429	-29.660	35.027	0.210	7.841	-14.161	-4.728	16.394	34.121	-15.980	38.165	28.041	12.769	24.056	-22.294	-28.784	-0.046
GLAC	-38.829	-5.190	-35.761	-39.233	20.630	-36.648	-5.878	-8.025	11.434	3.900	-20.637	-38.483	-2.903	-33.288	-45.306	-19.990	-38.998	5.841	11.613	0.071
GWAC	9.789	1.136	9.338	9.682	-4.612	9.088	1.046	4.544	-2.583	0.714	9.134	9.034	-1.734	9.159	12.079	27.376	-1.881	0.626	-13.718	0.039
LBRAC	29.828	4.331	27.085	30.173	-15.387	27.815	4.009	3.675	-9.101	-3.873	12.855	30.111	4.749	24.809	33.879	-2.704	39.359	-6.511	-0.033	0.06
ER	2.562	0.017	2.325	2.491	-1.775	2.484	0.605	0.743	-1.791	-1.381	0.477	2.735	-0.210	2.576	0.568	-0.101	0.729	-4.409	-2.835	0.068
EI	-5.008	1.436	-5.269	-4.914	7.046	-6.157	0.542	-2.411	2.867	0.799	-3.460	-5.424	6.193	-7.637	-2.595	-5.074	-0.008	6.510	10.126	0.049

GL-Grain length, GW-Grain width, GLBR-L/B ratio of grain, KL-Kernel length, KB-Kernel breadth, KLBR-Kernel length breath ratio, AC- Amylose content, GC- Gel consistency, HP- Hulling percent, MP- Milling percent, HRR- Head rice recovery, LMG- Length of milled grain, WMG-Width of milled grain, MGLBR-Milled grain L/B ratio, GLAC-Grain length after cooking, GWAC-Grain width after cooking, LBRAC-L/B ratio after cooking, ER-Elongation ratio, EI-Elongation index, GY- Grain yield

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