Character associationstudies for yield and quality traitsofrice landraces and mutants of Chhattisgarh

ABSTRACT

Background: The production of rice needs to grow as this is one of the major objective in plant improvement program to fulfill the requirement of the rapidly growing population.**Objective and Methods**: The field experiment was conducted to study character association among yield and its attributes among 58 rice genotypes at Indira Gandhi Krishi Vishwavidyalaya, College of Agriculture, Raipur (C.G.) to know the relationship among characters.**Results:**it is found out that Traits like panicle weight per plant, filled spikelets per panicle, harvest index, and biological yield per plant are having a high direct effect and significant correlation with grain yield per plant, and traits like milled grain length-width ratio, hulling %, and alkali spreading value are having a high direct effect and significant correlation with head rice recovery.**Conclusions:**Direct selection based on these traits for improvement of rice grain yield and grain quality can be effective.

KEYWORDS:Rice,Correlation, path coefficient, and yield.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the most extensively grown cereal worldwide.since it is the principal source of calories It supplies most of the requirementsof starch, protein, and micronutrient for over half of the world's population.Insufficient availability of grain yield is also typically associated with poverty in many regions of the globedespite that people also demanding the quality of rice such as grain size, grain type, puffiness, good cooking characteristics [4]. Knowledge of the inter-relationship between characters and grain yield, and head rice recovery (for grain quality) is essential for the improvement of crop production, and this can be possible through conventional breeding methods, which produces new varieties which having high yielding and good grain quality characteristics [4].

A correlation coefficient is a statistical measure that is used to find out the degree and direction of the relationship between two or more variables working at the same time. It also helps to know how the improvement in one character will bring simultaneous change in other characters. While path analysis splits the correlation coefficient into direct and indirect effects which specify the relative contribution of each character [10]. A study about the contribution of the direct and indirect effects of each character towards yield or quality traits could be an added advantage in aiding the selection process [2]. In the present paper, the correlation and path coefficients have been evaluated to estimate the contribution of characters on grain yield in rice.

2. MATERIALS AND METHODS

2.1 Experimental Site

The field experiment was conducted at Indira Gandhi Krishi Vishwavidyalaya, College of Agriculture, Raipur(C.G.) in India,during *the Kharif season* 2020. Geographically, this Indian state is located between 17°14' N and 24°45' N latitude and longitude of 79°16' E. The experiment was laid out by following a randomized complete block design with two replications. All the standard agronomic practices were adopted during the crop season.

2.2 Materials and methods

A total of 58 accessions including 06 checks *i.e.*, Dubraj Sel-1, CG Zinc Rice 1, CG Zinc Rice 2, Zinco Rice MS, Rajeshwari, and Protezinwere used in the experiment. All the genotypes were accessed from the Department of Genetics and Plant Breeding, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). Randomly five plants were selected from each replication for further studies.

Table 1Details of the 58 rice genotypes used as the base material in the study.

S. No.	Name of genotypes	Parentage	S. No.	Name of genotypes	Parentage
1	Red Barhasal	Landrace	30	Janadhan	Landrace
2	Rudra	Landrace	31	Reladhan	Landrace
3	Tulsibhog	Landrace	32	Ram Shree	Landrace
4	Loktimusi	Landrace	33	Karialcha	Landrace
5	Odhadhan	Landrace	34	Jhillisafri	Landrace
6	Gathuwan Dhan	Landrace	35	Sivar	Landrace
7	Raja Bangla	Landrace	36	Karhani	Landrace
8	Brown Rice-1	Landrace	37	Nandel	Landrace
9	Munibhog	Landrace	38	Safri	Landrace
10	Danighoda	Landrace	39	DhauraMundariya	Landrace
11	Saraitolia	Landrace	40	Karhani-2	Landrace
12	PangudiGoindi	Landrace	41	Sanchuriya	Landrace
13	Safri-17	Landrace	42	Alsakar	Landrace
14	Dubraj	Landrace	43	Luchai	Landrace
15	Byalo	Landrace	44	Maidubraj	Landrace
16	Badshahbhog	Landrace	45	TCDM-1	Mai Dubraj
17	Jonyaphool	Landrace	46	Vikram-TCR	Safri-17

18	Mohlyanbanko	Landrace	47	C.G. Jawaphool Trombay	Jawaphool
19	Kanakbhog	Landrace	48	Alsakar Mutant-3	Alsakar
20	Shwet Ganga	Landrace	49	Sanchuriya Mutant-6	Sanchuriya
21	Matkodhan	Landrace	50	Safri 17-5	Safri-17
22	Suapankhi	Landrace	51	Safri-17-2-48	Safri-17
23	Jhimipras	Landrace	52	Luchai Mutant -1	Luchai
24	Jauphool	Landrace	53	Dubraj Sel-1	Dubraj
25	Kalajeera	Landrace	54	CG Zinc Rice 1	Poornima x Annada
26	Chhindmauri	Landrace	55	CG Zinc Rice 2	IR681444-B-18-2-1-1 x HMT
27	Motipeera	Landrace	56	Zinco Rice MS	Lalmati x IR681444
28	Pedgadi	Landrace	57	Rajeshwari	R320-300 x ChaptiGurmatiya
29	Sonagathi	Landrace	58	Protezin	Ciherang x R-7586-106-28-3-B-B-B

2.2.1*Correlation coefficient analysis*

The correlation coefficient was determined to illustrate the mutual relation between seventeen agro-morphological traits like days to 50% flowering, leaf length (cm), leaf width (cm), leaf area, plant height (cm), panicle length (cm), total tillers per plant, effective tillers per plant, filled spikelets per panicle, unfilled spikelets per panicle, total spikelets per panicle, spikelet fertility percentage, biological yield per plant (g), panicle weight per plant, harvest index, hundred seed weight (g) and grain yield per plant (g) in all the genotypes. The correlation coefficients at phenotypic and genotypic standards were evaluated from the analysis of variance and covariance. The linear relationship between two variables was estimated by using Karl Pearson's coefficient of correlation which is based on the variance and covariance of the variables. The significance of the correlation coefficient was tested by comparing the observed value of the correlation coefficient with tabulated values for n-2 degree of freedom. If the observed value is more than the table value, the correlation coefficient is significant.

2.2.2*Path coefficient analysis*

Path coefficient analysis promotes the partition of the correlation into the measures of direct and indirect effects. The genetic composition of yield must be dealt with the genetic improvement of all other characters, affecting it directly or indirectly, the phenotypic and genotypic correlation coefficients were significantly partitioned into direct and indirect effects with the help of path coefficient analysis, as suggested by Wright, 1921 and elaborated by

Dewey and Lu, 1959. The path coefficient was assessed by clarifying and observing a series of simultaneous equations, specifying the basic relationship between correlation and path coefficients.

$$r_{iy} = P_{iy} + r_{i1}P_{1y} + r_{i2}P_{2y} + \cdots\cdots\cdots\cdots + r_{i(i-1)}P_{iy}$$

$$i = 1, 2, 3\ldots\ldots\ldots\ldots n$$

Where i is the number of independent characters r_{1y} to r_{iy} stands for the coefficient of correlation between independent variables (1….i) with dependent character y; r_{i1} to r_i(i-1) stands for the coefficient of correlation among all feasible consolidations of caused factors (independent variables); P_{1y} to P_{iy} stands for the direct effects of independent variables (1….i) on the dependent variable y.

The results of path coefficient analysis are interpreted as per the scale suggested by Lenka and Mishra (1973)

S. No.	Value of direct/indirect effect	Rate/Scale
1	0.00 to 0.09	Negligible
2	0.10 to 0.19	Low
3	0.20 to 0.29	Moderate
4	0.30 to 0.99	High
5	>1.00	Very High

3. STATISTICAL ANALYSIS

Statistical analysis for association study was evaluated through the standard software (Windostat version 9.2 from Indostat services, and MS-Excel-2010, etc.) whereReplicated data of each trait were used for the calculation of genotypic and phenotypic correlation coefficients and path correlation effect.

4. RESULTS AND DISCUSSION

Association analysis is an important approach in a breeding program. It gives an idea about the relationship among the various characters and determines the component characters, on which selection can rely for genetic improvement in the grain yield. It helps to know how the improvement in one character will bring simultaneous change in other characters. Phenotypic and genotypic correlations for various yield and quality attributing traits were estimated.

4.1 Correlation study based on agro-morphological traits.

In the present study grain yield per plant showed a positive and significant correlation at the phenotypic level with Panicle Weight Per Plant (0.817), Harvest Index (0.802), Biological yield per plant (0.331), Filled spikelet per panicle (0.290), Effective tillers per plant (0.261), Total spikelet per panicle (0.20), Total tillers per plant (0.194) and Spikelet fertility % (0.182)which means that improvement in these traits will leads to increase in grain yield. Where Hundred seed weight (0.135) and Days to 50% flowering (0.116) showed a positive correlation with rice grain yield per plant. Whereas it showed a significant negative correlation with Leaf length (-0.094), Leaf width (-0.052), Leaf area (-0.111), Plant height (-0.027), Panicle length (cm) (-

0.043), and Unfilled spikelet per panicle (-0.068), respectively which indicates that reducing the plant height can leads to increment in yields or vice versa. Singh *et al.,* (2018) andBagudam *et al.,* (2018) also revealed a positive and highly significant correlation of yield with HarvestIndex, Days to 50% flowering, Productivetillers per plant, Total tillers per plant, and Biological Yield per plant to emerge as the most important associates of grain yield in rice.

4.2 Correlation study based on grain quality traits

The phenotypic and genotypic correlations for grain quality attributing traits were estimated. The grain quality traits viz., milling% (0.336), hulling % (0.287), iron content (0.295), alkali spreading value (0.267), elongation ratio (0.262), milled grain L/B (0.245), zinc (0.238) and decorticated grain L/B (0.218) were having positive and significant correlation at phenotypic level with head rice recovery. Whereas Head rice recovery showed a significant negative correlation with Grain Length(-0.260), Decorticated Grain Length (-0.242), Milled Grain Length (-0.232), and Cooked Grain Length(-0.195). Thus, correlation analysis enables breeders to comprehend the shared character traits that might serve as the basis for selection for genetic improvement. In addition to this, understanding the type and extent of genetic diversity is crucial for enacting genetic improvement and for employing the appropriate selection techniques.

4.3 Path coefficient analysis based on agro morphological traits

Path coefficient analysissplits the correlation coefficient into the measure of direct and indirect effects of a set of independent variables on the dependent variable. If the correlation between yield and character is due to the direct effects of character, it reflects the true relationship between them. In the present study, a genotypic path coefficient was utilized for the study where grain yield per plant was considered as the dependent variable for agro-morphological traits and the head rice recovery was the dependent variable for grain quality traits, and the rest all the traits were considered as independent while correlation coefficient between grain yield and its attributing characters were partitioned into direct and effects in path coefficient analysis. further effects were scaled based on the scale of Lenka and Mishra (1973) for path analysis.

path analysis revealed that the very high positive direct contribution on grain yield per plant was expressed by Filled Spikelets Per Panicle (1.041), while Harvest Index (0.765), Biological Yield Per Plant (0.527) and Unfilled Spikelets per panicle (0.438) showed high positive direct effect whereas panicle weight per plant (0.288) showed a moderate positive direct effect on yield. Singh *et al.,* (2018) and Sivasankar *et al.,* (2018) also reported that the Biological Yield Per Plant, Harvest Index, Panicle Bearing Tillers Per Plant, Panicle Length, and Spikelet Per Panicle is the benefitted and efficient for selection for the enhancement of rice productivity.

Linking correlation with path analysis gives a better picture for selection compared to correlation alone, by employing this concept in this study it was observed that the trait viz;

Panicle Weight Per Plant, Filled Spikelets Per Panicle, Harvest Index, Biological Yield Per Plant showed high direct effect and positive significant correlation on Grain Yield Per Plant. However, grain quality traits like Milled Grain L/B, Hulling %, and Alkali Spreading Value are having a high direct effect and significant positive correlation with Head Rice Recovery.This shows their true and potent relationship and direct selection in those traits [11]will directly lead to high yield and good Head Rice Recovery.Similar results were reported by Hossain *et al.,* (2018); Parimala *et al.,* (2020); and Samudin *et al*., (2021).

5. CONCLUSION

In conclusion, character association analysis revealed that direct selection can be possible for the traits which are having a very high direct effect and strong positive correlation with grain yield per plantand head rice recovery for improvement in yield and grain quality in rice respectively.

ACKNOWLEDGMENT

We express our sincere gratitude to Indira Gandhi Krishi Vishwavidyalaya, Raipur, India. For providing the facility for the field experiment.

CONFLICT OF INTEREST STATEMENT

The author declares that there's no conflict-of-interest present in this study, its respondents, and its researcher. No Funding was provided for this article. However, the declaration of no conflict of interest still stands since the publication of research is a core requirement in the author's doctoral degree.

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Table2. Phenotypic (p) and genotypic (g) correlation coefficients of seventeen agro-morphological traits inrice.

Traits		DFF	LL	LW	LA	PH	PL	TTPP	ETPP	FSPP	SSPP	TSPP	SF	BYPP	PWPP	HI	HSW
Days to fifty % flowering	g	0.529**	0.108	0.414	0.392	0.201	-0.38	-0.325	0.307	0.155	0.338	-0.04	0.27	0.239	-0.07	-0.24	-0.009
	p	**0.478****	0.102	0.375**	0.383**	0.159	-0.29**	-0.238*	0.288**	0.144	0.319**	-0.038	0.274**	0.228*	-0.063	-0.232*	0.116
Leaf length	g		0.305**	0.844	0.428	0.427	-0.43	-0.397	0.217	-0.01	0.194	0.044	0.22	0.002	-0.27	-0.13	0.27
	p		**0.321****	0.852**	0.403**	0.344**	-0.335**	-0.305**	0.211*	-0.011	0.181	0.068	0.207*	0.01	-0.217*	-0.122	0.14
Leaf width	g			0.764**	0.203	0.19	-0.23	-0.26	-0.31	-0.09	-0.305	-0.03	0.09	-0.02	-0.15	0.254	0.331
	p			**0.763****	0.190*	0.163	-0.221*	-0.228*	-0.281**	-0.084	-0.285**	-0.012	0.098	-0.021	-0.135	0.239**	0.154
Leaf area	g				0.4**	0.374	-0.42	-0.412	-0.05	-0.07	-0.063	0.018	0.18	-0.04	-0.28	0.039	0.358
	p				**0.373****	0.306**	-0.347**	-0.329**	-0.027	-0.067	-0.054	0.044	0.177	-0.026	-0.230*	0.038	0.181
Plant height	g					0.583**	-0.46	-0.507	0.217	-0.07	0.16	0.134	0.47	0.089	-0.37	0.075	0.36
	p					**0.486****	-0.366**	-0.394**	0.209*	-0.064	0.156	0.121	0.443**	0.09	-0.324**	0.073	0.195*
Panicle length	g						-0.35**	-0.379	0.215	0.081	0.228	0.008	0.53	0.091	-0.32	-0.02	0.22
	p						**-0.279****	-0.281**	0.164	0.058	0.17	0.013	0.447**	0.08	-0.313**	-0.026	0.154
Total tiller per plant	g							0.88**	0.008	-0.15	-0.084	0.183	0	0.202	0.197	-0.05	-0.158
	p							**0.897****	-0.005	-0.13	-0.073	0.134	0.03	0.221*	0.188*	-0.056	-0.025
Effective tiller per plant	g								0.056	-0.12	-0.029	0.165	0.07	0.285	0.196	-0.11	-0.204
	p								**0.025**	-0.101	-0.035	0.116	0.102	0.283**	0.204*	-0.104	-0.086
Filled spikelet per panicle	g									0.064	0.865	0.386	0.2	0.323	0.185	-0.59	0.091
	p									**0.053**	0.860**	0.386**	0.186*	0.308**	0.172	-0.569**	0.045
Unfilled spikelet per panicle	g										0.552**	-0.84	0.01	0.076	-0.08	-0.21	-0.166
	p										**0.547****	-0.830**	0.013	0.068	-0.072	-0.204*	-0.042
Total spikelets per panicle	g											-0.11	0.18	0.308	0.099	-0.59	-0.009
	p											**-0.119**	0.174	0.291**	0.092	-0.569**	0.022
Spikelet fertility	g												0.02	0.058	0.179	-0.1	0.22
	p												**0.017**	0.06	0.163	-0.098	0.063
Biological yield per plant	g													0.413**	-0.31	0.032	0.108
	p													**0.401****	-0.280**	0.02	0.011
Panicle weight per plant	g														0.589**	0.226	-0.038
	p														**0.574****	0.202*	-0.058
Harvest index	g															0.137	-0.114
	p															**0.119**	-0.13
Hundred seed weight	g																-0.049
	p																**-0.019**
Grain yield per plant	**g**	**0.1199**	**-0.13**	**-0.065**	**-0.149**	**-0.04**	**0.003**	**0.162**	**0.221**	**0.32**	**-0.079**	**0.221**	**0.2**	**0.336**	**0.856**	**0.784**	**0.159**
	p	**0.116**	**-0.094**	**-0.052**	**-0.111**	**-0.027**	**-0.043**	**0.194**	**0.261**	**0.29**	**-0.068**	**0.2**	**0.182**	**0.331**	**0.817**	**0.802**	**0.135**

*, ** significant at 5% and 1% probability levels

Table3.Phenotypic (p) and genotypic (g) correlation coefficients for twenty-grain quality traits of rice.

Traits		M%	GL	GW	DGL	DGW	DGL/B	MGL	MGW	MGL/B	CGL	CGW	CL/CB	ER	ASV	GC	AC%	Iron	Zinc
Hulling %	g	0.86**	0.59**	-0.65**	0.64**	-0.56**	-0.62**	0.63**	-0.65**	-0.63**	0.78**	-0.54**	0.84**	-0.61**	-0.68**	0.04NS	0.28**	-0.52**	-0.67**
	p	0.71**	0.378**	-0.403**	0.366**	-0.357**	-0.392**	0.368**	-0.412**	-0.392**	0.442**	-0.302**	0.439**	-0.379**	-0.388**	0.049NS	0.166NS	-0.321**	-0.394**
Milling %	g		0.53**	-0.73**	0.61**	-0.62**	-0.71**	0.58**	-0.75**	-0.72**	0.78**	-0.49**	0.76**	-0.68**	-0.79**	0.21*	0.45**	-0.64**	-0.74**
	p		0.378**	-0.512**	0.403**	-0.420**	-0.511**	0.393**	-0.469**	-0.521**	0.486**	-0.308**	0.446**	-0.488**	-0.508**	0.160NS	0.281**	-0.440**	-0.445**
Grain length	g			-0.702**	0.955**	-0.636**	-0.627**	0.959**	-0.713**	-0.704**	0.917**	-0.403**	0.830**	-0.823**	-0.822**	0.312**	0.425**	-0.833**	-0.842**
	p			-0.699**	0.947**	-0.613**	-0.619**	0.942**	-0.677**	-0.696**	0.882**	-0.344**	0.753**	-0.815**	-0.787**	0.305**	0.404**	-0.693**	-0.763**
Grain width	g				-0.741**	0.929**	0.846**	-0.74**	0.932**	0.895**	-0.818**	0.613**	-0.774**	0.885**	0.916**	-0.388**	-0.506**	0.741**	0.906**
	p				-0.736**	0.895**	0.835**	-0.73**	0.888**	0.884**	-0.784**	0.512**	-0.698**	0.879**	0.878**	-0.376**	-0.484**	0.619**	0.821**
Decorticated grain length	g					-0.694**	-0.609**	0.988**	-0.752**	-0.712**	0.943**	-0.406**	0.849**	-0.849**	-0.839**	0.324**	0.462**	-0.795**	-0.857**
	p					-0.662**	-0.594**	0.975**	-0.713**	-0.699**	0.908**	-0.345**	0.772**	-0.840**	-0.799**	0.312**	0.436**	-0.661**	-0.775**
Decorticated grain width	g						0.690**	-0.68**	0.973**	0.779**	-0.771**	0.637**	-0.755**	0.841**	0.805**	-0.357**	-0.493**	0.595**	0.796**
	p						0.627**	-0.63**	0.938**	0.728**	-0.692**	0.501**	-0.635**	0.805**	0.744**	-0.324**	-0.458**	0.479**	0.692**
Deco. grain length/width	g							-0.61**	0.727**	0.983**	-0.722**	0.509**	-0.624**	0.854**	0.915**	-0.371**	-0.540**	0.860**	0.891**
	p							-0.60**	0.663**	0.971**	-0.689**	0.421**	-0.560**	0.841**	0.874**	-0.369**	-0.515**	0.713**	0.804**
Milled grain length	g								-0.750**	-0.705**	0.943**	-0.392**	0.837**	-0.850**	-0.834**	0.338**	0.415**	-0.786**	-0.866**
	p								-0.690**	-0.681**	0.895**	-0.351**	0.766**	-0.843**	-0.792**	0.323**	0.394**	-0.642**	-0.782**
Milled grain width	g									0.800**	-0.843**	0.616**	-0.815**	0.882**	0.837**	-0.370**	-0.452**	0.643**	0.818**
	p									0.722**	-0.756**	0.490**	-0.689**	0.833**	0.773**	-0.318**	-0.429**	0.542**	0.730**
Milled grain length/width	g										-0.791**	0.540**	-0.700**	0.915**	0.969**	-0.386**	-0.613**	0.901**	0.941**
	p										-0.762**	0.455**	-0.625**	0.897**	0.914**	-0.380**	-0.563**	0.735**	0.835**
Cooked grain length	g											-0.412**	0.886**	-0.878**	-0.904**	0.342**	0.514**	-0.867**	-0.888**
	p											-0.351**	0.848**	-0.816**	-0.826**	0.310**	0.453**	-0.687**	-0.795**
Cooked grain width	g												-0.733**	0.598**	0.552**	-0.188*	-0.247**	0.511**	0.555**
	p												-0.711**	0.509**	0.424**	-0.11NS	-0.15NS	0.373**	0.426**
Cooked grain length/width	g													-0.782**	-0.808**	0.272**	0.393**	-0.802**	-0.808**
	p													-0.685**	-0.690**	0.212*	0.327**	-0.611**	-0.685**
Elongation ratio	g														0.942**	-0.393**	-0.542**	0.862**	0.941**
	p														0.902**	-0.384**	-0.520**	0.717**	0.846**
Alkali spread. value	g															-0.408**	-0.569**	0.865**	0.942**
	p															-0.401**	-0.584**	0.774**	0.914**
Gel consistency	g																0.142NS	-0.437**	-0.381**
	p																0.153NS	-0.342**	-0.336**
Amylose content%	g																	-0.549**	-0.491**
	p																	-0.492**	-0.497**
Fe content	g																		0.831**
	p																		0.764**
Zn content	g																		
	p																		
Head rice recovery	g	0.287**	0.336**	-0.260**	0.146NS	-0.242**	0.103NS	0.218*	-0.232*	0.134NS	0.245**	-0.195*	-0.037NS	-0.115NS	0.262**	0.267**	-0.096NS	-0.181NS	0.295**
	p	0.26**	-0.17NS	-0.696**	0.369**	-0.612**	0.350**	0.606**	-0.634**	0.379**	0.685**	-0.454**	0.087NS	-0.284**	0.724**	0.557**	-0.272**	-0.342**	0.658**

**, ** significant at 5% and 1% probability levels.*

Table 4.Path coefficient analysis for seventeen agro-morphological traits for grain yield in rice.

Characters	Days to fifty % flowering	Leaf length	Leaf width	Leaf area	Plant height	Panicle length	Total tiller per plant	Effective tiller per plant	Filled spikelet per panicle	Unfilled spikelet per panicle	Total spikelets per panicle	Spikelet fertility	Biological yield per plant	Panicle weight per plant	Harvest index	Hundred seed weight	Grain yield per plant	Partial R²
Days to fifty % flowering	**-0.012**	-0.069	-0.003	0.038	-0.047	-0.006	0.019	0.025	0.320	0.068	-0.381	0.004	0.144	0.069	-0.054	-0.009	0.120	-0.001
Leaf length	-0.006	**-0.131**	-0.009	0.076	-0.052	-0.013	0.021	0.031	0.225	-0.004	-0.219	-0.004	0.117	0.001	-0.209	-0.005	-0.014	0.018
Leaf width	-0.001	-0.040	**-0.030**	0.069	-0.025	-0.006	0.012	0.020	-0.322	-0.040	0.344	0.003	0.047	-0.007	-0.112	0.010	-0.065	0.002
Leaf area	-0.005	-0.110	-0.023	**0.091**	-0.048	-0.011	0.021	0.032	-0.048	-0.032	0.071	-0.002	0.095	-0.010	-0.212	0.002	-0.149	-0.014
Plant height	-0.005	-0.056	-0.006	0.036	**-0.121**	-0.018	0.023	0.039	0.226	-0.029	-0.180	-0.013	0.248	0.026	-0.282	0.003	-0.056	0.004
Panicle length	-0.002	-0.056	-0.006	0.034	-0.070	**-0.030**	0.018	0.030	0.224	0.036	-0.257	-0.001	0.277	0.026	-0.246	-0.001	0.002	0.000
Total tiller per plant	0.005	0.056	0.007	-0.038	0.055	0.011	**-0.050**	-0.069	0.009	-0.068	0.095	-0.018	-0.006	0.058	0.151	-0.002	0.162	-0.008
Effective tiller per plant	0.004	0.052	0.008	-0.037	0.061	0.011	-0.044	**-0.078**	0.058	-0.053	0.033	-0.016	0.037	0.082	0.150	-0.004	0.221	-0.017
Filled spikelet per panicle	-0.004	-0.028	0.009	-0.004	-0.026	-0.007	0.000	-0.004	**1.041**	0.028	-0.974	-0.037	0.105	0.093	0.141	-0.023	0.320	0.333
Unfilled spikelet per panicle	-0.002	0.001	0.003	-0.007	0.008	-0.002	0.008	0.009	0.067	**0.438**	-0.622	0.080	0.005	0.022	-0.063	-0.008	-0.079	-0.035
Total spikelets per panicle	-0.004	-0.025	0.009	-0.006	-0.019	-0.007	0.004	0.002	0.900	0.242	**-1.126**	0.011	0.098	0.089	0.075	-0.023	0.221	-0.249
Spikelet fertility	0.001	-0.006	0.001	0.002	-0.016	0.000	-0.009	-0.013	0.401	-0.367	0.126	**-0.096**	0.011	0.017	0.137	-0.004	0.201	-0.019
Biological yield per plant	-0.003	-0.029	-0.003	0.016	-0.057	-0.016	0.001	-0.005	0.207	0.004	-0.208	-0.002	**0.527**	0.119	-0.235	0.001	0.336	0.177
Panicle weight per plant	-0.003	0.000	0.001	-0.003	-0.011	-0.003	-0.010	-0.022	0.336	0.033	-0.347	-0.006	0.218	**0.288**	0.451	0.009	0.856	0.247
Harvest index	0.001	0.036	0.004	-0.025	0.045	0.010	-0.010	-0.015	0.192	-0.036	-0.111	-0.017	-0.162	0.170	**0.765**	0.005	0.784	0.600
Hundred seed weight	0.003	0.018	-0.008	0.004	-0.009	0.001	0.003	0.008	-0.610	-0.094	0.660	0.010	0.017	0.065	0.105	**0.038**	0.159	0.006

(R^2=0.9804, Residual effect = 0.1401) diagonal Bold values represent the direct effect

(DFF = days to 50% flowering, LL= leaf length, LW= leaf width, LA= leaf area, PH= plant height, PL= panicle length, TTPP= total tillers per plant, ETPP= effective tillers per plant, FSPP= filled spikelets per plant, USPP= unfilled spikelets per panicle, TSPP= total spikelets per panicle, SF= spikelet fertility %, BYPP= biological yield per plant, PWPP= panicle weight per plant, HI= harvest index, HSW= head ricerecovery, GYPP= grain yield per plant).

Table 5.Path coefficient analysis for twenty-grain quality traits in rice.

Characters	**Hulling%**	**Milling %**	**Grain Length**	**Grain Width**	**Decorticated Grain length**	**Decorticated Grain width**	**Decorticated Grain L/B**	**Milled Grain Length**	**Milled Grain Width**	**Milled Grain L/B**	**Cooked Grain Length**	**Cooked Grain Width**	**Cooked L/B**	**Elongation Ratio**	**Alkali Spreading valu**	**Gel Consistenc**	**Amylose Con%**	Fe (ppm)	Zn (ppm)
H%	**1.437**	-0.627	1.188	0.818	0.229	2.403	0.191	-2.779	-4.8	-3.6	3.09	0.69	-2.7	0.42	-0.496	0.013	-0.044	0.096	0.286
M%	1.248	**-0.723**	1.068	0.925	0.219	2.683	0.219	-2.545	-5.52	-4.2	3.09	0.62	-2.438	0.47	-0.577	0.066	-0.069	0.119	0.314
GL	0.851	-0.385	**2.007**	0.881	0.342	2.728	0.193	-4.196	-5.2	-4.1	3.61	0.51	-2.661	0.56	-0.599	0.095	-0.065	0.153	0.356
GW	-0.937	0.533	-1.409	**-1.255**	-0.265	-3.981	-0.26	3.25	6.797	5.16	-3.23	-0.77	2.482	-0.6	0.667	-0.117	0.078	-0.136	-0.383
DGL	0.922	-0.443	1.916	0.929	**0.358**	2.975	0.187	-4.326	-5.48	-4.1	3.72	0.51	-2.721	0.58	-0.611	0.098	-0.071	0.146	0.362
DGW	-0.806	0.452	-1.277	-1.166	-0.248	**-4.287**	-0.212	2.982	7.099	4.49	-3.04	-0.8	2.421	-0.57	0.586	-0.108	0.076	-0.109	-0.336
DGL/B	-0.894	0.515	-1.259	-1.061	-0.218	-2.959	**-0.307**	2.702	5.305	5.67	-2.85	-0.64	2.002	-0.58	0.666	-0.112	0.083	-0.158	-0.376
MGL	0.913	-0.42	1.924	0.932	0.354	2.92	0.19	**-4.377**	-5.47	-4.1	3.72	0.49	-2.684	0.58	-0.607	0.102	-0.064	0.144	0.366
MGW	-0.946	0.547	-1.431	-1.17	-0.269	-4.172	-0.223	3.283	**7.295**	4.61	-3.33	-0.78	2.614	-0.6	0.61	-0.112	0.069	-0.118	-0.345
MGL/B	-0.908	0.526	-1.413	-1.123	-0.255	-3.34	-0.302	3.084	5.839	**5.77**	-3.12	-0.68	2.244	-0.62	0.706	-0.117	0.094	-0.165	-0.398
CGL	1.13	-0.57	1.84	1.03	0.34	3.3	0.22	-4.13	-6.15	-4.6	**3.94**	0.52	-2.84	0.6	-0.66	0.1	-0.08	0.16	0.38
CGW	-0.79	0.36	-0.81	-0.77	-0.15	-2.73	-0.16	1.71	4.5	3.11	-1.62	**-1.26**	2.35	-0.41	0.4	-0.06	0.04	-0.09	-0.23
CL/CB	1.21	-0.55	1.67	0.97	0.3	3.24	0.19	-3.67	-5.95	-4	3.49	0.92	**-3.21**	0.53	-0.59	0.08	-0.06	0.15	0.34
ER	-0.88	0.5	-1.65	-1.11	-0.3	-3.61	-0.26	3.72	6.43	5.28	-3.46	-0.75	2.51	**-0.68**	0.69	-0.12	0.08	-0.16	-0.4
ASV	-0.98	0.57	-1.65	-1.15	-0.3	-3.45	-0.28	3.65	6.11	5.59	-3.56	-0.7	2.59	-0.64	**0.73**	-0.12	0.09	-0.16	-0.4
GC	0.06	-0.16	0.63	0.49	0.12	1.53	0.11	-1.48	-2.7	-2.2	1.35	0.24	-0.87	0.27	-0.3	**0.3**	-0.02	0.08	0.16
AC	0.41	-0.33	0.85	0.63	0.17	2.11	0.17	-1.82	-3.29	-3.5	2.03	0.31	-1.26	0.37	-0.41	0.04	**-0.15**	0.1	0.21
Fe	-0.75	0.47	-1.67	-0.93	-0.28	-2.55	-0.26	3.44	4.69	5.19	-3.42	-0.64	2.57	-0.59	0.63	-0.13	0.08	**-0.18**	-0.35
Zn	-0.97	0.54	-1.69	-1.14	-0.31	-3.41	-0.27	3.79	5.97	5.42	-3.5	-0.7	2.59	-0.64	0.69	-0.12	0.08	-0.15	**-0.42**